CDK700 Software Guide

Last revised: 2016-08-19

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Network Configuration

The computer communicates with the telescope electronics via an Ethernet connection to the bottom of the control box. PlaneWave provides a USB-to-Ethernet adapter (see Figure 1) which can be used to add an extra Ethernet port to the telescope control computer in case the existing port is already being used to connect to the local network.

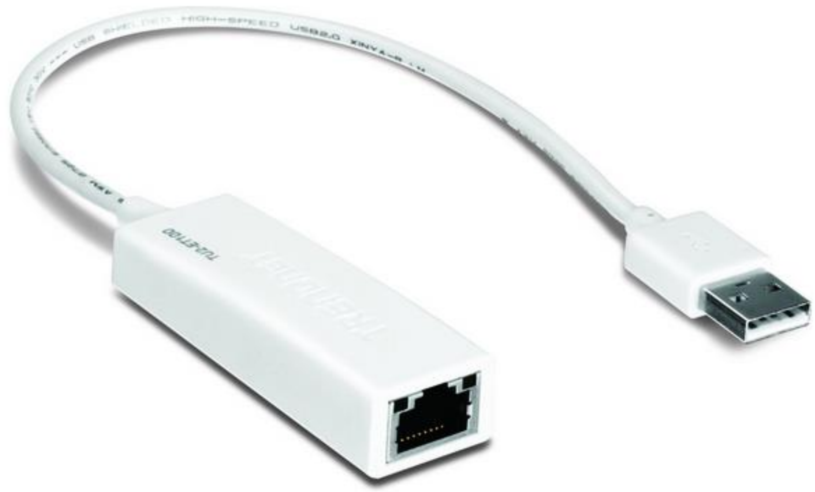


Figure 1: USB-to-Ethernet adapter

Note: Although it is technically possible for the computer to connect to the telescope through a switch or a wireless router, PlaneWave recommends connecting the computer directly to the telescope control box for maximum reliability.

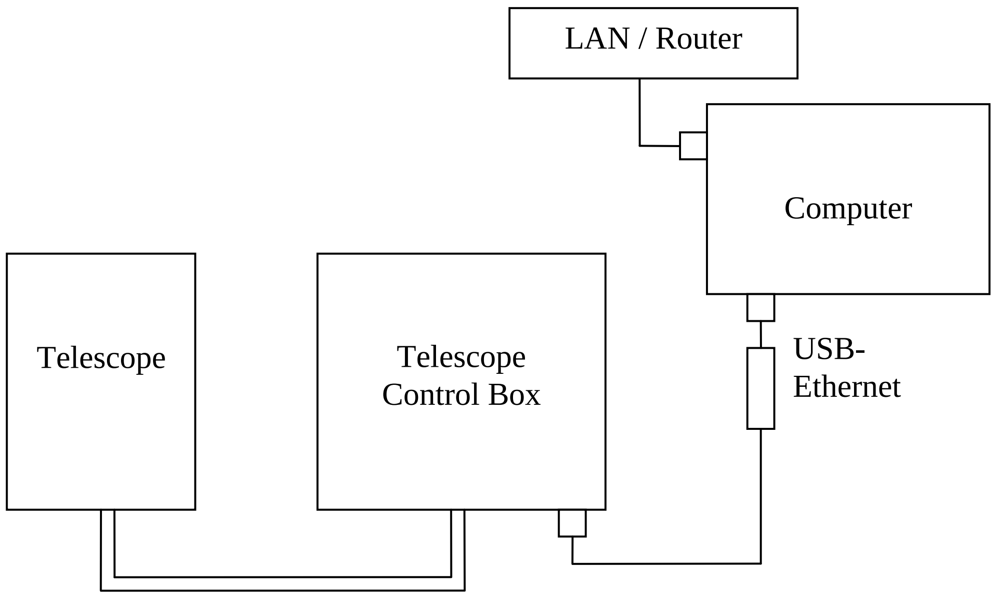


Figure 2: Recommended connection layout

Configuring the Network Adapter

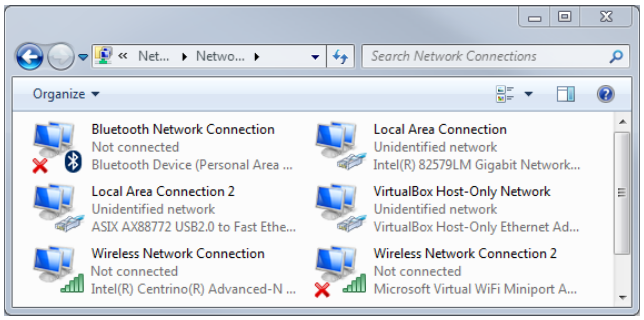
The telescope control electronics are configured with the IP address **192.168.10.40**. In order for the computer to connect to the telescope electronics, the network adapter must be configured to an IP address on the same subnet.

1. Navigate to the list of Network Adapters for your system.

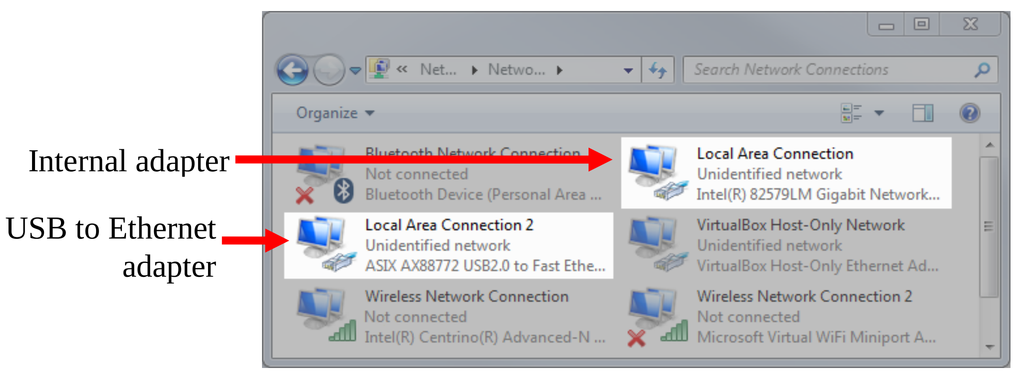
   Windows 7: Open the Start menu and type "View Network Connections" in the Search box.

   Windows 8 / 8.1: From the Start screen**,** type "View Network Connections". Click the "Settings" category, and then click the "View Network Connections" icon.

   Windows XP: From the Start menu, select "Settings" > "Network Connections"

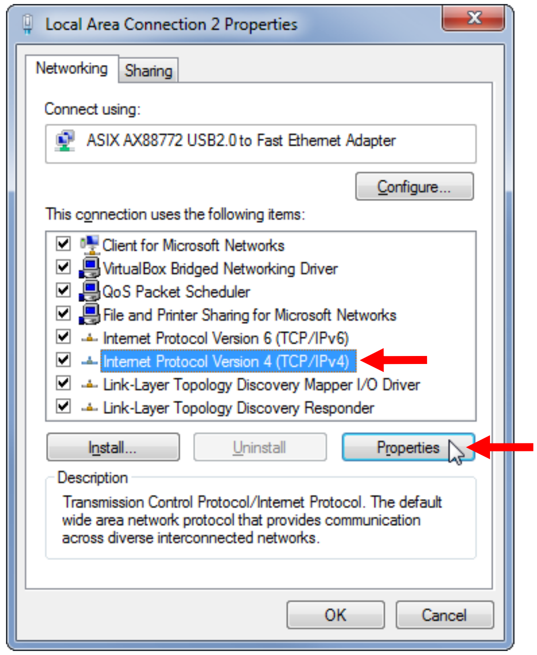


2. Identify which adapter is being used to connect to the CDK700. In general, it will be identified as one of the "Local Area Connection" options. The USB-to-Ethernet adapter is further identified in the screen below as "ASIX AX88772 US2.0 to Fast Ethernet".



3. Right-click the network adapter and select "Properties"

4. Select "Internet Protocol Version 4 (TCP/IPv4)" and click "Properties"

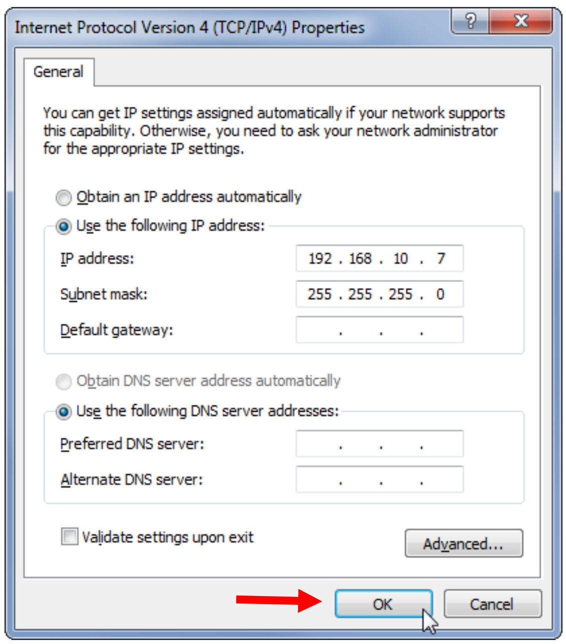

Local Area Connection 2 Properties
Networking
Sharing
Connect using:
ASIX AX88772 USB2.0 to Fast Ethernet Adapter
Configure...
This connection uses the following items:
Client for Microsoft Networks
VirtualBox Bridged Networking Driver
QoS Packet Scheduler
File and Printer Sharing for Microsoft Networks
Internet Protocol Version 6 (TCP/IPv6)
Internet Protocol Version 4 (TCP/IPv4)
Link-Layer Topology Discovery Mapper I/O Driver
Link-Layer Topology Discovery Responder
Install...
Uninstall
Properties
Description
Transmission Control Protocol/Internet Protocol. The default wide area network protocol that provides communication across diverse interconnected networks.
OK
Cancel

5. Configure the network with the following settings:

    Select **"Use the following IP Address"**
    IP address: **192.168.10.7**
    Subnet mask: **255.255.255.0**
    Default gateway: (leave blank)

    Select **"Use the following DNS server addresses"**
    Preferred DNS server: (leave blank)
    Alternate DNS server: (leave blank)

   Click "OK" when finished.



