Setup Guide

MI-500, MI-750, MI-1000 & MI-1250 Fork Mounts

Mathis Instruments

www.mathis-instruments.com

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MI-750/1000 Fork Mount

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Introduction

Congratulations, and thank you for purchasing your telescope mount from Mathis Instruments. We are confident that the design and construction of our mounts will serve you well in your astronomical pursuits. This manual will explain the components, setup, operation, and maintenance of your equatorial or altazimuth fork mount.

Each of our fork mounts is available in an equatorial or altazimuth configuration. Our family of mounts includes the following:

Model	Application
MI-500	12-16 inch telescopes
MI-500 /750	14-18 inch telescopes
MI-750	16-20 inch telescopes
MI-750/1000	18-20 inch telescopes
MI-1000	20-24 inch telescopes
MI-1250	24 inch telescopes

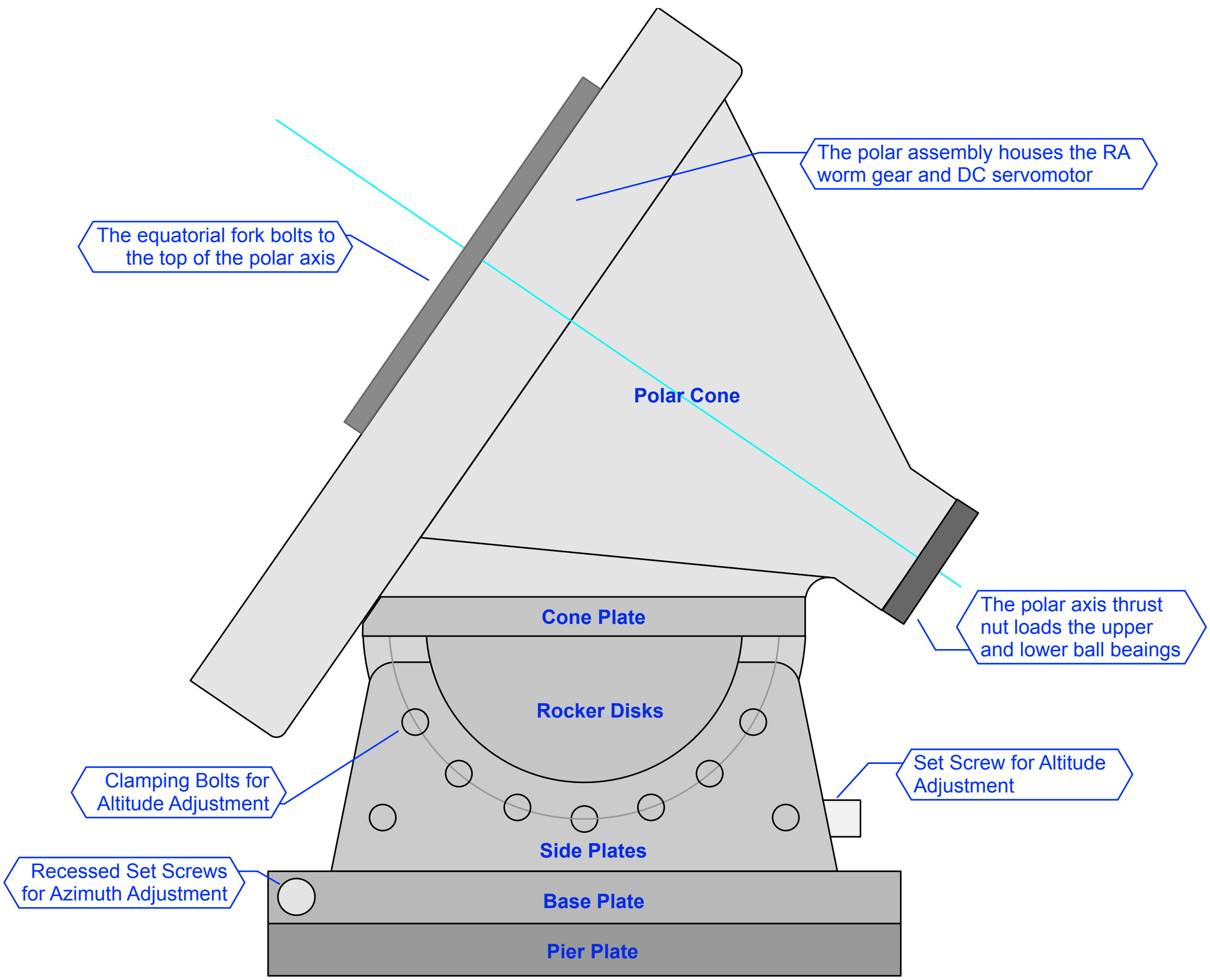
Our mounts are also available in a German equatorial configuration. The assembly and operation of fork and German mounts are very similar. In most cases, the size and weight of these mounts make it very challenging to transport the equipment to a remote site. In general, our mounts are designed to be permanently housed in an observatory setting. Only the MI-500 is light enough to be transportable, provided you have sufficient time, determination and strength. These instructions focus primarily on observatory installations.

Mount Components

Polar Assembly

Each equatorial fork mount has a polar assembly as one of the main components. This polar assembly contains the right ascension axis, the worm gear drive, and the servomotor that provides slewing and tracking to follow celestial objects across the sky.

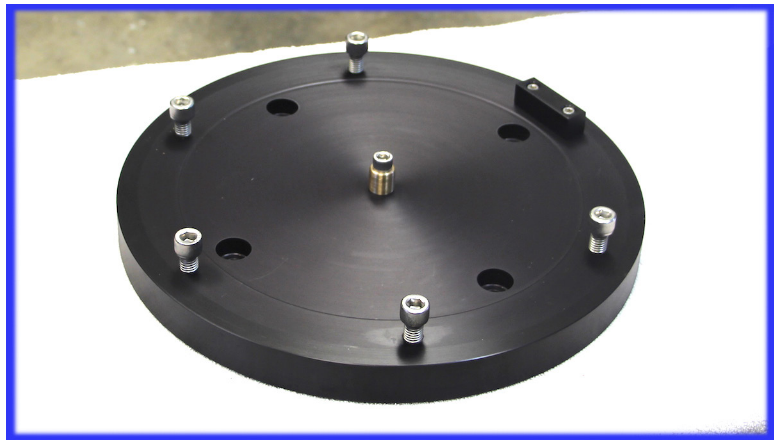
The polar assembly has the following parts: pier plate, base plate, side plates, rocker disks, cone plate, polar cone, right ascension (RA) axis, the RA worm gear, servomotor, and the gear casing with removable covers. The diagram below illustrates the parts of the polar assembly



Polar Assembly

Pier Plate

At the bottom of the polar assembly is the Pier Plate. This plate is attached to the observatory pier or column. The holes in the Pier Plate are custom drilled to match the existing hardware on the pier. These holes are counterbored, so that the hardware used to attach the pier plate will not extend above the top surface of the plate.

