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TELESCOPE CONTROL SYSTEM

DFM OPERATIONS MANUAL

REFURBISHMENT OF THE PERKIN ELMER 63 INCH APERTURE TELESCOPE

OBSERVATOIRE DU MT-MEGANTIC

NOTRE-DAME DES BOIS, QUEBEC

CANADA

By DFM ENGINEERING, INC. 2001

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Ship Date: April 16, 2001

CONTENTS

1.00 SECTION 1 GENERAL DESCRIPTION

1.10 MECHANICAL

The Perkin Elmer 63 inch aperture Telescope is an equatorial mounted Cassegrain telescope. After modification the RA drive is one stage of worm gears driven by a stepping servomotor through two timing belt and pulley stages. The HA encoder is driven off the HA worm shaft. The DEC drive is one stage of worm gears driven by a stepping servomotor through two timing belt and pulley stages. The DEC encoder is driven off the DEC worm shaft. The focus motion is provided by a servo-motor driven secondary mirror and focus position is recorded with a Potentiometer. The existing instrument rotator has been modified to allow operation with two AC motors driving the brakes and a variable speed DC motor driving the rotation pinion. The instrument rotator position is encoded with a multiple turn potentiometer which provides feedback for the software control.

1.20 ELECTRONIC

The telescope is controlled with a 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 handpaddle plugs into the motor driver chassis (MDC) and a second handpaddle 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 axes positions. An AD-574A (12 bit) analog to digital converter is used to read the focus position pot. The electronic chassis are housed in a 19 inch wide rack. Power for the chassis is 115 volts.

1.30 SOFTWARE

The software is written in 80486 assembly code and XPL0, a Pascal-like high level language. The software is multitasking, using a timer in one of the VIA chips to generate an interrupt for the executive. The executive distributes time between the tasks in such a way that the tasks appear to be executing at

the same time. Nine tasks and the executive share the control function. There is a minimum of linkage between tasks to simplify the control software.

TASK0 services the menu and keyboard input.

TASK1 calculates the telescope position display information.

TASK2 displays telescope status.

TASK3 executes menu and external computer commands.

TASK4 controls the Right Ascension motor.

TASK5 controls the Declination motor.

TASK6 services the handpaddle, limits and front panel inputs.

TASK7 controls the dome.

TASK8 services input over a serial port from an external computer.

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.

2.00 SECTION 2 ADJUSTMENTS

2.10 BALANCE

It is important to balance the telescope to optimize performance, increase instrument life, and for safety. Balance of both axes of the telescope may be checked with the amp-meters on the front panel of the motor driver chassis. The meters read +3 and - 3 amps full scale. Use the handpaddle to see that the same current is required to slew in the two directions for each axis. Adjust counterweights until balance is achieved.

1. Balance the telescope with trim weights added to the North or South side of the primary mirror cell with the tube pointed at the zenith.
2. Balance the tube assembly top to bottom with the tube nearly horizontal.
3. Balance the Right Ascension axis (tube in any position).

2.20 LIMIT SWITCH

There is a mercury limit switch assembly (by DFM) 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 over-ride switch is provided so that the telescope can be driven out of the limit with the handpaddle. This keyed over-ride switch should be used only when the fault has been corrected. The focus axis has two sets of limits. The first set provides logic to the hand paddle input. The second set cuts power to the servo-motor if there is a servo failure. There is a momentary focus limit-over-ride switch which may be used to bypass the second set of limits.

2.30 ALIGNMENT

The following procedure is recommended for polar alignment:

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

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

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

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

   Adjust in AZIMUTH to correct drift.

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

	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.

3.00 SECTION 3 OPERATION

3.10 STARTING UP

The control system is able to accommodate operation on either side of the pier. Choice of operation is selected from the initialization menu. The system defaults to West side operation at startup.

Turn on the main power breaker on the bottom of the front panel. Raise the computer door and press the round button to start the computer. After some disk access time the C:\TCS> prompt will appear. Type TCS <cr> 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 column (center bottom) 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 supplies power for the encoders. The latching HALT MOTORS button interrupts power to the servo-motors.

