The DFM 2.4m Telescope Control System Quicklist

Eric Galayda (MDM Observatory), John Thorstensen (Dartmouth College)
2022Apr06

⚪ **Quick link** to bringing the TCS software and systems online.

───────●─────────────────────────●───────

The Hiltner 2.4m telescope control system (TCS) underwent extensive upgrades during Sept/Oct 2017, with continued upgrades during the summer of 2018. The installation was performed by Damon Burke and Mark Kelley of DFM Engineering Inc., with a great deal of help from MDM's Tony Negrete and Eric Galayda. Justin Rupert and John Thorstensen took the first scientific observations on 2017Oct09, the last night that Damon and Mark were at MDM.

The intent of this document is to provide a reference to serve as a refresher when returning to the facility, as well as if anything requires a reboot. Presently, this document makes frequent reference to the 2.4m User's Guide, which gives a more complete account of the facility and its idiosyncrasies.   If you are new to observing at MDM, please be sure to read through that document as well. In no terms should an observer assume that this document can proficiently prepare them for use of the 2.4m telescope! The intent of the authors is to ultimately rework the usage documentation for the 2.4m telescope to reflect the current state of systems, as well as to contain user information more efficiently, as time permits.

Intent of This Document

Section 01 contains important general information—a brief description of the DFM hardware, the distinction between absolute and relative encoders, the overall scheme used to control everything, and some important notes about the look and feel of DFM's interface.

Section 02 is a step-by-step guide for a typical night of observing as related to the new TCS interface. The 2.4m User's Guide gives more comprehensive lists, including non-TCS specific materials.

Section 03 contains more detailed information in regards to specific tasks that come up in the step-by-step list. These include topics such as how to feed coordinates to the TCS, the expected target-file format for JSkyCalc, instructions for halting and re-starting the TCS, and finally a discussion on the positional limits of the telescope.

⚫Section 01 — General Information and Brief Description of the DFM System

The guts of the system are in the left rack of the 2.4m computer room, as seen in Figure 1. Contained are a rack-mounted PC running Win10 Pro and a customized box with front panel switches & buttons. This box contains the GALIL controller and power supplies that run the various motors.

In the control room, there are two monitors, a mouse and a keyboard to run the system. This is all located next to the MDM 2.4m workstation (mdm24ws1) as well as potentially another monitor (or two), depending on what instrument you

Figure 1: DFM TCS Electronics & Control

are running. A hand paddle is also located in the control room, which is used to manually move the telescope and focus, as well as to command CW & CCW dome motions. For telescope and focus motions, holding the *set* button while depressing a directional button makes the motion much faster; the *slew* button results in full-speed motion. In ordinary circumstances, observers should not need to slew by hand.

The dome contains a monitor that echoes the telescope information displayed in the control room. This is primarily used for setting the instrument rotator. There is also a telescope hand paddle hanging from the southwest part of the mount. A yellow paddle for larger-scale displacements of the rotator can be found on the north wall in the dome, under the dome shutter control box.

A box with buttons for opening/closing the dome is mounted on the dome's northwest wall. In order for these to work, the dome must be at its home position (azimuth **320**) so that the electrical contact boxes line up. The manual dome rotation switch on this box is no longer connected—hand-paddle buttons now offer manual control of the dome rotation as needed.

Absolute vs. Relative Encoders

The system now reads the telescope position using *absolute encoder* "Renishaw tape" strips wrapped around the HA and Dec axes. Another absolute encoder reads the focus position (set by raising/lowering the secondary mirror). These encoders know where they are at all times. By contrast, the *relative encoders* used for the dome and rotator operate by being 'zeroed' at some known location and then count up/down as their shaft turns. It's worthwhile to understand this distinction.

Overall Scheme

The TCS is controlled by a program running on the TCS PC. This provides a Graphical User Interface (GUI) that displays the telescope position and offers menu- and button-driven commands.

While it is possible to enter coordinates in the DFM TCS system by hand, it is somewhat awkward in use, so it is recommended to use *JSkyCalc24mGS* to efficiently send coordinates to the DFM GUI. This program runs on the MDM linux workstation and allows the user to import target lists and select from them in an intuitive manner. It also provides the guide-star selector. For alternate methods of entering coordinates, refer to the full [telescope manual](#).