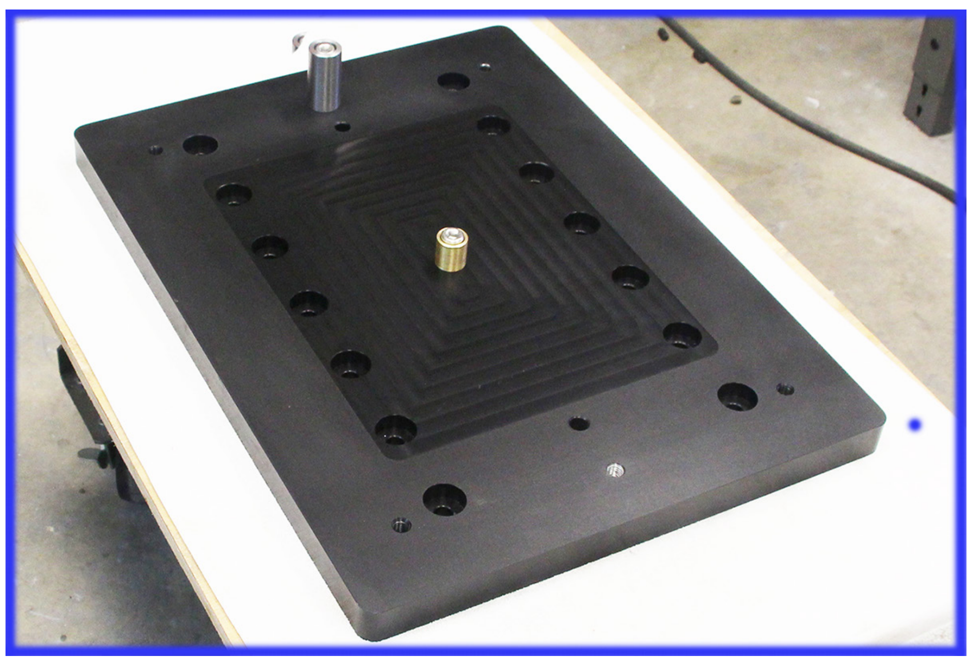


MI-750 Pier Plate

One can use hex head bolts passing through the Pier Plate and screwing into threaded holes on the top surface of the pier. Alternately, the bolts can pass through both the Pier Plate and the observatory pier with hex nuts on the bottom end of the bolts. Make sure that this plate is securely fastened to the top of your pier, since this is the foundation of the mount and telescope.

The Pier Plate has a brass pin at the center of the plate. This pivot pin is used to keep the Pier and Base Plates centered. The Pier Plate also has an azimuth push block or push pin on the north end of the plate. For the southern hemisphere, this block is on the south end. This block/pin is used to adjust the azimuth angle of the mount.

In some cases it is best to offset the Pier Plate such that the fork assembly is shifted to the north or south in the observatory. In these cases, an offset plate can be provided shifting the Pier Plate as needed.



MI-1250 Pier Plate

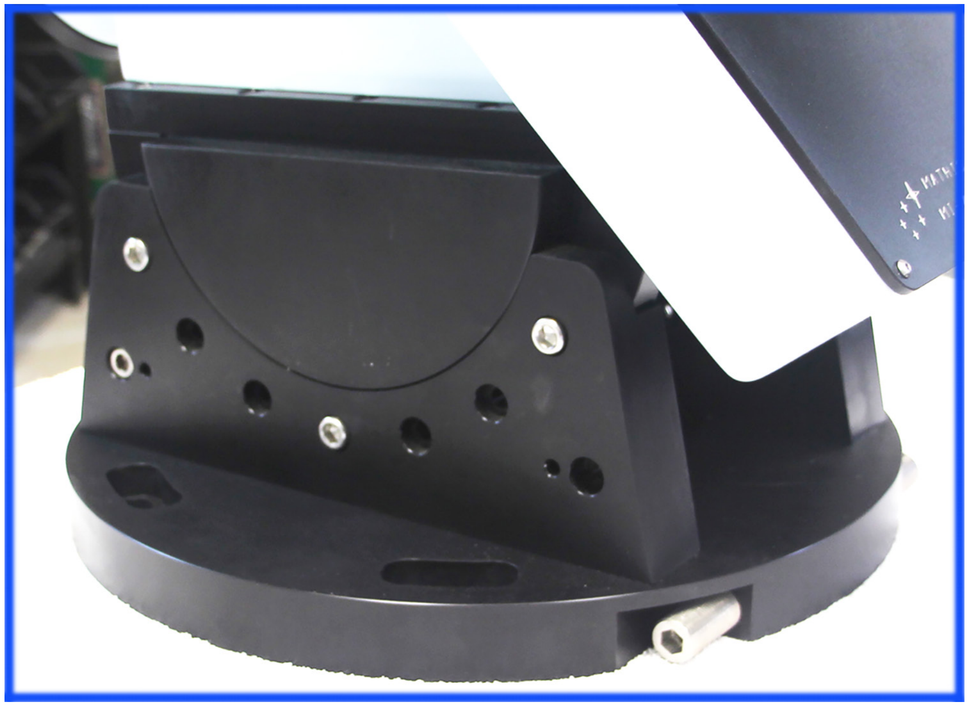
The Pier Plate and Base Plate for the MI-500 and MI-750 mounts are round, whereas for the MI-1000 & MI-1250 mounts, the plates are rectangular.

Base Plate

The Base Plate is bolted to the top surface of the Pier Plate using five slotted holes along the plate edge. These slotted holes allow the Base Plate to be rotated to adjust the mount azimuth angle. The Base Plate fits over the center pin and the push block/pin.

The two recessed set screws on the north side of the Base Plate are used to adjust the azimuth angle of the mount. The azimuth set screws for the MI-1000 and MI-1250 mounts thread into a block at the north end of the Base Plate

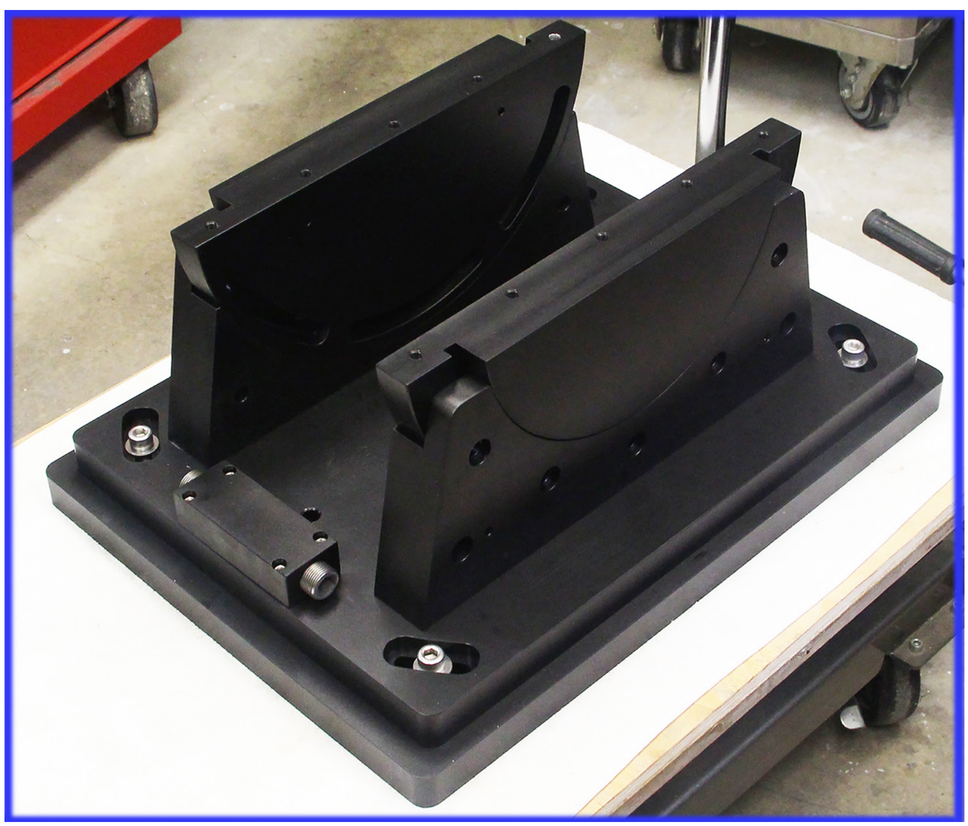
These set screws push against the push block/pin, allowing one to rotate the Base Plate to the required angle for alignment to the celestial pole.