3.20 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 selects, upon starting TCS, the EXCOM interface if it is in the ON position. In the OFF position this switch selects the interface to "The Sky", a planetarium program by Software Bisque. The EXCOM switch should not be changed while TCS is running. The AUTODOME switch enables the dome control. This switch should be turned off until the dome has been properly initialized with command 3, "set dome". 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 in the TCS display.

3.30 THE DISPLAY

The TCS display is a VGA monitor dedicated to the display of telescope position and status. Telescope position is 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 section of the display shows time, dome position, focus position,

instrument rotator position and error conditions if they are encountered. Errors include the limit conditions and target out of range. The lower left is reserved for display of the rates. The bottom center is reserved for the status display. The lower right is the terminal command device (Menu). TCS486 uses two keyboards and monitors to support local and remote command and display capability.

3.40 USING THE HANDPADDLE

The Handpaddle 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 handpaddle using IN or 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 1.5 degrees per second. SLEW is 1.5 degrees per sec. Automatic slews disable the handpaddle.

3.50 USING THE MENU

Menu commands control the telescope from the keyboard. Commands are divided into four sub-menus: Initialization, Movement, Rates, and Miscellaneous.

3.51 *** Initialization ***

Set date and 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. The PC's battery backed-up clock is reset to the universal time and 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. TCS time is kept in a hardware clock which runs at 200 Hz. Always check the UT and date after starting TCS. It the UT or the date are wrong then run this command to correct them.

Set telescope position (ZERO POINT): This command sets the position of the telescope based on operator input. Three zeros for input will initialize the telescope position to the next object coordinates.

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. If you want to set the dome position to North (0.) then use a small number like 0.1 degrees.

Set instrument rotator position: This command is used to move the instrument rotator.

Set focus position (ZFOCUS): This command is used to initialize the focus position display. The focus position uses an absolute potentiometer. This command applies an offset to the pot position.

Open data file: This command opens a file on the computer for storing pointing model data. The pointing model data is taken in the movement menu. TCS will add the suffix ".PAT" to the file name.

Close data file: This command closes the pointing model data file to the hard disk.

3.52 *** Movement ***

All of the motion commands may be canceled with the STOP command in the movement menu. The first set of limits will also terminate automatic motion commands. All motion commands except TRAIL require the Start slew command 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 its coordinates 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.

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.

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 500 entries possible. These objects are temporary storage in RAM only.

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.

Start trail (TRAIL): This command turns the trail function on. The stop command is used to cancel trailing.

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

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

Write data to file: This command records a data point to the pointing model data file. The resulting file may be used with the pointing model program to refine the pointing model coefficients.

3.53 *** 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.

Set 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.

Set handpaddle rates (GUIDE RATE), (SET RATE): Guide is a traditional handpaddle 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.

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.

3.54 *** Miscellaneous ***

Set switches (COSDEC), (RATECOR), (DOME), (HOME):

(COSDEC): This command turns on a feature that divides commanded Right Ascension handpaddle 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.

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

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 command. An entry number and three returns are sufficient to mark the present telescope location. There are 500 entries possible. When TCS starts it reads in a file named MARK.DAT which may contain objects of interest to a user. To use this feature, just copy a file MARK.DAT to the TCS directory before starting TCS. This file should have three real numbers for each object: RA, DEC, and EPOCH.

3.60 EXTERNAL COMPUTER INTERFACE

To use the standard DFM EXCOM interface, start TCS with the EXCOM front panel switch in the ON position. The external computer is user supplied and interfaces to the TCS486 telescope controller through a serial port. Commands from the external computer are documented in the file EXCOM.TXT which is an appendix to this document. This feature is designed to provide a telescope control system (TCS486) 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.

3.70 ASTRONOMICAL COMMAND LANGUAGE (ACL)

To use the ACL interface, start TCS with the EXCOM switch on the front panel in the OFF position. The TCS supports ACL as defined by Merlin Controls Corporation and may be commanded from "The Sky", a planetarium program by Software Bisque in Golden, Colorado. As with the DFM External Computer Interface, a second computer is required to run "The SKY". 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: COM1, 9600 Baud, ACL telescope.

