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

# TCS OPERATIONS MANUAL

## For DFM 1.0 meter telescope and accessories

*DFM ENGINEERING, INC*
*University of Western Australia*
*Dr. David Coward*
*35 Stirling Highway*
*Crawley WA 6009 Australia*

*Ship date: 3/20/2008*
*PO# 560910698*

**Man583_B**
**Document version date: 2008-09-08**

## 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 12 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.

## SOFTWARE LICENSE AGREEMENT

The license agreement between customer and DFM ENGINEERING, INC. for rights in technical data and computer software is located in section 6.30 of this manual.

## *TABLE OF CONTENTS*

# 1.00 SECTION 1 GENERAL DESCRIPTION

## 1.10 MECHANICAL

The DFM 1.0 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 RA 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 support consists of an multiple wiffle tree back support and thermally compensated defining points on the mirror ID. Mirror doors protect the primary mirror and a baffle 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.

## 1.20 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 axes position. An AD-574A (12 bit) analog to digital converter is used to read the focus position pot and focus x-y stage Linear Variable Differential Transformer (LVDT) positions. The Mirror Support Chassis (MSC) contains electronics and controls for the airbag back support as well as the mirror doors. The 5 Axis Focus Chassis (5AFC) contains logic and interface circuitry to control the focus housing x-y stages. All of the electronic chassis are housed in a pair of 19 inch wide racks. Power for the chassis is 115 volts. A step down isolation transformer is provided for conversion of Australian 240 volt power.

## 1.30 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.

## 2.00 SECTION 2 ADJUSTMENTS

### 2.10 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.

### 2.20 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 manually actuated 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 manually actuated 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 2.10).

### 2.30 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.

## 2.40 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 reticle 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.

| | | | |
|---|---|---|---|
| | \| | E star drifts N | \| |
| IF | \| | or | \| THEN |
| | \| | W star drifts S | \| |

ELEVATION OF POLAR AXLE IS TOO GREAT

| | | | |
|---|---|---|---|
| | \| | E star drifts S | \| |
| IF | \| | or | \| THEN |
| | \| | W star drifts N | \| |

ELEVATION OF POLAR AXLE IS TOO SMALL

Adjust ELEVATION to correct drift.

## 2.50 COLLIMATION

*** CAUTION *** The optical collimation of your optical tube assembly was done at 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.

Radial supports for the primary mirror are thermally compensated nylon pad assemblies at the cardinal points (N S E W). These pads define the radial position of the primary mirror and are adjustable from outside the primary mirror cell. Measure between the inside diameter of the primary mirror and the inside diameter of the cell (primary light baffle clearance diameter) with a depth micrometer. Adjust the radial defining pad screws until the mirror is centered in the cell.

Primary collimation tilt is adjusted with three set screws on the bottom of the mirror cell. These screws raise the mirror. Primary collimation is set mechanically by using a depth micrometer to adjust the tilt of the primary mirror until its front surface is parallel to the top flange of the mirror cell. This is done with the mirror in the cell and with the cell off of the telescope (typically just prior to installation of the primary mirror cell). Loosen two of the nylon radial supports on the primary mirror cell one turn. Clamp three machinist’s parallels onto the mirror flange so that they extend out over the mirror near each collimation point. Place a small piece of teflon sticky back tape on the tip of the depth micrometer and measure the depth from each parallel to the mirror at points on the edge nearest the tilt adjustment screws. Adjust the screws to some chosen depth and repeat the measurements and adjustments until the depth is uniform to .001 inches. The depth affects the focus position, so a standard depth should be maintained to about 1/32 inch. When tilt collimation is set, tighten the two radial supports which were loosened one turn each.

To translate the secondary mirror for preliminary collimation, the entire secondary assembly must be translated with radial bolts on the outboard ends of the spider vanes. Loosen one side first in the direction of translation, and then pull the assembly with the opposing spider vane bolt.