MI-500 Base Plate, Side Plates, Rocker Disk

The brass center pin in the Pier Plate keeps the two plates centered while changing the azimuth. One can adjust the azimuth by about 5 degrees to either side of center.

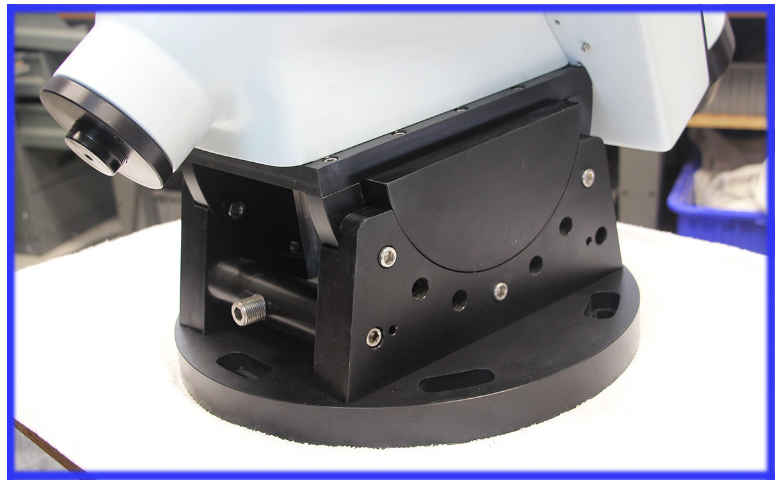
The picture to the right shows the MI-1250 Pier and Base Plates with Side Plates attached. The two plates are bolted together using the five slotted holes in the Base Plate. The azimuth set screws are on the north end.



MI-1250 Pier and Base Plates

Side Plates and Rocker Disk

The Side Plates are bolted to the Base Plate using cap screws on the under side of the Base Plate. The Rocker Disks are captured in the Side Plates on concentric slots allowing for altitude adjustment. The Polar Cone and Cone Plate are bolted to the top of the Rocker Disks. This assembly is shipped as a unit to the customer.



MI-750 Side Plates with Altitude Adjustment

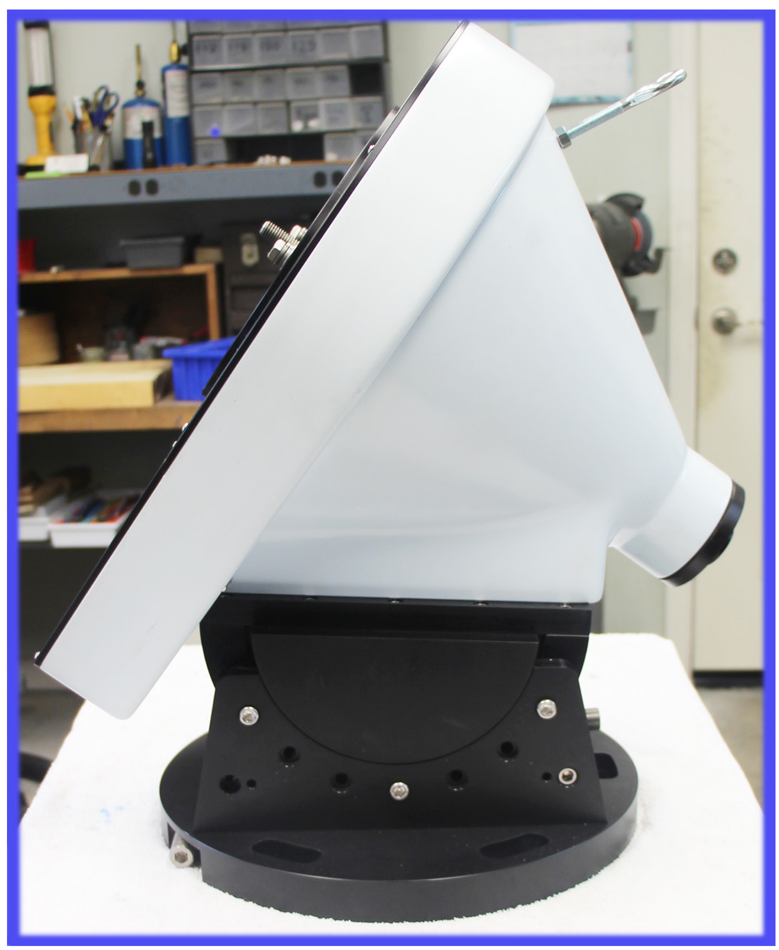
On the south end of the Side Plates, there is a set screw used to change the altitude angle. One can move the Polar Cone upward or downward over an altitude range of about 18 to 65 degrees.

Polar Cone

On the front of the polar cone is the gear casing. This casing encloses the right ascension worm gear, the worm, the motor assembly, and the casing covers. The casing itself is rigidly fixed to the polar cone and should never need to be removed. It provides the mounting surface for the worm assembly and servomotor.

The casing cover consists of two parts. The circular cover at the top of the casing provides protection for the worm gear and should be left in place except when cleaning is needed. The lower area of the casing is covered by a smaller trapezoidal plate that can be removed whenever lubrication or adjustment of the worm and motor assembly is needed. You can easily remove this cover to inspect the servomotor and drive gear.

The polar axis of the mount passes through the polar cone. It is supported by a large shielded bearing at the top of the cone and a smaller guide bearing at the bottom. A black anodized threaded nut provides a thrust load to the bearing assembly .

