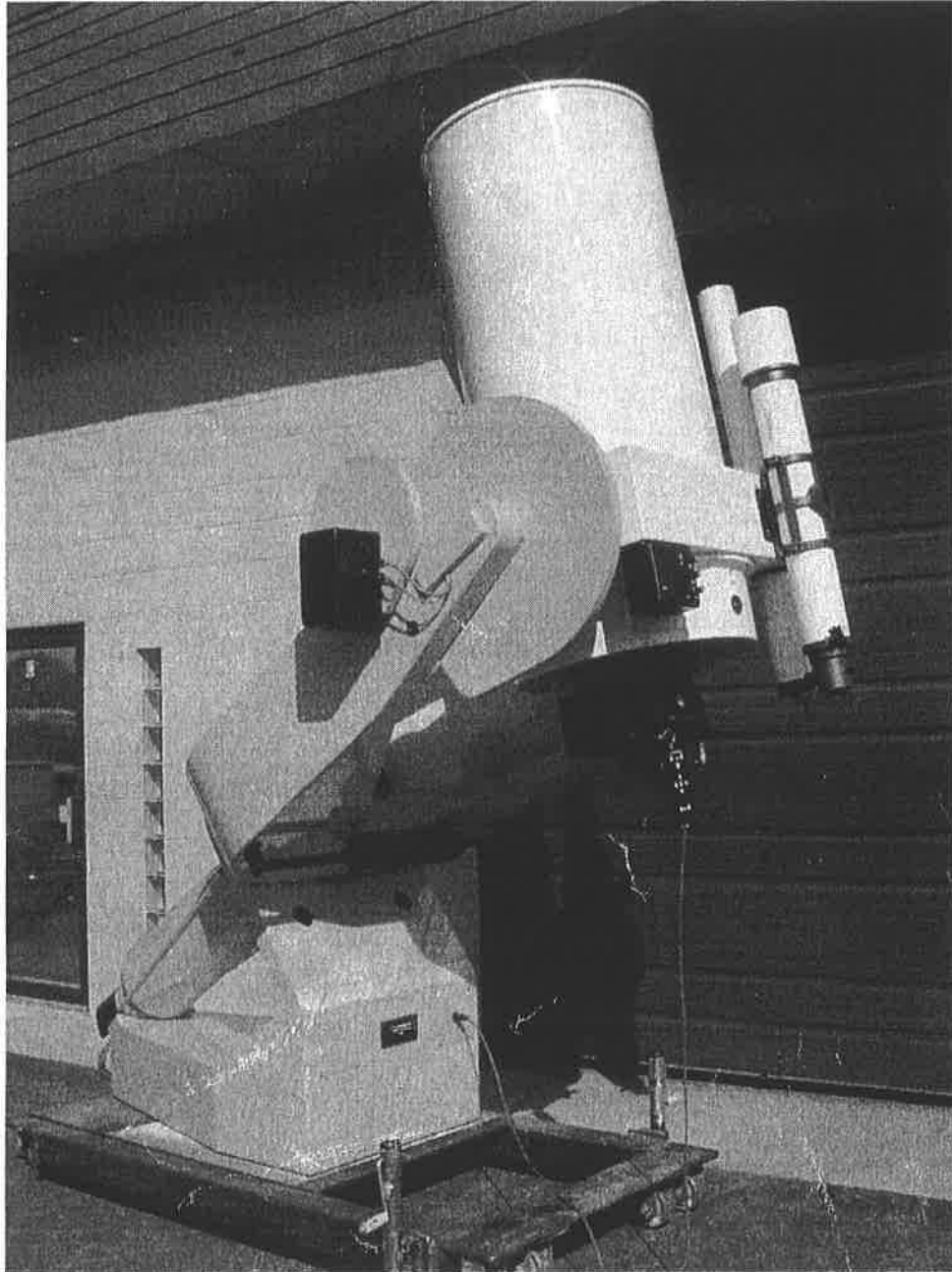


DFM TELESCOPE CONTROL SYSTEM FEATURES



With WinTCS control software

ELECTRONIC

The telescope is controlled using a IBM PC Computer. An interface card plugs into the PC, and controls the motor driver unit. Cables connect the PC and the telescope to the motor driver unit. A hand paddle plugs into the motor driver chassis (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 tube assembly. This final limit switch is a power interlock which cuts power to the motors at the horizon. The PC interface includes VIA's (versatile interface adapter) which 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 axis positions. An AD-574A (12 bit) analog to digital converter is used to read the focus position pot and the telescope absolute position pots. All of the electronic chassis are housed in a 19 inch wide rack. Power for the chassis is 115 volts.

SOFTWARE

The software is written in Turbo Pascal. The software is multi-threaded. 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 which is used to initialize system variables when the software is executed. Versions of this TCS are available to control Altitude over Altitude mountings and Altitude over Azimuth mounting.

