

DFM Engineering, Inc.  
1035 Delaware Avenue, Unit D  
Longmont, Colorado 80501  
Phone: 303-678-8143  
Fax: 303-772-9411  
Web: www.dfmengineering.com



**A. R. I. E.S. CONTRACT No.1 (Revised April 15,2009)**

**Tender NO. 4-3-12**

**OPERATION and MAINTENANCE MANUAL**

**For DFM 1.3 m astronomical optical telescope**

**(and accessories)**

*SHIPPED TO: THE DIRECTOR  
A.R.I.E.S.  
DEVASTHAL, DHANACHULI  
NAINITAL, INDIA 263002*

## **WARRANTY**

All DFM parts and labor specified in this contract are warranted by DFM Engineering, Inc. to be free from defects in materials and workmanship for a period of 24 months from the acceptance date. DFM will assign all manufacturer's warranties for parts that are not manufactured by DFM, but DFM gives no warranty and assumes no liability for those parts. ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, SPECIFICALLY INCLUDING WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE HEREBY DISCLAIMED.

Remedies for breach of this warranty are limited to repair or replacement of defects only, at the option and expense of DFM. In the event of any repair or replacement required by this warranty, such work shall be warranted for one year from completion under the terms of this warranty. DFM shall have no liability for any loss or damage arising from breach of this warranty, including incidental or consequential damages, except as expressly provided herein. DFM shall have no liability for defects or damages resulting from misuse, acts of God, war, vandalism, or theft. All maintenance during the warranty period shall be performed by or with the written consent from DFM, and any unauthorized maintenance shall relieve DFM from any liability under this warranty.

In the event DFM performs any work not covered by this warranty, the customer shall be fully responsible for all labor and material expenses incurred by DFM. The terms for such work shall be agreed to by the parties in writing prior to any work done by DFM.

## **ATTORNEY'S FEES**

In the event DFM retains an attorney because of the customer's failure to pay any amounts under this contract, the customer shall be responsible for all reasonable attorney's fees incurred by DFM, in addition to any other damages.

## **NON-DISCLOSURE AGREEMENT**

The non-disclosure agreement between customer (A.R.I.E.S) and DFM ENGINEERING, INC. for rights in technical data and computer software is located in section 6.6 of this manual.

## **TABLE OF CONTENTS**

### **1.0 GENERAL DESCRIPTION**

1.1 MECHANICAL

1.2 ELECTRONIC

1.3 SOFTWARE

### **2.0 ADJUSTMENTS**

2.1 DRIVE ROLLER TENSION

2.2 BALANCE

2.3 LIMIT SWITCHES

2.4 ALIGNMENT

2.5 COLLIMATION

2.6 DECLINATION BEARING PRELOAD

### **3.0 OPERATION**

3.1 MOUNTING INSTRUMENTS

3.2 PRIMARY MIRROR COVER

3.3 AUXILIARY POWER BOX

3.4 FINDER TELESCOPE

3.5 STARTING UP THE CONTROL SYSTEM

3.6 THE FRONT PANEL

3.7 THE DISPLAY

3.8 THE HAND PADDLE

## 3.9 THE MENU

### 3.9.1 File

3.9.1.1 Save Pointing Data

3.9.1.2 Exit

### 3.9.2 Telescope

3.9.2.1 Initialization

3.9.2.2 Movement

3.9.2.3 Rates

3.9.2.4 Misc

### 3.9.3 View Status/Error Log

### 3.9.4 Options

3.9.4.1 Communication (external computer)

3.9.4.2 Night Colors

3.9.4.3 Defaults

### 3.9.5 Help

## 3.10 CONTROL SYSTEM SHUTDOWN AND RESTART

## 4.0 MAINTENANCE

### 4.1 SOFTWARE BACKUPS

### 4.2 CLEANING

### 4.3 LUBRICATION

### 4.4 BELT TENSION

### 4.5 SERVO-MOTOR SETUP

### 4.6 OPTICAL MAINTENANCE

### 4.7 POINTING MODEL

### 4.8 INITIALIZATION FILES

## **5.0 TROUBLE SHOOTING**

5.1 ROLLER SLIPPAGE

5.2 MOTOR RUNAWAY

5.3 BAD COLLIMATION

5.4 BAD POINTING

## **6.0 APPENDICES**

6.1 EXCOM DOCUMENT

6.2 SERVO TUNEUP DOCUMENT

6.3 MIRROR SUPPORT DOCUMENT

6.4 FRAMEGRABBER DOCUMENT

6.5 5 AXIS FOCUS HOUSING DOCUMENT

6.6 Copy of NON-DISCLOSURE AGREEMENT

6.7 Copy of DFM PACKLIST

6.8 Copy of PURCHASE ORDER

## **1.0 GENERAL DESCRIPTION**

### **1.1 MECHANICAL**

The DFM 1.3 Meter is an equatorial fork mounted Cassegrain telescope. The drives are two stages of friction drive (a large disk driven by a small roller) driven by a stepping servomotor through a timing belt and pulley stage. The absolute 25 bit HA and DEC encoders are on-axis. The focus motion is provided by a stepper motor driven secondary mirror. Focus position is recorded with a belt driven potentiometer and an incremental optical encoder. Secondary mirror collimation is accomplished with 4 motorized and LVDT absolutely encoded x-y stages. These stages allow secondary translation and tilt in both X and Y, commanded and displayed from the control system computer. The primary mirror axial support consists of 36 counterweighted lever back supports and thermally compensated defining points on the mirror OD. The primary mirror radial support system consists of 16 passive radial counterweights, and 4 thermally compensated radial hark points. Mirror doors protect the primary mirror and a plate attached to one of the doors acts as a dust cover for the primary light baffle tube. A full mechanical drawing package of the telescope is provided.

## **1.2 ELECTRONIC**

The telescope is controlled using a PC Computer. An interface card plugs into the PC, and controls the motor driver chassis (MDC). Cables connect the PC and the telescope to the motor driver unit. A hand paddle plugs into the MDC and a second hand paddle may plug in at the pedestal. The MDC contains power supplies, and control logic hardware for the motors. There is a mercury limit switch assembly mounted on the center section. This final limit switch is a power interlock that cuts power to the motors at the horizon. The PC interface includes VIA's (versatile interface adapter) that the PC uses to control the telescope. Intel 8254 pulse rate generators are used to produce motion commands to the motors. LSI 7166 up-down counters are used to keep track of focus position. An AD-574A (12 bit) analog to digital converter is used to read the focus position pot and focus x-y stage LVDT positions. HA and DEC positions are encoded with a Heidenhain IK 220 card in the TCS computer. The Mirror Support Chassis (MSC) contains electronics and controls for the mirror doors. The 5 Axis Focus Chassis (5AFC) contains logic and interface circuitry to control the focus housing x-y stages. Roof and Gable control is accomplished contacting relays and solid state relays commanded by TCS. All of the electronic chassis are housed in a pair of 19 inch wide racks. Power for the chassis is 115 volts. An Isolation step-down transformer is provided to adapt to Indian 200 VAC power.

## **1.3 SOFTWARE**

The software is written in Turbo-Pascal. The software is a multitasking 32 bit windows application. The control software is written for a general purpose equatorial research grade telescope operating in either hemisphere. Coordinate handling allows operation in any epoch. Corrections are performed for precession, nutation, aberration, refraction, mechanical and optical misalignments, and mechanical flexure. Small changes are required to adapt the control system to site specific details including latitude, longitude, elevation, and dome type. These changes are made to the initialization file that is used to initialize system variables when the software is executed. The pointing model program may be used to modify the initialization file.

## **2.0 ADJUSTMENTS**

### **2.1 DRIVE ROLLER NORMAL FORCE**

The RA primary roller normal force is provided by gravity and requires no adjustment. The DEC primary roller normal force is set by turning a 3/8-24 screw in the DEC drive that pushes the primary roller into the disc with a spring. To adjust normal force:

1. Loosen the DEC normal force screw until the tube assembly moves freely.
2. Tighten the screw until a 5-8 pound pull on the top of the tube assembly perpendicular to the DEC axis does not cause rotation.

Right Ascension Secondary roller normal force is set at the factory and may be turned on and off with a cam built into the secondary drive assembly. Declination secondary roller normal force is adjusted by turning a ¼-28 socket head set screw that is located on the lower right corner of the Declination secondary disc housing on the east side of the fork. These rollers may be released to separate the secondary drives from the axis drive train during balancing or other maintenance procedures.



\*\*\*CAUTION\*\*\*

When the primary or secondary roller has been disengaged, the telescope is free to rotate, and rotation will occur if the telescope is out of balance.

## 2.2 BALANCE

It is important to balance the telescope to optimize performance, increase instrument life, and for safety. Both axes of the telescope may be balanced by using the amp-meters on the front panel of the motor driver chassis. The meters read +3 and - 3 amps full scale. Use the hand paddle to see that the same current is required to slew in both directions for each axis. Adjust the counterweights until balance is achieved. Counterweights provided include weights for the bottom of the primary mirror cell and motorized weights for Declination. RA balance should not need adjustment unless an asymmetrical instrument is used. If RA does need adjustment, the sliding fork weight can be adjusted. A better DEC balance may be achieved by releasing the primary drive roller and pulling on the mount with a spring scale and adjusting counterweights. DEC balance procedure:

1. Release DEC primary roller preload.
2. Balance the tube assembly with trim weights added to the north or south side of the primary mirror cell **with the tube at the zenith**.
3. Balance the tube assembly using the sliding or motorized counterweights and additional symmetrical mirror cell weights if required **with the tube nearly horizontal but slightly above the horizon**.
4. Reset the DEC primary roller normal force (see 2.1).

## 2.3 LIMIT SWITCH

There is a mercury limit switch assembly on the center section. These switches provide limits for the servo motors. The limits interrupt power to the motors if the tube assembly is nearly horizontal, if this limit has been reached a small green light on the motor driver chassis will go out. To recover from this final limit, the Halt Motors button on the motor driver chassis should be latched (it is latched in the IN position) and the telescope manually pushed out of the limit.

## 2.4 ALIGNMENT

Azimuth alignment is adjusted with push screws inside the pedestal behind the north access covers. Once alignment is complete, tighten both of the push screws to fix the position. Elevation alignment is adjusted with the screws inside the pedestal below the south polar axle bearing. A fine threaded screw is used to adjust height and a bolt cast into the concrete pier is used to hold the telescope down.

**\*\*\*WARNING\*\*\***

The telescope has a large overturning moment when assembled. The south hold down bolt should not be released unless the telescope fork has been removed.

The following procedure is recommended for polar alignment:

Note: A star is drifting in the direction pushed on the hand paddle to re-center the star.

1. Orient cross hairs N-S, E-W in an illuminated retical eyepiece.
2. Track a star near the meridian and about 0 degrees declination.

If the star drifts south then the polar axle lies NE-SW.

If the star drifts north then the polar axle lies NW-SE.

Adjust in AZIMUTH to correct drift.

3. Track a star at about 6 hours east or west and about 45 degrees declination.

IF		E star drifts N		THEN
		or		
		W star drifts S		

**ELEVATION OF POLAR AXLE IS TOO GREAT**

IF		E star drifts S		THEN
		or		
		W star drifts N		

**ELEVATION OF POLAR AXLE IS TOO SMALL**

Adjust ELEVATION to correct drift.

**2.5 COLLIMATION**

**\*\*\* CAUTION \*\*\*** The optical collimation of your optical tube assembly was adjusted during installation and should not be changed except by someone with experience, and the proper test equipment. Failure to observe this caution may result in partial loss of warranty.

Primary and secondary mirror initial collimation is typically set while installing the optics in the telescope (see "Optical Maintenance" below). Fine tuning the optical collimation is performed with the optics installed and the telescope in balance and operational. Final collimation adjustments are accomplished through commands to the 5 axis focus housing during periods of good seeing.

Gather the following tools and equipment (provided with installation):

1. "L" ball end Allen wrench set.
2. 5 dial indicators with extensions and mounting blocks.
3. Axial hardpoint wrench (dwg 621-155-1).
4. .003" feeler gage and handle.
5. Collimation laser.
6. White laser target board.
7. Circular projection laser attachment.
8. Collimation mirror tool (dwg. 621-017)
9. Feeler gage set.
10. 2" eyepiece adapter (dwg. 621-021)
11. 3/8" nut driver.
12. 1/2" combination wrench.
13. DFM Engineering maintenance drawing package.
14. 12 ft ladder or scaffolding.
15. 2" eyepiece or CCD camera.
16. 635 nm laser safety glasses.

Become familiar with the following drawings in the DFM maintenance drawing package:

- 621-011 Primary Mirror Cell Assembly.
- 621-155-1 Front Defining Bracket Assemblies .
- 621-156 Mirror Support Assemblies.
- 621-018 Secondary Mirror Assembly.

Note: Once the primary mirror cell is installed on the telescope, the primary mirror centering must not be disturbed.

Collimation with the laser collimation tool:

1. Verify that the 3 axial and 2 radial dial indicator assemblies are installed in the primary mirror cell, operating correctly, and set to zero. Note that the dial indicator assemblies are stamped to define their position on the cell: "N"= North, "W"= West, "NEB"= Northeast bottom, "WB"= West bottom and "SB"= South bottom.