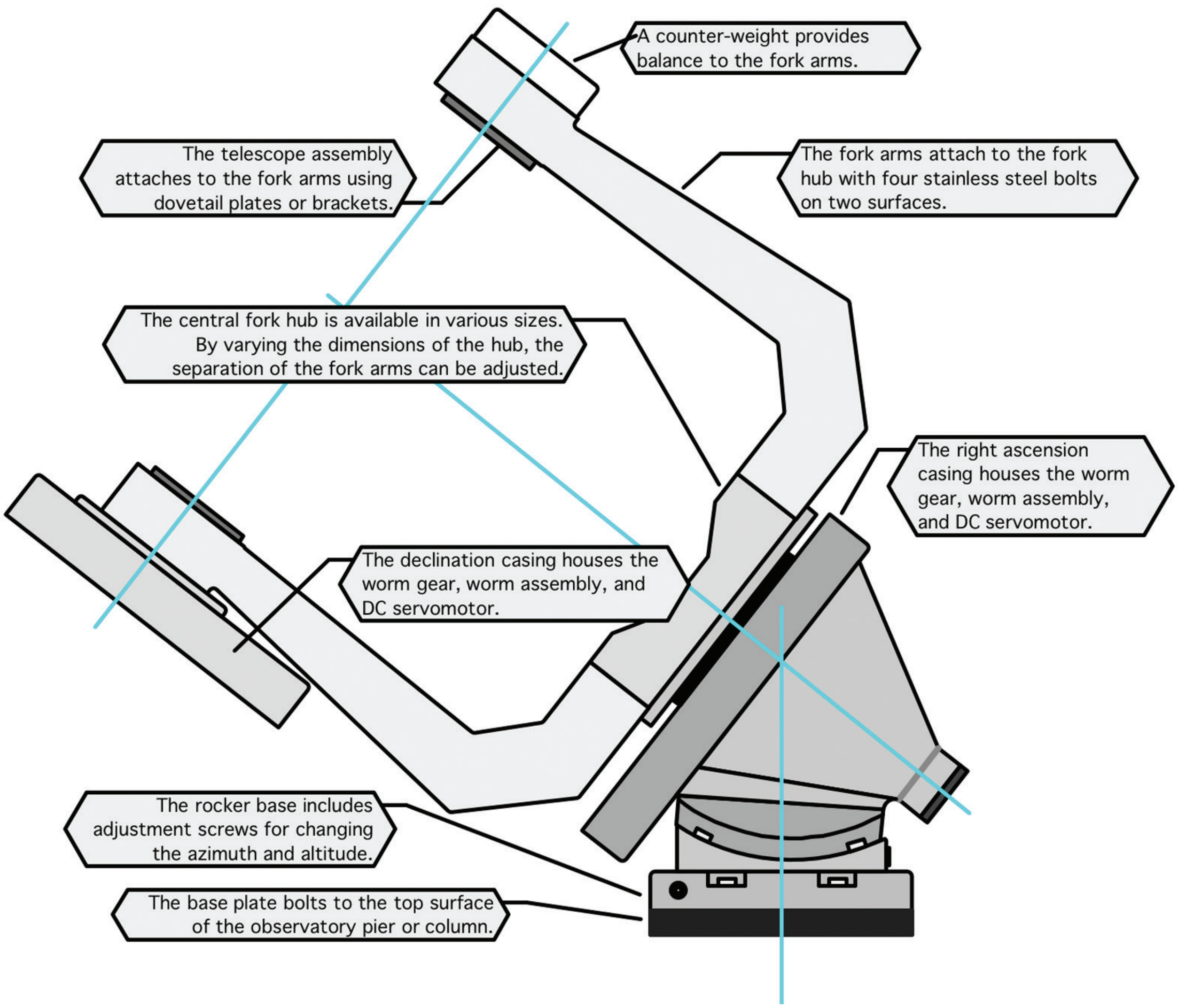


MI-750 Polar Assembly

Equatorial Forks

The equatorial fork assembly consists of the two fork arms, a central hub, and telescope mounting plates. One fork arm, usually on the east side of the mount, has a gear casing attached to the outside of the arm. This contains this declination drive assembly and functions the same as the worm gear drive on the polar axis.

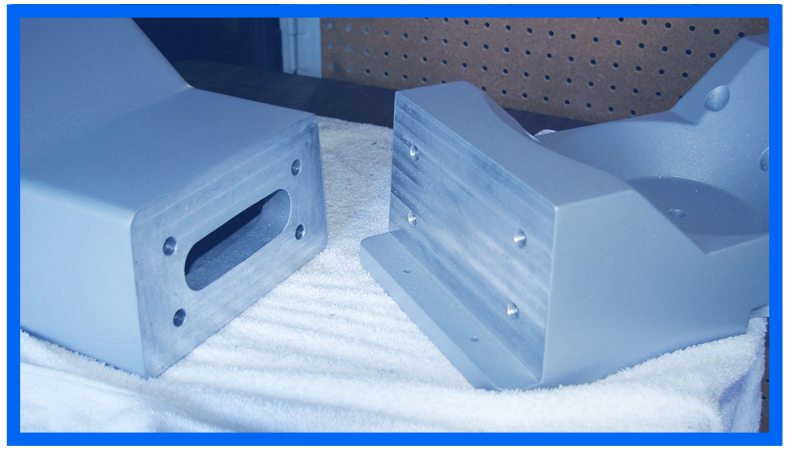
The second fork arm supports the declination axis opposite the gear fork arm. For mounts with Renishaw encoders, this second arm has a casing containing the declination encoder ring and the read-head assembly.



Equatorial Fork Mount

A counterweight is typically located inside of this fork arm or on the outside face of the arm. These weights balance the drive assembly on the opposite fork arm. This balance is done at the factory and should require minimal adjustment. To fine tune the fork arm balance, we provide auxillary holes in the fork arms in which one can attach small auxillary weights.

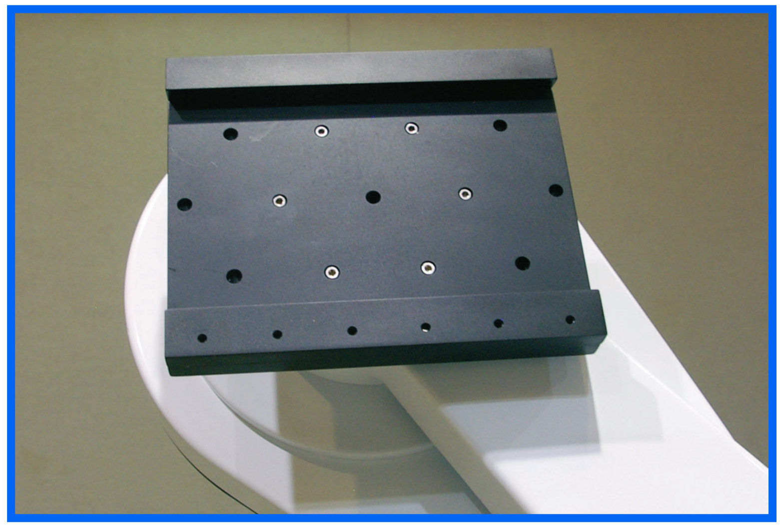
The two fork arms attach to the central hub, and the hub attaches to the top of the right ascension axis. When attaching the fork arms to the hub or the hub to the polar base, make sure that all surfaces are clean and free from dirt. These surfaces are machined flat, and for proper arm alignment, it is important that the components mate properly.



MI-750 Fork Hub

Telescope Plates

The telescope adapter plates connect the telescope to the fork arms. In general, these plates are custom made for each customer, and in most cases are dovetail plates or simple brackets. We can provide Losmandy style dovetails and PlaneWave dovetails.