Testing the Network Connection

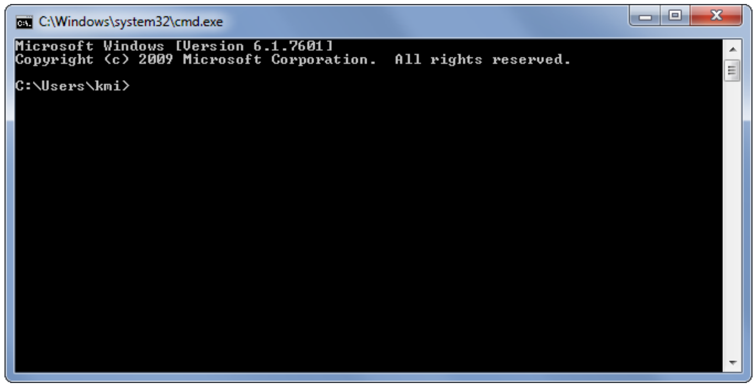
If the telescope control box is plugged in and turned on, you can use the "ping" program to verify that the computer and the telescope control box can communicate over the network.

Note: The telescope control box takes approximately 30 seconds to initialize after being powered up. Be sure to wait at least this length of time after powering the control box before trying to check for connectivity.

1. Open a Command Prompt window

   Windows 7: Open the Start menu, type "cmd" in the Search box, and press Enter.

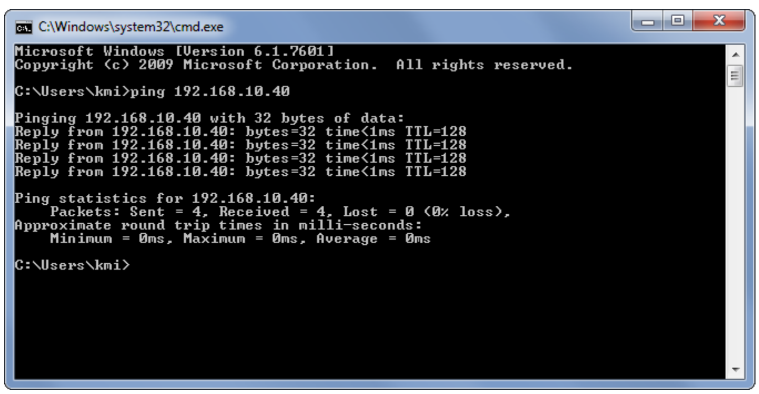
Windows 8: From the Start screen, type "cmd" and press Enter.
Windows XP: Open the Start menu, click "Run...", type "cmd" and press Enter.



2. In the Command Prompt window, type:

   ping 192.168.10.40

   and press Enter. If the connection is functioning, you should see four messages (one displayed per second)



3. Close the window when finished.

Software Installation

The CDK700 telescope system normally requires three pieces of software:
1. PlaneWave Interface 2 (requires .NET 3.5)
2. ASCOM Drivers for PlaneWave Interface 2 (requires ASCOM Platform 6)
3. Kepler All-Sky Catalog for PlateSolve.

Installing PlaneWave Interface 2 (PWI2)

PWI2 is the primary control software for the telescope mount, focusers, rotators, fans, and temperature sensors. Through this software you can build pointing models for high-precision pointing and tracking, slew the telescope, monitor tracking performance, perform automated best-focus routines, manage instrument de-rotation, and much more.

This software may be downloaded from the PlaneWave website. Users with CDK700 telescopes installed **after** March 2013 (serial numbers **0005 and greater**) should download the latest version of PWISetup from:

http://planewave.com/files/software/PWI2/widefield/

Users with CDK700 telescopes installed **before** March 2013 (serial numbers **0001 - 0004**) should download the latest version of PWISetup from:

http://planewave.com/files/software/PWI2/original/

Note about .NET Runtime: PWI2 requires the .NET 3.5 Runtime, which comes installed by default on Windows 7. Many other programs also depend on .NET, and it is commonly installed even on other versions of Windows. If .NET 3.5 cannot be found, the PWI2 installer will notify you.

If you are running Windows XP or Windows Vista, you can download the .NET 3.5 installer from:

http://www.microsoft.com/en-us/download/details.aspx?id=21

If you are running Windows 8 or 8.1, you can enable .NET 3.5 via Control Panel by following the instructions on this page:

http://support.microsoft.com/kb/2785188

Installing ASCOM Drivers for PlaneWave Interface 2

These drivers allow you to control the mount, focusers, and rotators using ASCOM-compatible third-party software such as TheSky, MaxIm DL, FocusMax, ACP, and CCDAutoPilot. When a third-party program connects to the PWI2 ASCOM driver, it will communicate with the telescope via a running instance of the PWI2 control software.

The mount, focuser, and rotator drivers are bundled in a single installer, which may be downloaded from the same page as the PWI2 control software (see above).

Note about ASCOM Platform: If you have not already done so, you will need to install ASCOM Platform 5.5 or later before installing these drivers. The installer can be downloaded from the official ASCOM website:

http://ascom-standards.org/

ASCOM Platform provides the framework and tools to allow various ASCOM-compatible programs and devices to communicate.

Installing Kepler All-Sky Catalog

PlaneWave Interface incorporates an all-sky PlateSolve routine that is able to match an image of a star field to a location in the sky without any prior knowledge of the image's approximate location, rotation angle, or pixel scale. This routine is used by PWI when building a pointing model to precisely correct for any repeatable pointing errors.

The catalog installer (2.0 GB compressed, 3.6 GB uncompressed) consists of two files and may be downloaded from:

http://planewave.com/files/catalogs/Setup_PlateSolve3_Catalog.exe
http://planewave.com/files/catalogs/Setup_PlateSolve3_Catalog-1.bin

Once downloaded, the catalog may be installed by running Setup_PlateSolve3_Catalog.exe. Note that:

1. The .exe and the .bin files must be located in the same directory
2. If one file is renamed, the other file must be renamed to match

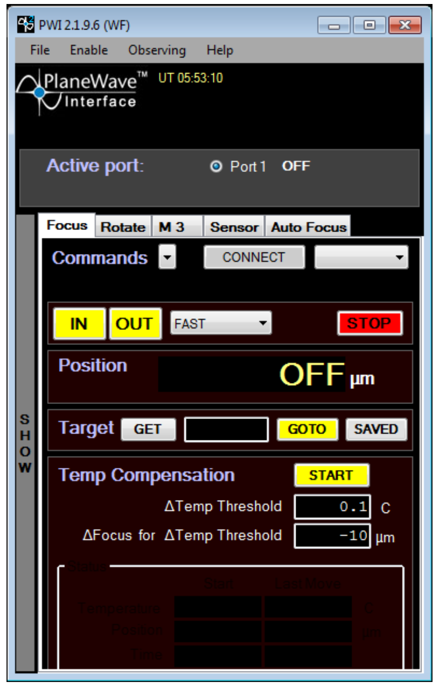
Once installed, the catalog files can be found under the user's **Documents** folder under **Kepler**. The general file layout is as follows:

```
Documents\
    Kepler\
        Orca\
            DistOrca0025.orc
            DistOrca0035.orc
            (37 more files...)
        UC4\
            Index.UC4
            Z000.UC4
            (179 more files...)
        UC4Mag14\
            Index.UC4
            Z000.UC4
            (179 more files...)
```

Configuring PlaneWave Interface 2

Enabling Mount and Rotating Focusers

The first time PWI2 is stared, the following screen will be shown:



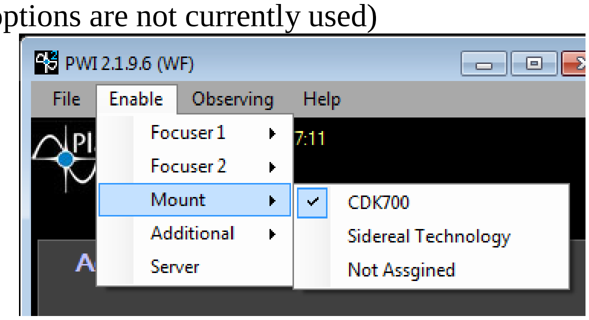
Locate the "Enable" menu along the top menubar, and ensure that the following options are selected:

Focuser 1: **Rotating Focuser IRF90**

Focuser 2: **Rotating Focuser IRF90** (or **Not Assigned** if not installed on Port 2)

Mount: **CDK700**

Additional: (options are not currently used)



Once the CDK700 Mount option has been enabled, you will have access to the "Mount" control tab. In addition, you can click the "Show" region to expand the window and display additional control screens.

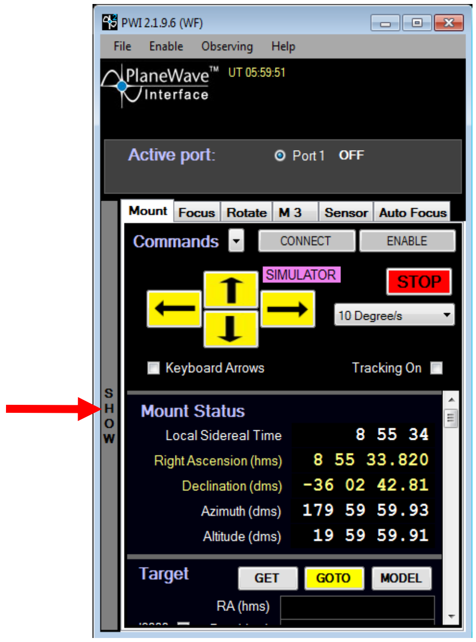


Figure 3: PWI window with Mount tab enabled

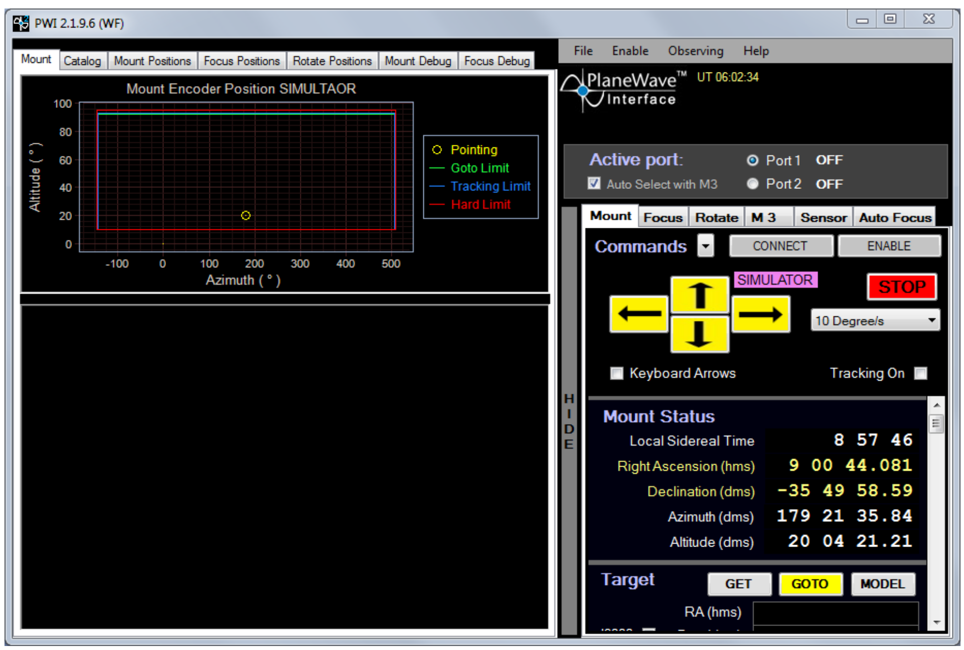


Figure 4: PWI window with additional tabs displayed

Connecting to the mount

PWI2 runs in Simulator mode at startup, as identified by the purple "SIMULATOR" label displayed next to the directional buttons. In this mode you can experiment with the various controls to get a sense for how the software works.