2. Use a 3/16" Allen wrench to reach through the slots in the 16 radial counterweight assembly covers on the primary mirror cell and check the radial counterweights: Gently push each of the 16 radial counterweights in and out to verify that none of the radial counterweights will contact the mirror cell or cover. Note which radial counterweight assemblies need adjustment.
3. If any radial counterweights are at their travel limits adjust them for mid travel. Move the telescope to the north service position and install the RA and DEC lock pins. Open the tube doors and climb up into the center section. Use a 1/2 " open end wrench to turn the brass nut to fine-tune the centering of the radial counterweights. For coarse adjustments remove the clevis pin from the mirror block and turn either the brass nut or rod end. Have an assistant monitor the counterweight position during adjustment. Re-install the clevis pin and safety ring.
4. Remove the secondary mirror hub cover and install the collimation mirror tool in its place. Remove the primary light shield cover.
5. Close the mirror doors, remove the RA and DEC lock pins, park the telescope at the zenith, and install the RA and DEC lock pins again. Press the "Halt Motors" button on the motor driver chassis to disable the drives.
6. Center the translate and tip/tilt axes of the 5 axis focus housing: Go to the DFM TCS control window and select "Telescope" / "Misc..." / "Focus". In the focus control window enter "0" in the "X Translate" and "X Tilt" command windows, and then click on "X Apply". This will command the X axis of the focus housing to self-center. Repeat for the Y axis. Click on the "Read and Update Tip/Tilt + Translate Display", and then check the "5 Axis Focus Housing Tip/Tilt + Translate" window in TCS to verify that the focus housing X-Y axis' position values are near zero.
7. Install the 2" eyepiece adaptor on the bottom of the mirror cell. Install the collimation laser with the white target board attachment into the 2" eyepiece adaptor.

CAUTION: The collimation laser provided is not eye-safe. Use the 635nm laser safety glasses provided whenever the laser is in use.

Note: With the mirror doors closed, it is possible to stand on the center section and reach the secondary mirror collimation bolts. Observe the target board on the laser tool by looking down the primary light baffle with the light baffle cover removed.

8. Climb up on the tube doors on the telescope center section. Tip/tilt the secondary mirror to center the laser reflection on the target board of the

- laser. Secondary mirror tip / tilt is adjusted using 4 screws at 90 deg. on the edges of the back support plate. These screws must be adjusted in pairs, loosening one first then tighten the opposite screw with a 3/16" Allen wrench. The screws cause the mirror back plate to rotate on a spherical washer set. Adjust secondary mirror tip/tilt until the laser reflection disappears into the laser source.
9. Replace the white target board on the collimation laser with the circular projection attachment, and then reinstall the laser into the 2" eyepiece adaptor. The laser collimator will now project concentric circles of light up toward the secondary mirror.
  10. Climb up on the tube doors on the telescope center section to view the illuminated circles of laser light projected onto the secondary mirror hub. Use a 3/8" Allen "L" wrench to adjust the 4 radial bolts that suspend the spyder vanes within the spyder ring. Loosen one bolt 1/2 turn opposite the direction of translation, and then pull the assembly by tightening the opposing spyder vane bolt 1/2 turn. Translate the focus housing assembly to center the secondary mirror hub in the concentric light circles.
  11. Turn off the laser and replace it with a 2" eyepiece or CCD camera.
  12. Clear the center section of foreign objects.
  13. Remove the RA and DEC lock pins and enable the telescope drives. Use the hand paddle to slew the telescope to the north service position.
  14. Remove the collimation mirror tool and install the secondary mirror hub cover.
  15. Open the tube doors and install the primary light shield cover.
  16. Slew to a relatively bright star within 30 degrees of the zenith. Center the star's image on the CCD camera or eyepiece. Orient the CCD camera or eyepiece so north-south and east-west directions are oriented up-down and left-right. Examine the image inside and outside of the focus. The image will appear as an illuminated annulus (bright circle with a hole in the center). The amount of de-focus should be adjusted until the annulus is sufficiently large to easily see the annular star image. Since the star light is spread out over the area of the annulus, its intensity will decrease with increasing size of the annulus. If the intensity is not sufficient, then you will need to select a brighter star.

Note: Choosing a star near the zenith is preferable to minimize the effects of atmospheric turbulence ("seeing"), and atmospheric dispersion (the prism effect of the atmosphere causes the blue and red images to be displaced). The image needs to be centered in the eyepiece or CCD camera since an off-axis image will show a non-concentric annulus. If an off-axis image is used for collimation, this will cause the collimation to provide the best images at that off-axis position.

Note: Diffraction at the edge of the primary mirror and at the edge of the telescope light shielding (i.e., the inside circle of the annulus) will appear differently when viewed inside and outside of focus. You will need to look for the concentricity of the inside circle and the outside circle and not be overly concerned about the brightness of the circular edges.

17. Look carefully at the out of focus image. If the inside and outside circles of the annulus are not concentric, then the primary mirror must be adjusted in tip/tilt. Look along the north-south and east-west directions and note the amount of decentering in each of these directions.
18. Remove the (3) 3/4" hole plugs from the side of the primary mirror cell. Remove the 3 defining bracket assembly covers and (36) 3/4" hole plugs from the bottom of the mirror cell.
19. Adjust the 4 earthquake guards such that there is at least a 1/8" gap between the primary mirror and each guard. Loosen the north and west radial supports 1 turn.
20. Use the axial hard point wrench to lower (unscrew) the axial hard points 3 turns. Watch the 3 axial dial indicator assemblies to make sure the primary mirror doesn't move.

Note: Do not tip the primary mirror more than .010" without re-adjusting the 36 back support counterweight assemblies. If the primary mirror must be tipped more than .010", then the mirror must be adjusted in several stages. Do not tip the primary mirror more than a total of .030".

21. Adjust the primary mirror tip/tilt to remove the decentering in the out-of-focus image. Use a 3/8 nut driver to turn the (brass) retaining nut on the appropriate front defining bracket assembly. Watch the 3 axial dial indicator assemblies to monitor the primary mirror movement. After an adjustment, center the image with the hand paddle and note the residual decentering. Continue adjusting primary mirror tip/tilt until the out of focus star image is concentric.

Note: Follow a systematic approach to adjusting the back supports so as not to overlook individual assemblies. Start adjusting the inner ring of 6 assemblies, then the middle ring of 12, then the outer ring of 18.

22. Hold an 1/8" Allen wrench by the short leg to adjust the 36 back support screws. Start by adjusting a back support counterweight assembly near the center of the mirror cell. Refer to drawing 621-156 to see the workings

of the mechanism. Loosen (unscrew) the adjusting screw until the load on the screw disappears. Tighten each back support screw until a slight increase in load is felt as the counterweight lifts up off the bottom of the cell. After 1/2 turn of the wrench the counterweight will contact the bottom of the primary mirror and the wrench will stop. From this position, unscrew with the wrench 1/4 turn. This will set the back support counterweight to mid travel.

23. Once primary mirror tilt adjustments are complete, tighten the north and west radial support screws until the 2 radial dial indicators return to zero.
24. Carefully raise (tighten) the 3 axial hardpoint screws until the 3 axial dial indicators show the hardpoints contacting the primary mirror, then lower (unscrew) each hardpoint until the wrench starts to turn freely.
25. Set the 4 earthquake guards .003" above the edge of the mirror. Use the .003 feeler gage (through the port below each earthquake guard) to insure the guards are not touching the primary mirror.
26. Repeat steps 2 and 3 as required

Note: The primary mirror should now have its weight distributed equally between the 36 back support assemblies while pointing at the zenith. The 16 radial counterweight assemblies and 4 radial supports support the primary mirror when the telescope is pointing near the horizon. When adjusted properly, the axial hardpoint screws, earthquake guards and radial supports work together to constrain the primary mirror during earthquakes or overturning events but do not distort the primary mirror during normal operation.

27. Install the (4) 3/4" hole plugs on the side of the mirror cell. Install the 36 hole plugs and 3 defining bracket assembly covers on the bottom of the mirror cell.
28. Set the 3 axial dial indicator assemblies to zero.
29. Slew the telescope to 70 degrees zenith distance toward the north, south, east, and west horizons and watch for tip/tilt motion of the primary mirror with the 3 axial dial indicator assemblies. If primary mirror tip/tilt motion of greater than .0005" (1/2 division on the indicator dial) is detected, the height of the radial counterweight assemblies must be adjusted. If the optical surface of the primary mirror tips down towards the horizon as zenith distance increases the counterweight assemblies must be moved down (away from the sky).

Caution: Due to their high lever ratio (25:1), the radial counterweight assemblies can exert tremendous loads on the primary mirror if handled improperly. While the counterweight covers are removed, use extreme care to avoid touching or bumping the exposed counterweight assemblies.

30. The radial counterweight assemblies are adjustable in the direction of the optical axis. Refer to DFM drawing 621-156. To enable this adjustment, remove the 16 counterweight assembly covers from the side of the mirror cell. Remove the 2 horizontal mounting screws from the counterweight mounting plate. The clearance holes for the remaining vertical screws are slotted to allow motion in the direction of the optical axis. Adjust the height of the counterweight assemblies to create or negate primary mirror tipping forces.

31. Install the 16 radial counterweight covers.

The residual collimation error will contain decentering and tip-tilt components. These small errors may be seen just inside and outside of a tightly focused image. Specifically, the image will elongate one way inside of focus and in the direction 90 degrees from the first, outside of focus. It is very difficult to see, and decide what to do. This is a difficult adjustment, requiring good seeing and patience. Using the 5 axis focus housing, adjust the tip/tilt and translation of the secondary mirror to minimize the image elongation. The 5 axis focus housing has very limited travel and is only suitable for these small final adjustments.

The 5 axis focus housing secondary cell tip-tilt motions are designed to act in north-south and east-west directions. The software only allows collimation adjustments in one axis at a time (either north-south or east-west).

The primary mirror collimation is a strong term in the pointing of the telescope that is modeled in software. Changes to the primary mirror collimation will require adjustment to the pointing model. Secondary collimation does not affect pointing.

## **2.6 DECLINATION BEARING PRELOAD**

The declination bearing axial preload is set to equal the weight of the tube assembly. The amount of deflection in the fork to achieve the proper preload distance for the DFM 1.3M telescope is stamped on the west bearing housing. The west bearing housing has slotted attachment holes and set screws that push against dowel pins in the end of the fork. To set the preload first loosen the Dec bearing lock-nut approximately three turns. Set up a magnetic base and dial indicator to verify the motion between the fork end and the west bearing housing. Loosen the four 3/8 allen cap screws securing the bearing housing to the fork two turns each. Use the set screws to move



the bearing housing outboard the distance stamped on the housing and then tighten the 3/8 allen cap screws to the torque listed on the telescope assembly drawing. Finally, preload the bearings by tightening the bearing lock-nut.

### **3.0 OPERATION**

#### **3.1 MOUNTING INSTRUMENTS**

There are four sets of tapped holes on the back of the mirror cell for attaching instruments:

SET	SIZE	HOLES	DIAMETER (of bolt circle)
1	3/8-24	12	19.000 in
2	3/8-24	12	20.000 in.
3	3/8-24	12	24.000 in.
4	3/8-24	12	36.000 in.

The locations of these tapped holes are accurate to .005 inches. Care should be taken to assure the accuracy of mounting holes on instrument flanges because badly matched holes may result in cross threading and damage to the mirror cell. Attachment screws must not engage the holes in the mirror cell more than 5/8 inch.

#### **3.2 PRIMARY MIRROR DOORS**

There are motorized doors that cover the top of the center section, protecting the primary mirror from dirt and moisture. The doors should be closed anytime the telescope is not in use.

#### **3.3 AUXILIARY POWER BOX**

There is a box mounted on the center section that supplies reticle power and 110 volt instrument power. There are two coax video cables with BNC connectors that are terminated in the control room.

#### **3.4 FINDER TELESCOPE**

The finder telescope is mounted on the center section and is adjusted in azimuth and elevation with push pull screws. The finder has a projection reticle eyepiece.

### **3.5 STARTING UP**

Turn on the switch for the isolation transformer. Turn on the switch on the 115 volt power strip. Press the start button on the control computer. After some disk access Windows will appear. Double Click the WinTCS shortcut on the desktop and the Telescope Control System (TCS) will be loaded and will start. The control system automatically auto-initializes (Updates time, date, and absolute position). When auto-initialization is over, the top line in the Status group box will indicate INITIALIZED.

To move the telescope it is necessary to turn on the motor driver chassis and make sure the latching HALT MOTORS button is out. It is also necessary to place the front panel DRIVES switch in the ON position. This chassis also supplies power for the focus encoder. The latching HALT MOTORS button interrupts power to the servo-motors.

### **3.6 FRONT PANEL**

The front panel is integrated into the Motor Driver Chassis. A cable labeled front panel plugs into the PC computer chassis. The TRACK / AUX track switch allows rapid selection of two preset track rates. The TRACK switch turns tracking on and off. The DRIVES switch is an input to the computer, and also turns off power to the motor driver chassis through a solid state relay. The EXTERNAL COMPUTER switch is not used in WinTCS. The AUTODOME switch turns on the dome control algorithm. When the AUTODOME switch is OFF, the dome may be controlled using the DOME LEFT, RIGHT buttons on the hand paddle. The DOME HOME/TRACK switch commands the dome to either track the telescope in azimuth, or to go to the preset home position. The home position is typically west, however it may be set to any value. Prevailing weather patterns may dictate a preferred dome storage azimuth. The status of these switches are displayed on the WinTCS display.

### **3.7 THE DISPLAY**

The WinTCS display is a window that appears on a pair of VGA monitors. The first group box of the display shows Telescope Position displayed in the first horizontal row in mean coordinates in the display epoch. The second row shows the next object coordinates in the next object epoch if a next object has been entered. The middle group box of the display shows Operating Modes, which include Regular-operation, Target out of range, Approaching limits, and Limit reached. The Time/Date group box shows the UTdate, UT, ST, Julian Date and GPS status. The Rates group box shows Track rates, Track rate corrections, Guide and Set hand paddle rates, Cosine of the Declination and Trail parameters. The Status group box displays the status of Dome control, Tracking, Drive power, Dome destination (home or track), hand paddle or guider inputs (NSEW), Slew Enabled, Slewing, Setting, and Trailing. The Misc. group box shows Telescope Azimuth, Dome Azimuth, focus position and absolute axes positions. In the lower right is

Communications group box that shows if ExCom, MNCP, or TCP/IP are active. Menus are provided at the top line of the WinTCS display.

