Isaac Newton Group of Telescopes

WHT-TCS-9

William Herschel Telescope
Telescope Control System

USERS' MANUAL

Version 2.0
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1 Starting and stopping the TCS

1.1 Startup

To start the TCS, log in to LPAS4 from the Tektronix X terminal in the WHT control desk. The username and password are displayed on the X terminal. You will be presented with a menu similar to:

```
  This is the WHT TELESCOPE CONTROL SYSTEM

  The default TCS version is W5-0-0

  Please enter an option -

 START   - Start the TCS, Info display on 161.72.6.89
                         USER window on  161.72.6.89
           using DECNET for communications


 STOP    - Stop the TCS

 OPTIONS - Select the options menu

 EXIT    - Exit this menu and log out

Option>
```

If you want to run a different version of the TCS, or if you want the display and user windows to appear on a different device to that shown, type:

```
Option> OPTIONS
```

This will display the options menu:

```
Option> options
 Please enter an option -

 VERSION  -  Select a different TCS version

 DISPLAY  -  Select a different display device

 SIMULATE -  Run the TCS in simulation mode, Info display on lpx03
                                            USER window on  lpx03

 TELD     -  Start the TELD task

 NFSMOUNT -  Mount the ICS Unix partition

 MAIN     -  Return to the main menu

Option>
```

Select the option required by typing: `VERSION` or `DISPLAY` and follow the instructions.

If you typed `VERSION`, you will see a list of the available versions. Select the one you want, or press RETURN if you want to keep the default value. If you typed `DISPLAY` you will be asked for the IP name

or address of the new device, pressing RETURN will keep the default value. The top-level screen then reappears. Type:
`START`
to start up the TCS. The display and user windows will appear, the user window will display a few lines of information and then the `USER>` prompt.

1.2 Stopping the TCS

Under normal circumstances, the TCS should be closed down using the `TCSEXIT` command at the user interface (see below). If the user interface is not working (e.g. its window disappears or is accidentally deleted), then the system can be stopped from another login session. Log in as described in the previous sub-section and type `STOP` at the `Option>` prompt.

2 TCS user interface commands: a classified list

This section contains a summary of the commands available at the user interface of the telescope control system, classified into functional groups. Details of individual commands are given in the alphabetical list of Section ??. Commands which require the telescope or one of its mechanisms to be moved are forbidden in engineering mode.

2.1 General TCS commands

All allowed in engineering mode.

- `ACKNOWLEDGE` Turn off a limit or engineering mode alarm.
- `CLONE` Make a copy of the display window on another device.
- `COMMS` Close current dtask link, allowing new connection to a different dtask.
- `HANDSET` Select handset mode.
- `HELP` Get help on a command.
- `RECALL` Recall a previous command.
- `TCSEXIT` Select engineering mode and close down the control system.
- `TRANSFER` Transfer control to or from a remote terminal.

2.2 Source data entry

All allowed in engineering mode.

- `DEC` Enter declination of edit source.
- `DIFF_RATES` Enter non-sidereal tracking rates for the edit source.
- `EPOCH` Enter epoch of position for edit source.
- `EQUINOX` Enter equinox for edit source.
- `PARALLAX` Enter parallax of edit source.
- `PM` Synonym for `PROPER_MOTION` (*q.v.*).
- `PROPER_MOTION` Enter proper motions of edit source.
- `RA` Enter right ascension of edit source.
- `RADIAL_VEL` Enter radial velocity of edit source.
- `RV` Synonym for `RADIAL_VEL` (*q.v.*).
- `SOURCE` Enter name, right ascension, declination and equinox for edit source.

2.3 Catalogue handling

All allowed in engineering mode.

- `ADD` Add the contents of the edit source data block to the catalogue as a named entry.
- `ERASE` Clear the user catalogue.
- `FIND` Get a named catalogue entry and put it in the edit source block.
- `INCLUDE` Append a text catalogue to the current user catalogue.
- `MARK` Store the current telescope position as a named catalogue entry.
- `OUTPUT` Output the current catalogue to an ASCII file, terminal or line printer.
- `REMOVE` Delete a catalogue entry.

2.4 Source change

None allowed in engineering mode.

- `BLIND_OFFSET` New source (from catalogue) with local corrections to the pointing model.
- `GOCAT` New source (from catalogue; specified by name only).
- `GOMOON` New source (moon coords from sla_DMOON)
- `GOTO` New source (direct input of name, right ascension, declination and equinox).
- `NEXT` New source (using data in edit source block).

2.5 Positional and Aperture offsets

`ENTER` is allowed in engineering mode; the remainder are not.

- `APERTURE` Execute a preset (numbered) aperture offset.
- `BEAMSWITCH` Execute an aperture offset with direct input of x and y.
- `ENTER` Input data for numbered aperture or positional offsets.
- `OFFSET` Execute a positional offset with direct input of $\Delta\alpha$, $\Delta\delta$ or ξ, η.
- `POSITION` Execute a preset (numbered) positional (ξ, η) offset.
- `STORE` Store aperture or positional offsets set up using the handset.
- `TWEAK` Apply a given (x_A, y_A, ρ_A) aperture offset.

2.6 Autoguiding

`AGSELECT`, `PROBE` and `TVCAMERA` are allowed in engineering mode; the remainder are not.

- `AGSELECT` Identify the autoguider currently in use.
- `AGVIEW` Aperture offset to move image to autoguider field.
- `AUTOGUIDE` Lock or unlock the autoguider loop.
- `PROBE` Input (r, θ) coordinates of guide probe.
- `TVCAMERA` Identify the TV camera currently in use.
- `TVGUIDE` Lock or unlock the TV guiding loop.

2.7 Calibration procedures

The keywords for this command which require the telescope to be moved are not allowed in engineering mode.

- `CALIBRATE` Determine encoder zero-points and collimation errors.

2.8 Mechanism control

`DFOCUS` is allowed in engineering mode; the remainder are not.

- `ALTITUDE` Move the telescope to a given altitude and stop it.
- `AZIMUTH` Move the telescope to a given azimuth and stop it.
- `DFOCUS` Set the focus offset.
- `DOME` Move the dome to a given azimuth and stop it.
- `ELEVATION` Synonym for `ALTITUDE` (*q.v.*).
- `FOCUS` Move the focus to a specified position.
- `PARK` Move the telescope (and optionally the rotator) to a defined position and stop.
- `ROTATOR` Move the rotator to a given sky PA (tracking) or mount PA (stopped).
- `STOP` Stop a mechanism or combination of mechanisms.
- `UNWRAP` Move azimuth or rotator by 360°.

2.9 Mechanism configuration

`TRACK` is not allowed in engineering mode; the remainder are allowed.

- `ENCODER` Set the combination of encoders used for pointing.
- `ENGINEERING` Select engineering mode.
- `RATE` Set the encoder used by the hardware position loop.
- `SENSOR` En/disable corrections from displacement transducers.
- `TRACK` Turn focus, dome, rotator or telescope tracking on or off.
- `WRAP` Override the azimuth wrap determined from the zone switch in case of failure.
- `ZEROSET` Determine incremental encoder zero-points.

2.10 Change of focal station and instrument

Both are allowed in engineering mode. Note that "Select" in this context means "set up software and drive the correct rotator": the Nasmyth flat is not moved.

- `STATION` Select focal station.
- `INSTRUMENT` Tell the TCS which instrument is in use.

2.11 Display functions

All allowed in engineering mode.

- `DISPLAY` Change the coordinate system of the displayed telescope position.
- `MOON` Give the current right ascension and declination of the Moon.
- `PAGE` Switch to another information display page.
- `SHOW` List the edit source block.

2.12 Logging of test data

All allowed in engineering mode.

- `LOG` Log tracking errors and associated data.
- `POINT` Write encoder coordinates to a data file.
- `RMS` Calculate and display mean and rms servo errors.
- `SNAPSHOT` Record the current information display page.

2.13 Meteorological and Earth-rotation data

All allowed in engineering mode.

- `HUMIDITY` Input relative humidity used in refraction calculation.
- `POLE` Input values of polar motion.
- `PRESSURE` Input barometric pressure used in refraction calculation.
- `TEMPERATURE` Input temperature used in refraction calculation.
- `UT1UTC` Input UT1 − UTC.
- `WAVELENGTH` Input wavelength used in refraction calculation.

3 TCS user interface commands: an alphabetical glossary

The following section gives a brief summary of the operation of each command together with examples and defaults.

Notation:

- Examples of commands entered at the terminal are in typewriter font: `DEC 12 34 56.78`;
- Angle brackets denote parameter values or keywords: `<angle>`;
- Square brackets denote optional parameter values or keywords: `[x,y]`; all other parameters and keywords are obligatory;

In most cases, TCS commands can be issued either at the local user interface terminal or at the VaxStation running ICL. Users who wish to coordinate control of telescope and instruments are encouraged to take advantage of the latter mode of operation. Every effort has been made to make the command syntax identical on the two machines, but differences between the DCL and ICL command languages may cause some confusion. In general, if a command is issued correctly with all of its parameters, then the two systems will behave similarly. Both command languages are set up for minimum matching of command strings and neither is sensitive to case. The main differences are:

1. ICL will always acknowledge completion of a command. Response will be almost instantaneous except for commands which move the telescope mechanisms. These complete when the mechanisms concerned are in position.
2. Prompting for unspecified input has differences of detail.
3. Error messages differ, usually in the sense that the TCS gives an additional, more accurate description of the problem.
4. ICL does not allow a command to be issued if a previous attempt at the same action is still in progress. The TCS allows the first command to be overridden by the second. This can sometimes lead to problems from ICL (*e.g.* if the wrong object is selected).
5. A few commands (primarily those which produce screen output) are not available from ICL. These are noted explicitly below.

3.1 ACKNOWLEDGE

Turn off the engineering mode and/or software limit alarms.

Format: `ACKNOWLEDGE <alarm_type>`
Defaults: `ACKNOWLEDGE ALL`
Parameters: None.
Keywords:

`LIMIT`	turn off an alarm caused by an altitude, azimuth or rotator software limit;
`ENGINEERING`	turn off an alarm caused by an unexpected switch into engineering mode;
`ALL`	turn off any alarm.

Example: `ACKNOWLEDGE`
Comments: An alarm (continuous bleeping) is triggered if the telescope or rotator encounters a software limit whilst tracking or when requested to slew to an object below the horizon or if a switch from computer to engineering mode occurs unexpectedly (i.e. not as a result of an `ENGINEERING` or `TCSEXIT` command).

3.2 ADD

Write the current contents of the edit source data area as a new entry in the user catalogue.

Format:	`ADD`
Defaults:	None.
Parameters:	None.
Keywords:	None.

3.3 AGSELECT

Select which autoguider to use.

Format:	`AGSELECT <autoguider_name>`
Defaults:	None. The Cassegrain autoguider is selected on startup.
Parameters:	None.
Keywords:	Valid autoguider names are:

`CASSEGRAIN`	the Cassegrain off-axis autoguider;
`UESSLIT`	the UES autoguider used to view the spectrograph slit and to guide on the object being observed;
`UESPROBE`	the UES autoguider used for off-axis guiding;
`PRIME`	the prime-focus off-axis autoguider;
`AF2_FIXED`	the fixed probe of the Autofib2 fibre positioner;
`AF2_MOVING`	the moving probe of the Autofib2 fibre positioner.
`WHIRCAM`	autoguider used with a beamsplitter at GHRIL;
`INTEGRAL`	Integral's autoguider;

Examples:	`AGSELECT CASS`
Comments:	The TCS needs to be told which autoguider is currently in use in order to perform the conversion between guide star pixel position and drive corrections.

3.4 AGVIEW

Perform an aperture offset to move an image onto the autoguider CCD.

Format:	`AGVIEW`
Defaults:	None.
Parameters:	None.
Keywords:	None.
Comments:	This command allows a field to be viewed using the autoguider. An offset is applied to move the image from the nominal aperture (usually the rotator centre) to the centre of the autoguider field. It is essential to tell the TCS which autoguider is in use and to define its position in the focal plane (use the `AGSELECT` or `PROBE` commands as necessary).

3.5 ALTITUDE

Move to the specified altitude and stop.