To connect to the mount, click the "CONNECT" button just above the "SIMULATOR" label. Once the software has connected successfully, you will see that:

1. The "CONNECT" button turns green
2. The "SIMULATOR" label changes to report the firmware version number of the mount electronics

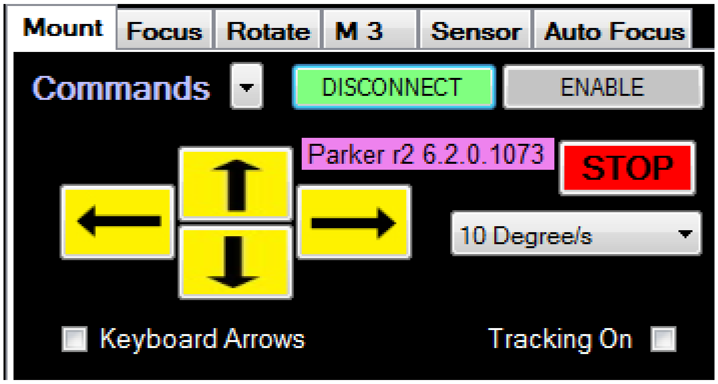


Figure 5: Mount display after a successful connection

> **Note:** If the connection is unsuccessful, the PWI software may become unresponsive for up to 30 seconds. This is due to a bug in the third-party communication library used to communicate with the telescope motion controller. We hope to fix this issue in a future release.

Understanding the range of axis motion

The CDK700 mount has two primary axes of motion: altitude (up and down) and azimuth (left and right). The altitude axis typically ranges from a lower limit of 0 - 10 degrees (near the horizon) to an upper limit of just over 90 degrees (near the zenith).

The azimuth axis can cover a range of approximately 660 degrees, or nearly two full rotations. This feature allows the mount to support continuous tracking of any object in the sky over a full night without ever risking a situation where the internal cabling will become wrapped excessively.

The "No Wrap" location is positioned at the middle of the range of motion. At this position the twist applied to any cables running up into the mount should be minimized. From the No Wrap position, the mount can rotate in either direction by approximately 330 degrees before hitting a hardstop.

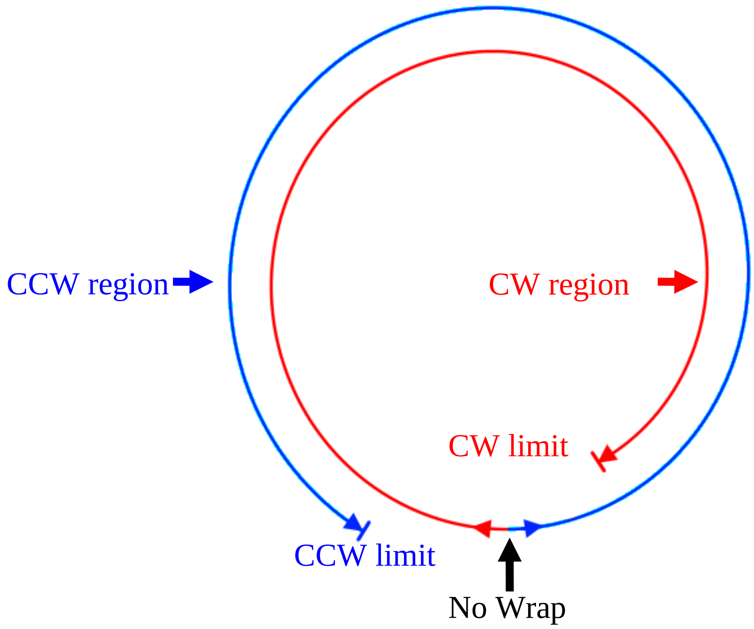


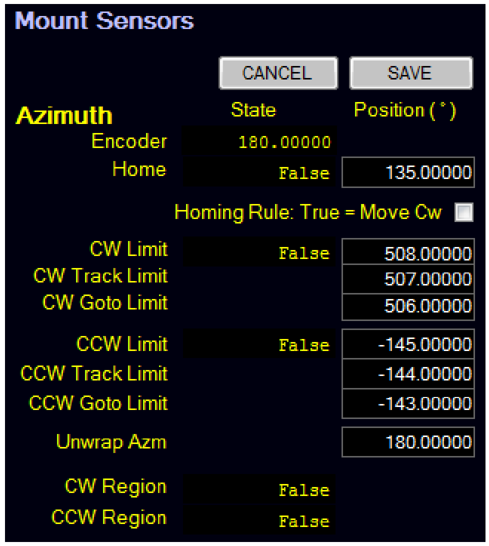
Figure 6: Azimuth regions and range of motion, viewed from above looking down. In the Northern hemisphere, the "No Wrap" position would be oriented to the South. In the Southern hemisphere, "No Wrap" is oriented to the North.

Calibrating the approximate mount position

When the mount is first powered up, it does not know its absolute position. In order to establish approximate motion limits and perform short-term tracking on the sky, the positions of the altitude and azimuth axes must be approximately calibrated. In later steps we will refine the axis positions using a PointXP pointing model and a set of Home switches that can be used to automatically align the telescope on power-up.

The telescope motors should currently be de-energized, meaning that you can push the telescope freely by hand. If the motors are currently energized, click the "DISABLE" button under the "Mount" tab.

A set of sensors in the azimuth axis allow PWI to recognize whether the mount is in the Clockwise Region or Counterclockwise Region relative to No Wrap. It will be useful to verify that these sensors are working properly as we calibrate the mount and find the limit positions. The status of these switches can be found by selecting the "Mount" tab and scrolling down to the "Mount Sensors" / "Azimuth" section.



With the motors de-energized, push the mount in azimuth by hand until the arrow on the rotating section of the fork is aligned with the "No Wrap" arrow on the stationary section of the fork base. If you encounter a hard stop, reverse direction and rotate the axis 330 degrees to arrive at the No Wrap position

At the No Wrap position, the Mount Sensor readouts should be as follows:

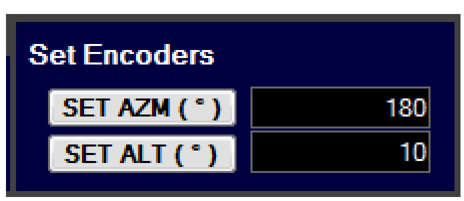
CW Limit: False
CCW Limit: False
CW Region: False
CCW Region: False

In addition, pull the altitude axis down until it is approximately 10 degrees above the horizon.

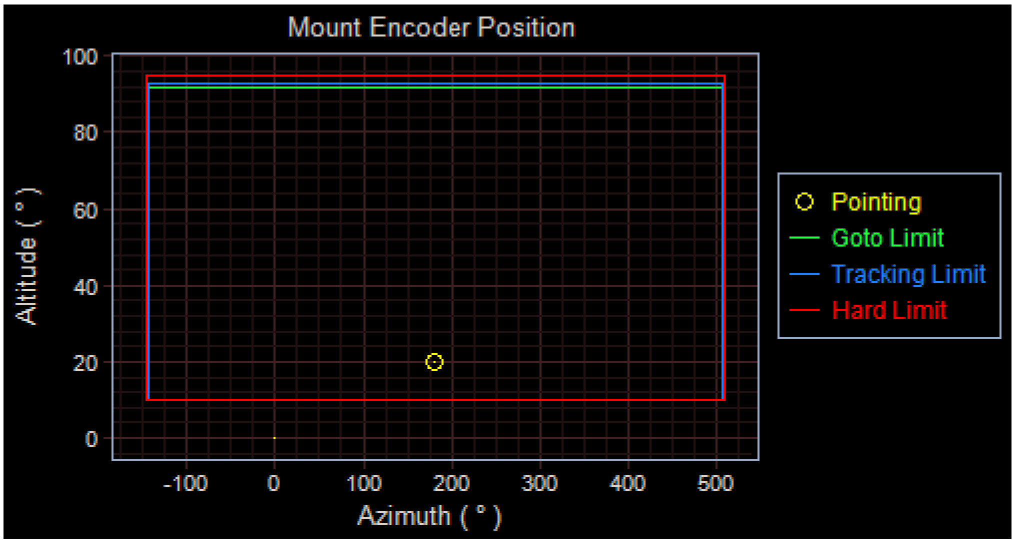
If the PWI window is not already expanded, click the "SHOW" button along the left side of the window. Next, select the "Mount Debug" tab in the left-hand display.

Under the "Set Encoders" section, enter the approximate azimuth of the OTA and then click "SET AZM". If the "No Wrap" position was installed correctly, this value should be close to 180 degrees for Northern Hemisphere telescopes (0 degrees for Southern Hemisphere telescopes). If you have a good way to visualize a particular azimuth position (e.g. due south or due north), rotate the OTA until it is pointed in that direction, and set the azimuth encoder to the appropriate value.