Secondary collimation tilt is adjusted by turning 4 screws at 90 deg. on the edges of the secondary collimation plate. These screws are tightened such that the collimation plate is bent slightly to maintain a preload. These screws must be adjusted in opposing pairs, loosening one first. These screws cause the mirror plate to rotate on a pair of spherical washers. Secondary collimation should be set with feeler gages at assembly so that the collimation plate and the back of the mirror plate are parallel. Subsequent fine tuning may be done with a collimation telescope attached to the back of the primary mirror cell, or by observing star images.

Summary: Set the primary mirror centering with the radial support adjustment screws. Set the primary tilt with the three wiffle tree adjustment screws before the primary mirror cell is installed on the center section. Adjust the secondary mirror centering when the mirror is placed in its cell. Set the secondary mirror tilt with feeler gages. Using an eye centering device at cassegrain focus, adjust the tilt of the secondary mirror to achieve concentric images inside the optical tube assembly. Observing intrafocal and extrafocal images, translate the primary mirror to center the central obscuration and tilt the secondary mirror to make tilt changes. Subsequent fine tuning may be done using translate and tip/tilt motions of the 5 axis focus housing. The 5 axis focus housing allows a total translation in X and Y of +/- 0.050 inches. Total allowed tilt is +/- 120 arc seconds. Translation and Tilt in the same direction for a single axis must not exceed 0.050 inches total. An image for collimation may be provided by a collimation telescope attached to the back of the primary mirror cell, or by observing star images. Use the star test to make small adjustments to secondary tilt and primary translation to optimize image quality.

The primary mirror tilt collimation is a strong term in the pointing of the telescope which is modeled in software. Changes to the primary tilt collimation will require adjustment to the pointing model. Secondary collimation only affects image quality.

## COLLIMATION USING A STAR IMAGE

Fine tune collimation by observing a relatively bright star image inside and outside of focus. The image will appear as an illuminated annulus or "donut". The inner circle should be concentric with the outside circle. The tip-tilt of the secondary and the centering of the secondary mirror are adjusted until the donut shows a uniform width between the inner circle and the outer circle (i.e., the inner circle and the outer circle are concentric).

When observing inside and outside of focus, any non-uniformity or lack of concentricity of the donut that stays on the same side when moving through focus is a centering error. Any non-uniformity or lack of concentricity of the donut that changes side when moving through focus is a tip-tilt error. The image needs to be centered in the eyepiece or CCD camera because an off-axis image will show a non concentric donut. If an off-axis image is used for collimation, this will cause the collimation to provide the best images at that off-axis position.

Diffraction at the edge of the primary mirror and at the edge of the telescope light shielding (i.e., the inside circle of the donut) 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.

Choosing a star near the zenith is preferable because the atmospheric turbulence, or "seeing", and atmospheric dispersion (the prism affect of the atmosphere causes the blue image and the red images to be displaced) will cause the least image degradation. Choosing a star near the horizon provides easier access to the adjustments of the secondary mirror, but is not recommended. We recommend choosing a star within 30 degrees of the zenith.

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 of one axis at a time (either north-south or east-west).

STAR IMAGE COLLIMATION PROCEDURE:

Choose 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 located in a convenient manner. Examine the image inside and outside of the focus. The amount of de-focus should be adjusted until the donut is sufficiently large to easily see the annular star image. Because the star light is spread out over the area of the annulus, its intensity will decrease with increasing size of the donut. If the intensity is not sufficient, then you will need to select a brighter star.

Look along the north-south and east-west directions and note the amount of decentering in each of these direction components. Remember that any decentering that appears to change from side to side when inside and outside of focus is caused by secondary mirror tip-tilt and any decentering that does not change from side to side when inside and outside of focus is caused by primary mirror decentering.

Adjust the appropriate mirror collimation one axis at a time to remove the decentering. Again, do not adjust the primary mirror collimation (tip-tilt) screws.

Typically, the decentering of the out of focus image will contain decentering and tip-tilt components. Using the 5 axis focus housing, adjust the appropriate collimation to remove the larger error first.

## 2.60 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 meter 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.

## 3.00 SECTION 3 OPERATION

### 3.10 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 | 20.000 in |
| 2 | 3/8-24 | 12 | 14.250 in. |
| 3 | 3/8-24 | 12 | 14.000 in. |
| 4 | 3/8-24 | 12 | 10.000 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.