### **3.8 USING THE HAND PADDLE**

The Hand paddle is used to move the telescope under manual control. There are the four directions: N S E W, and three speeds: GUIDE, SET, and SLEW. The focus may be adjusted from the hand paddle using IN and OUT. Simultaneously pressing SET with IN or OUT gives a fast focus motion. SET and GUIDE speeds are adjustable from the menu. If the COSDEC feature is turned on, the guide and set speeds in Right Ascension will be proportional to  $1/\cos(\delta)$  (cosine of the declination) up to a maximum of 3 degrees per second slew speed. SLEW is 3 degrees per sec. Automatic slews disable the hand paddle.

### **3.9 USING THE MENUS**

#### **3.9.1.1 File: Save Point Data**

*Save point Data* activates the pointing model data collection dialog box that lets the user collect, edit, and create a file of pointing data. The Save point Data dialog is non-modal and may be positioned on the display for convenience during pointing model tune-up.

#### **3.9.1.2 File: Exit**

*Exit* provides for ending your WinTCS session.

#### **3.9.2.1 Telescope: Initialization \*\*\***

*Date/Time (UPDATE)*: This command automatically executes when the TCS program starts. This auto-initialization uses the battery backed up clock in the PC and assumes the telescope is pointed at the zenith. This command calculates sidereal time based on input of the date and universal time. This command allows the user to manually enter the time and date for WinTCS. There is a button to tell WinTCS to get the time and date from the battery backed up clock in the PC. TCS time is kept in a hardware clock that runs at 200 Hz. Always check the UT and date after starting WinTCS. If the UT or the date are wrong then the PC time and date should be set using the control panel in Windows.

*Telescope Position (ZERO POINT)*: This command sets the position of the telescope based on operator input. A button is available that will initialize the telescope position to the next object coordinates. Optionally the telescope position may be set to the zenith or with the default absolute encoder offsets. A button is available to show the operator the current offset values for the encoders.

Other Positions: *Set dome position* (ZDOME): This command is used to initialize the dome position. North is zero azimuth, and azimuth increases clockwise looking down on the dome. A button tells WinTCS to set the dome azimuth based on the telescope position. These commands are not used with the ACL dome option.

*Set Rotator Position* (ZROTATOR): This command is used to initialize the instrument rotator position.

*Set focus position* (ZFOCUS): This command is used to set the focus position display.

### **3.9.2.2 Telescope: Movement**

The Movement dialog box is non-modal and may be positioned on the display for convenience. All of the motion commands may be canceled with the *Stop* button in the movement menu or on the main form. Approaching limits will also terminate automatic motion commands. All motion commands except TRAIL require the *Start slew* button to initiate motion after a slew has been ENABLED. This is a chance for the operator to double check that the area around the telescope is clear of people and obstructions. Horizon checks are performed before slews are ENABLED. If a destination is below the telescope horizon, a message will appear TARGET OUT OF RANGE. If a destination is above the telescope horizon, it will be displayed in the NEXT OBJECT row of the display and SLEW ENABLED will appear indicating that an automatic slew is pending. After an automatic slew is complete, the SLEW ENABLED message will disappear as well as the next object HA and AIRMASS.

*Set slew position* (SLEW): This command automatically slews the telescope to coordinates specified by the user. The commanded EPOCH will be the DISPLAY EPOCH if a zero is entered. If the telescope is not tracking, the slew may never terminate because the Earth's rotation is faster than the final automatic guide speed.

*Set offset* (OFFSET): This is a slew to coordinates relative to the present coordinates in the display epoch. Input is in seconds of arc. The speed of the offset is a function of the distance to be offset and not specified by the user.

*Set zenith position* (ZENITH): This command is used to slew the telescope to the Zenith. When Set Zenith Position is selected a prompt will appear that instructs the user to turn off tracking. Failure to turn off tracking may result in an un-terminated slew because the earth's rotation is faster than the automatic guide speed.

*Select library object* (OBJECT): This is a slew to a library of objects that are stored in the computer memory. All objects are stored in epoch 2000. The objects are the "Sommers-Bausch Observatory Catalog of Astronomical Objects". The catalog includes a set of ephemeris stars at one hour intervals that are useful for initializing the telescope position in the northern

hemisphere. A library for southern hemisphere users as well as custom libraries are available. WinTCS displays the library in a spreadsheet format and allows sort and search capability.

*Mark/Move Table* (MOVE/MARK): This dialog allows the user to load, save Mark files as well as edit Mark file entries, make entries of current telescope position and slew to Marked positions. There are 500 entries possible for each file.

*Start trail* (TRAIL): This button turns the trail function on. The stop button is used to cancel trailing. Note: other commands are ignored while TRAIL is active.

*Start slew* (GO): This button starts automatic slews.

*Stop* (STOP): This button is used to cancel automatic motion commands from the menu.

### **3.9.2.3 Telescope: Rates**

Track, guide, set, and trail rates may be set from the menu. Rates are arbitrary from zero to slew speed, allowing tracking of astronomical objects or satellites. All motion of the telescope is superimposed on the track rates specified. Slews to coordinates are optimized for astronomical objects with mean coordinates of the epoch specified. Slewing to coordinates with non-sidereal track rates may not be successful. The Auxiliary track rate feature allows a slew to position and then a rapid shift to non-sidereal rates with the front panel switch.

*Track rate* (TRACK RATE): This command allows modification of both RA and DEC track rates. There is an auxiliary track rate that is useful if moves are to be made between sidereal and non-sidereal objects. The auxiliary track rate is selected with a front panel switch. For external computer operation, the track rate may simply be changed with the track rate command for rapid changes.

*Hand paddle rates* (GUIDE RATE), (SET RATE): Guide is a traditional hand paddle function with rates superimposed on the track rate. Speeds between 3 and 10 arc seconds per second are recommended. Set is typically faster than Guide and convenient values are 50 to 300 arc seconds per second.

*Trail rates* (TRAIL RATES): This command sets up the parameters for the Trail function. Trail moves at a predetermined rate between two pre-calculated endpoints. This function is used to move an object back and forth along the slit in a spectrograph.

### **3.9.2.4 Telescope: Miscellaneous**

*Switches /Mirror doors* (COSDEC), (RATECOR), (DOME), (HOME):

(COSDEC): This command turns on a feature that divides commanded Right Ascension hand paddle rates by the cosine of the Declination so that the apparent motion of the object in the eyepiece is constant. (RATECOR): This

command turns on the track rate correction feature of the control system. Rate corrections are calculated by differentiating the pointing model and these corrections may be automatically applied to the track rates. (DOME): This command is used to enable or disable dome function from the menu. (DOME HOME): This command is used to set the dome home/track bit from the menu. This can be convenient if the user is in the dome instead of in the control room. The software command of the dome is only enabled if the front panel switch is in the Track position. If the switch is in the Home position, then the dome will go home and software command will be ignored.

*Open/Close Mirror doors:* To operate the mirror doors the MDC should be turned on. This command allows the user to open or close the tube doors from WinTCS. This command interacts with the switch on the mirror doors chassis as follows: If the switch is in the Close position, the doors will close and cannot be opened from software. If the switch is in the Open position, then software may command the doors to open or close. In the center OFF position, the switch removes power from the doors and they will not move. When TCS starts, it will be necessary to command the doors to open before they will open, even if the switch is in the open position.

*Open/Close Roll off Roof & Gable:* This command allows the user to open or close the Roof and Gable from WinTCS.

*Display epoch (EPOCH):* The display epoch may be set to any value.

*Move Focus Position:* This command allows the user to slew the telescope to focus using the focus encoder for feedback. The focus has 1 inch of motion at the secondary ram. Each digit is about .0002 inches of focus ram motion.

*Tip/Tilt and Translate secondary mirror:* These commands allow the user to adjust the secondary mirror collimation. The secondary has 0.05 inches of motion, that is available for translation and tip-tilt. The main form of the TCS display may be extended downward to show a complete accounting of the secondary tip/tilt and translate position. The 5 axis focus housing chassis must be powered on for these functions to work. Buttons allow adjustment of X and Y separately and only one axis should be adjusted at a time. There is a STOP motors button for canceling an adjustment in progress. The long button on the bottom reads the LVDT transducers and updates the display without moving the stages. After values for good collimation are determined, the values should be saved as defaults using the Save as Defaults button. If adjustments are made and it is desired to return to the saved values, use the Get Defaults button and use the defaults to drive to X and Y values.

### **3.9.3 View:**

Status/Error Log... shows the last 100 entries.

#### **3.9.4.1 Options: Communications**

Communications events may be logged.

*Excom:* To use the standard DFM EXCOM interface. The external computer is user supplied and interfaces to the telescope controller through a serial port. Commands from the external computer are documented in the file EXCOM & TCP/IP.TXT that is an appendix to this document. This feature is designed to provide a telescope control system that can be slaved to a data acquisition computer or general observatory computer used to provide a customer supplied interface to the telescope control system.

*MNCP:* WinTCS supports Astronomical Command Language (ACL) as defined by Merlin Controls Corporation using a serial port and may be commanded from "The Sky", a planetarium program by Software Bisque in Golden, Colorado. In brief: Double click on "The Sky" icon to start the planetarium software; Click on TELESCOPE and pull down the menu to "establish link". Once the link is established, you may use "The Sky" to SYNC and SLEW THE TELESCOPE from the dialog box for a given object shown by "The Sky". As the telescope moves, "The Sky" will display a circle with a cross to show the telescope position. Telescope data setup for "The Sky" is: 9600 Baud, ACL Telescope.

*TCP/IP:* To use the DFM TCP/IP (ethernet) interface. The external computer is user supplied and interfaces to the telescope controller through an ethernet connection. Commands from the external computer are documented in the file EXCOM & TCP/IP.TXT that is an appendix to this document. This feature is designed to provide a telescope control system that can be slaved to a data acquisition computer or general observatory computer used to provide a customer supplied interface to the telescope control system.

The normal serial port configuration for The AIRES 51 inch telescope will be:

Com1 = TCS MNCP

Com2 = GPS Time

Com3 = TheSky-MNCP

#### **3.9.4.2 Options: Night Colors**

This option uses dark colors to help the user maintain dark adaptation.

#### **3.9.4.3 Options: Defaults**

The user may save and retrieve WinTCS settings from these commands.

#### **3.9.5 Help**

WinTCS features on-line help.

### **3.10 CONTROL SYSTEM SHUTDOWN AND RESTART**

To stow the telescope for convenient restart:

***(in the dome)***

Turn off remote station.

***(in the control room or remote station).***

Close the tube doors.

Command the roof to close.

Wait for the roof to close.

Turn off tracking (front panel switch or command zero track rate).

Command the TCS to slew to the zenith (set zenith position).

Wait for the telescope to reach the zenith position.

Press the red HALT MOTORS button on the motor driver chassis to interrupt power to the telescope motors when the slew is complete.

Command the gable to close.

Exit WinTCS. Note: This will command the tube doors to close.

Shutdown the TCS computer.

Turn off main power switch on the TCS console.

To restart after shutdown

(This assumes the telescope was left at the zenith.)

***(in the dome)***

Turn on the remote station.

Check that the telescope was left in the normal shutdown position (at the ZENITH).

***(in the control room)***

Power up the system to Windows.

Start WinTCS (double click shortcut).

Let TCS Auto-initialize. This can take a minute due to focus initialization.

Open the tube cover.

Unlatch red HALT MOTORS button on the motor driver chassis.

Turn on tracking front panel switch.

Command the gable to open.

Command the roof to open.



***(move to the dome unless camera display is in the control room)***

Select and slew to an ephemeris star.

Center star in eyepiece.

Set telescope coordinates with "Set telescope position" in the Telescope/Initialization menu.

## **4.0 MAINTENANCE**

### **4.1 MAKING SOFTWARE BACKUP COPIES**

Since it is only a question of time before the system hard disk has a failure, it is a good idea to keep a copy of WinTCS on CD so that the system hard disk can be rebuilt. Windows was supplied with your computer and can be reinstalled if necessary. Use Windows utilities to make backups of your WinTCS files.

### **4.2 CLEANING**

The telescope will last longer and run better if it is kept clean. Use a soft damp cloth with soap and water on the painted parts and wipe the primary and secondary drive disks with oil to prevent corrosion. Carefully remove the RA and DEC primary disk covers and the RA secondary cover. Put a few drops of light machine oil on a clean paper towel and wipe the bare steel portions of the drive disks. Clean and wipe the disks as the telescope is slewed through its full range of motion. Continue cleaning until the paper towels stop picking up contamination from the disks. Use extreme care to avoid damage to the seals while replacing the covers. In damp climates this should be done every six months and yearly in dry climates. All metal parts except the alloy steel drive disks and rollers are plated or painted. Apply automotive wax to plated parts to minimize corrosion.

### **4.3 LUBRICATION**

The telescope is built entirely with sealed for life bearings. Fasteners should be treated with anti-seize compound as required when service operations are performed.

### **4.4 BELT TENSION**

There are timing belts between the motor and the secondary roller shaft in both Declination and Right Ascension. Access to the RA belt is through the drive cover on the south side of the north support. Access to the DEC belt is by removing the DEC secondary drive cover (rectangular box). Check the timing belts for wear and tension, they should be snug, but not tight.

## 4.5 SERVO-MOTOR SETUP

The servomotors can only be setup by a qualified technician using an oscilloscope, and the document Servo.doc that is an appendix to this manual.