Similarly, enter the approximate altitude and click the "SET ALT" button.



Now click on the "Mount" tab in the left-hand section of PWI. You will see a display of the current location of the mount in Cartesian coordinates, with the 660-degree Azimuth range displayed along the X axis and the approximately 90 degree Altitude range displayed along the Y axis. Try pushing the mount by hand and watch the telescope pointing position change on this graph.



This graph also displays various limits for the position of the mount. On a Northern Hemisphere telescope the default limits should be approximately correct. On a Southern Hemisphere telescope they will be offset in Azimuth by 180 degrees. In either case, we will adjust the limits in the section below.

Calibrating the software limits

From the No Wrap position, push the mount clockwise (viewed from above). As you start to move away from No Wrap, you should see the following Mount Sensors status for Azimuth:

CW Limit: False
CCW Limit: False
CW Region: **True**
CCW Region: False

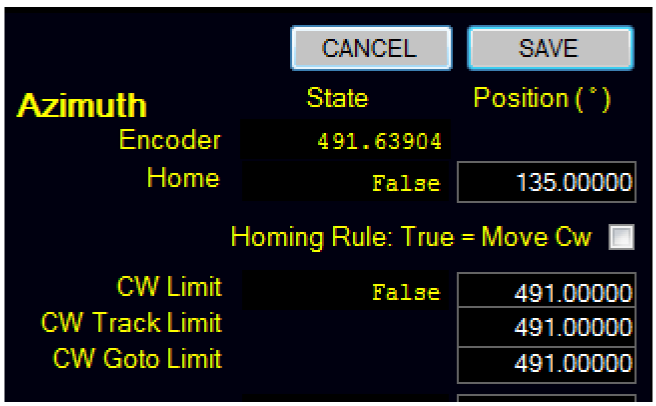
> Note: You may see the CCW Limit transition to True briefly while moving away from the No Wrap position in the CW direction. This is normal behavior. The CCW Limit is only valid if **both** CCW Limit **and** CCW Region are True. The same concept applies for the CW Limit.

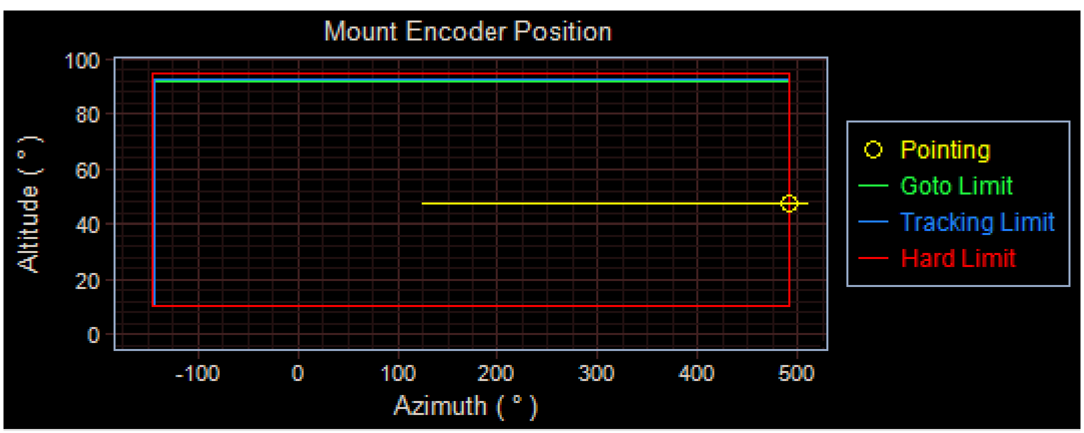
Continue to push the axis all the way around (approximately 330 degrees) until you hit the hard stop. If you back away from the hard stop by a few degrees, you should see the following status:

CW Limit: **True**

CCW Limit: False
CW Region: **True**
CCW Region: False

Back away from the limit by approximately another 15 degrees. Then, in the Mount Sensors window under the Azimuth section, enter the current "Encoder" readout in the "CW Limit", "CW Track Limit", and "CW Goto Limit" values. Click "Save" when finished. You should note that the limit boxes displayed in the "Mount Encoder Positions" graph change position when you modify these limit values, and that the Pointing position is right against these lines. In the example below, we found that the hardstop was approximately at a position of 512 degrees. We backed off 20 degrees to a position of approximately 492, and saved those values as the limits.





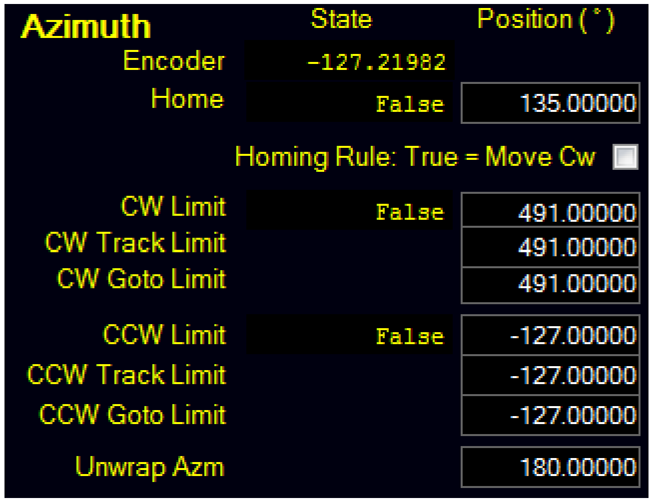
Note: In the Southern hemisphere (with No Wrap oriented to the North), the CW limit will be closer to 310 degrees.

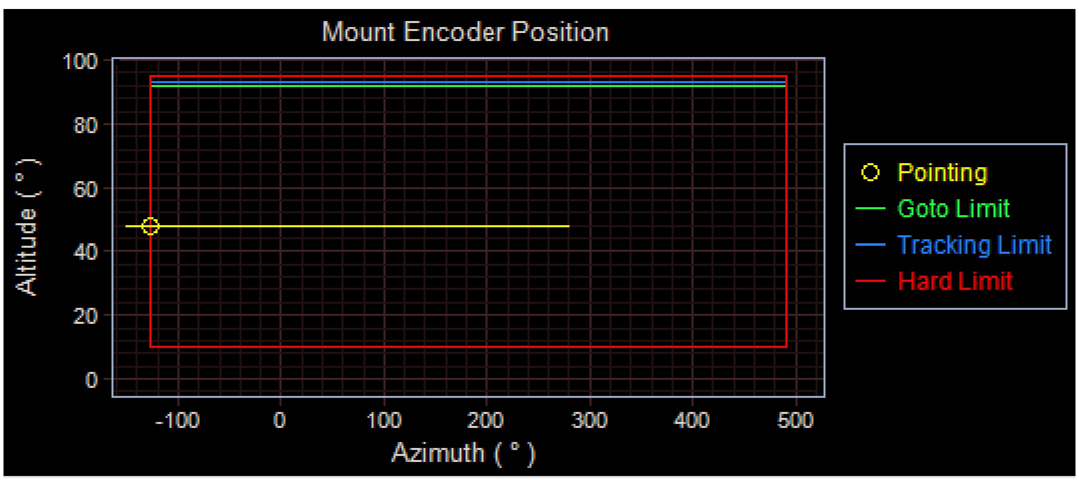
Next, spin the mount all the way back through the No Wrap position, and continue counterclockwise until you hit the hardstop in the other direction. Back off by a few degrees until you see the following Mount Status information:

CW Limit: False
CCW Limit: **True**
CW Region: False

CCW Region: **True**

Back off by approximately another 15 degrees, and record the current Azimuth Encoder value in the CCW Limit, CCW Track Limit, and CCW Goto Limit values. In the example below, we found the hardstop at a position of -148 degrees. Backing off by 20 degrees, we set the CCW limits to -128 degrees.





Finally, return to the No Wrap position, enter the approximate value as Unwrap Azm, and click "Save".

Note: In the Southern hemisphere (with No Wrap oriented to the North), the CCW limit will be approximately -310 degrees.

Energizing Motors

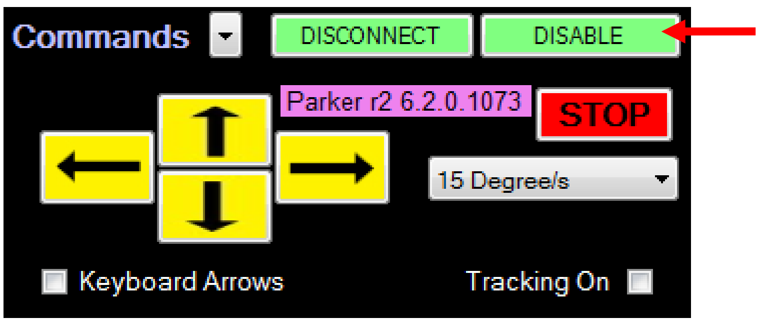
The direct drive motors on the CDK700 mount can operate in three different states:

Disabled / De-energized: No power is running to the motor coils, and the mount can be moved freely by hand.

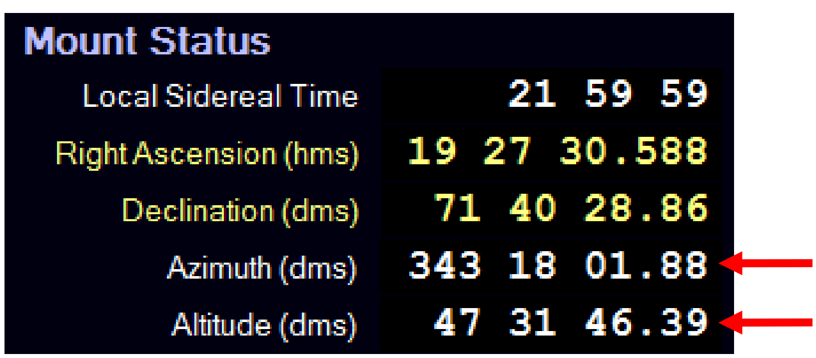
Enabled / Energized: Power is running to the motor coils to keep the axes in position and to respond to movement commands. If the mount is pushed out of position, it will try to return to its target position.

Commutating / Initializing: The motor is determining the relative orientation between the motor encoder position and the magnetic field being applied to the motor coils.