Format:	`ALTITUDE <angle>`
Defaults:	None.
Parameters:	The angle in degrees.
Keywords:	None.
Examples:	`ALTITUDE 85.72`
Comments:	To park the telescope at the zenith without moving it in azimuth, type `ALTITUDE 90`. This is much faster than the hardware ZENITH PARK function or the `PARK ZENITH` command and is all that is required in most circumstances. Tracking in azimuth and for the rotator are also disabled by this command.

3.6 APERTURE

Offset the telescope so that an object moves by a vector fixed in the focal plane.

Format: **APERTURE <aperture_number>**

Defaults: None. The reference position (aperture 0) is selected on startup. This is usually also the rotator centre, (0,0).

Parameters: The aperture number is in the range 0–10. The corresponding (x_A, y_A) displacement must have been set up previously in the initialisation file, or by using the **ENTER** or **STORE** commands. **APERTURE 0** is the reference position (see *Comments*).

Keywords: None.

Examples: **APERTURE 2**

Comments: An (x_A, y_A) shift in the focal plane is divided into two parts: the reference position, which is unaltered on source change and an aperture offset which is reset to zero on source change. The **APERTURE** command provides a means of switching between the reference position and previously-defined aperture offsets.

3.7 AUTOGUIDE

Lock or unlock the CCD autoguider loop.

Format: **AUTOGUIDE <state> [<x> <y> [<EW-gain> <NS-gain>]]**

Defaults: x and y default to zero. EW-gain and NS-gain default to those read from the initialisation file.

Parameters: The optional parameters x and y are the desired pixel coordinates for the guide star and are used with the **ON** keyword. If they are not specified, the system will adopt the current position of the guide star.
EW-gain and NS-gain must lie between 0 and 1.

Keywords: Valid autoguider states are:

- **ON** specifying that the telescope should be guided in response to guiding errors from the CCD autoguider.
- **OFF** specifying that autoguiding should be switched off, *i.e.* that any guiding errors from the CCD autoguider should be ignored.
- **SUSPEND** Put the TCS in a state where pixel coordinates are read from the autoguider and the current reference position is maintained, but guiding errors are not applied.
- **RESUME** Restart guiding if the loop has been suspended.
- **CENTRE** Autoguide on the centre of the chip

Examples: **AUTOGUIDE ON**
AUTOGUIDE ON 122.5 63.2

Comments: The autoguider sends xy pixel coordinates of a guide star to the telescope control computer. The TCS then adjusts the telescope drives to keep the star at a given location on the autoguider CCD. If the intention is to maintain the current positioning of a field (*e.g.* if acquisition onto a spectrograph slit has been verified), then the command **AUTOGUIDE ON** should be used. This takes the first position received from the autoguider after the command is issued, and keeps the guide star there. On the other hand, if the autoguider coordinates are already known, then the appropriate command is **AUTOGUIDE ON x y**. There are two cases where this is likely to be useful. The first is when an observation is to be repeated and the field is to be positioned at the same place on the detector. The guide probe and pixel positions should be repeated. The second case is guiding on the target object using the UES slit viewer. The x and y should be the pixel coordinates of the centre of the slit. Note that, for technical reasons connected with use of the command from ICL, the command **AUTOGUIDE ON -1 -1** means the same as **AUTOGUIDE ON**. The TCS must be told the autoguider in use (see **AGSELECT**) and, at Cassegrain, the orientation of the guide probe (see `PROBE`), otherwise the telescope corrections will be in the wrong direction. The function key F17 on the TCS keyboard is equivalent to the `AUTOGUIDE OFF` command. The function key F18 on the TCS keyboard is equivalent to the `AUTOGUIDE ON` command.

3.8 AZIMUTH

Move to the specified azimuth and stop.

Format:	`AZIMUTH <angle>`
Defaults:	None.
Parameters:	The angle in degrees. The azimuth axis has a range of $-175°$ to $355°$; the absolute encoder has a travel of exactly $360°$ after which it repeats. See `WRAP` and `UNWRAP`.
Keywords:	None.
Examples:	`AZIMUTH 275.34`
Comments:	Tracking in altitude and for the current rotator are also disabled by this command.

3.9 BEAMSWITCH

Offset the telescope so that an image moves by a vector fixed in the focal plane.

Format:	`BEAMSWITCH <offset_x> <offset_y>`
Defaults:	None. On source change (*e.g.* `GOTO`), offsets are reset to to the nominal values (this can also be done with the `BEAMSWITCH 0 0` or `APERTURE 0` commands: see `APERTURE`).
Parameters:	The aperture (x_A, y_A) positions in arcseconds.
Keywords:	None.
Examples:	`BEAMSWITCH 20.2 -100`

3.10 BLIND_OFFSET

Offset between a reference object which is centred on the acquisition TV and a faint target object.

Format:	`BLIND_OFFSET <source_name>`
Defaults:	None.
Parameters:	The name of the faint target object.
Keywords:	None.
Examples:	`BLIND 0512+22E`
Comments:	This is the standard method for locating very faint objects, which are difficult or impossible to see on the acquisition TV. Accurate positions for a brightish star and the faint target object must be entered in the catalogue. Slew to the bright star using `GOCAT` and centre it on the reference position with the handset keys. Then type `BLIND <source_name>` for the faint object. This offsets the telescope so that the faint object is accurately aligned with the reference position. The accuracy of the offset is better than 0.3 arcsec rms over offsets up to 20 arcsec. It can then be moved around the detector using the `BEAMSWITCH` or `APERTURE` commands. `BLIND_OFFSET` performs a local correction to the pointing model, assuming that the position of the reference object is accurate. Subsequent executions of `BLIND_OFFSET` all use this correction, so several faint objects can be observed using the same reference star. The `NEXT`, `GOTO` and `GOCAT` commands revert to the default global pointing solution.

3.11 CALIBRATE

Update pointing coefficients at the start of an observing session.

Format:	`CALIBRATE <solution>`
Defaults:	`CALIBRATE NEW`

Parameters: None.

Keywords:

`LAST`	recalls the last pointing solution. This may be useful if the running of the control program has been interrupted, but does not ensure very accurate pointing because the encoder zero-points may have changed.
`DEFAULT`	reverts to the default pointing solution in the initialisation file. This is a suitable course of action if the `CALIBRATE` command fails (*e.g.* gives very large rms errors).
`NEW`	packages a sequence of commands to do a short pointing calibration.
`FAINT`	as `NEW`, but using a grid of fainter stars with V magnitudes around 9.
`ZEROPOINT`	logs the current encoder reading and analyses it with a modified TPOINT procedure to calculate and install the 2 encoder zeropoints IA and IE.
`COLLIMATION`	logs the current encoder reading and analyses it with a modified TPOINT procedure to calculate and install the 2 collimation coefficients CA and IE.
`ANALYSE`	analyses the pointing log file generated by a series of `POINT` commands, then calculates and installs the coefficients IA, IE and CA. It is designed to be used when the procedure is run by the system computer rather than the TCS, and allows other TCS commands to be input during the procedure. This means that the autoguider can be used to centre the star, as `AUTOGUIDE` commands will be accepted.
`ANALYSE ZERO`	analyses the log file generated by a single `POINT CALIBRATE` command, then calculates and installs the 2 encoder zeropoints IA and IE.
`ANALYSE COLL`	analyses the log file generated by a single `POINT CALIBRATE` command, then calculates and installs the 2 collimation coefficients CA and IE.

Examples: `CALIBRATE`
`CALIBRATE LAST`

Comments: The `CALIBRATE NEW` command initiates an automatic sequence which does a restricted pointing measurement on 7 stars from the pointing grid in order to update the values for the encoder zero-points in azimuth and elevation and the collimation error in azimuth. Stars are selected to be close to the meridian and either North or South of the zenith, depending on the initial azimuth. A range of elevations must be covered. The telescope is driven to the first star and the handset mode is selected. When the telescope is tracking, the star should be moved on to the reference position using the handset keys. Once you are satisfied, press the HANDSET key. This logs the position and drives to the next star. Repeat these operations until all 7 positions have been logged. You will then be asked whether all of the stars were centred correctly. If you do not answer `Y` to this question, then the procedure will be aborted. The derived and previous values will be displayed, together with their r.m.s. errors, and you will be asked whether you want to accept the result. The errors should be in the range 0.5–1.0 arcsec for IE, 1.0–2.0 arcsec for CA and 1.0–3.0 arcsec for IA. If the errors are much larger than these values, then the solution should be rejected. Unless there has been a major change of configuration, the coefficients should not alter by more than a few arcseconds from night to night. Gross differences may indicate a problem. CTRL–Z may be used to abort the procedure at any time, but all of the measurements will be lost.
This command is not currently available on the system computer (from ICL).

3.12 CLONE

Create/delete a copy of the DISPLAY screen.

Format:	`CLONE <state> <device>`
Defaults:	None.
Parameters:	The name or ip address of the display device.
Keywords:	The allowed states are:
	`ON` creates a copy of the display screen on the specified device.
	`OFF` deletes all copies of the display screen from the specified device.
Examples:	`CLONE ON lpx31`
	`CLONE OFF 161.72.6.108`

3.13 COMMS

Close the current link to the dtask, set up ready for a new connection to another dtask.

Format:	`COMMS <linktype>`
Defaults:	None.
Parameters:	None.
Keywords:	The types of link allowed are:
	`DECNET`
	`DRAMA`
Examples:	`COMMS DECNET`
Comments:	The connection to a new dtask has to be made after this command has completed. To connect to the DRAMA dtask, log in as if starting the TCS and choose the menu item OPTIONS. Then choose the item TELD, which will start the DRAMA dtask, TELD. To connect to the DECNET dtask, use the ICL command tel_link_to_tcs.

3.14 DEC

Enter a declination in the edit source data area.

Format:	`DEC <dec_degrees> <dec_minutes> <dec_seconds>`
Defaults:	Value of declination: None,
	Sign of declination: '+'.
Parameters:	The declination in degrees, minutes and seconds of arc. The value is rejected if any of the components lie outside the following ranges:
	`dec_degrees` 0–89 inclusive
	`dec_minutes` 0–59 inclusive
	`dec_seconds` 0.0–59.99... inclusive
Keywords:	None.
Examples:	`DEC -12 34 56.78`

3.15 DFOCUS

Offset the focus to compensate for additional optical elements.

Format:	`DFOCUS <focus_offset>`
Defaults:	None.
Parameters:	Focus offset, in mm.
Keywords:	None.
Examples:	`DFOCUS 0.3`
Comments:	This command is intended to be used when the telescope focus has to be changed to compensate for the additional optical thickness of a filter. The virtual focus reading is unchanged, and the focus offset in use is displayed in the DF field on the bottom line of the Information Display.

3.16 DIFF_RATES

Enter differential tracking rate in right ascension and declination.

Format:	`DIFF_RATES <diff_rate_in_ra> <diff_rate_in_dec>`
Defaults:	None. Unspecified differential rates are assumed to be zero.
Parameters:	Right ascension and declination differential tracking rates in seconds/second and arcseconds/second, respectively.
Keywords:	None.
Examples:	`DIFF_RATES 0.01 -0.3`
Comments:	The differential (non-sidereal) tracking rates are added to the edit source data block. They must be actioned using the `NEXT` command. Note that differential rates are not included in a catalogue entry.

3.17 DISPLAY

Change the coordinate system of the information display.

Format:	`DISPLAY <coordinate_system>`
Defaults:	None. The default coordinate system on startup is **INPUT**.
Parameters:	None.
Keywords:	The allowed coordinate systems are:

`INPUT`	α and δ in the system used to input the source position;
`APPARENT`	α and δ in geocentric apparent coordinates;
`J2000`	α and δ in J2000 mean coordinates;
`B1950`	α and δ in B1950 mean coordinates;
`HA_DEC`	Topocentric hour angle and declination.

Examples:	`DISPLAY J2000`
Comments:	The systems are described in more detail in Section ??. For technical reasons, there are restrictions on the permitted combinations of input and display coordinates, as follows:

`INPUT`	always allowed;
`APPARENT`	always allowed;
`J2000`	not allowed for input in apparent coordinates;
`B1950`	not allowed for input in apparent or FK5 (J) coordinates;
`HA_DEC`	always allowed.

3.18 DOME

Move the dome to the specified azimuth and stop.

Format:	`DOME <angle>`
Defaults:	None.
Parameters:	The angle in degrees.
Keywords:	None.
Examples:	`DOME 275.34`

3.19 ELEVATION

Synonym for `ALTITUDE` (*q.v.*)

3.20 ENCODER

Set the combination of incremental encoders used for pointing.