The DFM system controls only the telescope systems—it does not control the instrument, or the MDM Multiple Instrument System (xmis2).

Auto-guiding is handled by the commercial program, [Maxim DL](#)*,* resident on the TCS PC. Guider focus is handled by a program, *Guider_Focus.exe*, also resident to theTCS PC. Environmental data (temperatures and humidity) and control of the primary mirror AC system has also migrated to within the new TCS software.

Instrument control programs (Prospero & Owl) need to communicate with the telescope to get pointing and focus information as well as to command the telescope for automated scripts. In the interest of getting things going quickly, Rick Pogge (OSU) wrote a short program called *bridge*. Using this, instruments make requests and commands using the syntax expected by

the old *xtcs*; bridge translates these to the syntax expected by the new system and sends them on. Going the other way, it translates information sent from the TCS to the old syntax and sends it out to the requester. *JSkyCalc24mGS* also communicates through *bridge*. We may eventually modify software to the new syntax and phase out *bridge*, but for now it is essential to observations.

Menus, Sub-Windows, Tabs and Apply Buttons

The DFM Telescope Control Program (TCP) uses menus and submenus that pop little windows containing tabs, buttons, entry boxes, etc. Instructions such as "From the Telescope menu, select *misc*, and in the resulting window select…" will be abbreviated in the following format: *Telescope->misc->… .*

In many cases, an attempt to open a sub-window when one is already opened will produce a sound but no window. In these cases, close any opened sub-windows and try again.

● Section 2 — A Typical Night with the TCS

Getting On-Sky

Refer to the [relevant section of the 2.4m User's Guide](#) for context around startup (e.g. closing the curtains, etc.). This manual is specific to telescope operations.

- **Enable the system.** On the TCS Interface & Electronics control panel ([MDC](#)) in the computer room, be sure that all switches are up (on) *excepting the mirror cover*. Likely the only switch that needs to be cycled is for *Drives*.
- **Start the TCS program if not already running**. Typically this is unnecessary. If the program is not running: on the left TCS monitor, double-click the yellow icon, labelled *TCS*. The TCS window will open and hover for a few moments in the middle of the displays before repositioning itself toward the top once initialization completes.
- **Start *bridge* if not already running.** Typically this is unnecessary. If the program is not running: on the MDM workstation, *mdm24ws1*, open a terminal and type:

    mdmTools start bridge

  Sometimes it takes a couple tries. You will know it's open when a terminal window pops up. The window displays chatter going back and forth and needs no input from the user. CTRL-C will stop and close the terminal window.
- **Open the dome and prepare to observe.** Ensure that it's safe to open the dome—no threat of precipitation, wind, humidity, dust. See the [list of steps in the 2.4m User's Guide](#) for advice on this as well as for a checklist of other tasks such as filling the dewar, opening the MIS dark hatch, closing the curtains, etc.
- **Open the mirror covers.** Do not open the mirror covers until the dome is fully open in case water or anything else falls from the moving dome shutter. To do this, *Telescope->Misc->Switches* tab: 'Open mirror doors'. All four mirror covers should come up within less than one minute. While mirror cover status can now be monitored through the TCP on the [Environmental Data/Control](#) page, it is worthwhile to verify within the dome that all covers are open. The primary mirror cooling system automatically disables when the covers are opened. It is of note that there is a mirror door switch on the MDC. It is a 3-position switch.

Typically, it is centered, which allows actuation through the TCP. Up forces the covers open and down forces them closed.