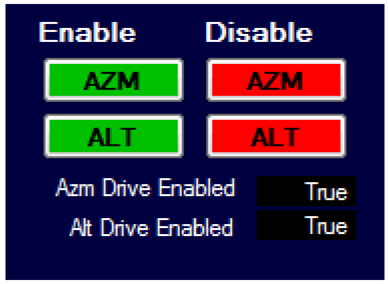
To energize the motors, click the "ENABLE" button located in the "Mount" tab next to the Connect/Disconnect button.



The first time you enable the mount axes after power-up, each axis will need to run through its automatic commutation procedure. This procedure takes approximately 30 seconds. During this time, you should see the Altitude and Azimuth coordinates change by small amounts in the "Mount Status" section:



If necessary, you can use the "Mount Debug" tab to enable or disable a single axis or to check whether a particular axis is energized or de-energized.



When the "Enable" button is first clicked, both "Azm Drive Enabled" and "Alt Drive Enabled" will read "True", even if the axis is only performing the automatic commutation sequence. If automatic commutation fails for any reason, the failed axis will change to "False" after a maximum of 45 seconds and an error message will be shown in yellow under the "PlaneWave Interface" logo. **If commutation fails repeatedly, contact PlaneWave Instruments. It may be necessary to fine-tune the commutation procedure after the telescope is fully installed.**

Note: Unfortunately there is no direct indication that the commutation procedure is being performed at this time. This will be addressed in a future release of PWI.

If commutation is successful, you will be able to move the axes using the yellow directional buttons under the primary "Mount" tab. As you watch the "Mount Encoder Position" graph under the secondary "Mount" tab on the left side of the screen, you will see the pointing indicator move around. If you move too close to a limit, the mount will stop.

Automatic Commutation: An Analogy

This section is optional, but may be of interest in order to understand the reason for the Automatic Commutation routine.

Imagine a standard magnetic compass. The needle is approximately aligned with a hidden magnet so that if you bring the north pole of another magnet near the compass, the needle will rotate to point at that magnet.

Now suppose that the needle is twisted at some random angle relative to the attached magnet. If you bring the north pole of a second magnet near the compass, the needle will still move but it may not point directly at the magnet.

In this analogy, the needle is the optical tube and the handheld magnet represents the magnetic field generated by the direct drive motor coils.

If you want to smoothly rotate the needle to a particular position, you must first determine the offset between the internal magnet and the needle so that you know how to position the second magnet.

One obvious way to do this is to simply bring the magnet close to the compass, wait for the needle to settle, and then drag the magnet around until the needle is positioned correctly. However, this could cause the needle (telescope) to swing around and oscillate wildly!

As an alternative, you can begin by holding the magnet far away from the compass and moving it in a circle around the compass. As you gradually spiral in closer to the compass, the magnetic force will eventually become large enough for the needle to begin wobbling back and forth slightly. Once the needle moves past some threshold, you can estimate the approximate position of the internal magnet, align the external magnet to match the estimated position, and bring it in very close to the compass. The two magnets will come into very close alignment without the needle needing to move very far, and it is now possible to move the needle in a controlled fashion by moving the external magnet around the compass.

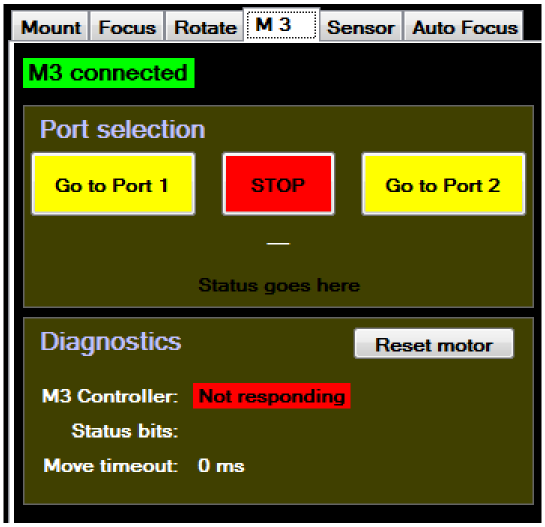
This process roughly corresponds to what is happening inside the motor during automatic commutation. However, instead of physically moving a magnet, a series of coils are energized in a particular way to produce a magnetic field oriented in a certain direction.

Configuring the Focuser

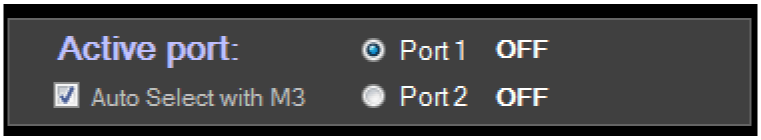
The next step in aligning the mount will involve taking images of the sky and matching the star positions to an existing star catalog to find the exact orientation of the telescope. However, before doing this it will be necessary to ensure that the camera is approximately focused.

The following instructions will assume that your imaging equipment is installed on Port 1 of the CDK700.

If you have a motorized M3 rotating mirror, click the "M3" tab in PWI and click "Go to Port 1". If your M3 mirror is not motorized, grab the primary baffle and rotate it about the primary optical axis until the M3 mirror is angled towards Port 1.



Next, verify that "Port 1" is selected under the "Active port" section at the top of the PWI window.



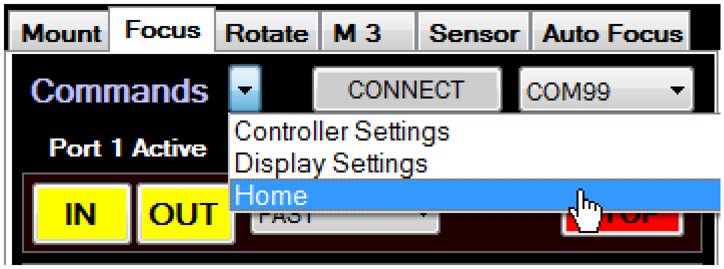
Select the "Focus" tab. Next to the "CONNECT" button you will see a menu of COM ports currently recognized by the system. The USB-to-Serial adapter used to communicate with the EFA on Port 1 should be assigned to one of these COM ports. If you are not certain which port to select, the following procedure may help:

1. With the USB-to-Serial adapter plugged in, pull down the COM port list and make a note of which entries are currently displayed.
2. Unplug the **USB** end of the USB-to-Serial adapter.
3. Pull down the COM port list again. One entry should be missing compared to the previous listing.
4. Reconnect the USB end of the USB-to-Serial adapter.
5. Pull down the COM port list again. The previously missing entry should be displayed again. Select that COM port.

Once the correct COM port is selected, click the "CONNECT" button. If the connection is successful, the button should turn green.

Test the focuser by holding the "IN" and "OUT" buttons and listening for the focuser motor. The reported Position should increase as you hold the "OUT" button, and decrease as you hold the "IN" button.

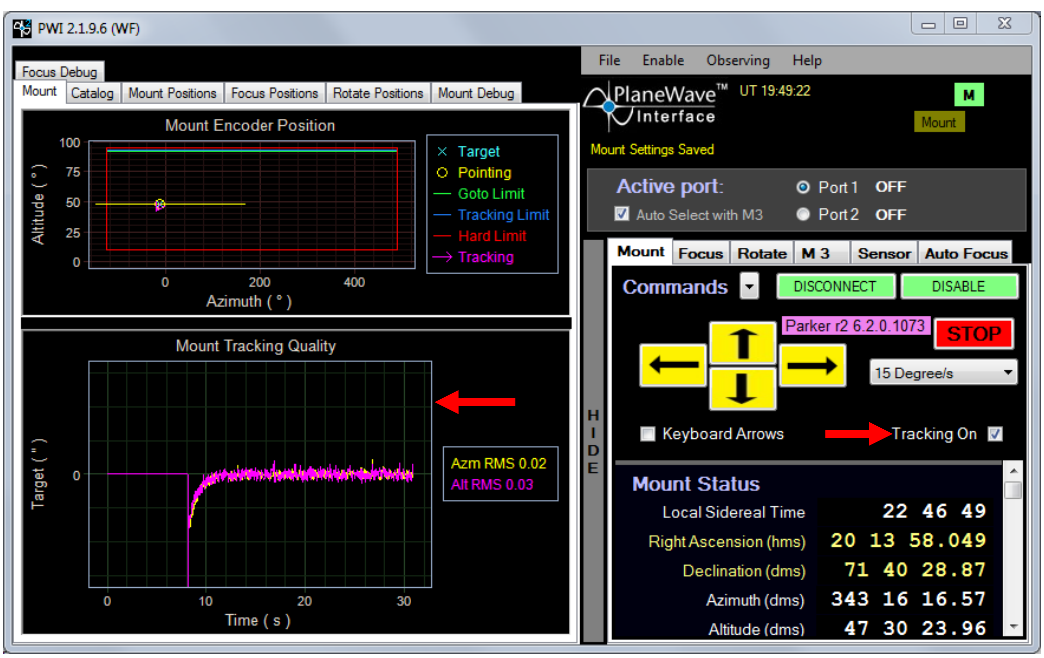
To calibrate the focus motor position, pull down the "Commands" menu and select "Home". The focuser will move to its fully racked-in position, and the reported Position value will reset to 0.



Roughly focusing the telescope

Use the directional buttons under the "Mount" tab to slew the mount to a clear part of the sky, away from the zenith position. (Because the mount has not been precisely calibrated yet, tracking performance near the zenith may be poor.) If possible, point the telescope near the galactic plane. Finding the best focus position for the first time can be tricky because if you are too far out of focus you may not be able to see any evidence of stars in your field. By pointing at the galactic plane, you increase the likelihood of having several bright stars in your image.

Click the "Tracking On" checkbox to activate sidereal tracking. Under the secondary "Mount" tab on the left-hand side of the screen, a graph will appear showing recent tracking performance.



Open MaxIm DL, connect to your camera, and turn on the camera cooler. If you have a filter wheel, select the filter that will allow the most light to pass through (e.g. Clear, Luminance, or an Empty slot.)