3.80 CONTROL SYSTEM SHUTDOWN AND RESTART

To stow the telescope for convenient restart:

(in the dome)

Move the telescope to a convenient position.
Cover the optics using covers provided.
Turn off tracking (command zero track speed).
Command the TCS to slew to the zenith.

(move to the control room).

Place dome home-track switch in the HOME position.
Wait for the dome to go home.
Wait for the telescope to go to the zenith.
Press the red HALT MOTORS button on the motor driver chassis to interrupt power to the telescope motors.

Turn off dome with the front panel switch.

Turn off main power switch on the transformer enclosure.

Close the dome shutter.

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 (usually at the ZENITH).

(in the control room)

Power up the system with the main circuit breaker on the lower front panel.

Start TCS (type TCS <cr>).

Let TCS Auto-initialize.

Unlatch red HALT MOTORS button on the motor driver chassis.

Turn on tracking.

Turn on dome.

Place Dome Home-Track switch in the track position.

Remove covers from the optics.

Select and slew to an ephemeris star.

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

Center star in eyepiece.

Set telescope coordinates with "Set telescope position" in the initialization menu (entering "0's will set telescope position to the NEXT OBJECT coordinates.

3.90 INSTRUMENT ROTATOR

The motorized instrument rotator must be commanded from TCS. The command is in the Initialization menu and the input units are degrees. Travel is limited to +/- 120 degrees with North = 0. The position is displayed below the telescope focus on the TCS display. Control electronics for the instrument rotator are in the Mirror Support Chassis.

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 TCS on floppy disk so that the system hard disk can be rebuilt. DOS was supplied with your computer and can be reinstalled if necessary. Use DOS utilities to make backups of your TCS files on floppy disks.

4.20 BELT TENSION

There are timing belts between the motor and primary gearing in both Declination and Right Ascension. Check the timing belts for wear and tension, they should be snug, but not tight.

4.30 SERVO-MOTOR SETUP

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

4.40 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 name ASU.DAT.

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 is sufficient for analysis. TCS includes commands which allow these data to be taken and stored on the hard disk for subsequent analysis. Commands in the Initialization menu OPEN and CLOSE a file. The command "Write data to file" in the Movement menu will record the data for a star position each time it is used.

***** 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, exit TCS with the RESET button and run the program PNTM. To do this type in: PNTM filename.PAT <cr>.

The program PNTM 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. During the process of exiting PNTM, the initialization file may be updated.

Analysis of the graphs is done 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.

RA vs HA This graph shows the HA scale factor in its slope. The asymmetric term is refraction.

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 should be corrected 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, and are not site dependent.

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

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 which 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, the site latitude and longitude are correct 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.

PNTM will run with or without a printer. If there is no printer, do not request a printout, and do not request a copy of the graphs. If there is a printer, a printout must be made before the graphs will print. If the program hangs up, it is because the printer is missing; to recover press reset and start the program over.

For setting up a new telescope:

1. Adjust the elevation with a bubble level protractor. Adjust the azimuth by sighting 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 determine the sense (direction) of the residual 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 need to change the collimation term after primary mirror movement due to collimation or cleaning.

4.50 INITIALIZATION FILES

There are three files which are read in by TCS when the program starts: LIB.DAT, MARK.DAT and ASU.DAT. The library of objects is named LIB.DAT. Each library object is stored as six integers and the EPOCH is assumed to be 2000. The library file should not be changed. The mark-move data is read in with a file named MARK.DAT. This file 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 ASU.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 simple text editor like ED or EDIT. The program PNTM can be used to modify ASU.DAT or the file may simply be edited. The following list shows the contents of ASU.DAT with a description for each entry.