- **Start the telescope tracking**. In the DFM control program, *Telescope->rates->Track Rates tab: Set Sidereal Rates->Apply*. Note that the *Set Sidereal Rates* button simply types the rate into the relevant field for you. The telescope does not track until you hit *Apply.*
- **Start the dome tracking.** Under *Telescope->Misc->Switches*, there is a section on the right related to dome control. The dome field has a little area next to it that is labelled *Off* (red) or *On* (green); clicking it toggles between the two. Turn the dome *On*, then below that, toggle from *Home* to *Telescope* so the dome will follow the telescope. Be sure to remember to hit *Apply* or the changes will not be executed. A word of caution: *Do not try to enable to the dome while the telescope is slewing. A [temporary?] bug in the code may cause the telescope to run away. Just wait until the telescope has moved to a demanded position before initially aligning the dome.*
- **Take flat fields if needed.** Recall that the MIS find/guide prism needs to be OUT in order to look at the sky with the instrument.
- **Move to an object.** To move to an object (perhaps a <u>bright star</u> as a sanity and pointing check), you need to:
    1. Load the coordinates into the TCS "Next Object" field—the second line at the top of the window. This enables the slew mode—you can tell if it's enabled if the "HA" and "airmass" fields in the "Next Object" line are populated. Loading coordinates is discussed in its own section <u>below</u>.
    2. Push the *Start Slew* button at the top-left. The telescope should start slewing.
    3. Note that the red STOP button will gracefully terminate the slew if necessary.
    4. When the slew completes, the HA and airmass fields in the Next Object line go blank.
    5. If the slew has terminated normally, the telescope coordinates should match the next object coordinates.
    6. On occasion the slew terminates before reaching the target. This may indicate that you have slewed into a limit—go out and check the telescope positioning. If the telescope looks OK and the termination is spurious, simply re-send the coordinates and hit *Start Slew* again.
- **If needed, set the coordinate offset.** <u>Do not do this unless there are issues finding targets as it's possible to mess things up</u>. This is usually done on a bright star close to zenith. The procedure is:
    1. Use the hand paddle to put the star where you want it on whatever instrument you're using (if using OSMOS and intend to use only the inner slit, DO NOT put the star in the inner slit position—put it in the center of the field (clear aperture) using *roi1k* and movie mode. The guide star selector needs to know where the optical axis is, not where the star is.
    2. Be sure the Telescope Position and the Next Object position are nearly equivalent. If they are, skip the next step.
    3. *If the Telescope and Next Object positions disagree badly at this point, don't reset since you will go wildly off if you set to the wrong star*. To recover, in *Telescope->Initialization->Telescope Position tab* press the *Defaults* button in the "Set Absolute Encoder Offsets" box. This will restore pointing pretty well. Go to another star and try again.
    4. When sure you're centered on the same star given in the Next Object field, go to *Telescope->Initialization->Telescope Position tab* and click on *Use Next Object Position* then hit *Apply*. This will set the absolute encoder offsets.
    5. Compare the Telescope Position and Next Object Position. They should agree. Note that if their equinoxes differ, these numbers will differ as well.
- **Optional—Set the Equinox**. The TCS program "wakes up" reporting positions in the current equinox (or actually midway through the current year). Your target lists are likely in J2000, so

you'll probably want to change this in *Telescope->Misc->Display Equinox/Dome Shutter tab*. Enter 2000 in the appropriate box and hit *Apply*. It is highly recommended that you change equinoxes as there may be some issue in how this value is transferred to header files which may cause the header to erroneously assign correct coordinates but incorrect equinox.