### 3.20 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.

### 3.30 AUXILIARY POWER BOX

There is a box mounted on the center section that supplies reticle power, 200 volt instrument power, and 110 volt instrument power.

### 3.40 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.

### 3.50 STARTING UP

Turn on the switch on the 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 assumes the telescope is pointing at the zenith). 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 encoders. The latching HALT MOTORS button interrupts power to the servo-motors.

## 3.60 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.

## 3.70 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 the Communications group box that shows if ExCom, MNCP, or TCP/IP are active. Menus are provided at the top line of the WinTCS display. The TCS display may be extended downward to show translation and tilt for the X and Y directions of the 5 axis focus housing. When not in use, this display may be shortened to hide the 5 axis information.

## 3.80 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/ (cosine of the declination) up to a maximum of 4 degrees per second slew speed. SLEW is 4 degrees per sec. Automatic slews disable the hand paddle.

## 3.90 USING THE MENUS

### 3.91.1 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.

### 3.91.2 File: Exit

*Exit* provides for ending your WinTCS session.

### 3.92.1 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 using the telescope fiducials.

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.

### 3.92.2 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". A library for southern hemisphere users is included. 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.

### 3.92.3 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.

### 3.92.4 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 mirror 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.

*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. The Travel Remaining display is updated each time a motion is commanded. The Travel Remaining is calculated for the direction of the translation. Commanded motions that are out of range will be ignored. 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.

## 3.93 View:

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

### 3.94.1 Options: Communications

*General* 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 UWA 1 meter telescope will be:

Com1 = ACP 9600 baud

Com2 = MNCP 9600 baud

### 3.94.2 Options: Night Colors

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

### 3.94.3 Options: Defaults

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

### 3.95 Help

WinTCS features on-line help.

## 3.A0 CONTROL SYSTEM SHUTDOWN AND RESTART

To stow the telescope for convenient restart:

(in the dome)

Close the mirror doors.
Close the dome shutter.

(in the control room or remote station).

Place dome home-track switch in the HOME position.
Wait for the dome to go home.
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
When the slew is complete, press the red HALT MOTORS button on the motor driver chassis to interrupt power to the telescope motors.
Turn automatic dome front panel switch to the off position.

Exit WinTCS. Note: This will command the tube doors to close regardless of their position.

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 and the dome at the home position).

(in the dome)

Open the dome shutter.

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.

Turn on auto-dome front panel switch.

Place dome home-track switch in the track position.

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

Select and slew to an ephemeris star (library objects # 400-423 are good “set up” stars, the last two digits roughly correspond to the sidereal time).

Center star in eyepiece.

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

## 4.00 SECTION 4 MAINTENANCE

### 4.10 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 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 on CD.

### 4.20 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.

### 4.30 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.

### 4.40 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.

### 4.50 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.

## 4.60 FIDUCIALS SETUP

The telescope is equipped with absolute potentiometers and fiducials that allow automatic initialization of telescope position. To properly function, these features must be calibrated with the telescope control software as follows:

If the encoder is a new one: Find the fiducial lines on the encoder using the trigger function of an oscilloscope connected to the encoder fiducial output (pin 8 on the connector). While the encoder shaft is aligned with the fiducial, file alignment marks on the end of the encoder shaft and encoder mounting flange.

Assemble the encoder / anti-rotation arm / potentiometer assembly.

Attach an ohm meter to the pot resistance and wiper and rotate the encoder shaft to find the pot's mid travel (~500 ohms).

Loosen the set screw that locks the pot timing belt pulley on the encoder shaft.

Align the marks on the encoder shaft and mounting flange while keeping the pot shaft at mid-travel, then tighten the pot pulley set screw.

With the telescope tube assembly approximately at the zenith, install the encoder assembly.

Start the TCS from the windows desktop.

Move the telescope to the zenith using a bubble level or other method.