Format:	`ENCODER <state> <axis> <encoder_name>`
Defaults:	None. The gear encoder is selected on startup.

Parameters: None.
Keywords: Valid states are:

ON	adds an encoder to the tracking combination;
OFF	removes an encoder from the tracking combination.

Valid axis names are:

AZIMUTH
ALTITUDE

Valid encoder names are:

GEAR	gear encoder;
ROLL	friction-driven roller encoder(not in use currently);
TAPEn	individual inductive tape encoder reading heads (n = 1, 2, 3 or 4); tape reading heads.

Examples: `ENCODER ON AZIMUTH TAPE2`
Comments: There are three independent incremental encoding systems on the WHT azimuth axis, any of which may be used for pointing and tracking. These are: a gear encoder, coupled to the telescope via the main drive gear; an inductive tape encoder with four reading heads and a friction-driven roller encoder. The roller encoder is not recommended, as it slips. The gear (default) is the best for normal use: the tape encoders are used for test purposes, and are not all guaranteed to be usable.

3.21 ENGINEERING

Put the telescope into engineering mode.
Format: `ENGINEERING`
Defaults: None.
Parameters: None.
Keywords: None.
Comments: This command should be used: as part of the normal shutdown procedure at the end of the night, to return to engineering mode at any time, or in an emergency to remove power from the drives and put on the brakes. It is equivalent to turning the COMP/ENG key on the engineering desk to the ENG position. To return to computer mode, turn the key to the COMP position and press the COMP/ENG button next to it on the desk.

3.22 ENTER

Set up aperture and positional offsets for repeated use.
Format: `ENTER APERTURE <aperture_number> <x_offset> <y_offset>`
`ENTER ARC_POSITION <position_number> <xi> <eta>`
`ENTER TIME_POSITION <position_number> <ra_offset> <dec_offset>`
Defaults: None.
Parameters: `<aperture_number>` is an integer in the range 0–10, 0 being the reference position (the default on source change).
`<position_number>` is an integer in the range 1–10. Position 0 is a zero offset and may not be redefined.
`<x_offset>`, `<y_offset>`, `<xi>`, `<eta>` and `<dec_offset>` are in arcseconds.
`<ra_offset>` is in seconds of time.
Keywords: Valid offset modes are:

APERTURE	sets up an aperture offset.

	`ARC_POSITION`	sets up a tangent plane positional offset; xi and eta are parallel to RA and Dec at the initial target position.
	`TIME_POSITION`	sets up an incremental positional offset

Examples: `ENTER APERTURE 3 1.5 20.3`
`ENTER ARC_POSITION 3 -3.0 12.0`
`ENTER TIME_POSITION 1 -0.33 -11`

Comments: Aperture offsets can be applied using the `APERTURE` command, positional offsets can be applied using the `POSITION` command.

3.23 EPOCH

Enter a value for the epoch of the position into the edit source data block.

Format: `EPOCH <date>`
Defaults: None.
Parameters: The epoch in years.
Keywords: None.
Examples: `EPOCH 1967.35`
Comments: The epoch is used in conjunction with the proper motions to compute the position of date.

3.24 EQUINOX

Enter a value for the equinox of the position into the edit source data block.

Format: `EQUINOX <equinox>`
Defaults: None.
Parameters: A code for the coordinate system, followed (for mean coordinates) by the equinox, in years. The allowed systems are:

`APPARENT`	Geocentric apparent coordinates;
`J<year>`	Mean coordinates (FK5 system);
`B<year>`	Mean coordinates (FK4 system).

Keywords: None.
Examples: `EQUINOX B1950`
`EQUINOX J1992.5`
`EQUINOX APP`
Comments: The year must be in the range 1800.0 to 2100.0.

3.25 ERASE

Erase all entries from the current user catalogue.

Format: `ERASE`
Defaults: None.
Parameters: None.
Keywords: None.

3.26 FIND

Retrieve data for the named source from the user or system catalogues and place them in the edit source data block.

Format: `FIND <source_name>`
Defaults: None.
Parameters: The name of the the source to be retrieved. It can be a string of up to 20 characters; extra characters are lost. To include spaces the whole string should be enclosed within double quotes.

Keywords: None.
Examples: `FIND HD123456`
`FIND NGC_4151`
`FIND "Supernova in LMC"`
Comments: The user catalogue is searched first, followed by the system catalogue.

3.27 FOCUS

Drive the focus to a specified setting and stop it.
Format: `FOCUS <setting>`
Defaults: None.
Parameters: The focus in mm (34.5 – 129.0 mm).
Keywords: None.
Examples: `FOCUS 50.5`
Comments: The focus is normally adjusted to compensate for changes in tube temperature and elevation. The input to FOCUS is a virtual position which should be independent of these corrections. It should not, therefore, vary from night to night.
Use the `DFOCUS` command to compensate for known changes of optical path (e.g. filters).

3.28 GOCAT

Retrieve the entry for the named source from the user or system catalogues and then send the telescope to track that source.
Format: `GOCAT <source_name>`
Defaults: None.
Parameters: `<source_name>` The name of the new source. It must be a string of up to 20 characters; extra characters are lost. To include spaces the whole string should be enclosed within double quotes.
Keywords: None.
Comments: The user catalogue is searched first, followed by the system catalogue.

3.29 GOMOON

Move the telescope to point at the moon, and then track it.
Format: `GOMOON`
Defaults: None.
Parameters: None.
Keywords: None.
Comments: If you stop the telescope while tracking the moon, and then wish to continue tracking it, use the `GOMOON` command again, do not use the `NEXT` command. The differential track rates will not be correct if the `NEXT` command is used.

3.30 GOTO

Move the telescope to a new source and track it.
Format: `GOTO <source_name> <right_ascension> <declination> <equinox>`
Defaults: None.
Parameters: `<source_name>` The name of the new source. It must be a string of up to 20 characters; extra characters are lost. To include spaces the whole string should be enclosed within double quotes.

`<right_ascension>` Specifies the right ascension of the new source in three fields separated by spaces. Format: `<ra_hours>` `<ra_minutes>` `<ra_seconds>`. The right ascension is rejected if any of the components lie outside the following ranges:

`<ra_hours>`	0–23 inclusive
`<ra_minutes>`	0–59 inclusive
`<ra_seconds>`	0.0–59.99... inclusive

`<declination>` Specifies the declination of the new source in three fields separated by spaces. The <dec_degrees> field may be signed. If not signed, the default is '+'. Format: `<dec_degrees>` `<dec_minutes>` `<dec_seconds>`. The declination is rejected if any of the components lie outside the following ranges:

`<dec_degrees>`	0–89 inclusive
`<dec_minutes>`	0–59 inclusive
`<dec_seconds>`	0.0–59.99... inclusive

`<equinox>` Specifies the equinox of the source coordinates. A valid equinox must have two components: a leading letter indicating the system of the coordinates; and a number indicating the epoch of the mean equator and equinox of that system. Format: `<letter-year>`, *e.g.* `B1950`, `J2000` or `APPARENT` (for which no number is required). Note that only `B`, `J` or `A` are acceptable as leading letters. The year must lie in the range 1800.0 to 2100.0.

Keywords: None.

Examples: `GOTO HD123456 12 34 56.78 76 54 32.10 J2000`

3.31 HANDSET

Place the TCS user interface in handset mode.

Format: `HANDSET`

Defaults: None.

Parameters: None.

Keywords: None.

Comments: In handset mode, the keypad may be used to guide the telescope, set up offsets or apertures, change the focus or move the rotator. See Section ?? for a more detailed description. This command is bound to the DO key on a standard DEC keyboard. To exit from the handset mode press the DO key and control will return to the `USER>` prompt.

3.32 HELP

Provide information about the commands available from the TCS user interface.

Format: `HELP [topic [subtopic]...]`

Defaults: Lists all available commands.

Parameters: The command you wish to receive help on.

Keywords: None.

Examples: `HELP GOTO EQUINOX`

Comments: Invoking the `HELP` command initiates an interactive dialogue with the user interface HELP library, a normal VMS HELP library. In response to a Topic? or subtopic prompt you may:

- Type the name of the command/topic for which you need help;
- Type a question mark (?) to redisplay recently requested text;
- Press the RETURN key one or more times to exit from HELP;
- Press CTRL–Z once to exit from HELP;

- Abbreviate any topic name, but note that ambiguous abbreviations result in *all* matches being displayed.

Note that this command is not currently available on the system computer (from ICL).

3.33 HUMIDITY

Enter the value of the relative humidity used in the calculation of refraction.

Format: HUMIDITY <relative_humidity>
Defaults: None. The value assumed on startup is 0.5.
Parameters: The fractional humidity in the range 0–1.
Keywords: None.
Examples: HUMID 0.5

3.34 INCLUDE

Read in a text format source catalogue.

Format: INCLUDE <catalogue_name>
Defaults: Node: LPAS4
Directory: USER_CAT,
Extension: .CAT.
Parameters: The name of the input catalogue.
Keywords: None.
Examples: INC USER_CAT:SPECPHOT.CAT or INC SPECPHOT to input a file called SPECPHOT.CAT in the default directory.
INC LPVF::DISK$LPVF_VMS:[OBSERVER]TARGETS to input a file called TARGETS.CAT in the top-level directory of the OBSERVER account on LPVF

3.35 INSTRUMENT

Tell the TCS which instrument is in use.

Format: INSTRUMENT <instrument_name>
Defaults: None. The parameters for ISIS are set on startup.
Parameters: None.
Keywords: Valid instrument names are:

ISIS	ISIS and FOS spectrographs.
TAURUS	Taurus imaging Fabry-Perot interferometer.
MES	Manchester Echelle Spectrograph.
DURPOL	Durham imaging polarimeter.
AUXCCD	Cassegrain auxiliary port CCD camera.
UES	Utrecht Echelle spectrograph.
INTEGRAL	Integral field unit.
LDSS	Low-dispersion survey spectrograph.
PFCCD	Prime focus imaging CCD camera.
AUTOFIB	Prime-focus automatic fibre positioner.
OWN	Spare for users' own instrument.

Examples: INSTRUMENT ISIS
Comments: This command sets the origin of position angle used for a specific instrument and the scale and orientation for the TWEAK command (*q.v.*). Position angle on the sky is normally defined to be along the slit in a spectrograph and aligned with one of the detector axes for an imaging instrument. The scale and orientation parameters are currently set to

match the standard TCS xy coordinate system except for the `LDSS` keyword, where they correspond to the system used by the LEXT software package.

3.36 LOG

Enables or disables the logging of tracking errors or telescope encoder values.

Format:	`LOG <system> <state> [<period>]`
Defaults:	The period parameter defaults to 20 cycles (1 second).
Parameters:	The period, in integer cycles of the synchronous loop (0.05 s). The allowed range is 1 – 20000. This parameter is only used with the `ENCODER` keyword.
Keywords:	`<system>` – valid keywords are: `TV` pixel coordinates produced by the acquisition TV system's GUIDE or I-GUIDE functions; `AUTOGUIDER` pixel coordinates produced by one of the CCD autoguiders, `ENCODERS` encoder readings, servo errors and drive demands for the altitude, azimuth and current rotator drives, `<state>` – valid keywords are: **ON** or **OFF**.

Examples:	`LOG TV ON`
	`LOG ENC ON 5`
	`LOG AZIMUTH ON`

Comments:	If TV or autoguider logging is turned on when it is already enabled, the log file is closed and a new one is opened. If encoder logging is turned on when it is already enabled the log file is not closed, the log continues to be written to the existing file, although the message on the USER display says otherwise. Any of the logging functions may be run simultaneously.

3.37 MARK

Store the current position of the telescope as a named catalogue entry.

Format:	`MARK <source_name>`
Defaults:	None.
Parameters:	The name of the source.
Keywords:	None.
Examples :	`MARK SUPERNOVA`
Comments:	This command stores the current position to allow return to an object at a later date. The position is stored in the current input coordinate system.

3.38 MOON

Display the geocentric and topocentric apparent right ascension and declination of the Moon.

Format:	`MOON`
Defaults:	None.
Parameters:	None.
Keywords:	None.
Comments:	This command is not currently available on the system computer (from ICL).

3.39 NEXT

Send the telescope to track the source whose data are in the edit source block.

Format:	`NEXT`
Defaults:	None.
Parameters:	None.