- **Go to a science target**. The quickest way is to click on your target in JSkyCalc, hit *Coords->TCS Next Object* in JSkyCalc and then press *Start Slew* on the TCS.
- **Find a guide star.** There is a rather verbose manual on this. To summarize:
    1. Pop open the JSkyCalc Guide Stars window. Click on a suitable star to the left-of-bottom and move the guide probe there.
    2. In Maxim DL, *Expose Tab->Start* (with "continuous" selected—the field will be rotated 90° from the JSkyCalc guide star cartoon. If your guide star doesn't appear, either move the guide stage 500 units in X & Y with *xmis2* or move the telescope a bit.
    3. If needed, focus the guider using the program *Guider_Focus.exe on the TCS control PC.*
    4. *Stop* exposures in Maxim DL. Select the *Guide* tab and the *Expose* button, then *Start* to take a single exposure. The system should find the guide star and fill in its pixel X & Y coordinates in the "Guide Star" fields. If that doesn't work, simply click on the star in the image to force XY coordinates.
    5. In the *Guide* tab, select the *Track* radio button and *Start*. The guide star window should shrink to postage-stamp size with the guide star appearing in the middle. The telescope is now guiding.
    6. Test the guider by pushing a couple of directional buttons on the telescope hand paddle. The guide star should return to center.
    7. It is worth noting that you should not need to "Calibrate" the guider unless it is really misbehaving. With the hand paddle rate set to 1.5 arcsec/sec, the numbers under Manual Calibration in the "Settings" sub window in the guide tab should be **X Speed = -7.8, y Speed = -7.3, Angle = 0.** If you rotate the instrument, the Angle becomes -1*(rotator setting).
- **Focus and Automated Focus Temperature Compensation.** As things cool (typically) through the night, telescope focus is impacted. For every drop of roughly 1°C, focus changes by approximately 45 microns. Control software automatically compensates for this change. Once optimal focus is set, the system will automatically maintain proper displacement between the primary and secondary mirrors, maintaining optimal focus. Focus settings can be found at *Telescope>Misc>Focus tab*: *Automatic Focus Temperature Compensation*. Temp Source should be set to 'Center Section'.
- **Start taking data!**
- **Directional limits…** If your science forces you to unusual telescope positions (e.g. high airmass), or if operator error puts the telescope near the horizon, you will want to consult the discussion of limits *below*.
- **Restarting the TCS during the night.** This shouldn't be necessary, but *here* are restarting instructions in case you need them. The procedure largely recapitulates the startup except you'll need to keep track of the dome and probably restart guider systems.

Closing Down

More context and detail are include in the 2.4m User's Guide. Here are the telescope-centric portions.

- **Turn off tracking.** In *Telescope->Rates->Track Rates tab*, type 0 into the "HA Rate" box and hit *Apply*. The telescope HA should stop changing and the RA should start.

- **Telescope to zenith**. In *Telescope->Movement->Offset/Zenith tab*, hit *Apply* and *Start Slew*. The telescope should move to the zenith.
- **Send the dome to home position.** The simplest procedure is to go to *Telescope->Misc->Switches tab* and make *Dome mode* into *Home* by clicking it (Home turns the button red), then *Apply*. This rotates the dome right (CW) until the contact is found and sets the dome azimuth to 320. If the dome is unfavorably placed (e.g. just to the right of the contacts), you may want to back the dome up onto the contacts (using the hand paddle) so its azimuth is at 320.
- **Rotate the instrument to zero if needed.** Remember that the rotator cannot be moved with the mirror covers closed!
- **Close the mirror covers.** *Telescope->Misc->Switches tab: 'Close mirror doors'*. All four mirror covers should lower within less than one minute. It is worthwhile to verify within the dome that all covers are fully closed. The primary mirror cooling system automatically starts when the covers are closed. The demanded temperature should be set to roughly 1°C lower than the low of the previous night. Typically, the temperature should not have to be changed.
- **Close the dome dropout and shutter**. While the shutter can now be closed via software interface, the dropout requires a button push from the panel in the dome. You might as well do both from the dome since the dropout must be closed first. Do this step *after* the mirror is fully closed to avoid having anything fall on the mirror surface.
- **Optional**: On the MDC, flip the "DRIVES" switch down. This is a precaution against failures that may result in unwanted telescope motion. It is typically unnecessary.
- **Run the rest of the checklist** from the *User's Guide*.

⬤ Section 3 — Detailed Information

Sending Coordinates to the TCS

There are several options for doing this:

1. **Use JSkyCalc24mGS.** Most users will probably use this method. JSkyCalc24mGS runs on the observatory workstation *mdm24ws1*, not on the TCS machine. Start it from the top menu with *Applications->Telescope Control->JSkyCalc24mGS*. Clicking *Object Lists…* brings up an *Object Selector* window and clicking *Load New Object List* then brings up a file-selector box. Select an *MDM-format target list* you've prepared and the targets will appear on the sky display as well as be listed in the *Object Selector* top window. Clicking a target on the sky display or its name on the list loads the object information into the *Object, RA, Dec* and *Equinox* boxes at the top-left of the main program window. From there, click the *Coords->TCS Next Object* button in the telescope sub-window and your target should load into the TCS. Once you're sure the target has been set properly, press *Start Slew* in the TCS window to start moving the telescope.