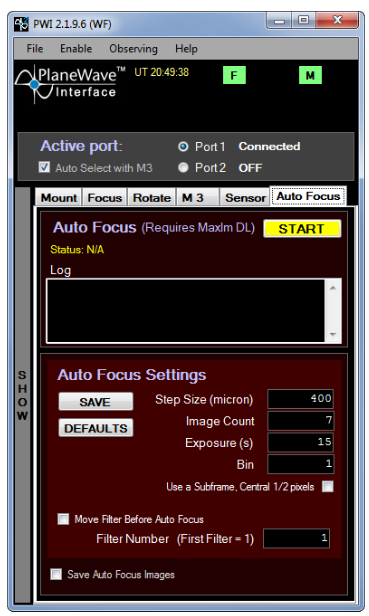
Take an exposure that is long enough to show some stars. A 10 second exposure is usually a good starting point. If you are very far out of focus, the stars will appear as large "donuts". If you do not see any stars, try taking a longer exposure or moving to a different field. If you still don't see any stars, double-check that the reported mount Azimuth and Altitude are approximately correct. If the reported position is very far off from the actual position, the axes may be tracking at the wrong rates for this part of the sky and the stars will appear as long streaks rather than points.

Select a direction (either IN or OUT), and move the focuser in that direction by about 1000 counts. (If you have just homed the telescope, you will have to move in the OUT direction since the focuser is already fully racked in.) Take another image. If the star circles become smaller, you are moving in the correct direction. If the star circles become larger, reverse direction.

Continue this process until the stars roughly appear as points (or small streaks).

Finding best focus

Once you are nearly focused, you can use PlaneWave's AutoFocus routine to find the best-focus position. Select the "Auto Focus" tab, and click the "START" button to begin.

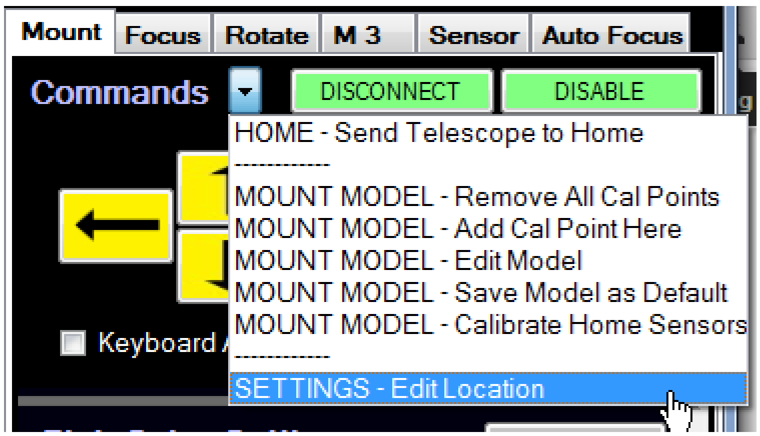


The Auto Focus routine will move the focuser to a series of evenly-spaced positions on either side of best focus and take images at those positions. It will then measure the diameters of all stars in each image and fit a model of star diameter versus focuser position. If a good fit is found, the focuser will move to the position that is predicted to have the smallest star diameter. If the routine is unsuccessful, the focuser will move back to its starting position.

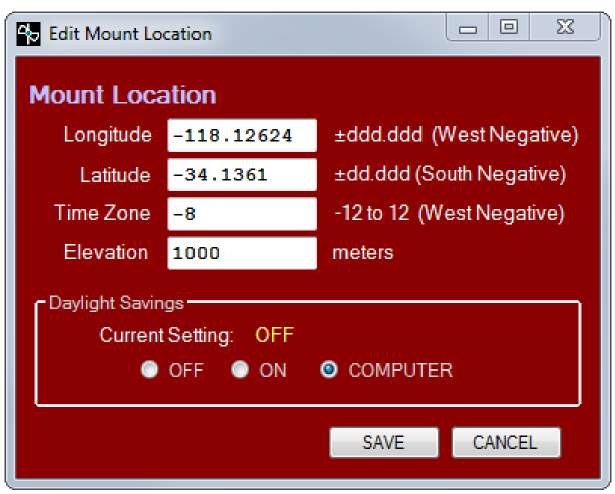
Note: For best performance, the Auto Focus routine must measure star diameters on both sides of the Best Focus position. Therefore, the camera should at least be roughly focused before starting this routine.

Calibrating the mount position: Configuring Mount Location

Under the Mount tab, click on the "Commands" menu and select "Edit Location".



In the Mount Location window, enter the decimal longitude, latitude, time zone, and elevation of the telescope site.



Click "SAVE" to apply these settings.

Calibrating the mount position: Configuring PlateSolve

In order to precisely determine the current position of the mount, PlaneWave Interface includes a routine called PlateSolve that can match a pattern of stars in an image to the corresponding pattern in a star catalog with no prior knowledge of the approximate image coordinates or rotation angle.

Note: MaxIm DL must be installed and configured with a valid connection to a camera in order to use the automated PlateSolve routine.

First, select the "Mount" tab and scroll down to the "PlateSolve Settings" section. Enter the approximate pixel scale for the telescope/camera system assuming 1x1 binning on the camera image. You can calculate the pixel scale as follows:

Arcseconds per pixel = Pixel size (microns) * 206.265 / Focal Length (millimeters)

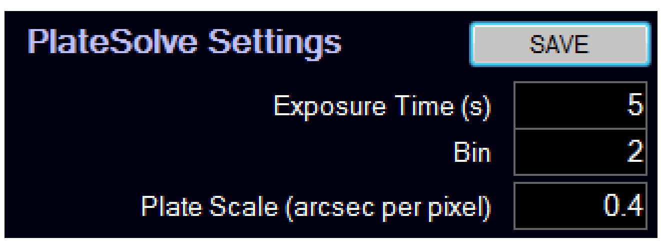
The focal length of the CDK700 is 4638mm. As an example, consider a system with a KAF-16803 CCD which has 9 micron pixels. The unbinned pixel scale will be:

9 * 206.265 / 4638 = 0.40 arcseconds per pixel

The exposure time should be long enough to get at least 10 clearly visible stars in any field around the sky. Values ranging from 3 to 10 seconds typically work well.

The binning value can be set to 2 to speed up the camera readout time.

Click "SAVE" to apply these settings.

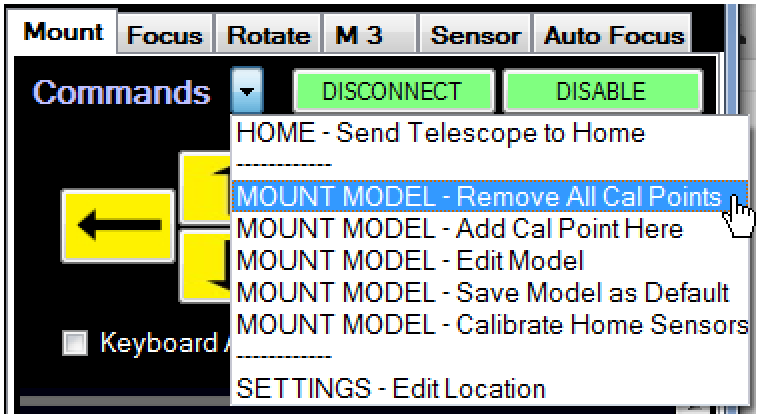


Calibrating the mount position: Aligning the first point

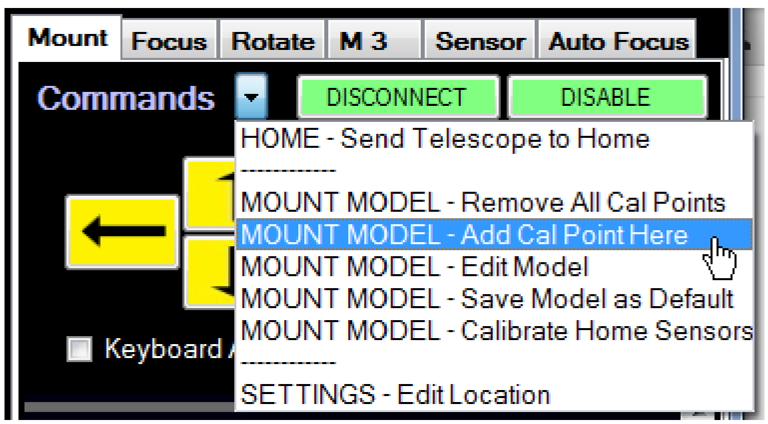
Once PlateSolve has been configured, use the directional arrows to point the telescope to a clear part of the sky, and make sure that tracking is turned on.

If you have a filter wheel installed, use MaxIm DL to select the filter that will allow the most light to pass through. Typically this would be a "Clear", "Luminance", or "Empty" filter slot.

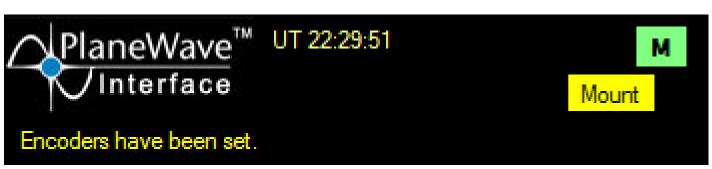
From the "Commands" menu under the "Mount" tab, click "Remove All Cal Points". If you are working with a fresh installation this step is technically not necessary, but if you have any existing pointing model information already loaded this will clear out that information and allow you to start with a clean slate.



Next, make sure that sidereal tracking is turned ON and that the telescope is pointed at a clear part of the sky. Open the "Commands" menu and select "Add Cal Point Here".



PWI will take an exposure from MaxIm DL and attempt to identify the image location using PlateSolve. If a solution is found, PWI will offset the axis encoder readouts to match the current telescope position as determined by PlateSolve. The status message at the top of the PWI window should report "Encoders have been set". Depending on how far off the initial mount position estimate was, you may see the pointing crosshairs and reported Altitude/Azimuth positions jump by several degrees.



If PlateSolve was unable to find a solution, try increasing the configured exposure length or move to a different field and try the "Add Cal Point Here" command again.