LIMIT SWITCH

There is a mercury limit switch assembly on the tube assembly. 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 is active 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 may be latched (it is latched in the IN position) and the telescope manually driven out of the limit. For worm drive telescopes a limit override switch is provided so that the telescope can be driven out of the limit with the hand paddle. This keyed override switch should be used only when the fault has been corrected.

STARTING UP

Turn on the switch on the power strip. Raise the door and 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 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.

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 AUTODOME switch turns on the dome control algorithm. 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.

THE DISPLAY

DFM - Telescope Control System

File Telescope View Options Help

Start Slew Start Trail Stop

Telescope Position

	HA	RA	Dec	Epoch	Airmass	Zenith Dist
Telescope:	00 00 00.1	18 40 08.2	-43 00 01	2002.5	3.512	73.6
Next Object:						

Operating Mode

Regular operation

Time/Date

UT Date: 11 11 2002
 UT: 21 47 26
 ST: 18 40 08
 Julian: 2452590.407939

Rates

	RA	Dec
Track:	0.000	0.000
Cor:	On -0.013	0.000
Guide:	5.000	
Set:	100.000	
Use Cosine of Dec:	On	

Status

INITIALIZED
 Dome: Off
 Track: Off
 Drives: Off
 Dome: HOME

Misc.

Telescope Azimuth: 180.0
 Dome Azimuth: 270.0
 Focus: 4095
 Analog HA: -10.1772
 Analog DEC: -143.448

Communication

ExCom: Off
 MNCP: Off
 TCP/IP: Off

Activity message

The WinTCS display is a window which 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, and Julian Date. The Rates group box shows Track rates, Track rate corrections, Guide and Set hand paddle rates, Cosine of the Declination status and Trail parameters. The Status group box displays the status of Dome control, Tracking, Drive power, Dome destination (home or track), handpaddle or guider inputs (NSEW), Slew Enabled, Slewing, Setting, and Trailing. The Misc. group box shows Telescope Azimuth, Dome Azimuth, focus position

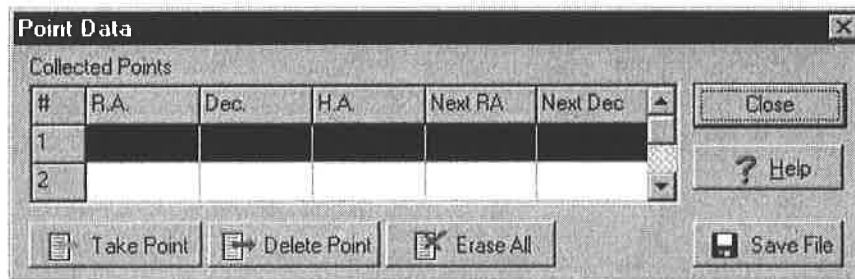
and absolute axes positions. In the lower right is the Communications group box which shows if ExCom, MNCP, or TCP/IP are active. Menus are provided at the top line of the WinTCS display.

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 faster 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 slew speed. SLEW is typically 4 degrees per sec on DFM telescopes. Automatic slews disable the hand paddle.

USING THE MENUS

File: Save Point Data

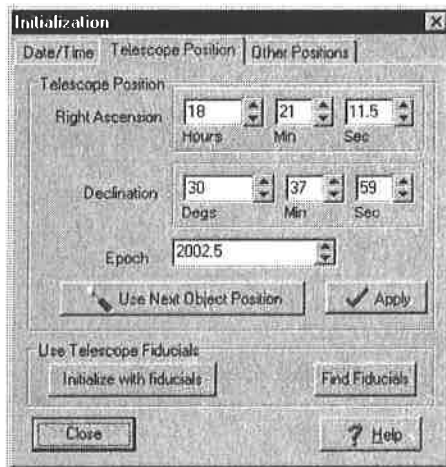


Save Point Data activates the pointing model data collection dialog box which lets the user collect, edit, and create files of pointing data. The Save Point Data dialog is non-modal and may be placed on the display for convenience during pointing model tuneup.

File: Exit

Exit provides for ending your WinTCS session.

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 which 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.

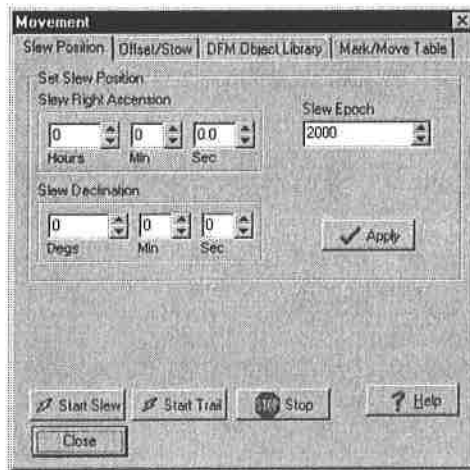
Telescope Position (ZERO POINT): This command sets the position of the telescope based on operator input. A button is available which will initialize the telescope position to the next object coordinates. Optionally the telescope position may be set using the telescope fiducials.