Run the pointing model program (winpntm) from the windows desktop (note that a .PAT file must be opened for the pointing model to run) and click on the appropriate "Adjust HAPOTOFF" or "Adjust DECPOTOFF" button and enter the Analog HA or Analog DEC value from the TCS display.

Click on the "Calculate new pot offset value" button and enter the result in the appropriate "HAPOTOFF", or "DECPOTOFF" field in the Telescope constants list. These are the offsets used by TCS to make the analog positions from the absolute potentiometers display 0.0 HA and the site latitude for DEC when the telescope is at the zenith.

Click the "Save Initialization file" button and save the initialization file.

Restart TCS so that it will use the new initialization file values.

Check that the Analog HA reads 0.0 and Analog DEC reads the latitude.

Z-Point on a star near the zenith.

Turn the telescope tracking OFF with the switch on the MDC front panel, then go to the Telescope / Initialization / Telescope Position menu and click on the "Find Fiducials" button. Finding the fiducials may take several minutes.

In the pointing model program find the "FIDHA", "FIDDEC", telescope constants and the "Convert Coordinates" button.

When the Activity Message field in the TCS displays "Fiducials are found", click on the convert coordinates button. Enter the HA or DEC coordinates from the TCS Telescope Position display into the convert coordinates dialog box. Click on the convert button to transform the HH:MM:SS coordinate to decimal hours. Note the same conversion works for DD:MM:SS, which gets converted to decimal degrees.

Enter the results from the conversion dialog box into the appropriate "FIDHA" or "FIDDEC" fields in the Telescope constants list. These are the coordinates that TCS will use to set the telescope position when commanded to "Initialize with fiducials".

Click the "Save Initialization file" button to update the Initialization file used by TCS.

Restart TCS so that it will use the new initialization file values.

Turn the telescope tracking OFF with the switch on the MDC front panel, then go to the Telescope / Initialization / Telescope Position menu and click on the "Initialize with Fiducials" button. Confirm that the initialization with fiducials works.

This tuneup should be performed every time the encoders or optics are removed from the mount.

## 4.70 OPTICAL MAINTENANCE

### 4.7.1 PRIMARY MIRROR

Use the mirror and lens covers provided. When the mirrors need washing the following procedure is recommended:

*** CAUTION *** Cleaning the mirrors is a delicate and involved procedure and should only be carried out by an experienced technician using proper equipment. Failure to observe this caution may result in partial voiding of the warranty.

*** CAUTION *** When the optics are removed from the telescope the telescope will be grossly out of balance. In this condition, <u>the lock pins must be used</u>, and when moving from one lock pin position to another, the movement of the telescope must be controlled by hand with sufficient personnel and equipment to make the movement safe. Make sure the HALT MOTORS button is pushed in before moving the telescope by hand. If both mirrors are to be removed, we recommend removing the secondary mirror before the primary, and installing the primary mirror before the secondary mirror.

Before removing the primary mirror cell, find and understand the following equipment:

Scaffolds and cross beam for supporting chain hoist.

Mirror cell spreader bar Dwg 583-008.

Primary mirror crate.

Four sided mirror lifting strap and triangular shackle Dwg DOM-009. This should be stored in the Primary mirror shipping crate.

Mirror insertion cart (with wheels) Dwg. 583-073.

Mirror cell lifting assemblies (MCLA) Dwg 583-081. These tools are stored in a wooden crate supplied by DFM.

If the optics are to be cleaned then secure these additional supplies.

Childs wading pool 1 ½ meters in diameter (used as a wash tub).

10 liters distilled water.

2 liters 99% isopropyl alcohol

3 boxes medical grade cotton balls or swabs.

Liquid dish soap.

Misting squirt bottle.