## 4.6 OPTICAL MAINTENANCE

*Note: read this section completely before performing any mirror maintenance or adjustments.*

*Note: When servicing both primary and secondary mirrors, the secondary mirror assembly should be removed first to avoid a dangerous top-heavy condition.*

Gather the following tools and equipment:

1. Primary mirror insert tool (dwg. 621-189-1).
2. Focus stand (dwg.621-191).
3. Primary mirror crate.
4. Secondary mirror crate.
5. Come-A-Long
6. Center section spreader bar
7. Ratchet hoist
8. Ball driver Allen wrench set.
9. "L" ball end Allen wrench set
10. 4 Mirror insertion guides (dwg. 621-155-2).
11. Straight bladed screwdriver with a 15cm long shank.
12. 5 dial indicators with extensions and mounting blocks.
13. MCLA (Mirror Cell Lifting Assemblies) dwg. G48-086. These tools are stored in a wooden crate supplied by DFM.
14. Primary mirror crate.
15. Primary mirror lifting strap (stored in the primary mirror crate).
16. Wide base depth micrometer with 5"-6" rod.
17. Axial hardpoint wrench (dwg 621-155-1)
18. .003" feeler gage and handle
19. 2 threaded 3/8" guide pins.
20. 18" long x 1" nylon tubular webbing sling.
21. 2 threaded 1/4" guide pins.
22. 5/8" combination wrench.
23. 1/2" combination wrench.
24. 4" telescoping gage.
25. Feeler-gage set.
26. 3/8" nut driver.
27. DFM Engineering maintenance drawing package.

Become familiar with the following drawings in the DFM maintenance drawing package:

- 621-011 Primary Mirror Cell Assembly.
- 621-155-1 Front Defining Bracket Assemblies .
- 621-156 Mirror Support Assemblies.
- 621-186 Mirror Cell Lifting Assembly.

#### 4.6.1 PRIMARY MIRROR

Primary Mirror Removal:

*Note: When servicing both primary and secondary mirrors the secondary mirror assembly should be removed first to avoid a dangerous top-heavy condition.*

1. Use a 3/16" Allen wrench to reach through the slot in the 16 radial counterweight assembly covers and check the radial counterweights. Gently push each of the 16 radial counterweights outboard to verify that none of the radial counterweights will contact the mirror cell or cover. If any radial counterweights are at their travel limits adjust them for mid travel as described in "Collimation".
2. Drive the telescope to the zenith and install the lock pins.
3. Close the mirror doors.
4. Remove the instrument, SAG, and mirror cell weights from the primary mirror cell.
5. Remove the field corrector assembly and primary light shield.
6. Verify that the 3 axial and 2 radial dial indicator assemblies are installed, active and set to zero. Note that the dial indicator assemblies are stamped to define their position on the cell: "N"= North, "W"= West, "NEB"= Northeast bottom, "WB"= West bottom and "SB"= South bottom.
7. Remove the 4 Invar rod bolts, 3 mirror retainer anti-rotation arm screws, 3 retainer covers, retainer nuts, and (slotted) washers from the bottom of the mirror cell.
8. Remove the 4 earthquake guard port covers from the mirror cell side and set the 4 earthquake guards .003" above the edge of the mirror. Insert the plastic .003 feeler gage and handle through the port below each earthquake guard to set the gap between the earthquake guards and the primary mirror.
9. Gently tighten the 4 primary mirror radial supports while watching the radial dial indicator assemblies. Do not translate the primary mirror in the cell.
10. Raise the 3 axial hardpoint screws until they just contact the bottom of the mirror. Watch the 3 axial dial indicators to see mirror motion when the hardpoints contact the mirror.

11. Unscrew the 36 back support counterweight screws 3 turns each to deactivate them. The primary mirror should now be resting on the 3 axial hardpoint screws and secured by the earthquake guards and radial supports.
12. Remove the north and west radial dial indicator assemblies.
13. Install both MCLA's onto the center section and mirror cell. Use the 1/4" guide pins to help install the upper MCLA pad first.
14. Take some load with the MCLA's.
15. Remove the 12 mirror cell flange bolts.
16. Lower the cell with the MCLA's. 2 persons should turn the MCLA handles, counting turns to keep the mirror cell level.
17. Lower the mirror cell onto the mirror insert tool so that the bottom of the cell is resting centered on the 3 posts of the mirror insert tool. DO NOT insert the legs of the tool into the holes in the cell yet.
18. Remove the earthquake guards.
19. Unscrew the 4 radial support push screws 6 turns each.
20. Disconnect the 16 radial counterweight assemblies by removing the clevis pins from the mirror blocks.
21. Use the 3 axial hardpoint screws to raise the mirror height 0.1". Be careful not to adjust any one hardpoint screw more than .025" (1/2 turn) each iteration, to avoid tipping the mirror and damaging the back support counterweight assemblies.
22. With a straight screwdriver, reach through the access ports on the bottom of the mirror cell and loosen the 3 spring plungers that keep the front defining bracket assemblies clamped on the mirror.
23. Remove the 3 front defining bracket assemblies by lifting on each assembly, gently pulling the top outward away from the mirror and rotating it 90 degrees to disengage it from the mirror. Do not lose the spring and 2 washers as each assembly is removed.
24. Remove the 3 axial dial indicator assemblies.
25. Install the 4 primary mirror guides evenly spaced around the flange of the primary mirror cell.
26. Use the MCLA's to raise the mirror cell 1/2" above the mirror insert tool, position the tool such that the 3 posts will go through the large holes in the bottom of the mirror cell.
27. Carefully lower the mirror cell with the MCLA's so that the mirror insert tool posts enter the 3 large holes in the bottom of the cell and contact the primary mirror. Continue to lower the cell around the mirror until there is no load in the MCLA's.
28. Protect the mirror as needed, then disconnect the MCLA's from the mirror cell and remove the north MCLA from the center section.
29. Roll the mirror insert tool, mirror, and cell to a safe position to the north of the center section.
30. Attach the spreader bar and ratchet hoist to the center section.
31. Roll the mirror insert tool back under the center section.

32. Sling the mirror with its lifting straps (in the primary mirror crate) and attach them to the ratchet hoist.
33. Lift the mirror.
34. Move the mirror insert tool and mirror cell away.
35. Position the open mirror crate below the mirror.
36. Lower the mirror into the crate and disconnect the mirror straps. Leave the mirror straps under the primary mirror in the crate.
37. Protect the mirror surface as needed and close the crate.
38. Clean the cell and cover it while it is out of service.

#### Primary mirror re-installation:

1. Install the spreader bar and ratchet hoist onto the bottom of the telescope center section. Use the 1/4" guide pins to help install 1 Mirror Cell Lifting Assembly (MCLA) onto the south side of the telescope center section.
2. Inventory the mirror cell parts: 12 stainless steel mirror cell bolts 3/8-24 x 1 1/4" long, primary light shield and flange, field corrector and corrector cell. 4 mirror cell flange guards, 3 front defining bracket assemblies, 3 axial dial indicator assemblies, 2 radial dial indicator assemblies, 16 radial counterweight clevis pins, and safety rings.
3. Prepare the primary mirror cell to receive the mirror: Set the top face of the 3 axial hardpoint screws to 1.75" above the inside surface of the mirror cell. Verify that the back support pads on the 36 back support counterweight assemblies are set to less than 1.55" above the inside surface of the mirror cell. Fully retract the 4 radial supports.
4. Position the primary mirror crate under the ratchet hoist.
5. Open the mirror crate, use the "X" mirror straps under the primary mirror to rig the primary mirror for lifting with the ratchet hoist.
6. Lift the primary mirror high enough to clear the mirror insert tool, then remove the mirror crate.
7. Position the mirror cell and mirror insert tool below the mirror.
8. Lower the mirror onto the insert tool. Verify that the north marks on the mirror and cell are aligned and that the mirror is centered over the cell.
9. Unhook the mirror straps from the hoist, then remove the mirror straps from under the mirror and store them in the mirror crate.
10. Move the mirror, cell and mirror insert tool away from the telescope center section.
11. Remove the spreader bar and hoist from the center section.
12. Screw the threaded 3/8-24 guide pins into 2 holes 180 degrees apart on the mirror cell bolt pattern on the center section. Do not tighten the guide pins.
13. Move the mirror, cell and mirror insert tool back under the telescope center section.
14. Use the 1/4" guide pins to help install the remaining MCLA onto the north side of the center section and attach both MCLA's to the mirror cell.

15. Install the 4 mirror insertion guides on the flange of the primary mirror cell.
16. Raise the mirror cell until the cell lifts the mirror off the insert tool and is clear of the mirror insert tool. Take care to align the north marks on the mirror and cell.
17. Remove the 4 mirror insertion guides.
18. Turn the mirror insert tool to a convenient orientation so that the cell will sit centered on top of the mirror insert tool, then lower the cell onto the mirror insert tool.
19. Install the 4 earthquake guards with the maximum gap between the primary mirror and guards.
20. Disassemble the primary light shield from the light shield flange, then install the field corrector cell into the light shield flange. Protect the field corrector with tissue paper taped to the edge of the cell.
21. Install the light shield flange and corrector cell (without the light shield) into the bottom of the primary mirror cell.
22. Use a 4" telescoping gage to measure the gap between the inside diameter of the primary mirror and the outside of the field corrector cell at approximately north, south, east and west. Use the radial supports to center the primary mirror in the cell until the gap between the mirror ID and field corrector OD are uniform to within .001".
23. Gently and uniformly tighten the 4 radial supports, then loosen them each  $\frac{1}{4}$  turn.
24. Remove the primary light shield flange, remove the protective tissue on the field corrector, and re-assemble the primary light shield onto the flange. Place the primary shield assembly aside.
25. Install the 3 axial dial indicator assemblies.
26. Refer to DFM drawing 621-155-1. Check that the Teflon tape on the 3 mirror retainers in the front defining bracket assemblies is intact. Replace the Teflon tape as required.
27. Install the 3 front defining bracket assemblies. Once the front defining bracket assemblies are seated on the edge of the primary mirror, use a straight screwdriver from below to carefully tighten the spring plungers until they stop, then back the spring plungers off  $\frac{1}{2}$  turn.
28. Install the 3 anti-rotation arm screws.
29. Refer to DFM drawing 621-011 to find the desired primary mirror height in the cell.
30. Use the provided depth micrometer to measure the distance from the mirror cell flange to the edge of the front surface of the primary mirror near each axial hardpoint screw.
31. Use the 3 axial hardpoint screws to set the mirror height to within .001" of the designed primary mirror height. Be careful not to adjust any one hardpoint screw more than .025" ( $\frac{1}{2}$  turn) each iteration, to avoid tipping the mirror and damaging the back support counterweight assemblies.
32. Set the 3 axial dial indicator assemblies to zero. These assemblies can now be used as a reference for the primary mirror location along the optical axis.

33. Adjust the length of the 16 connecting rod ends and adjusting nuts as required to set the radial counterweight assemblies at mid travel when the clevis pin is installed.
34. Lift the mirror cell with the MCLA's until it is slightly above the mirror insert tool.
35. Turn the mirror insert tool until the mirror insert tool posts are aligned with the large holes in the mirror cell.
36. Watch the 3 axial dial indicators and use the MCLA assemblies to slowly and evenly lower the mirror cell until the mirror insert tool posts just contact the mirror.
37. Watch the 3 axial dial indicators and lower the cell until the mirror is a maximum of 0.005 inches above the zero reference position. Now the cell may rotate independently of the mirror to allow alignment of the radial counterweight connecting rods and primary mirror blocks.
38. Insert the 16 clevis pins and safety rings to link the radial counterweight assemblies to the primary mirror blocks. Gently rotate the mirror cell as required.
39. Use the MCLA assemblies to lift the mirror cell slightly above the mirror insert tool.
40. Turn the mirror insert tool to a convenient orientation so that the cell will sit centered on top of the mirror insert tool, then lower the cell onto the mirror insert tool. Check the 3 axial dial indicator assemblies to see that the mirror position has returned to zero.
41. Use a 3/16" Allen wrench to reach through the slot in the 16 radial counterweight assembly covers and check the radial counterweights. Gently push each of the 16 radial counterweights outboard to verify that none of the radial counterweights will contact the mirror cell or cover. If any radial counterweights are at their travel limits adjust them for mid travel. If adjustment of the radial counterweight assemblies is needed, remove the clevis pins and adjust the threads of the rod ends or nuts as required, then re-install the clevis pins and safety rings.
42. Gently and uniformly tighten the 4 radial supports, then check the primary mirror centering again with the telescoping gage and dial calipers.
43. Repeat step 41 to insure that none of the radial counterweights are at travel limits.
44. Raise the primary mirror cell with the MCLA's, engaging first the invar rods and then the 3/8 guide pins. Continue raising the cell to within 1/4" of the center section. Start 10 mirror cell flange bolts.
45. Use the MCLA's to raise the cell into contact with the center section. Replace the 2 guide pins with mirror cell flange bolts, then tighten the 12 mirror cell flange bolts with the long leg of the 5/16" Allen wrench.
46. Remove the MCLA assemblies.
47. Install the 4 lower Invar rod bolts.
48. Install the 2 radial dial indicator assemblies and set them to zero.
49. Loosen the 4 radial support screws 1/2 turn.
50. Check that the 3 axial dial indicator assemblies still read zero.

*Note: Follow a systematic approach to adjusting the back supports so as not to overlook individual assemblies. Start adjusting the inner ring of 6 assemblies, then the middle ring of 12, then the outer ring of 18.*

51. Hold an 1/8" Allen wrench by the short leg to adjust the 36 back support screws. Start by adjusting a back support counterweight assembly near the center of the mirror cell, look at the assembly through the central hole in the mirror cell to see the workings of the mechanism. Tighten each back support screw until a slight increase in load is felt as the counterweight lifts up off the bottom of the cell. After 1/2 turn of the wrench the counterweight will contact the bottom of the primary mirror and the wrench will stop. From this position, unscrew with the wrench 1/4 turn. This will set the back support counterweight to mid travel.
52. As the back support assemblies become active the primary mirror will float up off the axial hardpoint screws approximately .010" as shown by the axial indicator assemblies.
53. Lower (unscrew) the 3 axial hardpoint screws 1 turn each.
54. See drawing # 621-155-3. On the bottom of the mirror cell, install the 3 slotted washers and 3 (brass) retainer nuts onto the studs of the 3 front defining bracket assemblies.
55. Use the 3/8" nut driver to tighten the 3 retainer nuts evenly until the primary mirror floats down .005" as shown by the 3 axial dial indicator assemblies.
56. Repeat step 51 to reset the back support counterweight assemblies to mid travel.
57. Use a 3/8" nut driver to tighten the 3 retainer nuts until the primary mirror is pulled down to zero position as shown by the 3 axial indicator assemblies.
58. Tighten the 4 radial support screws 1/2 of one wrench flat (1/12 turn) beyond where the load stops the screw, take care not to translate the primary mirror more than .001" (as shown by the 2 radial dial indicator assemblies).
59. Carefully raise (tighten) the 3 axial hardpoint screws until the 3 axial dial indicator assemblies show the hardpoints contacting the primary mirror, then lower (unscrew) each hardpoint until the wrench starts to turn freely.
60. Set the 4 earthquake guards .003" above the edge of the mirror. Use the .003 feeler gage (through the port below each earthquake guard) to insure the guards are not touching the primary mirror.