Keywords: None.

3.40 OFFSET

Offset the telescope by a given amount in right ascension and declination.

Format: OFFSET <offset_system> <offset_ra> <offset_dec>

Defaults: None.

Parameters: If the `ARC` keyword is specified (see below), the offsets in right ascension and declination must be in arcseconds. If the `TIME` keyword is specified (see below), the offset in right ascension must be entered in seconds of time and offset in declination must be entered in arcseconds.

Keywords: The valid offset systems are:

`ARC`	offsets the telescope by given amounts parallel to right ascension and declination in the tangent plane. Positive offsets imply that the right ascension and declination of the telescope both increase. The magnitude of the offset is independent of position.
`TIME`	offsets the telescope by given amounts in right ascension and declination. The magnitude of the offset depends on declination. $\Delta\alpha$ and $\Delta\delta$ are assumed to be in the input coordinate system.

Examples:
```
OFFSET ARC 12.6 -18.8
OFFSET TIME 0.32 -13.4
```

3.41 OUTPUT

Write out the current user catalogue in text format to the printer, TCS user interface or to a disk file.

Format: OUTPUT <output_device> [filename]

Defaults: There is no default output device. The defaults for `filename` are:
Node: `LPAS4` (telescope computer),
Directory: `USER_CAT`,
Extension: `.CAT`. If any other extension is given, it will be replaced by `.CAT`.

Parameters: The full path for the output file if the `FILE` keyword is specified.

Keywords: Valid output devices are:

`PRINTER`	sends the output to the WHT laser printer.
`TERMINAL`	sends the output to the user input terminal.
`FILE`	sends the output to the named file.

Examples:
```
OUTPUT PRINTER
OUTPUT TERMINAL
OUTPUT FILE MY.CAT
```

Comments: The catalogue may be saved in the default catalogue area `USER_CAT` on the telescope computer, whence it may be recovered on a subsequent night. Old catalogues in `USER_CAT` will be deleted periodically. To save the catalogue to another VMS computer, the file specification is:
[[[<node>"<username password>"]::<device>:]<directory>] <file>[.`CAT`]

3.42 PAGE

Display the next page in the cycle of information and status displays.

Format: PAGE <display_screen>

Defaults: `PAGE NEXT` – the next display screen in the cycle. The information display appears on startup.

Parameters: None.

Keywords: The various displays in the cycle are, in order:

NEXT	Display the next page in the cycle;
INFO	Top-level information display (appears on startup);
ENCODERS	Encoder readings;
SENSORS	Temperature and other sensors.
LIMITS	Limit indicators;
ALARMS	Alarm indicators;
DOME	Dome status and manual overrides.

Examples: `PAGE ENC`
`PAGE`

Comments: See Section ?? for more details.

3.43 PARALLAX

Enter a parallax into the edit source data area.

Format: PARALLAX <parallax_arcsecs>

Defaults: None. Unspecified parallaxes are assumed to be zero.

Parameters: The parallax in arcseconds.

Keywords: None.

Examples: `PARALLAX 0.023`

Comments: The parallax is rejected if it lies outside the range 0.0 to 10.0 arcseconds.

3.44 PARK

Move the telescope to a defined park position and stop it.

Format: PARK <park_position>

Defaults: None.

Keywords: The valid park positions are:

ZENITH	The zenith park position (azimuth = 298.64°; altitude = 90.28°).
AP1	Access Park 1 (azimuth = 298.64°; altitude = 19.62°).

Examples: `PARK ZEN`

3.45 PM

Synonym for `PROPER_MOTION` (*q.v.*).

3.46 POINT

Log, in TPOINT format, the present position of the telescope as read on the encoders.

Format: POINT <file_status>

Defaults: `POINT OLD`

Parameters: None.

Keywords:

NEW	opens a new set of log files in the POINTING directory, and logs the telescope position.
CALIBRATE	opens a new set of log files in the CALIBRATE directory, and logs the telescope position.
OLD	appends to the latest set of log files, unless none exist, in which case a new set of pointing files are opened in the POINTING directory.

Examples: `POINT`
`POINT NEW`

Comments: The data are logged to pointing data files in a format suitable for input to the TPOINT analysis package. The following pointing files are created in `[WHT.DATA.POINTING]` (yymmdd is the date, e.g. 980310 is equivalent to 1998 March 10).
`TRACKyymmdd.DAT` the current encoder combination used for telescope tracking (usually the gear encoders in both Azimuth and Altitude).
`DEMANDyymmdd.DAT` the demand position calculated by the TCS. Used for internal consistency tests only.
`GEARyymmdd.DAT` azimuth gear + altitude gear
`TAPE1yymmdd.DAT` azimuth tape head 1 + altitude gear
`TAPE1yymmdd.DAT` azimuth tape head 2 + altitude gear
`TAPE1yymmdd.DAT` azimuth tape head 3 + altitude gear
`TAPE1yymmdd.DAT` azimuth tape head 4 + altitude gear
The function key $\boxed{\text{F20}}$ is equivalent to the `POINT` command.

3.47 POLE

Input values of polar motion.

Format: `POLE <x_position> <y_position>`
Defaults: None. See comments below.
Parameters: The polar motion xy corrections in arcseconds.
Keywords: None.
Examples: `POLE 0.10 -2.10`
Comments: This command overrides the initial values for polar motion, which are derived from an interpolation formula supplied by the Earth Rotation Prediction Service. It makes a very small difference to the pointing of the telescope and is too esoteric for normal use.

3.48 POSITION

Move the telescope by a previously-stored (ξ, η) offset.

Format: `POSITION <position_number>`
Defaults: None. `POSITION 0` (zero offset) is automatically selected on startup or change of source.
Parameters: The position number is an integer in the range 0-10. The offset values for a given position number must have been set up using the `ENTER` or `STORE` commands. `POSITION 0` corresponds to a zero offset and returns the telescope to the reference position.
Keywords: None.
Examples: `POSITION 2`
Comments: The offset may be tangent-plane or incremental, depending on the way it was set up. `SHOW POSITION` displays the current list of offsets, their types and values.

3.49 PRESSURE

Enter the value of the barometric pressure used in the calculation of refraction.

Format: `PRESSURE <pressure>`
Defaults: None. The pressure assumed on startup is 779 millibar.
Parameters: The barometric pressure in millibars.
Keywords: None.
Examples: `PRESSURE 779.5`
Comments: The refraction correction is proportional to the pressure. An error of 5 millibar is just about noticeable (it corresponds to a pointing deviation of 1 arcsecond at a zenith distance of 75°).

3.50 PROBE

Enter current position of the currently selected autoguider probe.

Format: PROBE <coord1> <coord2>

Defaults: None.

Parameters: Valid autoguiders are:

CASSEGRAIN	<coord1> (radius) must be in the range 0 - 40000 microns; <coord2> (θ) must be in the range 0 - 180000 millidegrees.
PRIME	<coord1> must be in the range 0 - 11000 microns; <coord2> must be in the range 0 - 20000 microns.
UESPROBE	<coord1> must be in the range 0 - 73600 microns; <coord2> must be in the range 0 - 73200 microns.
AF2_MOVING	<coord1> must be in the range -128000 - 190000 microns; <coord2> must be in the range -180000 - 138000 microns.

The remaining autoguiders: UESSLIT, AF2_FIXED AND WHIRCAM are fixed, and the PROBE command is rejected if they are selected.

Keywords: None.

Examples: PROBE 10000 10000

Comments: These values can be read directly from the ICL mimic display. At the Cassegrain focus, the autoguider can rotate with respect to the field, and guiding errors will be applied incorrectly unless the PROBE command is issued. At the other relevant focal stations, it is only required by the AGVIEW command.

3.51 PROPER_MOTION

Enter proper motions into the edit source data area.

Format: PROPER_MOTION <pm_in_ra> <pm_in_dec>

Defaults: Unspecified proper motions are assumed to be 0.

Parameters: The proper motion in right ascension and declination in units of seconds/year and arc-seconds/year, respectively.

Keywords: None.

Examples: PROPER_MOTION -1.54 0.675

Comments: The synonym PM can also be used.

3.52 RA

Enter a right ascension in the edit source data area.

Format: RA <ra_hours> <ra_minutes> <ra_seconds>

Defaults: None.

Parameters: The right ascension in hours, minutes and seconds of time. The right ascension is rejected if the any of the components lie outside the following ranges:

ra_hours	0–23 inclusive
ra_minutes	0–59 inclusive
ra_seconds	0.0–59.99... inclusive

Keywords: None.

Examples: RA 12 34 56.789

3.53 RADIAL_VEL

Enter a radial velocity in the edit source data area.

Format: RADIAL_VEL <radial_velocity>

Defaults: Unspecified radial velocities are assumed to be 0.

Parameters: The radial velocity in km/sec. A positive velocity implies a receding source.
Keywords: None.
Examples: `RADIAL_VEL -98`
Comments: The synonym `RV` can also be used.

3.54 RATE

Set the encoder used in the Azimuth hardware position loop.
Format: `RATE <encoder>`
Defaults: None.
Parameters: None.
Keywords:

`GEAR`	The Azimuth gear encoder.
`TAPE`	The Azimuth tape encoder.

Examples: `RATE TAPE`
Comments: This is a specialist engineering command used to change the source of pulses received by the Marconi servo electronics and used in the hardware part of the position loop. Compare `ENCODER`, which changes the encoder combination used by the software part of the loop. The command forces a switch to engineering mode. Note that changes to the switch settings on the rate generator board are also needed.

3.55 RECALL

Recall a previous command.
Format: `RECALL <command_name>`
Defaults: Last command.
Parameters: A string containing the first part of the command you wish to recall.
Keywords: None.
Examples: `RECALL GOCAT`
Comments: `RECALL` is used to recover the last occurrence of a typed command within a 50-line buffer, just as in DCL.
Note that this command is not available on the system computer (from ICL).

3.56 REMOVE

Remove the entry for the named source from the user catalogue.
Format: `REMOVE <source_name>`
Defaults: None.
Parameters: The name of the source to be deleted. The name may be a string of up to 20 characters; extra characters are lost. To include spaces, the whole string should be enclosed within double quotes.
Keywords: None.
Examples: `REMOVE NGC_4151`
`REMOVE "Supernova in LMC"`

3.57 RMS

Turn calculation of mean and rms servo or guiding errors on or off, and display the results.
Format: `RMS <error> <state>`
Defaults: None.
Keywords: `<error>` is the source of errors:

`SERVO`	Main drive position errors.

`AUTOGUIDER`	Autoguider guiding errors.
`TV`	TV system guide errors.

`<state>` is either:

`ON`	Begin calculation of errors.
`OFF`	End calculation of errors and display results.

Examples: `RMS SERVO ON`

Comments: This command is used to check the performance of the main drives. To start accumulating data, type `RMS SERVO ON`, `RMS AUTO ON` or `RMS TV ON` . Wait for about 1 minute for `SERVO` (sampling is at 20 Hz) or for >50 autoguider or TV samples (`AUTO` or `TV`)and then type `RMS SERVO OFF` or `RMS AUTO OFF`, as appropriate. The results of `RMS SERVO` should be rms errors of <0.03 arcsec in Azimuth and Altitude and means whose absolute values are <0.0005 arcsec.

3.58 ROTATOR

Move the rotator to the specified mount or sky position angle or change its mode of operation.

Format: `ROTATOR <rotator_mode> <position_angle>`

Defaults: None.

Parameters: `<position_angle>` – the position angle in degrees. This parameter is only required when using the `SKY` and `MOUNT` keywords (see below). Sky position angle must be in the range 0° – 360° (the nearest corresponding mount position angle is selected). The Cassegrain rotator has mount position angle limits of −250° – +250°; the Nasmyth turntables currently have no limits enabled, since they are capable of continuous rotation.