PRIMARY MIRROR (removal, cleaning, & reinstallation)

1. Secure the telescope pointing at the zenith with the lock pins provided. This is necessary because with the mirror cell removed the tube assembly is extremely top heavy.
2. Remove any instrumentation from the bottom of the mirror cell.
3. Remove the 4 INVAR rod bolts from the bottom of the primary mirror cell.
4. Remove the GAM (guide acquire module) and the primary light baffle.
5. Install the mirror cell lifting assemblies (MCLA) on the north and south sides of the center section and then the mirror cell using the hardware provided (see Dwg 583-081).
6. Take some load in each MCLA.
7. Remove the mirror cell flange bolts.
8. Lower the mirror cell using the MCLAs until the cell rests on top of the mirror insertion cart. Make sure the cell is well centered on the cart.
9. Remove all of the earthquake clamps and loosen the four radial supports. (see Dwg 583-011).
10. Install the mirror insertion guides (see Dwg. # G40-055).
11. Raise the mirror cell with the MCLAs and rotate the mirror insertion cart to engage the mirror insertion cart legs into the corresponding holes in the bottom of the mirror cell.
12. Lower the mirror cell using the MCLA, extracting the mirror from the cell.
13. Remove the MCLAs from the mirror cell only.
14. Remove the south MCLA from the center section.
15. Carefully roll the mirror insertion cart S-E to a position away from the center section.
16. Install the center section spreader bar and ratchet hoist.
17. Carefully roll the mirror insertion cart back under the center section.
18. Note the mirror rotational orientation in the cell so the mirror may be replaced in the same orientation. The North side should be marked.
19. Sling the mirror with the four sided straps provided and lift the mirror off of the mirror insertion cart with the ratchet hoist.
20. Roll the cart with the mirror cell out of the way.
21. Place the wash tub and three spacer blocks under the mirror such that the mirror lifting strap can be removed before washing..
22. Lower the mirror with the ratchet hoist so that the mirror comes to rest on the blocks in the wash tub.
23. Remove the mirror lifting strap.
24. Rinse the mirror vigorously with a hose and water to remove loose debris from the surface.
25. Mist the surface of the mirror with distilled soapy water and let stand a few minutes.

26. Rinse the mirror with distilled water.
27. With a handful of clinical cotton, wipe a single swath across the mirror surface from the edge towards the central hole, using very light pressure. Do not scrub. Discard the cotton after one wipe. Repeat this until the entire surface has been wiped.
28. Rinse the mirror with distilled water. Inspect for dirty spots.
29. Repeat steps 23, 24, 25 and 26 until the mirror is clean.
30. Rinse the clean mirror with isopropyl alcohol applied from the edge towards the central hole. Adequate ventilation is required for this step as the alcohol constitutes a health and fire hazard.
31. Drain the contents of the wash tub and allow the mirror to dry.
32. Install the mirror-lifting strap and hoist the mirror higher than the mirror insertion cart, or into the shipping crate if the mirror is to be re-aluminized.
33. Roll the mirror insertion cart and cell into position under the mirror, and lower the mirror onto the mirror insertion cart posts. Make sure the “N” mark on the mirror is aligned to the “N” mark on the mirror cell.
34. Carefully roll the mirror insertion cart S-E to a position away from the center section.
35. Remove the center section spreader bar and ratchet hoist.
36. Carefully roll the mirror insertion cart back under the center section.
37. Install the south MCLA onto the center section.
38. Install the mirror insertion guides (see Dwg. #G40-055).
39. Remove the straps under the mirror and attach the MCLAs to mirror cell.
40. Raise the mirror cell with the MCLAs until the cell and mirror are lifted clear of the mirror insertion cart.
41. Turn the mirror insertion cart and lower the mirror cell until it rests on top of the mirror insertion cart posts. Make sure the mirror cell is well centered on the cart.
42. Center the primary mirror in its cell. (see section 2.50)
43. Collimate the primary mirror in its cell. (see section 2.50).
44. Install the 4 earthquake clamps.
45. Raise the mirror cell using the MCLA, carefully engaging the INVAR rods, until it is within ¼ inch of the center section.
46. Lubricate and then start all of the mirror cell flange bolts. Push the mirror cell around as required, it may be necessary to loosen the MCLA brackets on the bottom of the mirror cell slightly to do this.
47. Raise the mirror cell using the MCLA until it contacts the center section.
48. Torque the mirror cell flange bolts (3/8-24 SHCS) to 22 foot-lbs.
49. Remove the MCLA from the mirror cell and center section.
50. Reinstall the 4 INVAR rod bolts in the bottom of the mirror cell.
51. Reinstall the light shield, GAM, and instrumentation.