LATITUDE:= 43.5833	site latitude degrees
LONGITUDE:= 84.7833	site longitude degrees
TBAR:= 0.90	site temperature and pressure coefficient
ME:= 0.0	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

TFLX:= 0.0	tube flexure
HOME:= 270.	dome home position
ZDMAX:= 74.9	maximum zenith distance for automatic slew
XMTR:= .10756564	RA axis motor step size arcsec/step
YMTR:= .10756564	DEC axis motor step size arcsec/step
DOMERATIO:= 6.4160E-6	dome encoder ratio radians/encoder unit
HARATIO:= 1.062566	RA axis position encoder ratio arcsec/eu
DECRATIO:= 3.241048	DEC axis position encoder ratio arcsec/eu
UTRATIO:= 3.59137036E5	universal time clock scalar interrupts/hour
GAP:= 12.0	dome gap (telescope-dome aperture)/2 inches
RDOME:= 96.0	dome radius inches
WINDOW:= 2.5	dome control algorithm target window degrees
COAST:= 1.0	dome coast distance degrees
FOCRATIO:= .8	focus encoder ratio

5.00 SECTION 5 TROUBLE SHOOTING

5.10 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 failure of the encoder on the motor shaft. Repair of non connector failure modes should be made by an experienced technician or a representative of DFM Engineering Inc.

5.20 BAD POINTING

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

6.00 APPENDICES

6.10 EXCOM DOCUMENT

EXCOM2J 22 January 1997
DFM ENGINEERING, INC.
BY MARK S. KELLEY

This document is a supplement to the Operations Manual and it describes the DFM external computer interface (EXCOM). This is not the Astronomical Command Language (ACL) interface. Both the ACL interface and the EXCOM interface are resident in the control system and they are selected by the front panel switch.

EXTERNAL COMPUTER

To use the standard DFM External Computer Interface (EXCOM) interface, start TCS with the EXCOM front panel switch in the ON position. The external computer is user supplied and interfaces to the TCS486 telescope controller through a serial port. This feature is designed to provide a telescope control system (TCS486) 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 TASK0 (through the keyboard). 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 TCS serial port is COM1. 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.

FOR ALL OF THESE DESCRIPTIONS <CR> DENOTES THE CARRIAGE RETURN CHARACTER HEXADECIMAL $0D. IN DFM'S CHOSEN COMPUTER LANGUAGE (XPL0), I/O ROUTINES (RLIN, INTIN, CHIN), CARRIAGE RETURN IS USED TO TERMINATE AN INPUT OR OUTPUT CHARACTER STRING. THIS IS NOT UNCOMMON IN OTHER COMPILERS (COMPUTER LANGUAGES).

6.20 SERVO TUNEUP DOCUMENT

Servo.doc Dec 1996

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

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

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

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

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

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

The servo test program is named SHAKETST.EXE and is in the TCS sub-directory. To run the test program type:

SHAKETST<cr>

The program will prompt for the HA or DEC axis.

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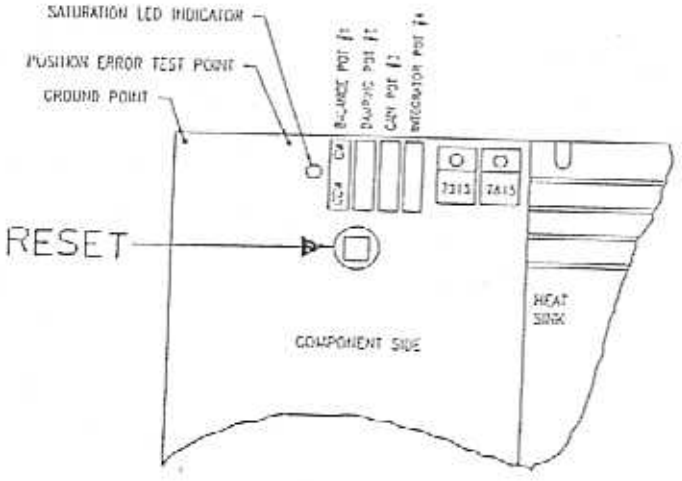
The four figures show representative oscilloscope traces of a step forward and then back. Figure 1 shows the servo with low gain and damping. The response to the step input is slow and the overshoot is large. The system continues to ring until the step in the opposite direction occurs. Figure 2 show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

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

After the HA axis is adjusted, press in the HALT MOTORS button and reset the computer. When the computer has rebooted, run SHAKETST again and select the DEC axis. Repeat the tuneup for the DEC axis.