PlaneWave Dovetail Plate

In the photo to the right, there is a custom dovetail plate for a CDK 20 telescope. Below to the right is a mounting plate for an older Celestron 14 telescope.

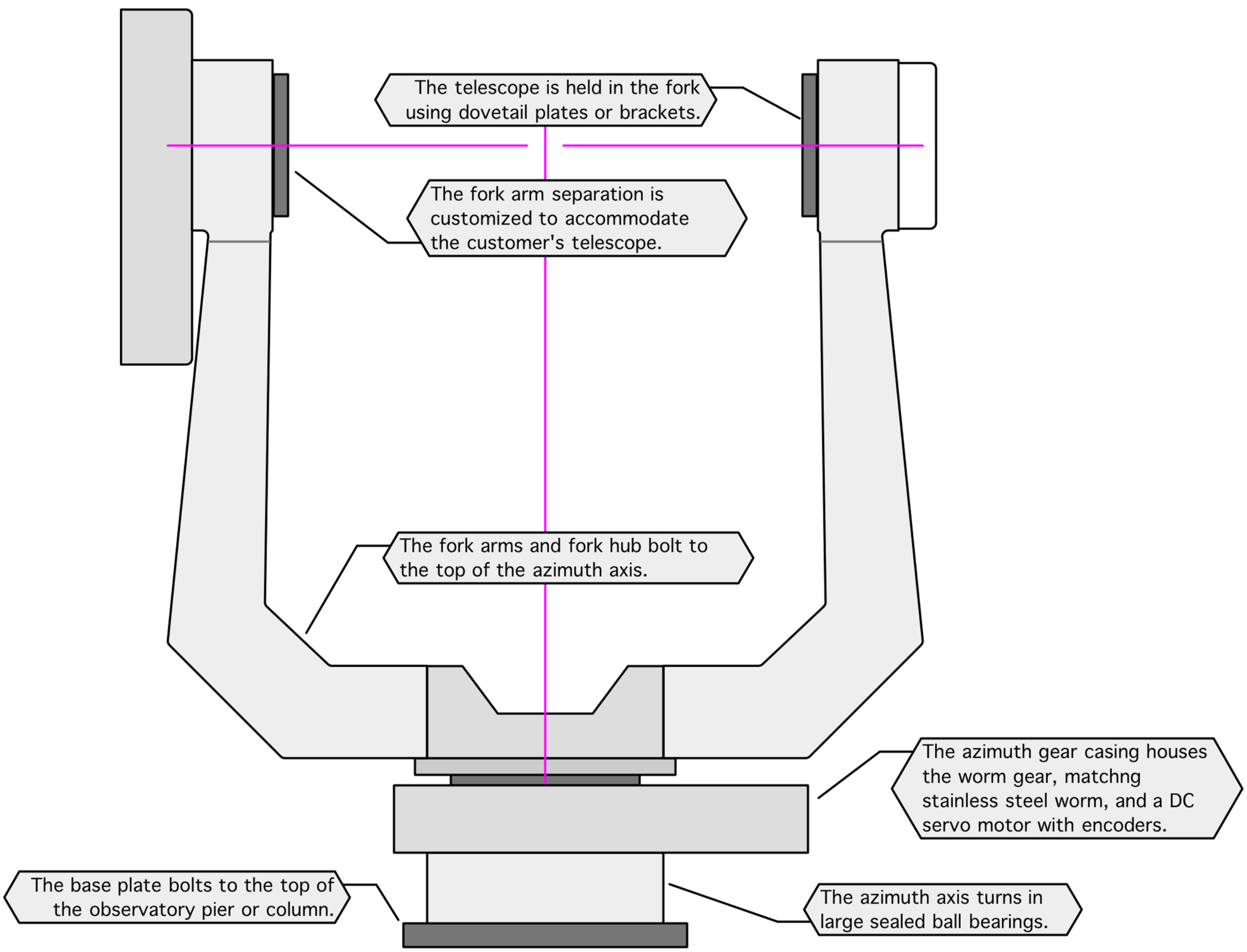
The separation of the fork arms is carefully calculated based on the dimensions of the customer's –optical tube assembly. We allow a small amount of clearance to facilitate sliding the optical tube assembly into the fork arms. This clearance is typically .020 inches, .50mm.

Brackets for a Classic C14

Altazimuth Fork Mounts

An equatorial fork mount uses celestial coordinates and moves along lines of right ascension and declination in the sky. An altazimuth fork mount uses local horizon coordinates, and moves along lines of azimuth and altitide in the sky.

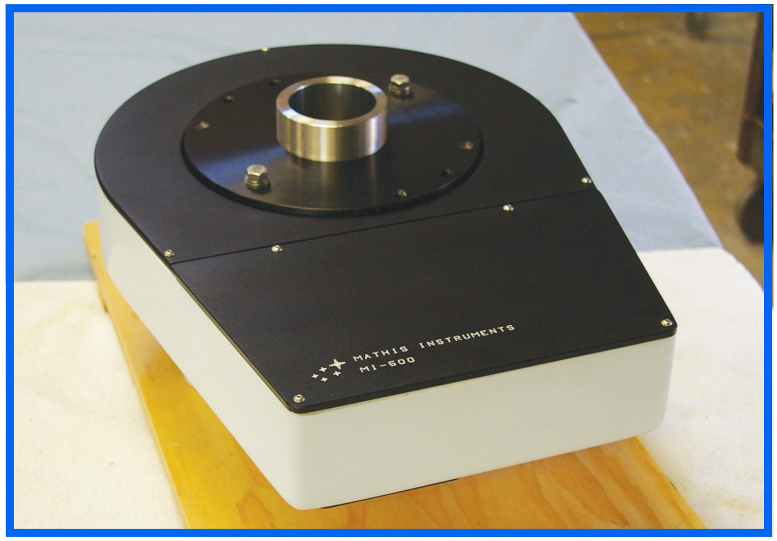
One major advantage of altazimuth fork mounts is that they can support a larger payload than an equatorial fork mount. The altazimuth fork assembly is supported directly over the observatory pier. The fork arms are vertical, and the azimuth base is horizontal. This simplifies the contruction of the mount, facilitates installation, and produces an instrument with a minimum “footpint”



Altazimuth Fork Mount

One disadvantage of the altazimuth mount is that as the mount tracks objects in the sky, the image plane rotates. When doing astro-imaging, one must use a motorized de-rotater to componsate for this image rotation.

Azimuth Base



Azimuth Base Assembly

The altazimuth fork mount has a base assembly. This base attaches to the top of the observatory pier.

Like the equatorial polar assembly, the azimuth assembly features a gear casing containing the worm gear drive and servomotor. The azimuth axis passes through the base, and it is supported by two bearings with a thrust nut on the bottom of the base.

Altazimuth Fork

The altazimuth fork assembly is nearly identical to the equatorial fork. It consists of two fork arms, a central hub, and telescope plates. The fork arms and fork hub are attached to the top surface of the azimuth axis.