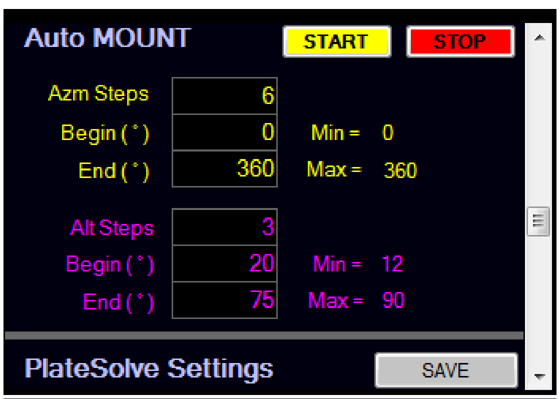
Building a PointXP Pointing/Tracking Model

PWI2 uses a package called PointXP to correct for any repeatable changes in telescope pointing and drift in tracking across the sky. PointXP compares the axis encoder positions against known telescope pointing positions calculated using PlateSolve and fits against these differences. PointXP can correct for a variety of physical effects, including:

- Tip-tilt (leveling) error in the base of the mount
- Non-perpendicular error between the Altitude and Azimuth axes
- Non-perpendicular error between the Altitude and Optical axes
- Telescope flexure under gravity
- Axis encoder centering error
- Effects at various other harmonics

A PointXP model with at least 16 points distributed across the sky will typically do a good job of putting a target within 20 arcseconds of the center of the field. A model with 50 points or more should do an excellent job of bringing a target within 10 arcseconds of center and tracking a target for at least 5 minutes without autoguiding.

To automatically build a pointing model, select the "Mount" tab and scroll down to the "Auto MOUNT" Section. From this screen you can set up a grid of Alt/Az targets around the sky.



Click "START" to begin building a model using the specified parameters. The mount will slew to a series of locations, taking and PlateSolving an image at each location. For example, using the sample parameters shown above:

- The mount will start by slewing to an azimuth of 0 degrees and an altitude of 20 degrees, take an image, PlateSolve it, and add the point to the PointXP model if a solution was found.

- The mount will remain at 0 degrees azimuth, but slew to an altitude of 47.5 degrees, take another image, PlateSolve it, and add the point to the PointXP model.
- The mount will slew to an altitude of 75 degrees to record the next sample.
- Now that 3 points have been sampled at this azimuth, the mount will then slew to an azimuth of 60 degrees and an altitude of 20 degrees, and repeat the sequence.
- The mount will continue to slew to a new azimuth and attempt to calibrate points at a total of 6 different azimuths.

With this configuration, PWI will attempt to add a total of 18 points to the model, as follows:

Azimuth	Altitude
0	20
0	47.5
0	75
60	20
60	47.5
60	75
120	20
120	47.5
120	75
180	20
180	47.5
180	75
240	20
240	47.5
240	75
300	20
300	47.5
300	75

Figure 7 shows the path taken by the mount to perform this Auto Mount sequence.

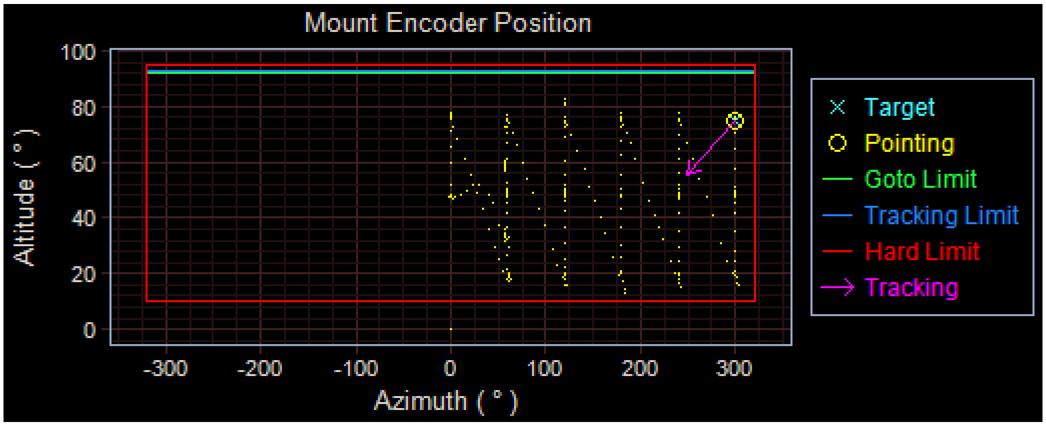


Figure 7: Mount position trace partway into an Auto Mount Model

Notice that although the axis has 660 degrees of total motion, it is only necessary to sample 360 degrees of that range to build an accurate model. For those azimuths that can be achieved with two different positions, the PointXP model will "wrap around" and continue to be applied.

To build a quick pointing model that will allow you to test the telescope, the following parameters should work well:

- Azm Steps: 6
- Begin: 0
- End: 360
- Alt Steps: 3
- Begin: 20
- End: 75

If every point is mapped successfully, this will result in a pointing model with 18 points (6 azimuth steps * 3 altitude steps).

To build a larger pointing model that is sufficient for regular observing, try the following parameters:

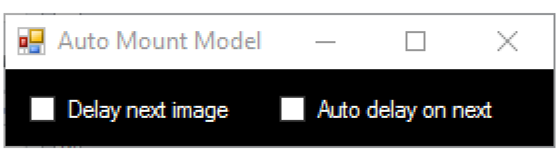
- Azm Steps: 18
- Begin: 0
- End: 360
- Alt Steps: 5
- Begin: 20
- End: 82

This will build a model with up to 5 * 18 = 90 total points.

Working with a rotating dome

Normally the Auto Mount Model sequence will take an image as soon as the mount has settled at its target position. If the observatory is equipped with a rotating dome, the exposure may begin before the dome is aligned with the telescope. To account for this, it is possible to pause and resume the mount model sequence.

Under the Observing menu at the top of the window, select “Auto Mount Helper”.



This window consists of two checkboxes:

Delay next image: As long as this box is checked, the mount will not start the next exposure when building the pointing model. This checkbox effectively pauses or unpauses the pointing model sequence.

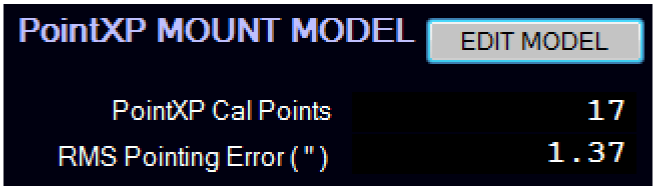
Auto delay on next: If this is checked, then “Delay next image” will automatically become checked whenever the pointing model sequence moves to a new target. In effect, the model will automatically pause itself with each new point, and the user will manually unpause when the dome is in position.

There are generally two ways that this feature can be used:

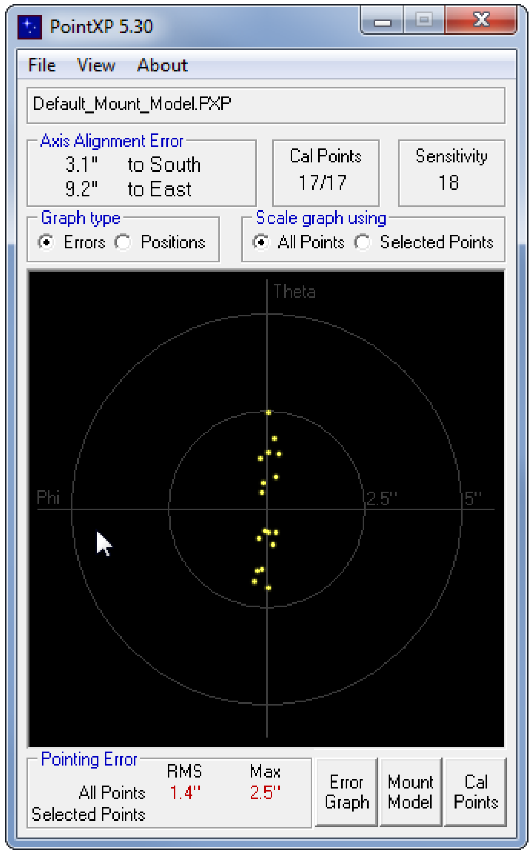
1. “Delay next image” is manually checked whenever the user sees that the telescope has moved to a position where the dome is not in alignment, and manually unchecked once the dome slit is aligned with the telescope. This allows the user to selectively pause the operation only when necessary – for example, when the telescope moves to a new azimuth.
2. “Auto delay on next” is checked. Then, the user manually unchecks the “Delay next image” box after each slew once the dome is aligned.

Inspecting the PointXP model

In the Mount tab, scroll down to the "PointXP MOUNT MODEL" section. This panel allows you to quickly view the number of points and residual error in the currently-loaded pointing model.



By clicking on "EDIT MODEL", you can view the data associated with the current model. The main window shows a scatter plot that displays the residual errors in the current model. Normally the scatter should be randomly distributed. In the sample plot shown below (generated from simulation data), there is significantly more scatter in the Altitude direction than in the Azimuth direction, which could indicate something loose in the OTA that would affect pointing repeatability at changing altitudes.

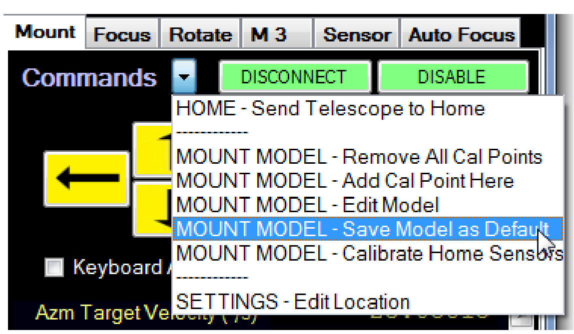


> **Note:** When clicking on the "EDIT MODEL" button, the PointXP window may initially be hidden behind other windows. If you do not see the window display immediately, look in the Windows taskbar to bring the PointXP window to the front.

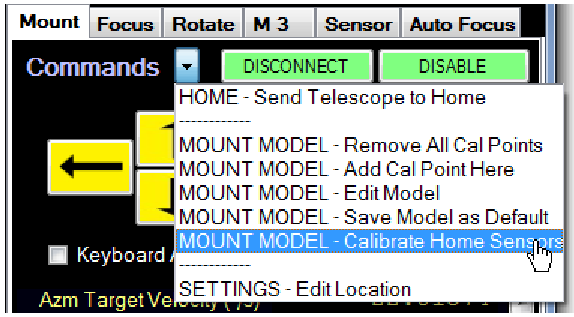
Saving the model and calibrating home sensors

In order to quickly start the telescope with the current model in the future, two steps are necessary.

First, in the "Mount" tab, expand the "Commands" menu and select "Save Model as Default".