JSkyCalc24mGS has a few notable issues—it can occasionally drop the thread that keeps it updated or lose the ability to send coordinates to the TCS. If this happens, it's completely harmless to quit JSkyCalc and start it again. Object lists will however have to be reloaded.

If you have a coordinate you'd like to enter by hand, just type them into the little boxes in JSkyCalc and send them. Note however that you'll be interrupted every 30 seconds by the refresh cycle. Send the coordinates right away—if you click on a target on the sky display, your entered coordinates will be overwritten.

2. **Enter coordinates by hand in the TCS program.** *Telescope->Movement->Slew Position tab*; enter the hours, minutes, seconds, degrees, minutes, seconds and slew equinox in their appropriate (and separate) boxes. Be sure to then hit *Apply*.

3. **Use TheSky**. This is useful for testing on bright stars or for sightseeing.
   Open TheSky on the TCS by double-clicking its icon (it is typically already open).
   Click on *Start Up* and select *Connect Telescope*.
   Click on a star and hit *Slew* on TheSky. The telescope (yellow bullseye) will move to the star (red bullseye).
   While unnecessary, it is a good idea to keep TheSky open and connected to the telescope as it provides an easy-to-view representation of just where the telescope is pointed.

   4. **Use a list file loaded directly into the TCP.** Under*Telescope->Movement->Mark/Move Table tab,* you can load a file containing coordinate information for a list of objects. This is further covered in the *Section 5 of the Telescope Manual*.

Target File Format for JSkyCalc24mGS

It is:

name_no_blanks   rah **ra**m **ra**s   **dec**deg **dec**m **dec**s   **equinox**
in free format. Keep the name under 10 characters. As an example:

4u2129+47   21 29 36.2   47 04 08   1950
Avoid blank lines.

Quickly loading a bright star

For pointing checks, it's handy to be able to load bright stars quickly
JSkyCalc24mGS offers two ways to do this:
1. Pointing at a bright star on the sky display and typing *h* (for "HR Catalog") will load that bright star into JSkyCalc. You can then do *Coords->TCS Next Object* to load it into the TCS. Then hit *Start Slew* on the TCS to slew to it.
2. Hit the "Nearest Bright Star" button in the bottom panel of the main JSkyCalc window to find a bright star nearest to the current telescope coordinates and load it into JSkyCalc, then follow the steps above to load it into the TCS. This is useful when you can't find your object and want to check your pointing locally. It should be noted that this command uses the current equinox.

Alternatively in TheSky, you can click on a star to select it with a red bullseye, then hit the *Slew* button in TheSky. TheSky always sends near-current equinox (this year + 0.5).

Restarting the TCS

In ordinary operation, it shouldn't be necessary to restart the TCS program. But crashes and such can happen. The DFM TCS system hardware in the computer room is confined to the left-most rack (refer to Figure 1 *above*). If a full reboot is necessary, the yellow switch on the control PC will perform that action.

1. Stop the telescope tracking with *Telescope->Rates->Track Rates* tab. Enter 0 for the HA rate and hit *Apply*.
2. Note the Dome Azimuth (toward the lower-right of the display). You'll need to re-enter this value after a reboot.
3. *File->Exit* to stop the TCS software.
4. Restart the program by double-clicking the yellow TCS program icon.
5. Bring up *Telescope->Initialization->Other Positions* tab and enter the appropriate dome azimuth. Hit *Apply*.
6. Under *Telescope->Misc->Switches*, turn the dome *On* and make the Dome Target *Telescope*. Hit *Apply*.
7. Restart tracking with *Telescope->Rates->Track Rates* tab. Choose *Set Sidereal Rate*, hit *Apply*.
8. Double-click the desktop icon to restart the *MaximDL* (guiding) software.