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.

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.

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

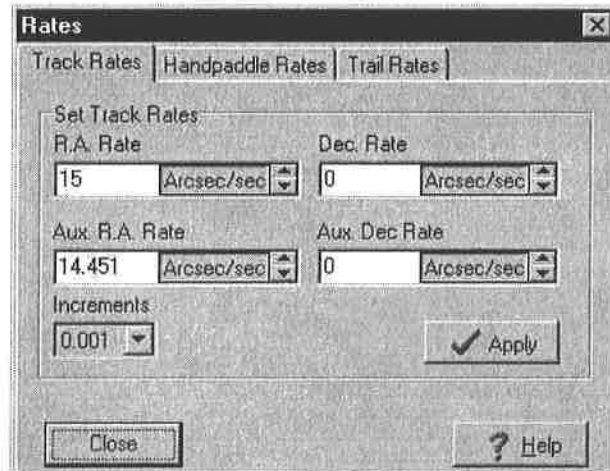
Mark/Move Table (MOVE/MARK): This dialog allows the user to load, save Mark files as well as edit mark file entries, make entries of current telescope position and slew to Marked positions. There are 500 entries possible for each file.

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

Start Slew (GO): This button starts automatic slews.

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

Telescope: Rates



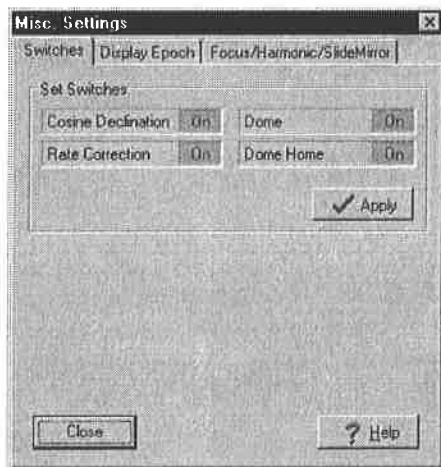
Track, guide, set, and trail rates may be set from the menu. Rates are arbitrary from zero to slew speed, allowing tracking of astronomical objects or satellites. All motion of the telescope is superimposed on the track rates specified. Slews to coordinates are optimized for astronomical objects with 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 which 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.

Telescope: Miscellaneous



Switches (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. 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.

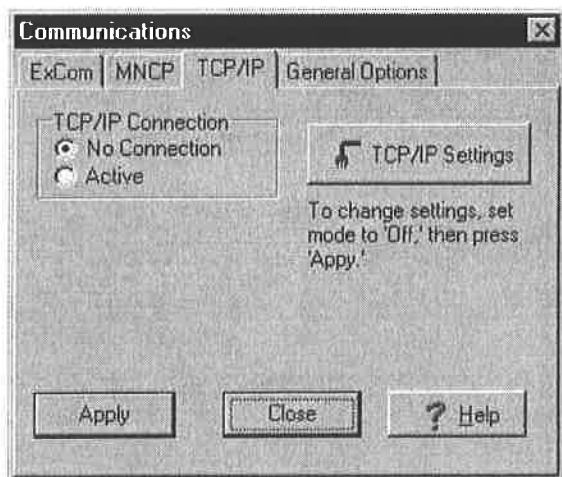
Display Epoch (EPOCH): The display epoch may be set to any value.

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.

View:

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

Options: Communications



Communications events may be logged.

Excom: To use the standard DFM EXCOM interface. The external computer is user supplied and interfaces to the telescope controller through a serial port. Commands from the external computer are documented in the file EXCOM & TCP/IP.TXT which is an appendix to this document. This feature is designed to provide a telescope control system which 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 (and by users of ASCOM software). 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 which is an appendix to this document. This feature is

designed to provide a telescope control system which can be slaved to a data acquisition computer or general observatory computer used to provide a customer supplied interface to the telescope control system.