*Note: The primary mirror should now have its weight distributed equally between the 36 back support assemblies while pointing at the zenith. The 16 radial counterweight assemblies and 4 radial supports support the primary mirror when the telescope is pointing near the horizon. When adjusted properly, the axial hardpoint screws, earthquake guards and radial supports work together to*



*constrain the primary mirror during earthquakes or overturning events but not distort the primary mirror during normal operation.*

61. Install the 4 earthquake guard port covers on the side of the mirror cell. Install the 36 back support covers and 3 defining bracket assembly covers on the bottom of the mirror cell.
62. Install the primary light shield and field corrector assembly.
63. Install secondary mirror assembly if required.
64. Install SAG and instruments.
65. Balance the telescope.
66. Proceed to "Collimation".

#### **4.6.2 SECONDARY MIRROR**

Secondary mirror removal.

Refer to the Secondary mirror assembly drawing 621-018.

*Note: To avoid a dangerous top heavy condition, the focus housing assembly should only be installed or removed when the primary mirror and cell are on the telescope.*

1. Remove the 4 Invar rod bolts on the bottom of the primary mirror cell.
2. Install the RA and DEC lock pins to secure the telescope at the North service position.
3. Rig the secondary service hoist, come-a-long, and focus stand (DFM drawing 621-191).
4. Move the motorized center section counterweights up to their top-heavy limits or the highest counter value.
5. Disconnect the focus housing cables at the truss ring.
6. Position the hoist above the spyder ring. Rig the spyder ring to the hoist with the 1" nylon webbing sling provided.
7. Raise the hoist to take a load on the secondary assembly.
8. Loosen the 4 flex-link bolts one turn each. Note: As the flex-link bolts are loosened and removed be prepared to adjust the hoist to minimize the strain on the flex-links.
9. Remove the flex link bolts and unscrew the INVAR rods from the spyder vanes.

10. The focus assembly should now be free from the telescope and hanging from the hoist. Use the come-a-long to pull the secondary assembly away from the telescope (to the north) until the light shield clears the truss ring.
11. Lower the secondary assembly onto the focus stand.
12. Use the strut on the focus stand to lock the spyder ring with the mirror facing up.
13. Open the secondary mirror crate to find the secondary mirror sling. Prepare the crate and sling to accept the mirror.
14. Remove the secondary light shield.
15. Remove the secondary mirror hub and carefully slip the secondary mirror sling under the secondary mirror.
16. Rig the secondary mirror and sling onto the hoist, and then lift the secondary mirror. Replace the secondary service stand with the secondary mirror crate and lower the secondary mirror into the crate.
17. Protect the mirror surface as needed and close the crate.
18. Clean the focus housing with glass cleaner and clean towels. Cover it while it is out of service.

Secondary mirror re-installation.

Refer to the Secondary mirror assembly drawing 621-018.

*Note: To service the focus housing the telescope RA and DEC lock pins must be installed to lock the telescope in the north service position.*

1. Install the secondary service hoist in position above the telescope truss ring.
2. Remove the 4 Invar rod bolts from the bottom of the primary mirror cell.
3. Inventory the secondary mirror assembly parts, note that some parts may be stored in the secondary mirror crate: secondary mirror hub, 6ea.10-32 x 4" long stainless soc cap screws, wave spring washer, laser collimation tool and mounting screws, mirror hub cover, secondary light shield and mounting screws, 4 flex links and screws.
4. Check that the focus assembly is locked on the secondary service stand with the mirror back plate up. Set the wave spring washer in place on the mirror back plate.
5. Check the condition of the Teflon tape on the secondary mirror hub. The secondary mirror hub flange should have a uniform, wrinkle-free layer of .003-.005 Teflon tape where it contacts the mirror. The 2.840" diameter of

- the secondary mirror hub should have 3, equally spaced, 3/4" squares of .003-.005 Teflon tape set 1" from the contact flange.
6. Open the secondary mirror crate and prepare the secondary mirror for lifting. The secondary mirror sling should be in the crate under the secondary mirror. Rig the mirror for lifting.
  7. Lift the secondary mirror from the crate.
  8. Swap the secondary mirror crate for the secondary service stand and set the secondary mirror on to the focus housing.
  9. Unhook the mirror sling from the hoist and, by gently tipping the mirror, slide the mirror sling out from under the mirror and centering hub. Put the secondary mirror sling in the secondary mirror crate, close the crate and set it aside.
  10. Install the secondary mirror hub.
  11. Install the 6 #10-32 x 4" long screws that secure the secondary mirror hub to the mirror back plate. Make sure the wave spring is seated properly. Torque the screws as tight as possible *by hand with the short leg of an "L" shaped Allen wrench*.
  12. Rotate the secondary mirror to align the north marks on the mirror and focus housing.
  13. Use a feeler-gage set to measure the gap between the focus housing back plate and mirror back plate. Adjust the gap, when measured near each adjusting screw, to be uniform to within .002". To pre-load the back plates, reduce the thickness of the feeler gage stack .020" and tighten the 4 adjusting screws to reduce the gap to this value.
  14. Install the secondary light shield and cover the shield to protect the mirror until installation.
  15. Rig the spyder ring to the hoist with the 1" nylon webbing sling. Be sure to hoist the focus housing with the south side up. Rig the come-a-long to out-haul the focus assembly.
  16. Use the come-a-long to pull the focus assembly away from (to the north of) the truss ring while it is hoisted into place. Hoist the spyder ring into position north the telescope truss ring.
  17. Adjust the hoist and come-a-long to move the focus assembly south into position to start the Invar rods.
  18. Start the threaded studs on the ends of the 4 Invar rods into the corresponding threaded holes in the spyder vanes. Tighten the 4 Invar rods and then back them off 1 turn.
  19. Install the 4 flex links between the truss ring and spyder ring.
  20. Install the 4 Invar rod bolts in the bottom of the mirror cell.

21. Use a 5/8" combination wrench to tighten the 4 Invar rods against the spyder vanes.
22. Use a 3/16 Allen driver to tighten the 8 flex link screws and 4 Invar rod bolts in the mirror cell.
23. Disconnect the hoist, come-a-long, and 1" nylon webbing sling.
24. Connect the 8 focus control cables.
25. Move the motorized center section counterweights down to zero on the counters.
26. Check the coarse balance of the DEC axis by trying to raise and lower the spyder ring by hand. Use the motorized counterweight assemblies to adjust the DEC axis balance until the DEC axis will remain where it is placed (not creep away).
27. Remove the lock pins and balance the telescope.
28. Proceed to "Collimation".

## ALUMINIZING

The mirrors should be re-aluminized at 3 to 5 year intervals depending on the atmosphere (pollution) at individual sites and user requirements.

### 4.7 POINTING MODEL

The pointing model program is used to determine the values of correction constants used by the TCS to point the telescope. The constants are changed in the initialization file on disc. This file is read by TCS when the program is executed. This file is named WinTCS.DAT.

The Data required is:

TR	TELESCOPE RA
TD	TELESCOPE DEC
SR	ACTUAL PUBLISHED RA
SD	ACTUAL PUBLISHED DEC
TH	TELESCOPE HA

The Display Epoch should be set to the same epoch as the star data.

Data may be recorded with TCS. Initialize the telescope coordinates on a star near the zenith and record this first star. Take a set of data from stars that lie near the meridian (near zero Hour Angle), this is called the DEC sweep. Take a second set of data near the equator (near zero DEC), this is called the RA sweep. Stars should be about 10 or 15 degrees apart, and can be found easily in the Bright Star Catalog of "The Astronomical Almanac". These two sweeps across the sky are important because they isolate the pointing model

terms. About 20 stars are sufficient for analysis. TCS includes commands that allow these data to be taken and stored on the hard disk for subsequent analysis. The Save Point Data dialog contains methods for saving pointing data to a file.

**\*\*\*\*\* NOTE!! \*\*\*\*\***

The first star in the data must be a star recently used to initialize the telescope position for valid error calculations. For this star the Published and Telescope values for RA and DEC are very nearly the same.

After pointing data is stored on disk, run the program WinPNTM. The pointing model program will begin by asking you to open a pointing data file.

WinPNTM requests values for the constants and then calculates the pointing errors. The program repeats allowing new constants to be tried in an iterative manner until the user is satisfied. In addition to the pointing model coefficients, other initialization values (for example site Latitude) may be changed using PNTM. As an option, PNTM will update the initialization file.

Analyze the graphs to determine the values of the coefficients.

DEC VS. DEC This graph shows the DEC scale factor in its slope. The asymmetric terms are refraction and tube flexure. For a telescope with an on axis Dec encoder, the curvature is DEC encoder eccentricity.

RA vs HA This graph shows the RA scale factor in its slope. The asymmetric term is refraction. Symmetric shape is polar axle twist and offset, (encoder eccentricity and phase angle for an on-axis encoder).

DEC vs HA This graph shows the elevation and azimuth misalignment of the polar axle. The elevation is curvature, and the azimuth is slope.

HA vs DEC This graph shows the collimation and non perpendicularity of the DEC and Polar axes. Collimation is curvature and non perpendicularity is slope.

It is desirable for the physical misalignments to be small before the computer model is calibrated because the interaction of terms will then be small. The drift test for azimuth and elevation should be at the level of a few arc seconds of drift in one half hour or better. Large collimation errors (greater than 25 seconds of time) should be corrected mechanically by adjusting the tip-tilt of the primary mirror. Refraction can be adjusted in software to compensate for the altitude and temperature of the site. The tube flexure and non perpendicularity terms are mechanical characteristics of the mount.

The terms have units as follows:

SCLRA	ARCSEC/DEG	RA scale factor
SCLDEC	ARCSEC/DEG	DEC scale factor

ME	ARCSEC	elevation misalignment (+ = above pole)
MA	ARCSEC	azimuth misalignment (+ = NW--SE)
CH	SEC	optical collimation
NP	SEC	non-perpendicularity of RA & DEC axis
TFLX	ARCSEC	tube flexure
TBAR	NONE	temp & pressure coefficient (refraction)
TWIST	SEC	polar axle twist
TWISTOFF	DEG	offset of polar axle twist
ECCDEC	ARCSEC	Dec encoder eccentricity
PHADEC	DEG	Phase angle of Dec eccentricity

This is a physical model and each term has real significance that is directly related to some aspect of the telescope mount. The determination of constants should be done in a methodical way that isolates individual terms by working on the shapes of the graphs. Attempts to minimize the overall error with any single term will result in poor pointing. Each term should be adjusted to remove the corresponding slope or curvature.

Before you get started on a new installation, make sure all the terms in the TCS pointing model are zero and the encoder scale factors are about theoretical. Make sure site specific data are correct. TBAR should be a number between 1.0 for sea level and .75 for 7000 feet above sea level. At higher altitudes, TBAR should be smaller.

For setting up a new telescope:

1. Adjust the elevation with a bubble level protractor. Adjust the azimuth with a sighting of the north star (eyeball method).
2. Use the drift test to do the rough alignment using a reticle eyepiece or CCD camera.
3. Take pointing data (the DEC and RA sweeps).
4. Run the pointing model programs and determine the coefficients.
5. If the residual misalignments for azimuth or elevation are larger than 60 arc seconds, dial off the error mechanically using a magnetic base and dial indicator. Additional drift alignment should be performed to verify the sense (direction) of the residual alignment errors.
6. Take a second set of data, and determine the coefficients.
7. Take more data to confirm the pointing performance.

In a pointing tune-up of an established telescope there may be no need to correct the azimuth or elevation alignment if the mount has not been moved. There should never be a need to adjust the ratios for the encoder drives unless the friction drive surfaces have been reground. For a telescope with on-axis encoders, the encoder offset and eccentricity terms may change if the encoder has been adjusted. The non-perpendicularity will be a constant for the life of the mount unless the DEC bearing housings are shimmed or

machined. A common problem is the model needing adjustment in collimation due to primary mirror movement after washing.

#### 4.8 INITIALIZATION FILES

The TCS initialization file is named WinTCS.DAT. This file contains the pointing model data and other data required by TCS. The files are ASCII data files and they may be modified with a text editor. The program PNTM can be used to modify WinTCS.DAT or the file may simply be edited. The following list shows the contents of WinTCS.DAT with a description for each entry.