SECONDARY MIRROR

Lock the telescope in the North storage position using the lock pins provided. Install the HA lock pin. Close the primary mirror doors. Erect scaffold modules east and west of the telescope spider ring. Place the support beam on top of the scaffolds, spanning above the telescope. Install the ratchet hoist on the support beam above the spider ring. Attach the sling provided to the spider ring and to the ratchet hoist. Take up some load with the ratchet hoist. Remove the 4 flex-link bolts from the spider ring. Remove the 4 INVAR rod bolts from the spider ring. Pull the spider ring north until the secondary shield is north of the truss ring and then lower the spider ring to the spider ring service stand. Attach the anti-rotation pin in the stand and remove the strap from the ratchet hoist.

Remove the secondary light shield by removing 4 radial screws near the spider vanes. Place the secondary shield in a safe place where it will not be damaged. Rotate the spider ring to position the secondary mirror looking straight up. There are 8 screws on the secondary mirror cell plug, which attaches the secondary mirror to the mounting plate. Four collimation screws hold the mounting plate to the collimation plate. Remove 3 collimation screws. With an assistant holding the mirror plate, remove the 4th collimation screw and lift off the mirror plate. The secondary mirror position is center and front defined with the plug. Remove the plug and clean the mirror using the same technique described for the primary mirror. Note the spherical washers which form the pivot for the secondary mirror cell. The washer pair should be installed so that the center of curvature of the washers coincides with the front surface of the secondary mirror. This minimizes translation when the secondary mirror is tilted. See section 2.50 for secondary mirror collimation prior to installation.

ALUMINIZING

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

## 4.80 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 that 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.

## 4.90 INITIALIZATION FILES

There are three files that are read in by TCS when the program starts. The library of objects file is named LIB.DAT. Each library object is stored as six integers and the EPOCH is 2000. The library file should not be changed. The mark-move data is read in with a files named NAME.MRK. These files may be changed to set this table of objects to whatever the user desires. Each of these objects is three real numbers: RA, DEC, EPOCH. Up to 500 entries may be used. 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 fiducial real hours |

| | |
|---|---|
| FIDDEC:= 31.0 | DEC fiducial real degrees |
| HAPOTOFF:= 2053 | HA absolute postion pot offset |
| DECPOTOFF:= 2035 | DEC absolute postion pot offset |

## 5.00 SECTION 5 TROUBLE SHOOTING

### 5.10 ROLLER SLIPPAGE

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

### 5.20 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.

### 5.30 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.

### 5.40 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.

### 5.50 MIRROR DOORS MISBEHAVE

The doors fail in two basic ways. Each door has an open limit switch and a close limit switch. These are plain Cherry microswitches. The doors are run by reversible AC synchronous gear motors. The pulleys and belts on the mechanism drive a custom linear actuator that raises and lowers the door. Be extremely careful not to get your fingers in these belts. The doors are in pairs with a top pair and bottom pair. The pairs open in sequence with the first (top) pair completely open before the second (bottom) pair starts opening. Similarly, the second pair closes completely before the first pair starts to close.

Failure 1) The East and West doors open first and if they don't both completely open (tripping their limit switches) , then the North &West doors are not going to open. A door can open without making its limit switch, if the mechanism stops on structure before the switch contacts. In the open position, all the doors should be open and the switches made. In this position, it should be possible to turn each of the motor pulleys by hand. If a motor is still running because its switch didn't make, the pulley will be tight. Motors in this condition will also get hot to the touch. For an axis with this problem, adjust the switch to make sooner. It is possible to adjust the switches by bending the little metal arms that have the roller on the end. Have a helper at the remote console to command the doors to open and close for testing while adjustments to the switch actuator arms are made. It will take a little practice and skill to get the switches adjusted right.