Altazimuth 750 Fork Mount

A gear casing is attached to the outside of one fork arm, and it contains the altitude drive gear with stainless steel worm and servomotor.

On the opposite arm, there is a counterweight located inside the arm and a smaller weight on the outside face of the arm. For mounts with Renishaw encoders, this arm features a casing that contains the altitude encoder ring and the read-head assembly.

The two arms have approximately the same weight, so that the fork assembly is balanced.

Electronic Controls

Servo II

Each telescope mount includes a computer control system. Our mounts are normally supplied with the Servo II computer control from Sidereal Technology. This is the standard computer control package we use with our mounts.

The Servo II control has a rich set of features including the following:

Can be used with a variety of servomotors including Pittman and Maxon
Supports both equatorial and altiazuth mounts
Uses high quality industrial Turck cabling and connectors
Provides continuous tracking and full “GoTo” capability
Features adjustable drive rates for tracking any solar system object
Outputs 4 amps per axis at 24 volts
Uses separate cables for encoder signals and power lines to the motor
Features hardware sensors on the worm shaft for PEC correction
Supports homing sensors on each axis for remote operation
Offers high resolution encoders for arc second tracking and pointing
ASCOM capable for use with most PC software

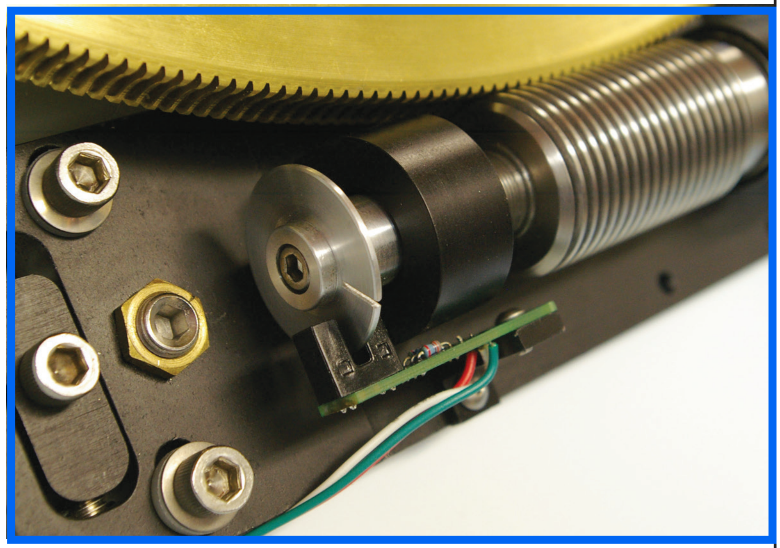
The Servo II control supports German mounts, equatorial fork mounts, and altazimuth fork mounts. It has an open architecture that gives access to nearly every motor and control parameter. Using Pittman 9000 or 14000 series motors, the Servo II provides a motor encoder resolution of about 0.10 arc seconds per count.

The Servo 2 control includes industrial quality cables, two for each axis of the mount. One cable provides power to the servomotor. A separate cable is used for motor encoders, the PEC sensor, and the home sensor. This feature isolates any electronic noise from the servomotors and sensors.

Servo II Control

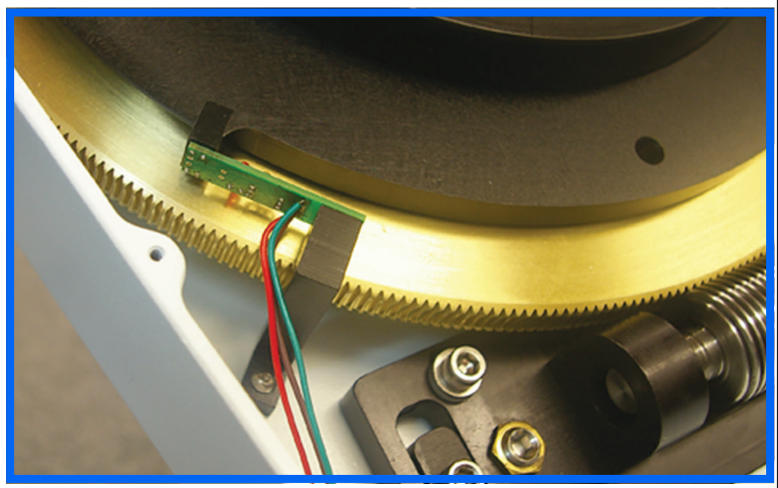
The Servo 2 control requires a regulated 12-24 volt power supply with a minimum output of 5 amps. The maximum slew rate depend on the input voltage

The Servo II control features a PEC (periodic error correction) sensor on the RA worm shaft. This sensor records the phase of the worm rotation. Since the phase of the worm is always known, a periodic error profile can be applied to the worm rotation, even after powering down the controller. The PEC does not depend on timing the rotating worm. Rather, the worm phase is determined by the infrared sensor on the worm shaft.



Servo 2 PEC Sensor

The Servo II also supports mount homing. This feature enables telescope control from a distant location. Homing disks are installed on the right ascension and declination axes. An infrared sensor on the axes records the zero home position.



Servo 2 Homing Sensor

This home position allows one to know the mount orientation from any remote location. With this information, one can initialize the mount and then remotely control the telescope.

As an option, the Servo II supports Renishaw high resolution encoders. These encoders are attached to the axes of the mount. With a typical resolution of .10 to .20 arc seconds, they precisely record all angular motion of the mount, independent of the drive gears and motors.

Renishaw encoders measure the position of the mount to an accuracy 10x greater than the gears alone. This results in very precise tracking with typical errors less than 1 arc second, and pointing. accuracy of 10-20 arc seconds.

AstroPhysics GTO4

The AstroPhysics GTO4 Control is a popular telescope control that offers many advanced features. As an option, we offer this control for our M-500 and MI-750 mounts.

AstroPhysics GTO4 Control

Using Swiss DC servo motors, this drive system provides smooth tracking with motor encoder resolution of 0.10 arcseconds per encoder count. The GTO4 has a speed range of 4800:1, which provides 0.25x sidereal rate for guiding and 1200x sidereal rate for slewing. The GTO4 includes a very detailed operation manual.

The GTO4 keypad is a handheld computer with features and functions to control the telescope. The GTO4 control can be used with a laptop or desktop computer in conjunction with planetarium software. You can position the telescope, center an image and control the tracking rate, set the reticle brightness, and then park the telescope at the end of the night.

The GTO4 control requires a regulated 12-18 volt power supply with a minimum output of 4 amps. This control can be used with our MI-500 and MI-750 equatorial fork mounts.

In comparison with smaller portable mounts, our MI mounts are large and capable of carrying heavy tube assemblies. In using the GTO4 control, we recommend that you set the maximum slew rate to 600x sidereal. If you slew at a faster rate, the motors will not be damaged, but they will not slew at the higher rate. The motors could possibily be overloaded, and this could cause premature failure. Keep the maximum slew rate to 600x.

Installation

Shipping

Most mounts are shipped by truck freight or by airfreight. Typically, a shipment consists of two or three containers. A typical shipping box weighs 200 to 350 pounds.