LATITUDE:= 39.25	site latitude degrees
LONGITUDE:= 76.709	site longitude degrees
TBAR:= 0.95	site temperature and pressure coefficient
ME:= 60.0	polar elevation misalignment
MA:= 0.0	polar azimuth misalignment
CH:= 0.0	optical collimation misalignment
NP:= 0.0	non-perpendicularity of RA and DEC axes
TWIST:= 0.0	polar axle twist
TWSTOF:= 0.0	polar axle twist offset
ECCDEC:= 0.0	DEC encoder eccentricity
PHADEC:= 0.0	DEC eccentricity phase angle
TFLX:= 0.0	tube flexure
HOME:= 268.	dome home position
ZDMAX:= 75.0	maximum zenith distance for automatic slew
XMTR:= 0.0920100	RA axis motor step size arcsec/step
YMTR:= 0.0927	DEC axis motor step size arcsec/step
DOMERATIO:= 3.08E-6	dome encoder ratio radians/encoder unit
HARATIO:= 1.163663	RA axis position encoder ratio arcsec/eu
DECRATIO:= 1.0125	DEC axis position encoder ratio arcsec/eu
UTRATIO:= 3.59137036E5	universal time clock scalar interrupts/hour
GAP:= 15.0	dome gap (telescope-dome aperture)/2 inches
RDOME:= 120.0	dome radius inches
WINDOW:= 2.5	dome control algorithm target window degrees
COAST:= 2.5	dome coast distance degrees
FOCRATIO:= 0.2633	focus encoder ratio
FIDHA:= 0.25	HA offset real hours

FIDDEC:= 31.0	DEC offset real degrees
HAPOTTOFF:= 2075	HA absolute position pot offset (not used)
FIDDEC:= 2044	DEC absolute position pot offset (not used)

## **5.0 TROUBLE SHOOTING**

### **5.1 ROLLER SLIPPAGE**

If the telescope is out of balance, or the telescope contacts some obstruction the hardened steel roller-disc interface may slip.

### **5.2 MOTOR RUNAWAY**

If the servomotors run out of control when the motor driver chassis is turned on, and the HALT MOTORS button is enabled, the most likely problem is that the servo control system is not getting motor encoder feedback. Check the motor encoder cables on the motor driver chassis and at the axis drive cover for dislodged pins or other failure. Inside the drive cover, check the connector on the encoder on the back of the motor. If all connectors are OK then there is a failure in the encoder 5 volt power, component failure on the servo control card, or an encoder failure on the motor shaft. Repair of non connector failure modes should be made by an experienced technician or a representative of DFM Engineering Inc.

### **5.3 BAD COLLIMATION**

Check that the primary mirror radial supports are just snug and not tight. Check for instrument attachment screws that are too long. If the tube assembly has an excursion past the limit switch or past horizontal, the primary mirror may have rocked forward and not settled back onto the back supports properly. To fix this, loosen two of the radial supports at 90 Deg. and then retighten these until they are just snug.

### **5.4 BAD POINTING**

Check the Universal time (UT) and the date on the TCS display. Verify the setup star. Check for mechanical problems with the optics. Follow instructions for tuning up the pointing model.

## **6.0 APPENDICES**



## 6.1 TCP/IP & EXCOM DOCUMENT

6 March 2002

DFM ENGINEERING, INC.  
BY MARK S. KELLEY

This document is a supplement to the Operations Manual and it describes the DFM external computer interfaces (TCP/IP & EXCOM). This is not the Astronomical Command Language (ACL) interface. The ACL interface, TCP/IP and the EXCOM interfaces are resident in WinTCS.

### EXTERNAL COMPUTER

To use the standard DFM External Computer Interface (EXCOM) or the TCP/IP interface they must be activated using the communications menu in WinTCS. The external computer is user supplied and interfaces to the telescope controller through a serial port (EXCOM) or the ethernet network card (TCP/IP). This feature is designed to provide a telescope control system that can be slaved to a data acquisition computer or general observatory computer used to provide a customer provided interface to the telescope control system. The program PCEXCOM.XPL is an example of an external computer user interface.

The commands used by the external computer are the same as those used by WinTCS. The commands are given here in numerical order with the input and output shown for the excom users information. All I/O is character I/O. The WinTCS serial port is selectable. The port setup is 9600 Baud, 8 data bits, 1 stop bit, no parity. Transmit, receive and ground are required. The external computer (user supplied) may have special requirements for serial port control lines. For example, DOS machines typically require jumpers between pins 4 & 5 and that 6, 8 and 20 be jumpered together. Command numbers are all integers. Interrogation of the status integers will reveal command status. TCS does not store up commands. Commands will be ignored if a previous command is still in progress. The TCP/IP connection uses standard ethernet technology. Ports must be set in WinTCS as well as in the client. The TCP/IP commands are packetized and begin with "#", subsequent numbers are separated with "," and packets are terminated with ";". For an example a SLEW command sent over the TCP/IP interface looks like: #6,18.3457,35.3456,2002.5; To summarize, the TCP/IP commands are like EXCOM commands except send a "#" first, use "," instead of the <cr> to separate values, and end with a ";". WinTCS will return the same strings to the external computer running TCP/IP as it does to the external computer running EXCOM except the characters will be packetized with a leading "#", number separators will be "," and the last character will be a ";".

FOR ALL OF THESE DESCRIPTIONS <CR> DENOTES THE CARRIAGE RETURN CHARACTER HEXADECIMAL \$0D.

**UPDATE            COMMAND 1            INITIALIZE / UPDATE TIME AND DATE**

THIS PROCEDURE INITIALIZES THE FOCUS ENCODER, SETS THE CLOCKS AND WILL INITIALIZE COORDINATES TO THE ZENITH IF THE SYSTEM IS NOT YET UPDATED. INITIALIZES DATE AND TIME IF SYSTEM IS INITIALIZED.

EXCOM SENDS	CHARACTERS	COMMENTS
	1 <CR>	COMMAND #
	1994.0 <CR>	YEAR
	11. <CR>	MONTH
	22. <CR>	DAY
	17.123456 <CR>	UNIVERSAL TIME (REAL HOURS)
TCS RESPONDS	NO RESPONSE	INITIALIZES FOCUS ENCODER INITIALIZES TELESCOPE POSITION SETS TIME & DATE. AFTER FIRST INITIALIZATION, SETS TIME & DATE ONLY.

\*\*\* Initialization \*\*\*

Set date and time (UPDATE): This command calculates sidereal time based on input of the date and universal time. TCS Time is kept in a hardware clock that runs at 200 Hz. The PC Computer has a battery backed up clock that is reset along with the date when the update command is executed. If zero is entered for the year in the update command the program gets the time and date from the battery backed up clock in the PC.

The clocks are updated and the telescope position will be at its last position (UPDATE). After initialization, the status INITIALIZED will appear on the display screen.

**ZDOME COMMAND 2**

INITIALIZE THE DOME ENCODER

EXCOM SENDS	CHARACTERS	COMMENTS
	2 <CR>	COMMAND #
	270. <CR>	POSITION (0.-->360.)
TCS RESPONDS	NO RESPONSE	SETS DOME UP DOWN COUNTER

Set dome position (ZDOME): This command is used to initialize the dome position. North is zero azimuth, and azimuth increases clockwise looking down on the dome. If zero is entered as the dome azimuth, TCS will set the dome azimuth based on the telescope position.

**ZPOINT      COMMAND 3**

SET OFFSETS FOR THE RA AND DEC POSITION ENCODERS  
ENTER ZEROS FOR NEXT OBJECT

EXCOM SENDS	CHARACTERS	COMMENTS
	3 <CR> 12.012345 <CR> 12.345678 <CR> 1950. <CR>	COMMAND # RA (HOURS) DEC (DEGREES) EPOCH
TCS RESPONDS	NO RESPONSE	SETS TELESCOPE POSITION TO RA, DEC DOES NOT MOVE TELESCOPE

Set telescope position (ZERO POINT): This command sets the position of the telescope.  
Three ZERO's will set the telescope position display to the next object coordinates.

**Spare      COMMAND 4**

Spare

EXCOM SENDS	CHARACTERS	COMMENTS
	4 <CR> 0 <CR>	COMMAND #

TCS RESPONDS      NO RESPONSE

**ZFOCUS      COMMAND 5**

INITIALIZE THE FOCUS POSITION

EXCOM SENDS	CHARACTERS	COMMENTS
	5 <CR> 2000.1 <CR>	COMMAND # POSITION (0.-->4096.0)
TCS RESPONDS	NO RESPONSE	SETS FOCUS UP DOWN COUNTER

Set focus position (ZFOCUS): This command is used to initialize the focus position display.  
The focus is an absolute pot. This command offsets the focus display to the input value.

### **SLEW COMMAND 6**

SETS UP AUTOMATIC SLEW  
CHECKS DESTINATION COORDINATES FOR HORIZON  
SETS NEXT OBJECT COORDINATES  
CONVERTS FROM NEXT OBJECT EPOCH TO DISPLAY EPOCH IF REQUIRED  
CONVERTS FROM APPARENT COORDS (EPOCH = -1) TO MEAN COORDS IN  
DISPLAY EPOCH IF REQUIRED

EXCOM SENDS	CHARACTERS	COMMENTS
	6 <CR>	COMMAND #
	12.012345 <CR>	RA (HOURS)
	12.345678 <CR>	DEC (DEGREES)
	1950. <CR>	EPOCH
TCS RESPONDS	NO RESPONSE	ENABLES SLEW TO RA, DEC

Set slew position (SLEW): This command prepares TCS to automatically slew the telescope to the coordinates specified. The EPOCH will be the display epoch if a ZERO is received. If the telescope is not tracking, the slew may never terminate because the Earth's rotation is faster than the final automatic guide speed. After the slew is ENABLED (status bit set) by COMMAND 6, a COMMAND 12 (GO) is required to initiate the slew. If the coordinates are below the telescope horizon, the TARGET OUT OF RANGE status bit will be set.

### **OFFSET COMMAND 7**

OFFSETS ARE MOTIONS IN ARC SECONDS FROM THE TELESCOPE MEAN COORDINATES IN THE DISPLAY EPOCH.

EXCOM SENDS	CHARACTERS	COMMENTS
	7 <CR>	COMMAND #
	100. <CR>	OFFSET RA (ARC SECONDS + = EAST)
	150. <CR>	OFFSET DEC (ARC SECONDS + = NORTH)
TCS RESPONDS	NO RESPONSE	ENABLES SLEW TO OFFSET

Set offset (OFFSET): This is a slew to coordinates relative to the present coordinates in the display epoch. Input is in seconds of arc. The speed of the offset is a function of the distance to be offset and not specified by the user. Status bits for ENABLED and TARGET OUT OF RANGE apply. COMMAND 12 must be sent to move telescope.

**OBJECT      COMMAND 8   SLEW TO OBJ WITH LOOKUP**

SLEW TO LIBRARY OF OBJECTS

EXCOM SENDS	CHARACTERS	COMMENTS
	8 <CR> 13 <CR>	COMMAND # LIBRARY #
TCS RESPONDS	NO RESPONSE	ENABLES SLEW TO LIBRARY OBJECT

Select library object (OBJECT): This is a slew to a library of objects that are stored in the computer memory. All objects are stored in epoch 2000. The objects are the Sommers-Bausch Observatory Catalog of Astronomical Objects and a printout of the catalog is supplied with the telescope. The catalog includes a set of ephemeris stars at one hour intervals that are useful for initializing the telescope position in the northern hemisphere. A library for southern hemisphere users as well as custom libraries are available. Check the status bits for ENABLED and TARGET OUT OF RANGE. A COMMAND 12 must be sent to move the telescope.

**TMOVE      COMMAND 9**

PROCEDURE SLEWS TO AN OBJECT PREVIOUSLY STORED WITH THE MARK COMMAND

EXCOM SENDS	CHARACTERS	COMMENTS
	9 <CR> 32 <CR>	COMMAND # TABLE #
TCS RESPONDS	NO RESPONSE	ENABLES SLEW TO TABLE ENTRY

Select table entry (MOVE): This command is the partner of the Set table entry (MARK) command in the Miscellaneous submenu. Select table entry is used to slew to locations previously stored in memory with the Set table entry command. There are 40 entries possible. Check the status bits for ENABLED and TARGET OUT OF RANGE. A COMMAND 12 must be sent to move the telescope.

**ZENITH      COMMAND 10**  
SLEWS THE TELESCOPE TO THE ZENITH

EXCOM SENDS	CHARACTERS	COMMENTS
	10 <CR>	COMMAND #
TCS RESPONDS	NO RESPONSE	ENABLES SLEW TO ZENITH

Set zenith position (ZENITH): This command is used to slew the telescope to the Zenith. Use TRACK, COMMAND 14 to set the track rates to zero before the zenith command is used. Failure to set track speed to zero may result in an un-terminated slew to zenith because the earth's rotation is faster than the automatic guide speed. Recover from an un-terminated slew with STOP COMMAND 13. Status bits for ENABLED and TARGET OUT OF RANGE apply. COMMAND 12 must be sent to move telescope.

**TRAIL      COMMAND 11**

START TRAIL

EXCOM SENDS	CHARACTERS	COMMENTS
	11 <CR>	COMMAND #
TCS RESPONDS	NO RESPONSE	BEGINS TRAILING

Start trail (TRAIL): This command turns the trail function ON. STOP COMMAND 13 or the CANCEL button on the front panel are used to end trailing. Guide while trailing is allowed, so it may be a good idea to stop any autoguider inputs while trailing.

**GO COMMAND 12**  
INITIATE MOTION COMMANDS

EXCOM SENDS	CHARACTERS	COMMENTS
	12 <CR>	COMMAND #
TCS RESPONDS	NO RESPONSE	BEGINS AUTOMATIC MOTION

Start slew (GO): This command starts automatic slews.

**STOP COMMAND 13**  
CANCELS AUTO SLEW IN PROGRESS  
CANCELS SLEW ENABLED IF MOTION NOT BEGUN  
THIS COMMAND CANCELS AUTOMATIC MOTIONS AND COMMANDS

EXCOM SENDS	CHARACTERS	COMMENTS
	13 <CR>	COMMAND #
TCS RESPONDS	NO RESPONSE	STOPS AUTOMATIC COMMAND

Stop (STOP): This command is used to cancel automatic motion commands.