Failure 2) When the doors close, it is possible that the doors close quite hard before the limit switch makes and this can cause the mechanism to bind so much that the motor has insufficient torque to back out. Sometimes this situation is recovered by repeated attempts to open the doors. Again the solution is in the adjustment of the close switches. In the closed position, each door motor should be off and the door mechanism should be free enough that you can turn the pulley, raising the door slightly by hand. Be advised that the door will close again if you raise the door beyond the switch. Watch out for your fingers! You can use the center-off position of the door switch on the chassis downstairs to be sure there is no motor power for certain tests.

So, close the doors, put the chassis switch in the center off position and check the belts and pulleys for binding. Put the switch in the close position and check for motor power on. Adjust the switches as required with the chassis switch in center off position and test again.

Next, open the doors put the switch in the center off position and check the pulleys and belts for binding. Place the switch in the open position and check for motor power. Adjust switches with the chassis switch in the center off position and re-test.

## 6.00 APPENDICES

## 6.10 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 TO ZENITH
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 will be assumed to be at the zenith (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**

INITIALIZE THE RA AND DEC POSITION ENCODERS
ENTER ZEROS FOR NEXT OBJECT

| EXCOM SENDS | CHARACTERS | | COMMENTS |
|---|---|---|---|
| | 3 | <CR> | COMMAND # |
| | 12.012345 | <CR> | RA (HOURS) |
| | 12.345678 | <CR> | DEC (DEGREES) |
| | 1950. | <CR> | 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.

**ZFIDUCIAL COMMAND 4**

INITIALIZE THE POSITION OF THE TELESCOPE WITH THE FIDUCIALS

| EXCOM SENDS | CHARACTERS | COMMENTS |
|---|---|---|
| | 4 <CR> | COMMAND # |
| | 0 <CR> | (Set the encoders at fiducial) |
| | | (1 <CR> Go to fiducial and stop) |

TCS RESPONDS NO RESPONSE

Set fiducial position (ZFIDUCIAL): This command is used to initialize the telescope position using the absolute pots and encoder reference lines.

**ZFOCUS COMMAND 5**

INITIALIZE THE FOCUS POSITION

| EXCOM SENDS | CHARACTERS | | COMMENTS |
|---|---|---|---|
| | 5 | <CR> | COMMAND # |
| | 2000.1 | <CR> | 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> | COMMAND # |
| | 13 <CR> | 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> | COMMAND # |
| | 32 <CR> | 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, & ANGLE

| EXCOM SENDS | CHARACTERS | COMMENTS |
|---|---|---|
| | 17 <CR> | COMMAND # |
| | 200.0 <CR> | RATE (ARC SECONDS/SECOND) |
| | 50. <CR> | LENGTH (ARC SECONDS) |
| | 0. <CR> | 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> | COMMAND # |
| | 0 <CR> | 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> | COMMAND # |
| | 0 <CR> | 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> | COMMAND # |
| | 0 <CR> | 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> | COMMAND # |
| | 0 <CR> | 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> | COMMAND # |
| | 2000.0 <CR> | 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) |
| | 0.8 | <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 INTEGERS | 2345 <CR> | STATL | THREE STATUS |
| | 0023 <CR> | STATH | |
| | 1034 <CR> | STATLH | |

STATUS: This command is like COORDS (COMMAND 25) 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.

**MIRROR DOORS COMMAND 29**

COMMAND THE PRIMARY MIRROR DOORS TO OPEN OR CLOSE.

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

(MIRROR DOORS): This command is a convenience to allow the user to command the mirror doors remotely.

**INIT WITH FIDUCIALS COMMAND 30**

COMMAND THE PRIMARY MIRROR DOORS TO OPEN OR CLOSE.

| EXCOM SENDS | CHARACTERS | COMMENTS |
|---|---|---|
| | 30 <CR> | COMMAND # |
| | 0 <CR> | INITIALIZE WITH FIDUCIALS (1 FIND FIDUCIALS) |
| TCS RESPONDS | NO RESPONSE | |

(FIDUCIALS): This command is a convenience to allow the user to initialize position remotely.

**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. Combined translation due to translation and tilt must not exceed .050 inches.

**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. Combined translation due to translation and tilt must not exceed .050 inches.