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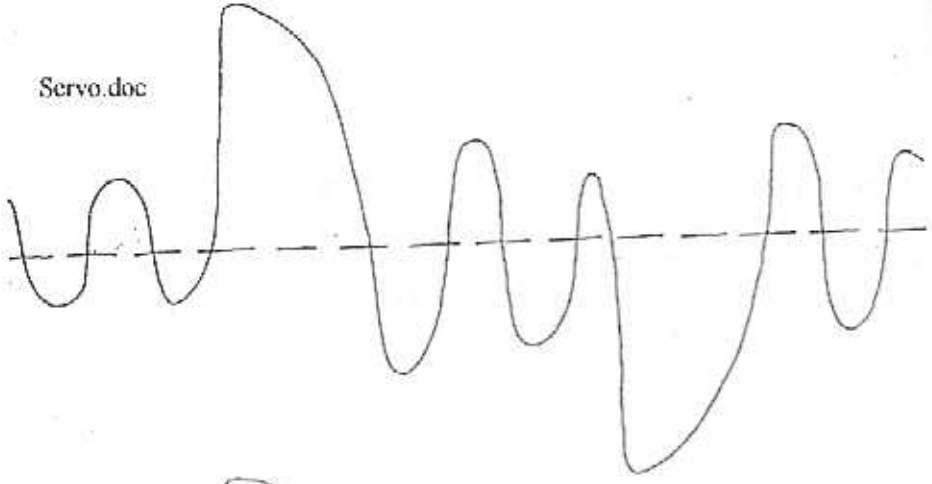