Polar Cone in Shipping Box

Fork Arms in Shipping Box

We crate the mount components in heavy wooden boxes and secure the parts using wood screws, nuts, and bolts. This ensures that there is no shifting of the parts during transit. Over the past 12 years, we have had essentially no damage to any mount component during shipment.

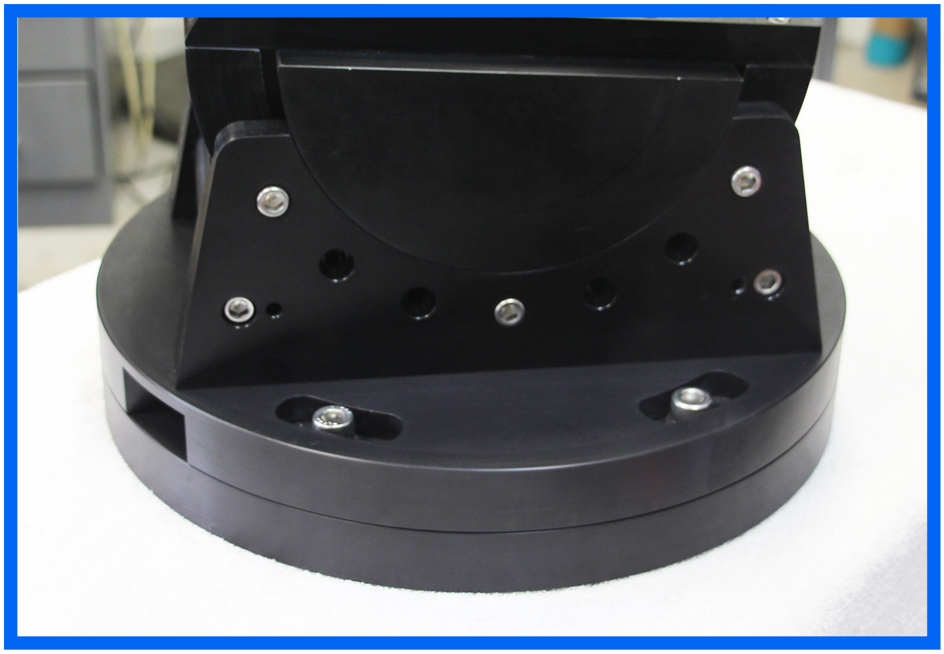
To disassemble the shipping boxes, you will need a power drill and Phillips head driver. Proceed slowly. First remove the top of the box. and then remove the sides. Some large components are bolted to the bottom of the box, and others are attached to wooden platforms. It may take an hour or more to uncrate the mount.

Each mount is shipped with the necessary tools and hardware. We include a set of American hex wrenches and other special tools that you will need to assemble the mount components.

Pier and Base Plates

The first step in installing the mount is to attach the Pier Plate to the observatory pier. It is important that the plate be firmly attached, since the weight of the mount and telescope is supported by the Pier Plate. Holes have been machined in to the Pier Plate to match the top holes in the pier.

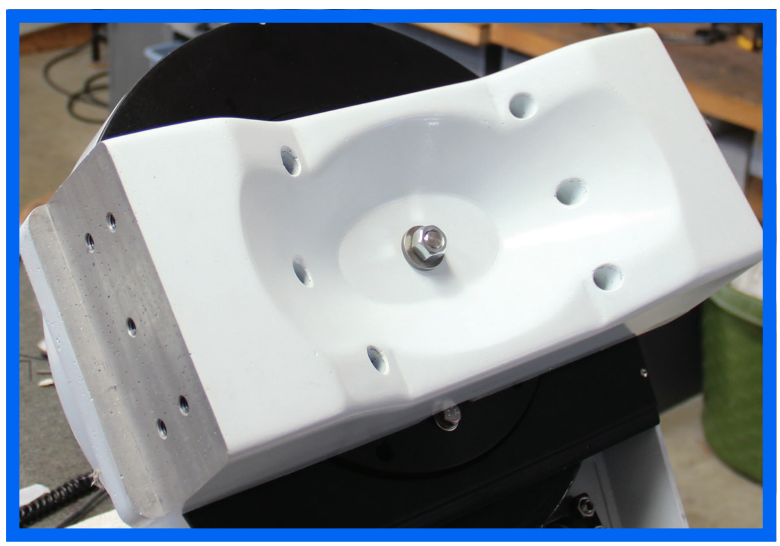
After the Pier Plate is bolted on the observatory pier, the BasePlate and Polar Assembly are bolted to the Pier Plate. Bolt the Base Plate base to the Pier Plate plate using five stainless socket head bolts. These bolts pass through the slotted holes along the edge of the Base Plate.


Polar Assembly and Base Plate on Pier Plate

As you lower the BasePlate and Polar Assmbly on to Pier Plate, apply a small amount of grease on to the mating surfaces. This will permit the Base Plate base to slide easily on the Pier Plate, facilitating making changes in the azimuth angle of the mount.

The Polar Cone is shipped with a hook on the top of the cone. Use this hook to guide the Polar Assembly as you lower it on to the Pier Plate. The brass center pin in the Pier Plate passes through the center hole in the Base Plate. This pin keeps the polar assembly centered on the Pier Plate when changing the azimuth angle of the mount.

Fork Hub


Fork Hub on Polar Axis

In most cases, it is best to first attach the fork hub to the polar axis, and then attach the fork arms to the hub. With the polar assembly in place, attach the fork hub to the top of the polar axis. First thread the 1/2 inch threaded guide pin in to the center of the polar axis. This 1/2 inch threaded pin is for alignment and to temporarily support the fork hub in place.

Insert the socket head cap screws through the holes in the fork hub. Screw these into the threaded holes in the top of the polar axis. This will secure the fork hub to the polar axis.

If your mount has a polar assembly with a hollow stainless axis, slide the hub over the center tube and then install the screws through the holes in the hub. The fork hub is not secure until it is attached to the polar axis with all the provided hardware. You are now ready to attach the fork ams.

Fork Arms

Each fork arm uses four socket head cap screws to attach the arm to the hub. These screws pass through the four holes deep inside the fork arm. We supply a special extended-length hex wrench that allows one to tighten these screws.

Fork Arm and Fork Hub

With one arm attached to the hub, rotate the fork 180 degrees, and attach the second arm. In most cases, it is best to have the arm with the declination drive gear on the east side of the mount.