Options: Night Colors

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

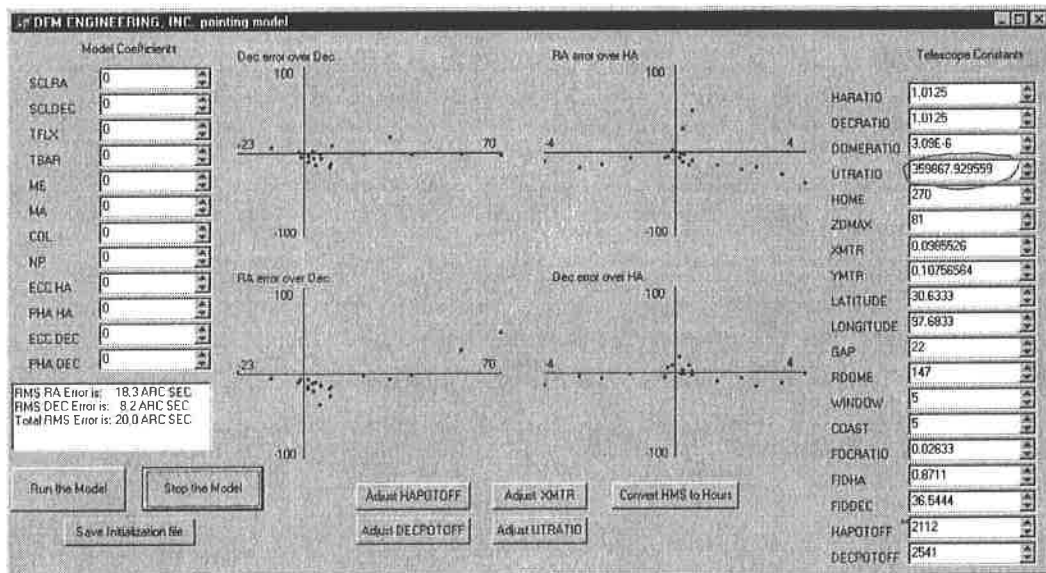
Options: Defaults

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

Help

WinTCS features on-line help.

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.INI.

The Data required is:

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

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 which 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 which 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 the 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 which is directly related to some aspect of the telescope mount. The determination of constants should be done in a methodical way to isolate 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 scale factors are about theoretical. 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. 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 pointing collimation needing adjustment after primary mirror movement due to re-aluminizing or cleaning.

INITIALIZATION FILES

There are three files which 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 file 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.INI. 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.INI or the file may simply be edited. The following list shows the typical contents of WinTCS.INI 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
degrees

dome control algorithm target window

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

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 all resident in the control software.

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 which 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 the 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 here is the SLEW command sent over the TCP/IP interface: #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 which runs at 200 Hz. The PC Computer has a battery backed up clock which 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> 13 <CR>	COMMAND # LIBRARY #
TCS RESPONDS	NO RESPONSE	ENABLES SLEW TO LIBRARY OBJECT

Select library object (OBJECT): This is a slew to a library of objects which 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 which are useful for initializing the telescope position in the northern hemisphere. A library for southern hemisphere users as well as custom libraries are available. Check the status bits for ENABLED and TARGET OUT OF RANGE. A COMMAND 12 must be sent to move the telescope.

TMOVE COMMAND 9

PROCEDURE SLEWS TO AN OBJECT PREVIOUSLY STORED WITH THE MARK COMMAND

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

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

ZENITH COMMAND 10
SLEWS THE TELESCOPE TO THE ZENITH

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

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

TRAIL COMMAND 11

START TRAIL

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

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

GO COMMAND 12
INITIATE MOTION COMMANDS

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

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

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

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

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

TRACK COMMAND 14
CHANGE TRACK RATE RA & DEC

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

Set track rate (TRACK RATE): This command allows modification of both RA and DEC track rates. There is provision for an auxiliary track rate which 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 handpaddle GUIDE rates: Guide is a traditional handpaddle 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 handpaddle 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. Handpaddle guide while trailing is supported.

COSDEC COMMAND 18

TURN ON FUNCTION WHICH DIVIDES THE COMMANDED RA HANDPADDLE 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 handpaddle 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> 0 <CR>	COMMAND # STATUS (OFF) (1 ON)
TCS RESPONDS	NO RESPONSE	CHANGES DOME STATUS BIT

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

GUIDER COMMAND 21

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

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

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

DOEPOCH COMMAND 22

SET THE DISPLAY EPOCH

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

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

MARK COMMAND 23

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

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

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

COEFFICIENTS COMMAND 24

CHANGE TELESCOPE AND POINTING MODEL PARAMETERS FROM EXCOM

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

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

COORDS COMMAND 25

RETURN TELESCOPE COORDINATES, TIME AND DATE TO THE EXCOM

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

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

STAT COMMAND 26

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

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

Status Byte Assignments:

BYTE	BIT	DESCRIPTION
STATL	0	INITIALIZED
	1	GUIDE ON/OFF
	2	TRACK ON/OFF
	3	SLEW ENABLED
	4	DOME ON/OFF
	5	APPROACHING LIMIT
	6	FINAL LIMIT
STATH	7	SLEWING
	0	SETTING
	1	TRAILING
	2	EXCOM ON/OFF
STATLH	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
	31 <CR>	COMMAND #

0 <CR>

CLOSE
(1 OPEN)

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