Keywords: `<rotator_mode>` – the following keywords represent the valid rotator modes:

`SKY`	This keyword gives a position angle on the sky (measured anticlockwise from North which is 0° and defined by a natural axis in the instrument such as a spectrograph slit). If rotator tracking is enabled (as is the case on startup), then the rotator will follow this position angle as the telescope moves.
`MOUNT`	This keyword specifies that the parameter gives a mount position angle, *i.e.* measured with respect to a fiducial mark fixed to the mirror cell. `ROTATOR MOUNT` stops the turntable at the requested position angle (it makes no sense to track a mount position angle).
`FLOAT`	This option is designed to minimise unnecessary rotation in the case where the precise value of the sky position angle is unimportant. On source change, the rotator is set to a sky position angle corresponding to its current mount value. Thereafter, it rotates as for the `SKY` keyword.
`VERTICAL`	This keyword sets the reference axis in the instrument to the vertical direction and stops the rotator tracking. It is intended to minimise loss of light due to differential refraction during spectroscopic observing. Note that autoguiding is not possible, since off-axis images move in the focal plane.
`VFLOAT`	This keyword sets the slit to the vertical direction on source change and then tracks at a constant sky position angle. It is therefore equivalent to typing: `ROT SKY <parallactic_angle>`. This is generally more useful than the `VERTICAL` option, since autoguiding is possible.

Examples:

```
ROTATOR SKY 275.34
ROTATOR MOUNT 28.0
ROTATOR FLOAT
```

3.59 RV

Synonym for `RADIAL_VELOCITY` (*q.v.*).

3.60 SENSOR

Enable or disable tracking corrections derived from displacement transducers.

Format: `SENSOR <sensor_type> <state>`

Defaults: None.

Parameters: None.

Keywords: `<sensor_type>` This selects the sensors whose tracking corrections are to be en/disabled.

`SECONDARY`	The three displacement transducers which are used to measure the tilt of the secondary mirror.
`HORIZONTAL`	The two transducers which measure the horizontal movement of the telescope. These are used to provide tracking corrections in Azimuth for the gear incremental encoder, but are not relevant if the tape encoder is used (see `ENCODER`, *q.v.*).
`<state>`	
`ON`	enables corrections.
`OFF`	disables corrections.

Examples: `SENSOR HORIZ ON`

3.61 SHOW

Display data on the topic indicated by the keyword.

Format: `SHOW <show_topic>`

Defaults: None.

Parameters: None.

Keywords: `<show_topic>` – The following keywords are valid show topics:

`APERTURES`	Displays the x_A and y_A coordinates of apertures 0 – 10 and the currently-selected aperture. See `APERTURE`, `BEAMSWITCH`, `ENTER` and `STORE`.
`ASTROMETRY`	Displays the user-modifiable astrometric parameters: wavelength, pressure, temperature, relative humidity (all used to calculate refraction); UT1-UTC, and polar motion. TDT-UTC is also shown. See `WAVELENGTH`, `PRESSURE`, `TEMPERATURE`, `HUMIDITY`, `UT1UTC` and `POLE`.
`AUTOGUIDER`	gives the autoguider currently selected by the TCS (see `AGSELECT`), the associated probe position (see `PROBE`), the guiding pixel coordinates and the state of the guiding loop (unlocked, locked or suspended: see `AUTOGUIDE`).
`CALIBRATE`	displays the values of elevation index error, azimuth index error and azimuth collimation, together with their rms errors and the sky sigma for the last `CALIBRATE` at the current focal station. The corresponding parameters for the default pointing model are also given.
`CATALOGUES`	gives a directory listing of user catalogues.
`CLONES`	lists the address of each device that is displaying a copy of the display screen.
`EDIT`	displays the parameters of the edit source, which will be selected by the `NEXT` command.
`ENCODERS`	lists the encoders and transducers currently being used by the TCS to control the telescope. See `ENCODER`, `RATE` and `SENSOR` for information on how to change the configuration.

`FOCAL_STATION` gives the current hardware and software selection of focal station. This option is intended to allow the user to check that the combination of optical configuration, TCS selection of focal-station, autoguider and instrument is self-consistent. See `STATION`, `INSTRUMENT` and `AGSELECT`.

`LIMITS` lists the software position limits in altitude, azimuth, rotation (all focal stations) and focus.

`LOGGING` shows the current status of data logging (see `LOG`).

`MECHANISMS` displays the status of all of the main mechanisms. Altitude, azimuth and rotator are said to be "following" during a sidereal track. For the dome, "following" means that it is tracking the telescope and for the focus, that it is being adjusted to compensate for temperature changes (see `TRACK`). The software and hardware limit status for the mechanism is shown next (including the cable wrap for the Cassegrain rotator). The mechanism is "moving" if it is being driven under computer control, otherwise "stopped". The next field reads "in position" if the mechanism is either tracking or stopped within a defined position error, depending on its requested state. The final field shows whether the mechanism can be driven under computer control (if not, the status shown is "Manual override" or "Engineering mode".

`NET_COMMS` displays the dtask communication protocol currently defined. See `COMMS`.

`POSITIONS` Lists the RA-Dec offsets (1 – 10) currently defined and any offset in use. See `OFFSET`, `POSITION`, `ENTER` and `STORE`.

`TV` gives the TV camera currently selected by the TCS (see `TVCAMERA`), the guiding pixel coordinates and the state of the guiding loop (unlocked or locked: see `TVGUIDE`).

`VERSION` displays the TCS version currently in use.

Comments: This command is not currently available on the system computer (from ICL).

3.62 SNAPSHOT

Dump a copy of the information display screen to a file.

Format: `SNAPSHOT [<filename>]`

Defaults: Directory: `SNAP_LOG` on the telescope computer,
Filename: `SNAPSHOT`,
Extension: `.SNAP` If any other extension is given, it will be replaced by `.SNAP`.

Parameters: The name of the file.

Keywords: None.

Examples: `SNAPSHOT ENCODERS`
`SNAPSHOT`

Comments: This command may be used to record information relevant to an observation or to provide evidence of problems. In case of a problem with the telescope, please record all of the information display screens on disk, and include the filenames in any defect report.

3.63 SOURCE

Enter new source data into the edit source data area.

Format: `SOURCE <source_name> <right_ascension> <declination> <equinox>`

Defaults: Name, right ascension, declination, equinox: None.
All other source values: User defaults.

Parameters: `<source_name>` The name of the new source. It must be a string of up to 20 characters; extra characters are lost. To include spaces the whole string should be enclosed within double quotes.

`<right_ascension>` Specifies the right ascension of the new source in three fields separated by spaces. Format: `<ra_hours>` `<ra_minutes>` `<ra_seconds>`. The right ascension is rejected if any of the components lie outside the following ranges:

`<ra_hours>`	0–23 inclusive
`<ra_minutes>`	0–59 inclusive
`<ra_seconds>`	0.0–59.99... inclusive

`<declination>` Specifies the declination of the new source in three fields separated by spaces. The `<dec_degrees>` field may be signed. If not signed, the default is '+'. Format: `<dec_degrees>` `<dec_minutes>` `<dec_seconds>`. The declination is rejected if the any of the components lie outside the following ranges:

`<dec_degrees>`	0–89 inclusive
`<dec_minutes>`	0–59 inclusive
`<dec_seconds>`	0.0–59.99... inclusive

`<equinox>` Specifies the equinox of the source coordinates. A valid equinox must have two components: a leading letter indicating the system of the coordinates; and a number indicating the epoch of the mean equator and equinox of that system. Format: `<letter-year>`, *e.g.* `B1950`, `J2000` or `APPARENT` (for which no number is required). Note that only `B`, `J` or `A` are acceptable as leading letters. The year must lie in the range 1800.0 to 2100.0.

Keywords: None.

Examples: `SOURCE HD123456 12 34 56.789 11 22 33.44 B1900`

Comments: `SOURCE` copies the user default values for all source values into the edit source entry and then takes the command line or prompted input for source name, right ascension, declination and equinox.

3.64 STATION

Select a focal station.

Format: `STATION <focal_station>`

Defaults: None.

Keywords: Valid focal-station names are:

`CASSEGRAIN`	Cassegrain focus
`PRIME`	Prime focus
`GHRIL_ROT`	GHRIL Nasmyth focus with mechanical derotation
`GHRIL_IRDEROT`	GHRIL Nasmyth focus with optical derotation (IR optimised)
`GHRIL_OPTDEROT`	GHRIL Nasmyth focus with optical derotation
`GHRIL_NOROT`	GHRIL Nasmyth focus with no field rotation
`UES_ROT`	UES Nasmyth focus with mechanical derotation
`UES_UVDEROT`	UES Nasmyth focus with optical derotation (small field, UV optimised)
`UES_OPTDEROT`	UES Nasmyth focus with optical derotation (5 arcmin field)
`UES_NOROT`	UES Nasmyth focus with no field rotation

Comments: Applies the appropriate pointing model and configures the rotator. Note that the Nasmyth flat *cannot* be stowed under computer control, so the button on the engineering desk must be used for this purpose.

3.65 STOP

Stop the named mechanism by ramping the velocity to zero.

Format:	`STOP <mechanism>`
Defaults:	`STOP ALL`
Parameters:	None.
Keywords:	Valid mechanism names are: `ALL`, `ALTITUDE`, `AZIMUTH`, `DOME`, `FOCUS`, `ROTATOR`, `CASS`, `PRIME`, `GHRIL`, `UES`.
Examples:	`STOP DOME` `STOP`
Comments:	The `STOP` and `STOP ALL` commands stop all mechanisms.

3.66 STORE

Store aperture and positional offsets.

Format:	`STORE <offset_type> <offset_number>`
Defaults:	None.
Parameters:	`<offset_number>` is the aperture number if the `APERTURE` keyword is specified (see below). It must be an integer in the range 0–10. `APERTURE 0` is the reference position and is not reset on source change. `<offset_number>` is the position number if the `POSITION` keyword is specified (see below). It must be an integer in the range 1–10 (position 0 corresponds to a zero offset and cannot be overwritten).
Keywords:	Valid offset types are: `POSITION` sets up a positional offset which can be added to the telescope reference position using the `POSITION` command. `APERTURE` sets up a beamswitch position which can be applied to the telescope using the `APERTURE` command.
Examples:	`STORE APERTURE 3`
Comments:	The command may be used to store positional or aperture offsets which have been found using the APOFF or OFFSET handset modes or input using the `BEAMSWITCH` or `OFFSET` commands. They may then be recalled for future use with the `APERTURE` or `POSITION` commands. When `STORE` is executed, the aperture or offset stored becomes the current one and the Information Display is updated.

3.67 TCSEXIT

Initiate an orderly shutdown of the telescope control system.

Format:	`TCSEXIT`
Defaults:	None.
Parameters:	None.
Keywords:	None.
Comments:	This command puts the telescope into engineering mode before shutting down the control system. Note that this command is not currently available on the system computer (from ICL).

3.68 TEMPERATURE

Enter the value of the outside air temperature used in the calculation of refraction.

Format:	`TEMPERATURE <temperature>`
Defaults:	None. A temperature of 5° C is assumed on startup.
Parameters:	The outside air temperature in degrees Centigrade.
Keywords:	None.

Examples: `TEMPERATURE 7.5`
Comments: An error of 10°C gives a pointing error of 1.7 arcseconds at an elevation of 45°.

3.69 TRACK

Turn the focus, dome, rotator or telescope tracking on or off.

Format: `TRACK <mechanism> <state>`
Defaults: None.
Parameters: `<mechanism>` selects the mechanism which is to have its tracking state changed. The allowed mechanisms are: `DOME`, `FOCUS`, `ROTATOR`, `TELESCOPE`.
Keywords: Valid states are:

`ON`	turns tracking on
`OFF`	turns tracking off

Examples: `TRACK FOCUS OFF`
Comments: The effect of the `TRACK ROTATOR ON` command is to cause the instrument rotator to start tracking at its current sky position angle. It is therefore useful if there is no constraint on the detector position angle, as it causes the rotator to slew by the minimum amount (this is equivalent to the `ROTATOR FLOAT` command).

3.70 TRANSFER

Control the operational state of remote terminals.

Format: `TRANSFER <state> [<remote_host>]`
Defaults: None.
Parameters: <remote_host> is the IP name or address of the remote host.
Keywords: The `<state>` keyword may take the following values:

`ON`	This keyword allows command input from a remote terminal. This would usually be in the GHRIL room. It also copies the control-room user-interface display to the remote terminal.
`OFF`	This keyword disables the remote terminal entirely, returns command input to the control room terminal and clears the remote display.

Examples:
```
TRANSFER ON
TRANSFER ON lpx28
```

3.71 TVCAMERA

Identify the TV camera currently in use for autoguiding using the GUIDE or I-GUIDE options.