figure 1
GAIN too low
DAMPING to high
overflow LED
may come on

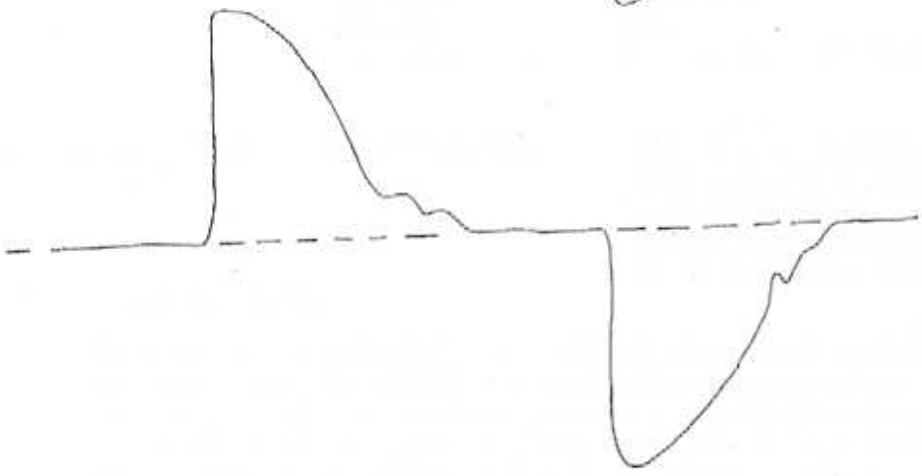

figure 2
GAIN too high
DAMPING too high
drives noisy

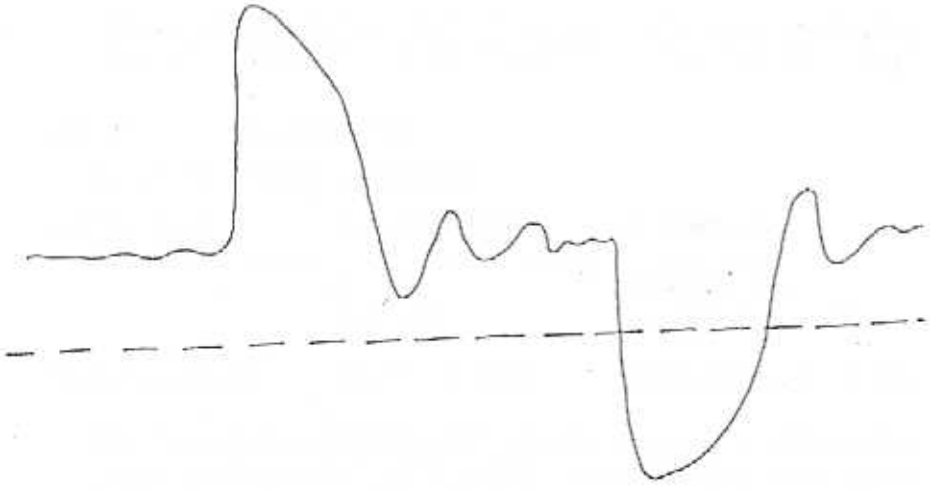

Figure 3
Adjust INTEGRATOR
to remove DC offset

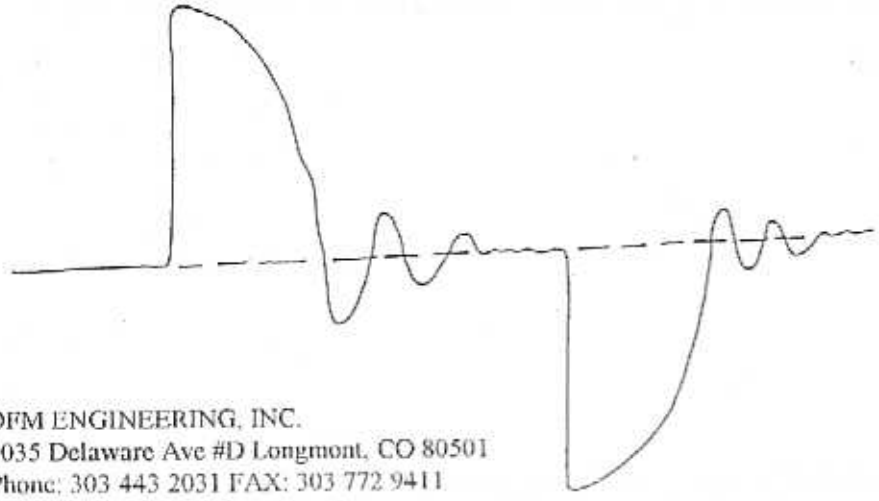

Figure 4
Normal servo response
for a telescope

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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.

ZROTATOR COMMAND 4

SET THE POSITION OF THE INSTRUMENT ROTATOR

EXCOM SENDS	CHARACTERS	COMMENTS
	4 <CR>	COMMAND #
	45.0 <CR>	POSITION (+/- 120. Degrees)
TCS RESPONDS	NO RESPONSE	

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 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>	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 500 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>	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 IS A CONVENIENCE FOR SETTING THE DISPLAY ONLY.
THE GUIDER IS HARDWARE OR'D WITH THE HANDPADDLE.

EXCOM SENDS	CHARACTERS	COMMENTS
	21 <CR>	COMMAND #
	0 <CR>	STATUS (OFF)
		(1 ON)
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 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 500 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
	2054.1 <CR>	TELESCOPE FOCUS
	167.2 <CR>	DOME POSITION
	10.0 <CR>	INSTRUMENT ROTATOR POSITION

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

STAT COMMAND 26

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

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

Status Byte Assignments:

BYTE	BIT	DESCRIPTION
STATL	0	INITIALIZED
	1	GUIDE ON/OFF
	2	TRACK ON/OFF
	3	SLEW ENABLED
	4	DOME ON/OFF
	5	APPROACHING LIMIT
	6	FINAL LIMIT
	7	SLEWING
STATH	0	SETTING
	1	TRAILING

	2	EXCOM ON/OFF
	3	DOME OK
	4	TARGET OUT OF RANGE
	5	COSDEC ON/OFF
	6	RATE COR ON/OFF
	7	DRIVES ON/OFF
STATLH	0	SLEW COMPUTING
	1	DOME TRACK / FREE
	2	"N"
	3	"S"
	4	"E"
	5	"W"
	6	NEXT OBJECT ACTIVE
	7	AUX. TRACK RATE

STATEX 0 FOCUS SLEW
1 ROTATOR SLEW

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.