## 6.30 SOFTWARE LICENSE AGREEMENT

### LICENSE AGREEMENT BETWEEN CUSTOMER AND DFM ENGINEERING, INC. FOR RIGHTS IN TECHNICAL DATA AND COMPUTER SOFTWARE

(A) DEFINITIONS

1. COMPUTER, as used in this agreement means a data processing device capable of accepting data, performing prescribed operations on the data, supplying the results of these operations, and/or performing control functions based upon commands supplied, or logical decisions made using input data or commands. For example, a PC (Personal Computer) may be used for controlling a telescope.

2. COMPUTER DATA BASE, as used in this agreement means a collection of data in a form capable of being processed and operated on by a computer.

3. COMPUTER PROGRAM, as used in this agreement means a series of instructions, statements, procedures, etc. in a form acceptable to a computer, designed to cause the computer to execute an operation or operations. Computer programs include operating systems, assemblers, compilers, interpreters, data management systems, utility programs, sort-merge programs, real time control programs, etc. Computer programs may be either machine-dependent or machine-independent, and may be general purpose in nature or be designed to satisfy the requirements of a particular user.

4. COMPUTER SOFTWARE, as used in this agreement means computer programs, software, and/or computer data bases. This includes source code, binary code, memory images, or any intermediate form of the programs.

5. COMPUTER SOFTWARE DOCUMENTATION, as used in this agreement includes technical data, including computer listings and printouts, in human-readable or machine readable form which (a) documents the design or details of computer software, (b) explains the capabilities of the software, or (c) provides operating instructions for using the software to obtain desired results from the control system or computer.

6. TECHNICAL DATA, as used in this agreement means recorded information, regardless of form or method of recording.

7. DETAILED DESIGN DATA as used in this agreement means technical information or data that describes the physical or electrical configuration and performance characteristics of an item or component in sufficient detail to allow understanding of its function or to allow duplication of the item or component. Examples include, but are not limited to, drawings, CAD files, schematics, software listings, flow charts, etc.

8. LIMITED RIGHTS as used in this agreement means rights to use, duplicate, or disclose technical data, in whole or in part, by the customer or any of the customer's employees or staff with the express limitation that such technical data shall not, without written permission of DFM Engineering, Inc. , be: (i) released or disclosed to a third party, or (ii) used for any purpose except in conjunction with a DFM Engineering, Inc. product. Detailed design data (examples include, but are not limited to, mechanical and electrical drawings or schematics) shall not be used for manufacture or preparation of the same or similar devices.

9. RESTRICTED RIGHTS as used in this agreement means rights to use, duplicate, or disclose technical data in whole or in part by the customer without written permission of DFM Engineering, Inc. This data may be used, duplicated, or disclosed to a third party subject to the following express limitations: The data may be used, duplicated, or disclosed in whole or in part only in a human-readable form and at no cost to the third party.

(B) LICENSE TO CUSTOMER

The customer is granted LIMITED RIGHTS to the technical data and computer software. The software may be copied for safekeeping (archives) or backup purposes only. The software may be used with a backup computer only when the computer it was supplied for is non functional. The software may only be used at the original site that it was supplied for and may not be transported to another site even if the computer which it was supplied for is transported to another site. The software may not be used in whole or in part as a portion of another computer program. The detailed design data may not be used for manufacture or preparation of the same or a similar device.

The customer is granted RESTRICTED RIGHTS TO the computer data base containing the data for the library of objects as supplied by DFM Engineering, Inc. The customer may add to, change, or subtract from this data base as they deem necessary for efficient operation.

Acceptance of the technical data acknowledges the acceptance of this agreement in totality and customer agrees to pay all costs involved in prosecution required to enforce this agreement and to pay all damages to DFM Engineering Inc. for unauthorized use of the technical data. This agreement shall remain in effect until the year 2020 AD.

## 6.40 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 Framegrab shortcut on the desktop.

Click the Frame grabber icon to run the framegrabber.

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 or the ROI box.

- RESET BOX (not used, use mouse to reset)
- RESTART GRAPHS (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)
- 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)

## 6.50 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.