**TRACK      COMMAND 14**  
CHANGE TRACK RATE RA & DEC

EXCOM SENDS	CHARACTERS	COMMENTS
	14 <CR>	COMMAND #
	15.002. <CR>	RA RATE (ARC SECONDS/SECOND)
	.05 <CR>	DEC RATE (ARC SECONDS/SECOND)
	14.545 <CR>	AUX RA RATE (ARC SECONDS/SECOND)
	0. <CR>	AUX DEC RATE (ARC SECONDS/SECOND)
TCS RESPONDS	NO RESPONSE	CHANGES TRACK RATES

Set track rate (TRACK RATE): This command allows modification of both RA and DEC track rates. There is provision for an auxiliary track rate that is useful if comparisons are to be made between sidereal and non- sidereal objects. The auxiliary track rate is selected with a front panel switch. For external computer operation, the track rate may simply be changed with the track rate command for rapid changes. Positive DEC rate is north.

**GUIDE      COMMAND 15**  
CHANGE THE GUIDE RATE RA & DEC

EXCOM SENDS	CHARACTERS	COMMENTS
	15 <CR>	COMMAND #
	7. <CR>	RATE (ARC SECONDS/SECOND)
TCS RESPONDS	NO RESPONSE	CHANGES GUIDE RATE

Set hand paddle GUIDE rates: Guide is a traditional hand paddle function with rates superimposed on the track rate. Speeds between 3 and 10 arc seconds per second are recommended. The response of TCS to guide inputs may be adjusted with the GUIDE command. An autoguider may require specific rates.

**SET      COMMAND 16**  
CHANGE THE SET RATE FOR RA & DEC

EXCOM SENDS	CHARACTERS	COMMENTS
	16 <CR>	COMMAND #
	200.0 <CR>	RATE (ARC SECONDS/SECOND)
TCS RESPONDS	NO RESPONSE	CHANGES SET RATE

Set hand paddle SET rates: SET is similar to GUIDE and convenient values are 50 to 300 arc seconds per second.

**TRAIL COMMAND 17**

SET TRAIL RATE, LENGTH, &amp; ANGLE

EXCOM SENDS	CHARACTERS	COMMENTS
	17 <CR> 200.0 <CR> 50. <CR> 0. <CR>	COMMAND # RATE (ARC SECONDS/SECOND) LENGTH (ARC SECONDS) POSITION ANGLE (NORTH) (90. EAST)
TCS RESPONDS	NO RESPONSE	CHANGES TRAIL RATES

Set trail rates (TRAIL RATES): This command sets up the parameters for the trail function. Trail moves at a predetermined rate between two pre-calculated endpoints. This function is used to move an object back and forth along the slit in a spectrograph. Hand paddle guide while trailing is supported.

**COSDEC COMMAND 18**

TURN ON FUNCTION THAT DIVIDES THE COMMANDED RA HAND PADDLE RATE BY THE COSINE OF THE DECLINATION. SPEED CLIPS AT SLEW SPEED

EXCOM SENDS	CHARACTERS	COMMENTS
	18 <CR> 0 <CR>	COMMAND # STATUS (OFF) (1 ON)
TCS RESPONDS	NO RESPONSE	CHANGES COSDEC STATUS BIT

(COSDEC): This command turns on a feature that divides commanded Right Ascension hand paddle rates by the cosine of the Declination so that the motion of the object in the eyepiece is constant.

**RATECOR COMMAND 19**

TURN ON TRACK RATE CORRECTION FUNCTION

EXCOM SENDS	CHARACTERS	COMMENTS
	19 <CR> 0 <CR>	COMMAND # STATUS (OFF) (1 ON)
TCS RESPONDS	NO RESPONSE	CHANGES CORRECTION STATUS BIT

(RATECOR): This command turns on the track rate correction feature of the control system. Rate corrections are calculated by differentiating the pointing model and these corrections may be automatically applied to the track rates.



**DOME            COMMAND 20**

THE DOME ON-OFF FLAG INTERACTS WITH THE FRONT PANEL SWITCH. IF THE SWITCH IS ON, THE COMMAND CAN TURN THE DOME ON OR OFF, IF THE SWITCH IS OFF, THE DOME IS OFF AND THIS COMMAND IS IGNORED

EXCOM SENDS	CHARACTERS	COMMENTS
	20 <CR> 0 <CR>	COMMAND # STATUS (OFF) (1 ON)
TCS RESPONDS	NO RESPONSE	CHANGES DOME STATUS BIT

(DOME): This command is used to enable or disable dome function from the EXCOM.

**GUIDER            COMMAND 21**

THIS COMMANDS THE DOME CONTROL ALGORITHM TO SEND THE DOME HOME OR TO TRACK THE TELESCOPE. THE FRONT PANEL SWITCH MUST BE IN THE HOME POSITION.

EXCOM SENDS	CHARACTERS	COMMENTS
	21 <CR> 0 <CR>	COMMAND # STATUS (TRACK) (1 HOME)
TCS RESPONDS	NO RESPONSE	SETS DISPLAY MESSAGE

(GUIDER): This command is a convenience to the user to set the dome HOME/TRACK switch in the desired position from the EXCOM. A 1 will send the dome home; a 0 command the dome to track the telescope azimuth.

**DOEPOCH            COMMAND 22**

SET THE DISPLAY EPOCH

EXCOM SENDS	CHARACTERS	COMMENTS
	22 <CR> 2000.0 <CR>	COMMAND # EPOCH
TCS RESPONDS	NO RESPONSE	CHANGES DISPLAY EPOCH

Set display epoch (EPOCH): The display epoch may be set to any value by the menu.

**MARK                    COMMAND 23**  
 STORE R.A., DEC. & EPOCH INTO THE MARK TABLE AT INDICATED POSITION

EXCOM SENDS	CHARACTERS	COMMENTS
	23 <CR>	COMMAND #
	1. <CR>	TABLE #
	21.000000 <CR>	RA
	12.000000 <CR>	DEC
	2000.0 <CR>	EPOCH
TCS RESPONDS	NO RESPONSE	MAKES ENTRY IN TABLE

Set table entries (MARK): The Set table entries command is used to set up a list of coordinates that may be slew destinations using the Select table entry (MOVE) command. An entry number and three ZERO's are sufficient to mark the present telescope location. There are 40 entries possible. The table is initialized to zeros.

**COEFFICIENTS                    COMMAND 24**  
 CHANGE TELESCOPE AND POINTING MODEL PARAMETERS FROM EXCOM

EXCOM SENDS	CHARACTERS	COMMENTS	UNITS
	24 <CR>	COMMAND #	
	120. <CR>	ME	(ARC SECONDS)
	35. <CR>	MA	(ARC SECONDS)
	10. <CR>	CH	(SECONDS OF TIME)
	3. <CR>	NP	(SECONDS OF TIME)
	.8 <CR>	TBAR	(NO UNITS 0-1)
	10. <CR>	TFLX	(ARC SECONDS)
	.000019673 <CR>	HARATIO	(HOURS / ENC. UNIT)
	.00027743 <CR>	DECRATIO	(DEG. / ENC. UNIT)
TCS RESPONDS	NO RESPONSE	TCS CHANGES THE VARIABLES	

Set model coefficients (COEFFICIENTS): This command is used for testing, or for updating the coefficients from the external computer.

**COORDS      COMMAND 25**

RETURN TELESCOPE COORDINATES, TIME AND DATE TO THE EXCOM

EXCOM SENDS	CHARACTERS	COMMENTS	UNITS
	25 <CR>	COMMAND #	
TCS RESPONDS		EIGHT REAL NUMBERS FOLLOWED BY CARRIAGE RETURNS	
	2.034567 <CR>	HA	
	20.234567 <CR>	RA	
	33.345674 <CR>	DEC	
	1994.5 <CR>	EPOCH	
	1.3456 <CR>	AIRMASS	
	22.034523 <CR>	SIDEREAL TIME	
	5.234153 <CR>	UNIVERSAL TIME	
	1994.82345 <CR>	YEAR	

COORDS: TCS sends the telescope coordinates out over the serial port to the external computer.

**STAT      COMMAND 26**

EXCOM SENDS	CHARACTERS	COMMENTS	
	26 <CR>	COMMAND #	
TCS RESPONDS	2345 <CR>	STATL	THREE STATUS INTEGERS
	0023 <CR>	STATH	
	1034 <CR>	STATLH	

STATUS: This command is like COORDS except it sends the three status bytes out over the serial port to the external computer.

Status Byte Assignments:

BYTE	BIT	DESCRIPTION
STATL	0	INITIALIZED
	1	GUIDE ON/OFF
	2	TRACK ON/OFF
	3	SLEW ENABLED
	4	DOME ON/OFF
	5	APPROACHING LIMIT
	6	FINAL LIMIT
	7	SLEWING
STATH	0	SETTING
	1	TRAILING
	2	EXCOM ON/OFF
	3	DOME OK
	4	TARGET OUT OF RANGE
	5	COSDEC ON/OFF
	6	RATE COR ON/OFF
	7	DRIVES ON/OFF

STATLH	0	SLEW COMPUTING
	1	DOME TRACK / FREE
	2	"N"
	3	"S"
	4	"E"
	5	"W"
	6	NEXT OBJECT ACTIVE
	7	AUX. TRACK RATE

**AFOCUS      COMMAND 27**

SLEW TO FOCUS

EXCOM SENDS	CHARACTERS	COMMENTS
	27 <CR>	COMMAND #
	2000.0 <CR>	DESIRED FOCUS
TCS RESPONDS	NO RESPONSE	TCS SLEWS TO FOCUS

Move to Focus (AFOCUS): This command slews the focus ram to an encoded focus position.

**POINT      COMMAND 28**

RETURN POINTING MODEL POSITION DATA TO THE EXCOM

EXCOM SENDS	CHARACTERS	COMMENTS
	28 <CR>	COMMAND #
TCS RESPONDS		FIVE REAL NUMBERS SEPARATED BY CARRIAGE RETURNS
	2.345678 <CR>	NEXT OBJECT RA
	25.012345 <CR>	NEXT OBJECT DEC
	3.000000 <CR>	TELESCOPE RA
	25.000000 <CR>	TELESCOPE DEC
	2.000000 <CR>	TELESCOPE HA

POINT: This command is intended for use by the external computer only. It returns the position of the telescope in the format used by the pointing model programs: NORA, NODEC, RA, DEC, HA.

**ROOF      COMMAND 29**

COMMAND THE ROOF TO OPEN OR CLOSE.

EXCOM SENDS	CHARACTERS	COMMENTS
	29 <CR>	COMMAND #
	0 <CR>	OPEN ROOF (1 CLOSE ROOF)
TCS RESPONDS	NO RESPONSE	ROOF OPEN OR CLOSE

(ROOF): This command is a convenience to allow the user to command the roof remotely

**GABLE COMMAND 30**

COMMAND THE GABLE TO OPEN OR CLOSE.

EXCOM SENDS	CHARACTERS	COMMENTS
	30 <CR>	COMMAND #
	0 <CR>	IOPEN GABLE (1 CLOSE GABLE)
TCS RESPONDS	NO RESPONSE	

(GABLE): This command is a convenience to allow the user to command the gable remotely

**SET ENCODER OFFSETS FOR ZENITH      COMMAND 31**

SET THE ENCODER OFFSETS FOR ZENITH.

EXCOM SENDS	CHARACTERS	COMMENTS
	30 <CR>	COMMAND #
TCS RESPONDS	NO RESPONSE	

This command is a convenience to allow the user to initialize at zenith

**SET ENCODER OFFSETS TO DEFAULT      COMMAND 32**

SET ENCODER OFFSETS TO DEFAULT (VALUES FROM WinTCS.DAT file).

EXCOM SENDS	CHARACTERS	COMMENTS
	30 <CR>	COMMAND #
TCS RESPONDS	NO RESPONSE	

**RETURN COMMAND NUMBER      COMMAND 33**

RETURNS THE CURRENT TCS COMMAND NUMBER.

EXCOM SENDS	CHARACTERS	COMMENTS
	30 <CR>	COMMAND #

TCS RESPONDS      0 <CR>      ACTIVE COMMAND #

**Read 5 Axis Focus Housing      COMMAND 41**

RETURN 5 AXIS FOCUS HOUSING POSITION TO THE EXCOM

EXCOM SENDS	CHARACTERS	COMMENTS	UNITS
	41 <CR>	COMMAND #	
TCS RESPONDS		EIGHT REAL NUMBERS FOLLOWED BY CARRIAGE RETURNS	
	-0.021 <CR>	X1	
	0.011 <CR>	X2	
	0.023 <CR>	Y1	
	0.014 <CR>	Y2	
	-0.000034<CR>	XTHETA	
	-0.0006 <CR>	XTRANS	
	0.000018 <CR>	YTHETA	
	0.0152 <CR>	YTRANS	

Read 5 Axis Focus: TCS sends the 5 Axis Focus Housing coordinates out over the excom port to the external computer.

**Move 5 Axis Focus Housing X                      COMMAND 42**

Moves 5 axis focus housing to commanded Translation & Tilt

EXCOM SENDS	CHARACTERS	COMMENTS
	42 <CR>	COMMAND #
	0.01<CR>	Translation (+/- 0.050 Inches)
	15 <CR>	Tilt (+/- 120 Arcsec)
TCS RESPONDS	NO RESPONSE	Commands MOVE TO Translate, Tilt

The 5 axis focus housing can be translated +/- 0.05 inches in 0.0001 inch increments. Tilt may be commanded in 1 arcsec increments a total of +/- 120 arcsec.

**Move 5 Axis Focus Housing Y                      COMMAND 43**

Moves 5 axis focus housing to commanded Translation & Tilt

EXCOM SENDS	CHARACTERS	COMMENTS
	43 <CR>	COMMAND #
	-0.01<CR>	Translation (+/- 0.050 Inches)
	-15 <CR>	Tilt (+/- 120 Arcsec)
TCS RESPONDS	NO RESPONSE	Commands MOVE TO Translate, Tilt

The 5 axis focus housing can be translated +/- 0.05 inches in 0.0001 inch increments. Tilt may be commanded in 1 arcsec increments a total of +/- 120 arcsec.