   Figure 2: Camera Control

   a. Click on the little camera icon (Figure 2) in the menubar to bring up the camera controls. If you hover the mouse over it, it says "Toggle Camera Control". The camera-control window will open.
   b. In the *Setup* tab, connect to the camera.
   c. Select the *Guide* tab and click on *Settings*.
   d. In the *Autoguider* output section of the settings box, there should be a little selector that says "ASCOM Direct". Click the *Setup* button in the *Autoguider* output section (Figure 3).
   e. In the resulting window (Figure 4 below), the selector should read "TCSGalilHybrid.Telescope". Click *OK* to select this choice. You must click *OK*. Clicking *Cancel* will de-select the interface.
   f. When you start guiding again, test that the guider is working by pushing paddle buttons to displace the star. Be sure it comes back on its own.
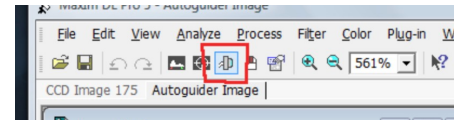

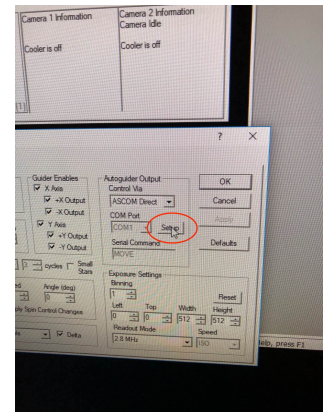   Figure 3: ASCOM Direct

9. Open the program *Guider_Focus.exe* from the desktop to allow for focusing the guider camera. It will likely need to be moved to a more convenient location. To do so, hit the 'STOP' button, drag the GUI somewhere different (and resize if desired), then hit the *run* arrow above the GUI. If the program is not running, pushing the various buttons on the GUI will have no impact on focus.
10. Double-click *TheSky* icon and click *Connect to Telescope*. This should move the yellow bullseye to the position of the telescope.

The telescope and TCP should now be back online. The bridge program should not need to be restarted. You can verify it is still talking by going to the *tcs* terminal on the workstation and typing *tcstatus*. It should return header information. You should also see a simultaneous push from the bridge.

Telescope Positional Limits

The TCS has positional limits to keep the telescope out of unsafe locations. While most programs require observations near the meridian, there are times when observations near the horizon are desired.

There are several levels of limits:

- The **APPROACHING LIMIT** condition starts when the telescope is set at a zenith distance of 75° (airmass=3.8) and at hour angles beyond ±5hr 50min. These are handled thusly:
  - The telescope will refuse to auto-slew to these locations. The message *TARGET OUT OF BOUNDS* will appear in one of the black areas in the *Operating Mode* part of the TCS window.
  - You are allowed to move to targets in these bands using the hand paddle to slew. The TCS will move at 1/4-speed in these areas.
  - You are allowed to track into this zone (West). The error message will display but the telescope will continue to track.
- The **LIMIT REACHED** condition occurs at 80° zenith distance (airmass~5.5) and hour angles greater than ±6hr 10min. The telescope will stop tracking when it reaches this zone and the condition will be reported in the *Operating Mode* part of the TCS window. You can back out of these zones via the hand paddle—just be sure you are moving in the right direction.
- The previous two limits depend on the telescope coordinates being at least approximately correct. There are also magnets mounted on each axis that form directional limits on that axis. In HA, limits are set ~ ±6hr 10min. In Dec, limits are set at ~ -43° (south) and 10° past the pole (north).
- The final limit system is known as the *horizon interlock limit (HIL)*, which is more drastic than the previous ones. Mercury switches cut power to the motors when the zenith distance gets somewhere over 80°. If the HIL is tripped, the *Horizon Limit* light on the TCS box will go from green (normal) to off.

Recovery From Limits

You can back out of *Approaching Limit, Limit Reached,* and the *directional limits* via the hand paddle. The directions that put you deeper into the limits *should* be disabled, but use caution to only go in the appropriate direction anyways. Once out of the limits, the telescope should behave normally.

Getting out of the HIL is potentially dangerous as the limits have to be physically overridden. If it is late at night, consider this an indication that observations for the night are over and bed is awaiting. If early enough, contact MDM staff and there's a chance we can talk you through the procedure to get out of the limits. Thankfully, it should be extremely difficult to get to this point.