Format: `TVCAMERA <camera_name>`
Defaults: None.
Parameters: None.
Keywords: The `<camera_name>` keyword specifies the TV camera currently in use for autoguiding. The options available are:

`SLIT_DIRECT`	Cassegrain slit view (4.5 arcsec/mm)
`SLIT_REDUCE`	Cassegrain slit view (12 arcsec/mm)
`FIELD_DIRECT`	Cassegrain field view (4.5 arcsec/mm)
`FIELD_REDUCE`	Cassegrain field view (12 arcsec/mm)
`SH_CASS`	Radiospares camera on Shack-Hartmann Box at Cassegrain.
`SH_PRIME`	Radiospares camera on Shack-Hartmann Box at Prime.

Examples:
```
TVCAMERA SLIT_REDUCE
TVCAMERA SH_CASS
```

Comments: This command is used to tell the TCS to use scale and orientation parameters for a particular TV camera. These are needed when using the `TVGUIDE` command to autoguide or when logging test data.

3.72 TVGUIDE

Turn TV guiding off, or turn it on with an optional xy position.

Format: `TVGUIDE <state> [x y]`

Defaults: None.

Parameters: The optional parameters x and y are the desired pixel coordinates for the guide star. If they are not specified, then the system will adopt the current position of the guide star.

Keywords: Valid states are:

- `ON` specifying that the telescope should be guided in response to guiding errors from the TV system in GUIDE or I-GUIDE mode.
- `OFF` specifying that TV guiding should be switched off, *i.e.* that any guiding errors from the TV system should be ignored.

Examples: `TVGUIDE ON`
`TVGUIDE ON 122.5 63.2`

Comments: When the TV system's GUIDE or I-GUIDE function is selected, xy pixel coordinates of a guide star are sent to the telescope control computer. The TCS then adjusts the telescope drives to keep the star at a given location on the TV camera. If the intention is to maintain the current positioning of a field (*e.g.* if acquisition onto a spectrograph slit has been verified), then the command `TVGUIDE ON` should be used. This takes the first position received from the TV system after the command is issued, and keeps the guide star there. On the other hand, if the TV coordinates are already known, then the appropriate command is `TVGUIDE ON x y`. This is likely to be useful when an observation is to be repeated and the field is to be positioned at the same place on the detector. Note that, for technical reasons connected with use of the command from ICL, the command `TVGUIDE ON -1 -1` means the same as `TVGUIDE ON`. The TCS must be told the camera in use (see `TVCAMERA`), otherwise the telescope corrections will be in the wrong direction.

3.73 TWEAK

Apply a given (x_A, y_A, ρ_A) aperture offset to align a field on an instrument.

Format: `TWEAK <x_offset> <y_offset> [<rotation>]`

Defaults: `<rotation>` defaults to 0.

Parameters: `<x_offset> <y_offset>` are displacements in x_A and y_A, in arcsec.
`<rotation>` is the rotation of the field in degrees.

Keywords: None.

Examples: `TWEAK 0.5 -0.6 0.1`

Comments: This command is used to position a field precisely on an instrument. It can be used whether or not the telescope is being autoguided. Its main application is with LDSS, where the objective is to centre a large number of target objects on the slit mask, but it may also be useful for long-slit spectroscopy, especially when two objects are to be placed on the slit simultaneously. It is not advisable to use displacements of more than 1 arcsec or rotations of more than $0.1°$ when autoguiding, since the guide star may be lost. Larger offsets can be split into successive smaller ones, or autoguiding may be suspended whilst the CCD window is moved. For LDSS, the sign convention corresponds to that used by the LEXT software package (the `INSTRUMENT LDSS` command must be used to inform the TCS). For other instruments, the TCS focal plane (aperture) coordinate system is used, with position angle measured anticlockwise.

3.74 UNWRAP

Rotate either the Azimuth axis or the current rotator by 360° from its current position, if this is possible.

Format: `UNWRAP <mechanism>`

Defaults: None.

Parameters: None.

Keywords:

`AZIMUTH`	The azimuth axis.
`ROTATOR`	The currently-selected rotator.

Example: `UNWRAP ROTATOR`

Comments: The azimuth axis, and those rotators which have limits enabled (Cassegrain and Prime foci) have more than 360° of travel and part of their ranges are ambiguous. The `UNWRAP` command is used to rotate these mechanisms by 360° in order to avoid tracking into a limit or to reset the mechanism if a limit has been hit during observing. There are four possible modes of operation, depending on the initial state. Firstly, if the mechanism is tracking normally, and is in its ambiguous range, then it is rotated by 360° and tracking is resumed. This is useful if there is insufficient time to complete an observation before a limit is hit. Secondly, an azimuth or rotator software limit may be encountered whilst the telescope is tracking. `UNWRAP` then moves the mechanism to the correct position, as on change of source, and tracking is resumed (this is always possible provided that the target is still above the horizon limit). Thirdly, if the mechanism in question is stopped in an ambiguous part of its travel, then `UNWRAP` will drive it to a position 360° away and stop it. Finally, if the mechanism is in the process of moving to a fixed position (as a result of an `AZIMUTH` or `ROTATOR MOUNT` command, for example), then the demand position is altered by 360° if possible. In all cases, an error message is generated if the mechanism is on the unambiguous part of its range. `UNWRAP ROTATOR` is not useful for the Nasmyth rotators, which do not have limits enabled, and is not allowed if they are in use.

3.75 UT1UTC

Enter the value of the correction to Universal Time (UT1–UTC) used in the control system.

Format: `UT1UTC <correction>`

Defaults: None. This command overrides the startup value of $UT1 - UTC$, which is determined from an interpolation formula supplied by the Earth Rotation Prediction Service.

Parameters: The correction in seconds.

Keywords: None.

Examples: `UT1UTC -0.0222`

Comments: The IERS bulletin is pinned up on a noticeboard in the WHT control room; it is also available on the TO's web pages. The correction UT1–UTC for each night is listed in a table which starts on page 3 of the bulletin.

3.76 WAVELENGTH

Enter the value of the effective wavelength of light used in the calculation of the refraction correction.

Format: `WAVELENGTH <wavelength>`

Defaults: None. The startup value is 0.4 μm.

Parameters: The wavelength in microns.

Keywords: None.

Examples: `WAVELENGTH 0.55`

3.77 WRAP

Override the azimuth wrap value (*i.e.* the multiple of 360° which must be added to the raw encoder reading to give the correct azimuth).

Format: `WRAP <wrap_value>`

Defaults: None.

Parameters: The wrap value in units of multiples of one revolution. The allowed values are '0' and '−1'.

Keywords: None.

Examples: `WRAP -1`

Comments: The absolute encoder in azimuth has a travel of exactly 360°, after which it repeats. The telescope has a total travel of 530° in azimuth, and the ambiguity must therefore be resolved on startup by reading the position of a zone switch. The `WRAP` command should only be necessary when the zone switch fails, in which case the azimuth reading will be incorrect by 360° and the telescope will sometimes slew into a hardware limit. In this case, `WRAP` may be used to enter the correct value.

3.78 ZEROSET

Set the zero-points of incremental encoders by a variety of methods.

Format: `ZEROSET <mechanism> <method> [<position>]`

Defaults: None.

Parameters: The position parameter is required only if the keyword `TO` is specified (see below). The position should be entered in the format: `<degrees> <minutes> <seconds>`.

Keywords: `<mechanism>` – The following mechanisms may be zeroset:

`ALTITUDE`	
`AZIMUTH`	
`ROTATOR`	(the currently-selected rotator)

`<method>` – Several different methods are provided to set the zero-points of the incremental encoders, in order to reduce the dependence on individual bits of electronics. These are:

`TARGET` This method is, in principle, capable of the highest accuracy. A mechanical target is used to provide a fixed reference point. Currently, this method may be used on the altitude and azimuth axes only. Their targets are located at an altitude 88° 39′ and azimuth −02° 27′, respectively. The mechanism is driven slowly through the standard position in engineering mode and the encoder is reset when the target is detected electronically, in which case the user terminal will bleep and output a suitable message. Altitude and azimuth target zerosets may be active simultaneously.

`CANCEL` This is used to cancel a target zeroset request if, for some reason, it fails.

`ABSOLUTE` The incremental encoders are forced to read the same as the absolute encoders for the same mechanism. This is done automatically on startup, to provide an initial estimate. It is prone to failure because the bulbs in the absolute encoders are not especially reliable, although this situation will be improved once the new LED encoders are operational.

`TO` Allows the current position of the mechanism to be input. This would normally be derived from the engineering-desk synchros (in altitude and azimuth) or from the scale on the Cassegrain rotator and is corrected for known zero-point errors. This method provides a starting point for the `TARGET` procedure and a backup in case of failure of both the absolute encoder and the target electronics.

`PARK ZENITH` This is used to set the zero-points in altitude and/or azimuth assuming that the telescope is at its hardware zenith park position. This is a useful backup option when there is a problem with one of the absolute encoders, since the telescope can be moved to a reproducible position independently of the encoders.

`PARK AP1` As for `PARK ZENITH` but using the hardware Access Park 1 position.

Examples:

```
ZEROSET ALTITUDE ABSOLUTE
ZERO AZIMUTH TARGET
ZERO AZ PARK ZENITH
ZERO ROT TO 60 00 00
```

```
-------------------------------- HANDSET ---------------------------------
    0.1    0.3    1.0    3.0   10.0   30.0  100.0          0.0   arcsec
 Total    X =    0.00    Y =    0.00
 ALT_AZ   RA_DEC     X_Y           OFFSET    APOFF
```

Figure 1: An example of the handset display. This example applies an increment in x, y coordinates to the reference position and is the default on startup.

4 The TCS Handset

4.1 General

The handset provides an interactive way of incrementing the position of the telescope in various coordinate systems, setting apertures and offsets and altering the focus and rotator position angle. The handset is selected by pressing the HANDSET key or typing **HANDSET** at the user interface. Pre-defined and user-selectable increments may be used and the arrow keys are used to input the steps. These auto-repeat when held down, so a continuous motion may be generated by selecting a small increment and holding down the appropriate key. The left INC and right INC keys select the next smaller and next larger increments, respectively. OWN requests the input of an increment value. Enter the value, in the appropriate units, and then hit the RETURN key. Just hit RETURN to escape from increment selection if you press OWN by accident. The handset display (a variant of that shown in Figure ??) is drawn at the top of the user-interface screen. It shows the available increment values, the accumulated increments and the modes. Currently-selected values are in reverse video. Only the keys labelled in Figure ?? remain active. The HANDSET key is used to return to the **USER>** prompt. The default on first selecting the handset is the X_Y mode with an increment of 1.0 arcseconds. Thereafter, the accumulated increments in each mode and the currently-selected mode and increment value are remembered on exit to **USER>** level and restored when the handset is next used. They are reset on source change (using the **GOTO**, **GOCAT**, **NEXT** or **BLIND_OFFSET** commands).

4.2 Handset modes

There are seven handset modes, each of which can be selected using the labelled function key on the user interface keyboard. The seven functions divide naturally into three groups:

- ALT_AZ, RA_DEC and X_Y increment the demand position in the input coordinate system and differ only in the directions of the increments. The increments displayed are therefore the accumulated values from all three modes in the coordinate system of the current mode. The tracking position on the information display also changes.
- OFFSET and APOFF are used in conjunction with the **STORE** command to set up positional and aperture offsets interactively. The tracking coordinates do not change.
- FOCUS and ROTATOR move individual mechanisms.

We describe each handset mode in more detail below:

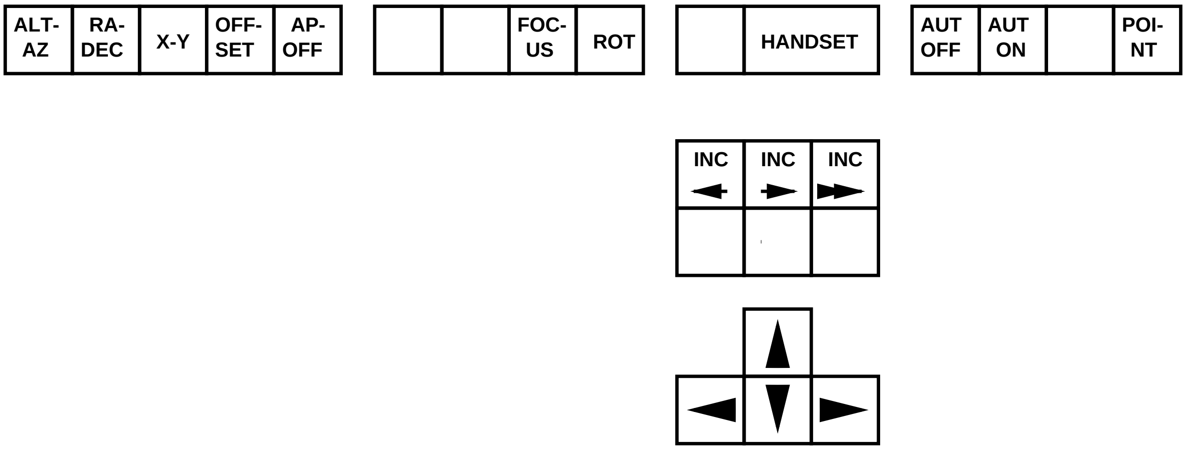

Figure 2: The portion of the Xterminal user-interface keyboard used in handset mode. Only those keys with labelled functions are active.