## 6.2 SERVO TUNEUP DOCUMENT

The servo motor controller board 073-16C has four trimpots at the top of the board. The silkscreen labels are B D G I. These are for Balance, Damping, Gain, and Integrator respectively. There is a large pushbutton switch near the center of the board which is the RESET button for the GALIL controller chip on the board.

The MDC motherboard has the eurocard connectors labeled RA and DEC for identification of the boards for an axis.

NOTE: It is important to not let the telescope run away while the servo-adjust procedure is being performed. It is probably a good idea to remove the motor timing belt at least for the initial setup. After the initial setup, replace the belt to add the inertia and damping of the entire structure to the servo-loop.

Attach an oscilloscope probe to the position error test point located at the top of the board beside the LED. Attach the ground lead to the GND test point. Set the scope at 2V/div. and 1ms/div. Switch ON the MDC and release the latching red HALT MOTORS button (STOP button on older systems).

First adjust the balance. With the RESET button depressed, observe the voltage on the test point and use the balance pot to get a zero offset. The motor shaft should remain in a fixed position. Additional adjustment of the balance pot may be required to achieve zero shaft rotation. Release the RESET button.

Next adjust the response of the servo loop. This is done by commanding a change in position with the servo test programs. The servo test programs are used to adjust the servo amplifier circuits. The servo test programs are run independently of TCS. The servo-test program commands a burst of motor steps at high frequency (to simulate a step position error) waits a few milliseconds, and commands an identical burst of motor steps in the opposite direction. The motion of the motor shaft resulting from the servo test program is an oscillation which allows a technician to observe the response of the servo with an oscilloscope.

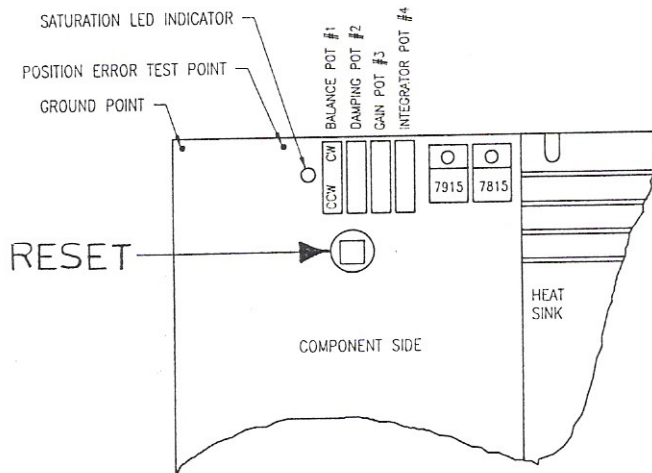
The servo test program is named ServoTune.EXE and is in the TCS sub-directory. To run the test program double click the icon.

The program has buttons for the HA or DEC axes. The number of steps as well as the delay between steps may be changed dynamically.

The four figures show representative oscilloscope traces of a step forward and then back. Figure 1 shows the servo with low gain and damping. The response to the step input is slow and the overshoot is large. The system continues to ring until the step in the opposite direction occurs. Figure 2 show the servo setup with too much gain and damping. There is no low frequency ringing and the response to the step input is very fast. Figure 3 shows a DC offset which may be removed with the integrator pot. The integrator pot should be increased. Figure 4 shows a normal servo with minimum gain and a reasonable amount of ringing with no offset.

Set the Oscilloscope to 1V/div. and 10ms/div.. Observe the trace and adjust the GAIN and DAMPING pots to achieve the best response with minimum GAIN. Too much GAIN will make the motors noisy (like stepper motors). If the GAIN is too low the motors may not respond; or run away. As the GAIN is increased, the magnitude of the response should equal about 1V. Increasing the DAMPING will reduce overshoot and stabilize the system response. After this is accomplished, adjust the INTEGRATOR pot to remove offsets.

After the HA axis is adjusted, select the DEC axis. Repeat the tuneup for the DEC axis.





Servo.doc

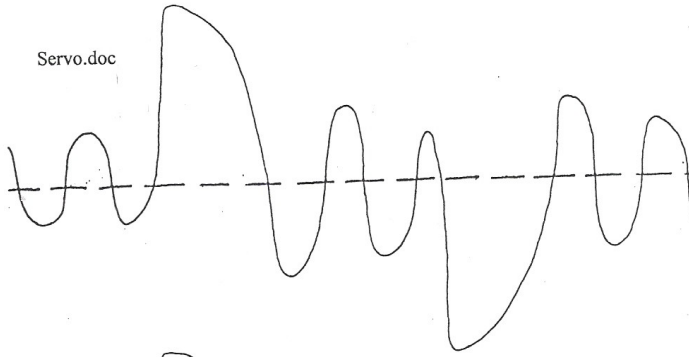


figure 1  
GAIN too low  
DAMPING too high  
overflow LED  
may come on

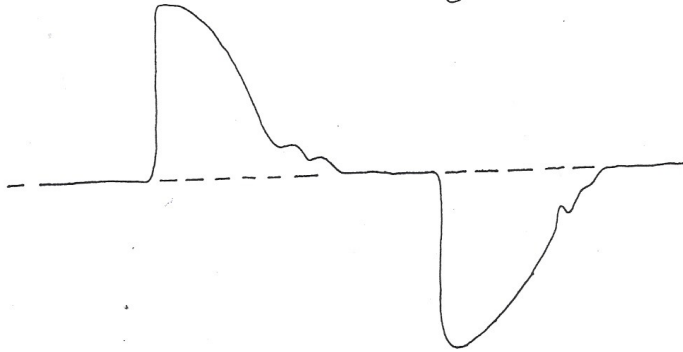


figure 2  
GAIN too high  
DAMPING too high  
drives noisy

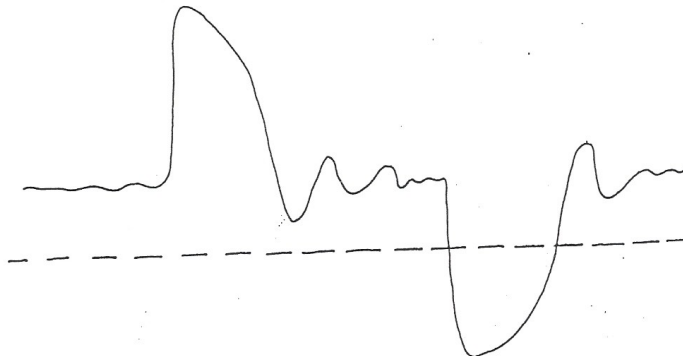


Figure 3  
Adjust INTEGRATOR  
to remove DC offset

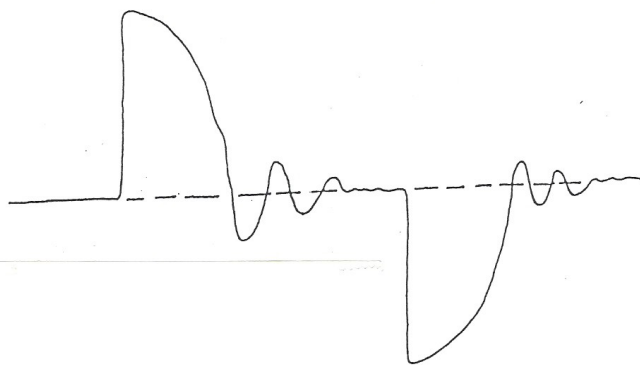


Figure 4  
Normal servo response  
for a telescope

### **6.3 MIRROR SUPPORTS**

Refer to the following DFM Engineering drawings:

621-011 Primary mirror cell assy.

621-155-1 Mirror support parts.

621-156 Mirror support assembly.

The Primary mirror is supported axially by 36 counterweight lever actuators that “float” the primary mirror. Axial location is controlled by 3 front defining bracket assemblies that attach to the front and back edge of the mirror, front defining the mirror in piston and tilt. The primary mirror is radially supported by 16 counterweighted lever assemblies and radially defined by 4 thermally compensated blocks that press on the edge of the mirror. To avoid damage to the counterweighted radial supports the primary mirror must not be translated after it is set up in the cell. Primary tilt will be performed with the 3 front defining bracket assemblies. After a tilt adjustment it will be necessary to adjust the 36 axial counterweight actuators back to the center of their range of motion.

The collimation procedure will be as follows:

Rough collimate the primary mirror in its cell and install the cell on the telescope.

Position the telescope at the zenith.

Set the 5 axis focus housing X1, X2,Y1,Y2 stages to 0.

Use the laser collimation tool to adjust the center and tilt of the secondary mirror using the spyder ring bolts for translation and the collimation screws for tip-tilt.

Look at intra-focal and extra-focal images to see the decentering of the central obscuration in the out of focus image.

Tilt the primary mirror with the adjustable retainer assemblies to center the central obscuration.

Re-adjust the 36 radial supports to mid travel.

Observe star images and refine collimation with the 5 axis focus housing.

### **6.4 FRAME GRABBER OPERATION**

The Frame Grabber consists of an Imagination PXC200AL circuit board and a DFM written windows application named FrameGrab.exe. The circuit board plugs into a PCI slot on the computer mother board. When the computer starts the first time, the OS will report new hardware and a wizard will help you install drivers. The driver files are in C:\Program files\DFM Job directory\Frame Grabber. There

are two hardware drivers that will need to be installed and they are in folder WinXP init. Manually instruct the wizard to look in winxp init. Once the drivers are installed, run the program Setup.exe on the winxp init directory. The frame grabber card supports 4 NTSC video inputs through the DB15 connector, but the typical DFM installation uses a single channel by connecting a coax cable to the BNC cable on the mounting strip of the circuit board. We install a video cable in the telescope wiring bundle to support a NTSC output CCD camera for testing. This engineering tool has been popular with customers, so some operational instruction is presented here.

Create a Framgrab shortcut on the desktop.

Click the Frame grabber icon to run the framgrabber.

Buttons:

- CAPTURE VIDEO / STOP CAPTURE
- SELECTION BOX (Region of Interest or ROI)

The ROI button creates a Region Of Interest box. Click and move the border of the box to change its size, click and drag the interior of the box to reposition it. Note that the x and y axis graphs auto-scale to the size of the ROI box.

- RESET BOX (not used, use mouse to reset)
- RESTART GRAPHS (or click inside the ROI box to restart the graphs)
- PLACE MARKER (places a red index line on the graphs)
- MODE: (selects the mode of data display in the ROI box)
  - Centroid (pixel)
  - Centroid (Arc sec)
  - Hot Spot (not used)
  - Histogram (not used)
- MARK FIDUCIAL (places one index mark on the graphs every revolution of the harmonic drive input shaft. G16 telescopes only).
- AVERAGE VALUES (not used)

Menu Options:

File/

- /Save Chart
- /Print chart
- /Save current Image

Edit/Copy Chart

View/

- /Capture Video
- /Show ROI Box

(Not used as these functions are also controlled with buttons on the display window)

## Options/

/Settings/

/Channel (1-4): Select which video channel is displayed

/Video: On board control of the video camera contrast, brightness and video level

The brightness and contrast controls are used to adjust the sensitivity of the video display. Many cameras have on-board brightness and contrast control that can conflict with these functions in the frame grabber.

/Centroid: Control of the video signal threshold floor and cursor size

The threshold floor is used to subtract off the background signal in the ROI. The cursor displays the moment by moment centroid (or center of gravity) of the contents of the ROI box. If the threshold floor value is set to too low the cursor will seek the center of the ROI box. If the threshold floor is set too high the cursor ignores all image signals and disappears to the top left corner of the screen. The threshold floor should be set to the highest level possible that still prevents the cursor from disappearing. Note that changing either the contrast or brightness will affect the optimum threshold floor.

/Frame: (not used yet)

/Averaging: (not used yet)

/Plate scale: match OTA and CCD chip parameters for proper graph calibration (a quick check can be performed by commanding an offset in RA or DEC & comparing the resultant image motion with the graph scale factors)

/Graph Options/

/Parameters: Re-sizes the ROI

/Format: Set graph time scale and number of divisions on the graphs

/Graph Titles: (not used, these are selected automatically with the mode)

/Defaults: Save user defaults or restore user or factory defaults.

Help/ (not available)

## **6.5 FIVE AXIS FOCUS HOUSING**

### **MECHANICAL**

Focal plane motion is provided by a stepper motor driven secondary mirror. Focal plane position is recorded with a potentiometer providing absolute encoding at the 25 mm level and an incremental optical encoder providing encoding with high precision and repeatability. Secondary mirror collimation is accomplished with 4 motorized and LVDT absolutely encoded x-y stages. These stages provide secondary translation and tilt in both X and Y, commanded and displayed from the telescope control system (TCS) computer. X and Y directions each use a pair of translating stages to achieve translation and tilt. Individual stages are supported on crossed roller slides. The stages move with a high mechanical gear ratio using differential pitch lead screws driven by DC motors with an integral 90 degree worm and worm gear output. The stages will not back drive.

### **ELECTRONIC**

The 5 Axis Focus Chassis (5AFC) contains power, logic and interface circuitry to control the focus housing X-Y stages. The circuit board is divided into two parts. One part controls the motors and the other provides signal conditioning for reading out the absolute Linear Variable Differential Transformers (LVDT). Each axis is accessed using a multiplexing technique, which selects both the motor and its associated LVDT. The LVDT position is passed to the TCS computer and used for position feedback to servo the stage to position. Axes positions are absolutely encoded in translation and displayed to 0.0001 inches (2.5um).

### **SOFTWARE**

Focal plane motion may be commanded from the TCS menus as well as from the hand paddle. Motions of the X1, X2, Y1 and Y2 stages are coordinated by software, using equations describing the focus housing geometry to assure that commanded translation is pure translation and tilt is pure rotation of the secondary mirror about its front surface center point. Translation may be commanded to .0001 inch increments and tilt may be commanded to 1 arc second.