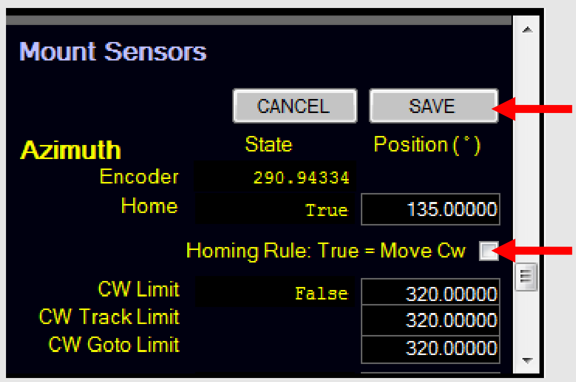


Next, expand the "Commands" menu and select "Calibrate Home Sensors".



The mount will begin to rotate in azimuth towards the "No Wrap" position. Once this position is found, it will rotate towards the home sensor. The position of the sensor should be labeled with an arrow at the bottom of the mount.

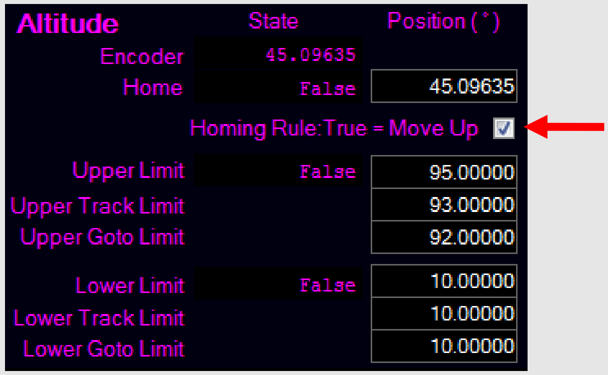
Note: If the mount rotates the wrong direction and finds the home position to be 180 degrees away from the labeled position, STOP the homing process, invert the "Homing Rule" checkbox in the Azimuth section of the "Mount Sensors" panel, and save the new setting.



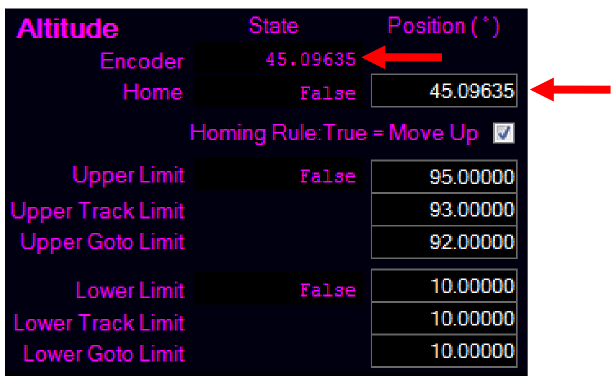
The homing sequence will approach the home sensor at 7 progressively slower speeds. The 7th and final approach is particularly slow in order to ensure high positioning accuracy. The whole process may take up to 3 minutes to complete.

Once the Azimuth home sensor has been found, the OTA will rotate in Altitude to find the home position. Once again, the axis will approach the sensor at 7 progressively slower speeds before finishing.

Note: The OTA should be pointed at approximately 45 degrees altitude at the home position. If the OTA moves in the wrong direction when finding home (i.e. down to the horizon or up to zenith), STOP the homing process, invert the "Homing Rule" checkbox in the Altitude section of the "Mount Sensors" panel, and save the new setting.



Once both axis home sensors have been calibrated, you should see that the "Home" setting under the Azimuth and Altitude sections of the "Mount Sensors" panel have been updated to the current position of the telescope.



At this point it is safe to shut down the software and turn off the telescope. The next time you turn on the telescope and launch PWI, you will be able to quickly load the pointing model and calibrate the axis positions by finding the telescope home position.

Basic Telescope Operation

Startup

If a pointing model has been built and saved in the system, and if the home sensors have been calibrated with that model, it is possible to start the telescope fairly quickly.

1. Turn on the telescope control electronics if they are not already powered up. Wait at least 30 seconds to allow the control system to fully initialize.

2. Launch PlaneWave Interface 2
3. In the Mount tab, click "CONNECT". The button should immediately turn green.
4. In the Mount tab, click "ENABLE". This will energize the axis motors. If this is the first time you have energized the axes since powering on the system, the axes will need to perform an Automatic Commutation routine, which takes up to 45 seconds.
5. In the Mount tab under the "Commands" menu, click "HOME - Send Telescope to Home". The Azimuth motor will rotate to the "No Wrap" position, and then rotate to the "Home" position in 7 progressively slower steps. Once the Azimuth home position has been found, the Altitude motor will rotate towards the home position, which is approximately 45 degrees altitude. Again, the axis will advance towards the home position in 7 progressively slower steps.
6. (optional) Expand the left-hand side of the window and select the "Catalog" tab. Select a bright start that is currently visible, and click "GOTO" to slew the mount to that star. Take a short exposure to verify that the bright star is properly centered in the CCD camera.
7. Select the "Focus" tab. Verify that the correct COM port is selected, and click "CONNECT". The button should immediately turn green and the current focuser position should be displayed.
8. Select the "Rotate" tab. The rotator should already be connected, since both the focuser and the rotator communicate through the same controller. The mechanical range of the rotator is shown under the Rotate tab. Move the rotator near the middle of its range, well away from either the clockwise or counterclockwise limits, and enable the "Alt Az Derotate" checkbox. The rotator will now compensate for any field rotation effects caused by the Alt-Az mount geometry. By moving the rotator away from the its limits of motion, you can maximize the amount of time you will be able to track on an object before the rotator stops.

Joystick Control

PlaneWave Interface includes experimental support for controlling the CDK700 mount via a USB gamepad or joystick. PlaneWave recommends the **Logitech F710 Wireless Controller**.

It is strongly recommended that you run **PlaneWave Interface 2.2.0.4** or later if you plan to use joystick control.

To set up the Logitech F710 joystick:

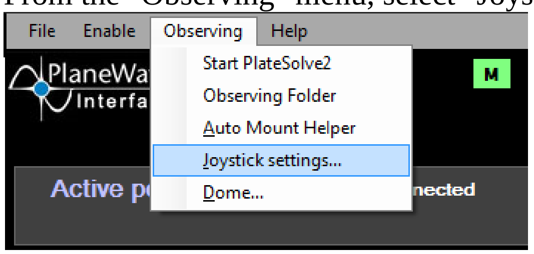
1. Plug the Logitech Nano Receiver into a USB port. Windows should recognize the device and install the correct drivers after a few moments.

2. On the forward surface of the joystick, there is a switch that can be in either the **X** position or the **D** position. This switch rearranges some of the functions on the joystick. For standard usage, make sure the switch is in the **X** position.

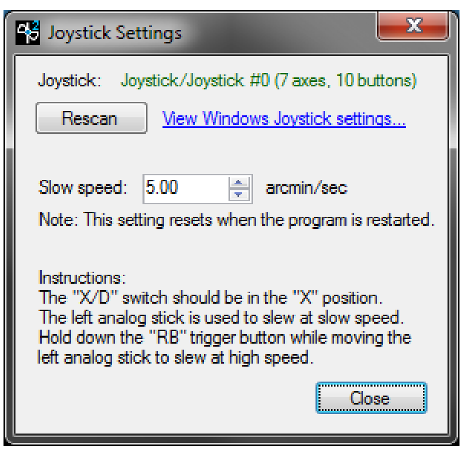
3. Turn on the joystick by pressing the center "Logitech" button.

4. Launch PWI 2.2.0.4 or later and connect to the mount

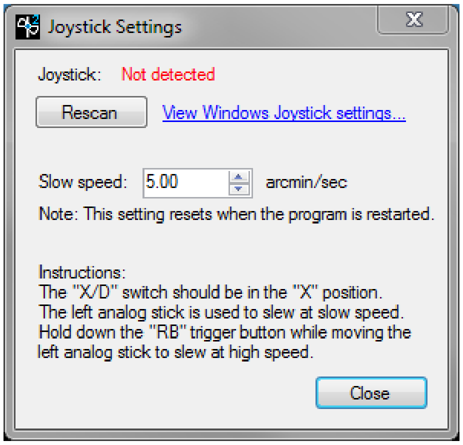
5. From the "Observing" menu, select "Joystick Settings"



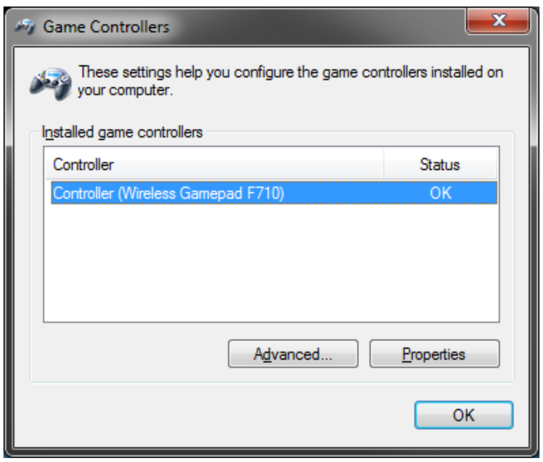
6. If the joystick is recognized by PWI, a brief description of the joystick will appear at the top.



If the joystick is not detected, you may see the following screen:



Click on the link to open the Windows Game Controller settings. Verify that the game controller is detected and correctly identified. Then click the "Rescan" button in PWI.



The joystick will power off after 5 minutes of inactivity. To turn the joystick back in, simply press any button.

To move the mount with the joystick, use the analog stick on the left side. There are two modes for moving the telescope:

- Pan Mode: moves the telescope slowly, and is intended for centering objects or exploring fields during visual observing. This is the standard mode when moving the analog joystick by itself.
- Slew Mode: moves the telescope quickly, up to the maximum slew speed. To enable this mode, hold down the **"RB"** trigger button while moving the analog joystick.

The farther you move the analog stick, the faster the mount will slew.

The maximum speed in Pan Mode is defined in the "Joystick Settings" window. By default the speed is 5 arcminutes per second, which is reasonable speed while doing visual observing of a standard target in the sky. If you would like to use the joystick to manually track a faster-moving object (such as a satellite or an airplane), you can increase this speed.

Shutdown

Before shutting down PWI, be sure to specifically STOP mount tracking and Alt-Az derotation. If any software is connected to PWI through its ASCOM driver (e.g. TheSky, MaxIm DL, FocusMax), be sure to either disconnect or shut down that software before closing PWI.