4.2.1 ALT_AZ mode

Changes the demand position in altitude and azimuth (units are arcseconds). The image is moved horizontally or vertically on the sky. Increments are defined in the tangent plane, so their magnitudes do not depend on elevation. This mode is used to establish the vertical direction (*e.g.* when worrying about differential refraction) or to ascertain whether a failure in telescope tracking or pointing is predominantly in azimuth or elevation.

4.2.2 RA_DEC mode

Changes the demand position in right ascension and declination (units are arcseconds). The image is moved in the east-west or north-south direction. Increments are defined in the tangent plane, so their magnitudes do not depend on declination. Image movement on the TV and detector will depend on the chosen sky position angle. At a sky position angle of 0°, the movements in X_Y and RA_DEC are identical. RA_DEC mode is most useful for wandering around finding charts and establishing orientations on the instrument. It can also be used for offsetting from a reference source although this can be done more flexibly with other methods such as the `BLIND_OFFSET` command.

4.2.3 X_Y mode

Changes the demand position in directions fixed in the focal plane (units are arcseconds). This is the most commonly used of all the modes. It moves the telescope in a sensible way corresponding to the customary sense of x, y coordinates on the acquisition TV screen (independent of rotator orientation and with equal steps in x and y) and is the normal method for final alignment of an object on to an instrument aperture such as a spectrograph slit, unless the guiding loop is already locked (see APOFF, below). It cannot, however, be assumed that the same xy increments can be used for more than one observation of the same field. The reason is that the handset is being used to compensate both for pointing errors (which tend to be functions of azimuth and elevation and therefore rotate with respect to the focal plane when the *mount* position angle changes) and for errors in the position of the object (which are fixed on the sky and therefore rotate when the *sky* position angle changes).

4.2.4 OFFSET mode

This is used in conjunction with the `STORE POSITION` command to set up positional offsets which may be recalled with the `POSITION` command. To define an offset, move an object to the start position using one of X_Y, RA_DEC or ALT_AZ. Then switch to OFFSET mode, move the object to the end position, exit from the handset and store the offset with `STORE POSITION` <`position_number`>, where <`position_number`> is in the range 1–10. `POSITION` <`position_number`> recalls the offset, which is defined in the tangent plane.

4.2.5 APOFF mode

This mode changes the aperture offset interactively. It is intended to be used to shift an object to an instrument aperture away from the reference position. The aperture coordinates may be recorded for future use with the command `STORE APERTURE`. The image moves in x and y on the TV and/or detector. To set up a new aperture, move an object to the reference position using X_Y, RA_DEC or ALT_AZ mode, switch to APOFF, move it to the new aperture (spectrograph slit or whatever), exit from the handset and type `STORE APERTURE` <`aperture_number`>, where <`aperture_number`> is in the range 0–10. `STORE APERTURE 0` redefines the reference position.

The APOFF mode may be used even when the autoguider loop is locked. This is useful for making small corrections (*e.g.*to optimise a target position on the spectrograph slit). The telescope offset and the reference pixel coordinates on the autoguider are changed simultaneously in such a way that the guiding errors remain zero. The image appears to move in the same way as in the X_Y mode. Small increments (<1 arcsec) should be used, in order to avoid losing the guide star.

4.2.6 FOCUS mode

Changes the telescope focus (units are millimetres). Always allow time for the focus to settle after an increment, as the drive is a bit sticky. It should eventually stop within 0.01 millimetres of the requested position.

4.2.7 ROTATOR mode

This increments the *sky* position angle of the rotator (units are degrees). It therefore only works when the rotator is tracking.

4.3 Sign conventions

The first five of the handset modes cause an image to move in the focal plane. The sense of motion for the keys has been set so that the *image* moves in the obvious way. The displayed cumulative totals for each mode refer to the motion of the *telescope*. This, coupled with the variety of different 'hand' conventions of astronomical coordinate systems, requires the sign conventions summarised below:

- **ALT_AZ** mode.
  - $\Leftarrow$ Image moves left on the sky; −azimuth displayed;
  - $\Rightarrow$ Image moves right on the sky; +azimuth displayed;
  - $\Uparrow$ Image moves up on the sky; −altitude displayed;
  - $\Downarrow$ Image moves down on the sky; +altitude displayed.
- **RA_DEC** mode.
  - $\Leftarrow$ Image moves east; −right ascension displayed;
  - $\Rightarrow$ Image moves west; +right ascension displayed;
  - $\Uparrow$ Image moves north; +declination displayed;
  - $\Downarrow$ Image moves south; −declination displayed.

- **X_Y** mode. The sign convention has been used to be consistent with that used for apertures (set up with the `BEAMSWITCH` and `ENTER APERTURE` commands).
  - $\Leftarrow$ Image moves left on TV; $-x$ displayed;
  - $\Rightarrow$ Image moves right on TV; $+x$ displayed;
  - $\Uparrow$ Image moves up on TV; $-y$ displayed;
  - $\Downarrow$ Image moves down on TV; $+y$ displayed.
- **OFFSET** mode. As for **X_Y**.
- **APOFF** mode. As for **X_Y**.
- **FOCUS** mode.
  - $\Leftarrow$ $-$Focus;
  - $\Rightarrow$ $+$Focus.
- **ROTATOR** mode.
  - $\Leftarrow$ $-$Sky position angle;
  - $\Rightarrow$ $+$Sky position angle.

If the image appears to move in a direction opposite to that expected, check that the TV scan switches are in their correct positions for the optical configuration in use.

Figure 3: The telescope information display. This is the first of the display screens and is the default on startup.

5 The TCS Display

5.1 General

The display has five screens, arranged as follows:

- Source and telescope information (appears on startup);
- Encoder and transducer readings;
- Limit, computer mode and emergency stop indicators;
- Alarm indicators;
- Manual overrides, dome and mirror cover status, access park interlocks and focal station information.

The first screen is intended for normal operation, the rest for fault-finding. The user-interface command `PAGE` (*q.v.*) is used to cycle through them. The following sub-sections describe the contents of the pages in more detail.

5.2 Source and telescope information

The layout of this, the default screen, is shown in Figure ??. Its contents are as follows:

- Time.
  - Date
  - UT—Universal time (UTC) from the time service.
  - ST—Local apparent sidereal time.

  - MJD—Modified Julian date (*i.e.* Julian date − 2400000.5), in days.
- Input data for the current source.
  - Name.
  - Right ascension.
  - Declination.
  - Equinox—Mean pre-IAU76 (B), post-IAU76 (J) or apparent.
  - Differential tracking rates (blank if not specified).
  - Proper motions and epoch (blank if not specified).
  - Parallax and radial velocity (blank if not specified).
- Apertures and offsets.
  - Positional offset currently enabled (blank if zero). If the `POSITION` command was used, then the offset number (1 – 10) is given in the first field (this is left blank if the `OFFSET` command was used instead). The second two fields give the offset components in the RA and Dec directions, in arcsec.
  - Aperture offset currently enabled (blank if zero). If the `APERTURE` commmand was used, then the first field gives the aperture number (1 – 10); if `BEAMSWITCH` was used instead, then the field is left blank. The next two fields give the x_A and y_A components of the offset, in arcsec.
  - Reference position (alias aperture 0) offset from the rotator centre in x_A and y_A (arcsec).
- Telescope state. The possible messages are:
  - ENG MODE: (the system is in engineering mode.
  - STOPPED: the telescope drives are stopped.
  - MOVING: the telescope is in motion, but has not yet reached its required position.
  - TRACKING: the telescope is within 1 arcsecond of its demanded position during a sidereal track.
  - TV GUIDE: autoguiding on signals provided by the TV system.
  - A/GUIDE: autoguiding on signals provided by the CCD autoguider.
  - S/W LIM (flashing): the demanded position is inaccessible. This will occur when the telescope tracks into a software limit or, on source change, when the new object is below the horizon.

  These messages exclude the instrument rotator which is treated separately below.
- Telescope position.
  - Right ascension or hour angle and declination (displayed only when the telescope is tracking). This is in the coordinate system set by the `DISPLAY` command and indicated by the equinox field (see below).
  - Equinox (usual conventions).
  - Topocentric azimuth (A) and elevation (E).
  - Position errors in azimuth and elevation. Note that the pointing error in azimuth *on the sky* is ΔAcosE, so a relatively large ΔA may be tolerated at high elevation.

  Note that the coordinate system may be changed using the `DISPLAY` command. The available `DISPLAY` options are:
  - `INPUT` (default)—the coordinate system used to input the source data. Any space motions have been removed, so the position refers to the *current* epoch. If proper motions, parallax or radial velocity are specified, then the position will differ from the input position even in the absence of offsets.
  - `B1950`—available for pre-IAU76 mean input coordinates only. Current epoch.
  - `J2000`—available for any mean input coordinates. Current epoch.

  - `APPARENT`—geocentric apparent coordinates of the current date. Always available.
  - `HA_DEC`—topocentric hour angle and declination. Always available.

- TV / autoguider coordinates
  - If the telescope is being autoguided using a TV camera or CCD autoguider, then the pixel coordinates of the requested position of the guide star are displayed.
- Limit information
  - Elevation limit information (this refers to the *software* limit of 10°). If the object is circumpolar, the message displayed is "No El limit". If it is currently visible above the limit, but will eventually set, the message "Sets in", together with the sidereal time remaining is shown. If the object has set, the message is "Rises in", followed by the sidereal time interval until it becomes visible again. Finally, for objects which are too far South ever to be seen by the WHT, the message is "Never rises".'
  - Other telescope limits. There are two of these, which cannot both occur for the same object. The first is the zenith blind spot, which affects objects with Declinations between 28.55° and 28.97°. If the object will track into the blind spot, the message "Blind spot in", followed by the sidereal time remaining, is displayed. The second is the positive azimuth software limit of 355°. This is rarely encountered, since it affects only objects with Declinations between 70.66° and 85.62° tracked below the Pole. The message is "Az limit in", again followed by the sidereal time interval. The field is left blank if neither limit is relevant.
  - Rotator limits. This applies to the Cassegrain and Prime rotators only (the Nasmyth rotators are allowed to go round continuously). The Cassegrain software mount position angle limits are ±250°; those for Prime are −85° and 273°. Which (if any) rotator limit can be hit is a complicated function of hour angle, Declination and starting position angle. The messages are "+Rotator limit in", "−Rotator limit in" and "No rotator limit", followed by the sidereal time interval in the first two cases.
- Turntable information.
  - The message STOPPED, MOVING, TRACKING or S/W LIM is displayed, with the same meanings as for the telescope, except that the software limit can only be encountered during tracking, never on source change and the meaning of TRACKING is that the rotator is within 30 arcsec of its demand position (equivalent to 0.1 arcsec in position at the maximum field radius).
  - The focal station currently selected. This means that the software has been configured for that focal station and that the appropriate turntable will be driven. It does *not* refer to the position of the Nasmyth flat. The options are CASSEGRAIN (default), PRIME, GHRIL_ROT, GHRIL_IRDEROT, GHRIL_OPTDEROT, GHRIL_NOROT, UES_ROT, UES_UVDEROT and UES_OPTDEROT. Options ending in DEROT indicate that the turntable is to be driven at a rate appropriate for the derotation optics rather than a directly-mounted instrument.
  - Demand sky position angle (as input using `ROTATOR SKY` and modified subsequently using the handset. Blank if the rotator is not tracking (*e.g.* for a `ROTATOR MOUNT` command).
  - Mount position angle.
  - Mount error, *i.e.* the error in mount position angle (only displayed when the rotator is tracking). Note that an error of 1 arcsecond corresponds to a displacement on the sky of 0.003 arcseconds at a typical maximum field radius of 10 arcminutes.
  - Parallactic angle.
- Miscellaneous.
  - Focus position (mm). This is a virtual focus position which should not depend on temperature, elevation or the presence of filters in the beam. It should, in theory, remain constant for a given focal station.

Figure 4: The encoder display screen.

- The focus offset, TC (mm) applied to compensate for expansion of the structure.
- The focus offset, DF (mm) used to correct for additional optical elements (*e.g.*filters) in the beam.
- Dome azimuth. The label flashes if the dome is out of position. This will occur during a slew and, briefly, during tracking. If the flashing is continuous and the dome is mot moving to the correct azimuth, then there is likely to be a fault in the dome drive (most likely the TEM-L system).
- Air mass (relative to the zenith).

5.3 Encoder display

The second page displays the encoder readings for altitude, azimuth and all of the instrument rotators, together with relevant displacement transducer values. In addition, the positions of the dome, shutter, windshield, primary mirror cover are shown. The layout is shown in Figure ??. In case of pointing difficulties, it is particularly useful to compare the absolute and (tape or gear) incremental encoders on the same axis. The values displayed are as follows:

- Azimuth (units are degrees:minutes:seconds). The encoder combination used for tracking can be changed using the `ENCODER` and `RATE` commands.
  - Absolute (AZ ABS).
  - Incremental gear (AZ GEAR).
  - Incremental roller (AZ ROLL)—not currently in use.
  - Incremental inductive tape encoder. There are 4 reading heads (AZ TAPE1 – AZ TAPE4).
- Elevation (units are degrees:minutes:seconds).

  - Absolute (EL ABS).
  - Incremental gear (EL GEAR).
  - Incremental roller (EL ROLL)—not currently in use.

- Cassegrain rotator (units are degrees:minutes:seconds).
  - Absolute (CA ABS).
  - Incremental gear (CA INC).

- Prime focus rotator (units are degrees:minutes:seconds).
  - Absolute (PF ABS).
  - Incremental gear (PF INC).

- Nasmyth (UES/Drive side—units are degrees:minutes:seconds).
  - UES Absolute
  - UES Incremental gear

- Nasmyth (GHRIL/cable-wrap side—units are degrees:minutes:seconds)
  - GHRIL Absolute
  - GHRIL Incremental gear

5.4 Sensor display

- Secondary mirror position transducers. These are used to measure the tilt of the secondary mirror in its cell. Tracking corrections are applied to compensate for the resulting image motion. The raw readings are displayed as integers in the range ± 2047 (± 100 μm). The readings are expected to fluctuate by ± 5 or so during normal tracking. Wild excursions or unchanging readings indicate problems and should be reported.
  - SECONDARY 1: transducer channel 7 (bottom); expected range ± 1200 units (± 60 μm); reading -1200 units -60 μm at zenith.
  - SECONDARY 2: transducer channel 8 (GHRIL side); expected range ± 800 units (± 40 μm); reading 0 at zenith.
  - SECONDARY 3: transducer channel 9 (UES side); parameters as for SECONDARY 2.

- Horizontal displacement transducers. These are used to correct the azimuth gear encoders for the effects of sideways movements of the telescope. They do not affect the tracking if the tape encoder is used. The raw readings are displayed as integers in the range ± 2047. Fluctuations should be around ± 5 units when the telescope is stopped. The expected range *in computer mode* is about ± 1600 units (± 120 μm). The range is limited by the Camac ADC: values close to ± 2047 indicate saturation and should be reported. Note that the transducers are normally saturated in engineering mode.
  - HORIZONTAL 1: transducer channel 5.
  - HORIZONTAL 2: transducer channel 6.

- Temperature sensor readings.
  - GHRIL Up Truss Temp
  - UES Up Truss Temp
  - Lower Truss Temp
  - Top end ring Temp

Figure 5: The limits screen.

5.5 Limit page

This page displays the state of the hardware limits and pre-limits for the altitude, azimuth, rotator and focus drives, together with emergency stop, power and engineering/computer mode indicators. The layout is shown in Figure ??.

- Emergency stop. This shows the state of the red emergency stop buttons (ACTUATED or RELEASED). None of the drives will function unless *all* the buttons are out, in which case the display shows RELEASED.
- Telescope power. Should be ON.
- Computer reset button. This is the button on the engineering desk which is pressed to switch from engineering to computer mode. It is ENABLED (lamp on) when switch-over is allowed; DISABLED if not.
- Mode selected. COMPUTER or ENGINEER (duplicated on the top-level display).
- Azimuth limits. These are *hardware* limits and should not be encountered in normal (computer-controlled) operation. The pre-limits are hit first, and cause the system to revert to engineering mode. The telescope can only be driven out of a main limit by hand. The display should show CLEAR for all limits and pre-limits in normal operation and SET (with the message in reverse video) if the limit has been hit. The nominal hardware limit positions are:
  - ◦ LIMIT+ 362°;
  - ◦ PRE-LIMIT+ 360°;
  - ◦ PRE-LIMIT− -180°;
  - ◦ LIMIT− -182°.

- Altitude limits. As for azimuth, except that the final limit refers to the Access Park 3 position, which can only be reached under engineering-mode control from the balcony. The nominal positions are:
  - LIMIT+ 97°;
  - PRE-LIMIT+ 95°;
  - PRE-LIMIT− $6^\circ.5$;
  - LIMIT− $6^\circ.0$;
  - FINAL LIMIT− $0^\circ.75$.
- Prime focus turntable limits. There are no pre-limits and no cable wrap limits. If a hardware limit is hit, then the system switches to engineering mode.
  - LIMIT+ 274°;
  - LIMIT− -86°.
- Cassegrain turntable limits. There are no pre-limits. If a limit is hit, the drive is turned off and the system switches to engineering mode. The turntable must be driven out of the limit using the + and − buttons on its base or from the engineering desk. The Cassegrain cable-wrap is driven independently (using a simple hardware servo) and therefore has its own limits (activated if it is more than $1^\circ.75$ out of phase with the turntable. If it hits one, then the *turntable* must be driven under engineering control until the cable-wrap limit is cleared.
  - LIMIT+ 253°;
  - LIMIT− -254°.
- Nasmyth turntable limits. Usually the Nasmyth turntables are allowed to rotate continuously, as they normally carry derotation optics, if anything. The GHRIL-side limits are used for INTEGRAL to avoid damaging the fibres. *Warning:* the status bits may indicate that both limits are SET if they are disconnected. This should be ignored.
- Focus limits. Hitting a limit stops the focus drive, but does not cause a switch to engineering mode.
  - LIMIT+ 129.5 mm;
  - LIMIT− 34.0 mm.

5.6 Alarms page

This page contains alarm indicators for serious faults, principally in the hydraulic support system, mirror support and power supply. All except the control room temperature and dome emergency stop alarms have counterparts on the alarm panel of the engineering desk (red light + audible alarm). The layout is shown in Figure ??.

- Hydraulic and lubrication system.
  - Oil pad alarm. Indicates high or low pressure at one of the hydraulic support pads. Check the engineering desk to ascertain which pad(s) are involved. Warning only—does not cause switch to engineering mode. Normal state CLEAR, alarm state SET.
  - Gearbox oil alarm. Indicates incorrect oil pressure in the gear-boxes. Warning only. Normal state CLEAR, alarm state SET.
  - Oil pump alarm. Normal state CLEAR, alarm state SET.
  - Altitude and azimuth oil filter alarms. Normal state CLEAR, alarm state SET.
  - Oil temperature. Should read NORMAL, alarm state HIGH.
  - Oil level. Should read NORMAL, alarm state LOW.

Figure 6: The alarms screen.

- Power.
  - Mains alarm. Normal state CLEAR, alarm state SET.
  - Power amplifier. Normal state WORKING, alarm state FAULTY.
- Primary mirror support.
  - Nitrogen pressure. Normal state NORMAL, alarm state LOW. A failure here generally means that the nitrogen supply has run out.
  - Load cell alarm. Indicates that the forces on the radial or axial load cells which control the position of the mirror are excessive. Normal state CLEAR.
  - Mirror height. Normal state NORMAL.
- Nasmyth gate alarm. This is triggered if one of the Nasmyth access gates on the balcony is open, but there is no Nasmyth platform next to it. It causes a switch to engineering mode. Normal state NOT OPEN.
- Dome emergency stop. Normal state CLEAR.

5.7 Dome status and manual overrides page

This page contains the engineering override indicators for individual mechanisms and the status bits concerning dome and shutters. The layout is shown in Figure ??.

- Engineering overrides. These cause computer control for individual mechanisms to be disabled and are controlled by latching buttons on the engineering desk. Overrides are on when the buttons are latched down. The yellow lamps will be lit when the mechanisms concerned are under engineering control, either because the system as a whole is in engineering mode or as a result of overrides. The

Figure 7: Dome status and manual overrides screen.

display shows ENGINEER when the mechanism is overridden; COMPUTER otherwise. Mechanisms which may be overridden and their states in normal (computer-controlled) operation are:

- ∘ Dome manual override (normally DISABLED);
- ∘ Focus manual override (normally DISABLED; note that the focus drive does not work under override);
- ∘ Shutters manual override (normally DISABLED);
- ∘ Mirror cover manual override (normally ENABLED).

- Control locations. These show the state of the remote/local/off keyswitches on the gallery control panel. REMOTE means that the mechanism can be driven from the control room; LOCAL that it must be driven from the balcony panels.
  - ∘ Dome (normally REMOTE);
  - ∘ Shutter (normally LOCAL);
  - ∘ Windshield (normally LOCAL).
- Power. Normally ON; alarm state OFF.
  - ∘ Dome;
  - ∘ Shutter;
  - ∘ Windshield.
- Overtravel alarms. Normally CLEAR; alarm state SET.
  - ∘ Shutter;
  - ∘ Windshield.

- Torque trip alarms. Shut down the drive until reset on the gallery control panel. Normally CLEAR; alarm state TRIPPED.
  - Shutter;
  - Windshield.
- Windshield parked indicator: PARKED or NOT PARKED.
- Shutter and windshield OPEN/CLOSED.
- Platform pin. If IN, this disables dome rotation. Normally OUT.
- Dome interlock. Normally DISABLED; alarm state ENABLED.
- Focal station in use (displays SELECTED).
  - Cassegrain (secondary mirror on; Nasmyth flat stowed).
  - Prime (prime focus unit on).
  - GHRIL Nasmyth focus (secondary mirror on; Nasmyth flat in GHRIL position).
  - UES Nasmyth focus (secondary mirror on; Nasmyth flat in UES position).
  - Folded Cassegrain (secondary mirror on; Nasmyth flat in folded Cassegrain position; used for WYFFOS calibration unit).
- Primary mirror cover.
  - CLOSED/NOT CLOSED. Reads CLOSED when the cover is *fully* shut; NOT CLOSED otherwise.
  - OPEN/NOT OPEN. Reads OPEN when the cover is *fully* open; NOT OPEN otherwise.
- Nasmyth flat. STOWED is the appropriate position for Cassegrain and prime foci; NOT STOWED for Nasmyth and folded Cassegrain. The flat should always be STOWED when not in use.
- Secondary mirror cover. Always OFF, since the cover is only used when the mirror is not on the telescope.
- Azimuth zone. This gives the position of the switch that is read on startup to resolve the ambiguity in the azimuth absolute encoder. RED $\Rightarrow -180^\circ <$ azimuth $< +120^\circ$ and YELLOW $\Rightarrow +120^\circ <$ azimuth $< +360^\circ$, approximately.
- Access/zenith park ties. These are inserted to stop the telescope moving when it is out of balance (*e.g.* when the mirror cell has been removed or during an end change) and force engineering mode. Normal state OUT; alarm state IN.
- Revolving floor latch. This stops the telescope moving in azimuth when it is at the correct position for the mirror to be removed (*i.e.* with the fixed and moving parts of the mirror trolley rails lined up). Normal state CLEAR; alarm state SET.
- AP 3 access platform. This stops the telescope being driven in azimuth when the barrier is removed to give access to the top-end ring. Normal state STOWED; alarm state DEPLOYED.