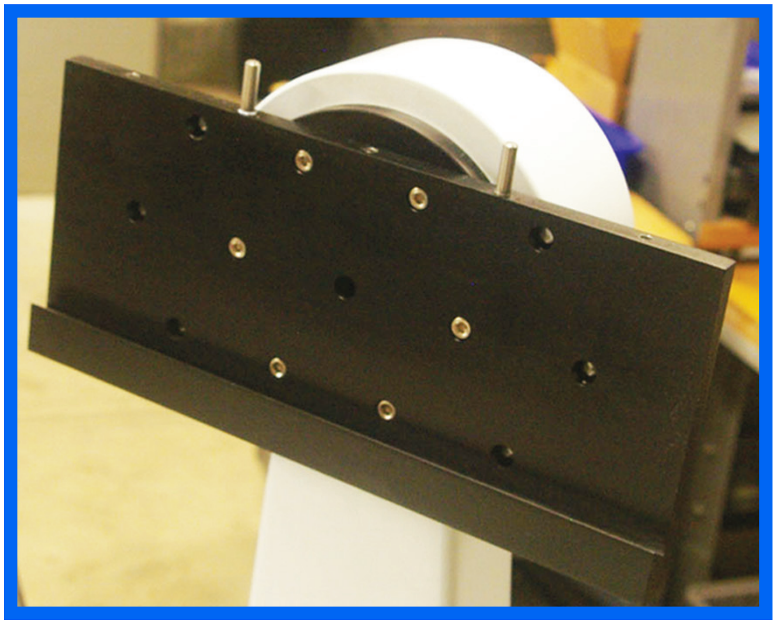
For the MI-500 mount, this is a two-person job. For the larger mounts, a team of three or four persons will be necessary. For the larger MI-1000 and MI-1250 fork mounts, it may be necessary to use special equipment to the install the fork and polar base. This is particulaly true if the top of the observatory pier is far above the floor of the observatory.

Crane Installation of Fork Assembly

In this case, it may be necessary to lift the polar assembly and fork through the opening in the observatory dome or through the roof of a roll-off observatory. This will require a crane or simliar equipment. This gives you improved control and a measure of safety as you move the heavy components into position.

Installing the Telescope

For fork mounts, telescope plates are used to attach the-optical tube assembly to the fork arms. These plates are often dovetail plates or simple brackets that are compatible with your telescope. Attach each plate to the respective fork arm using the appropriate hardware.



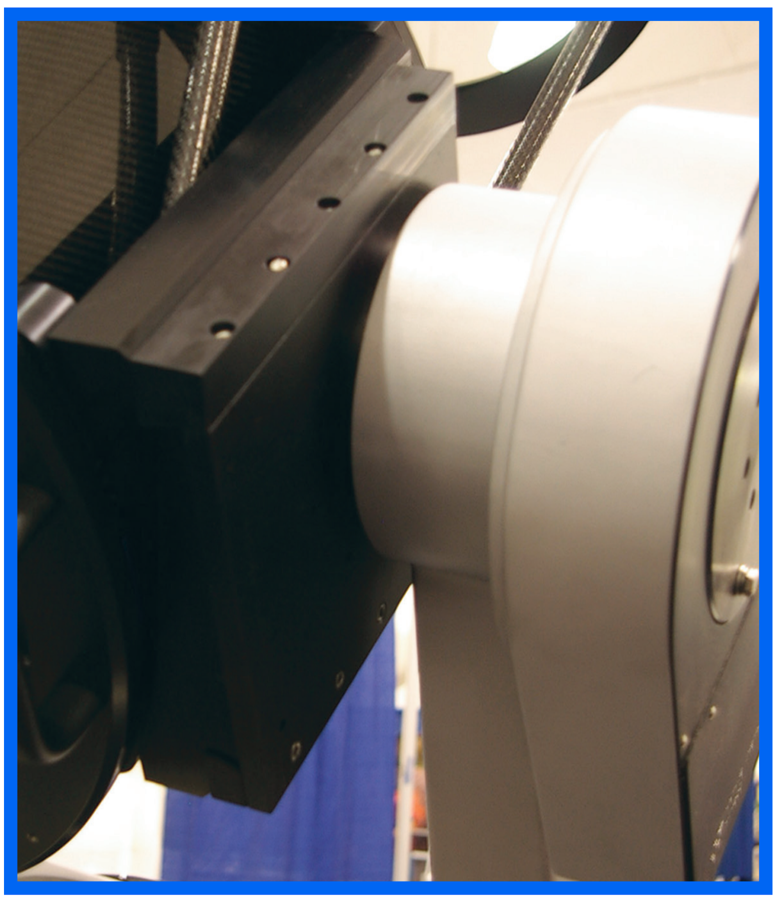
Open Dovetail Plate Attached to Fork Arm

The separation between the fork arms have been machined to match the dimensions of your telescope. The dovetail plates have a floating upper bar. Before sliding the telescope into the fork assembly, remove the upper bar so that the telescope can be lowered in to the fork from above.

With the telecope in position, replace the upper bar on the dovetail plate and tighten the socket head bolts. This will secure the instrument in the fork arms.

We machine the fork arms and fork hub to match your telescope with a clearance of about .02 inches or .50 mm. If the fit seems tight, slightly loosen the bolts that secure one fork arm to the hub.

This will increase the arm separation, allowing you to more easily slide the telescope into the fork. When the telescope is in place, tighten the four bolts to secure the fork arm.



Dovetail Plate Supporting CDK 17

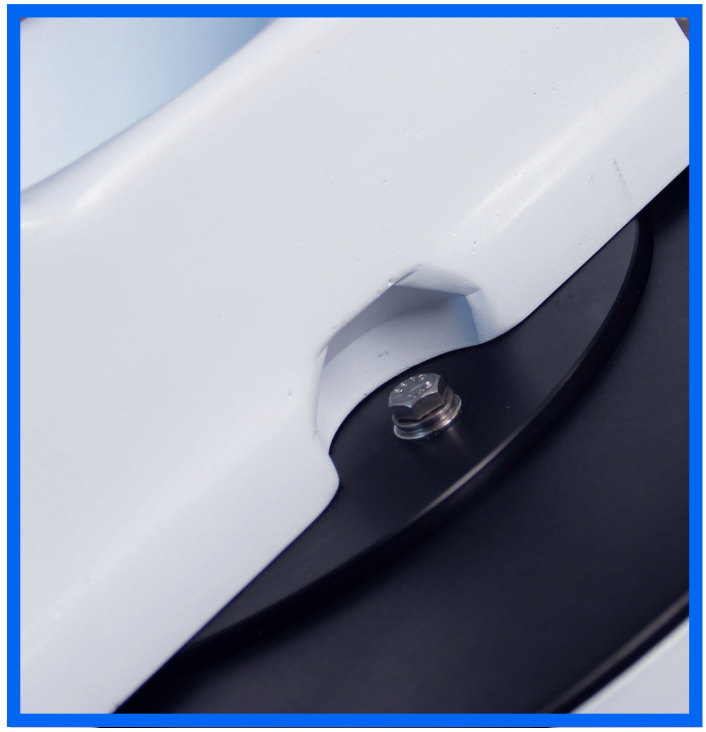
Installing the telescope is definitely a team effort. You are dealing with a heavy and expensive optical system. Proceed slowly and with caution. You do not want your telescope in pieces on the floor of the observatory.

If you are using dovetail plates, you should adjust the telescope position so that the telescope is balanced. First loosen the declination (or altitude) clutch bolts so the telescope moves freely. Loosen the dovetail clamping bar and slide the telescope as needed. Then tighten the dovetail plates and clutch bolts.

Hercules 20-inch Newtonian with Losmandy Dovetails

Slip Clutch

Each axis of the mount has are two hex head bolts that control the tension of the clutch. The right ascension (or azimuth) clutch bolts are located in pockets on opposite sides of the fork hub. These two bolts pass through the axis and thread into a clutch plate below the worm gear.

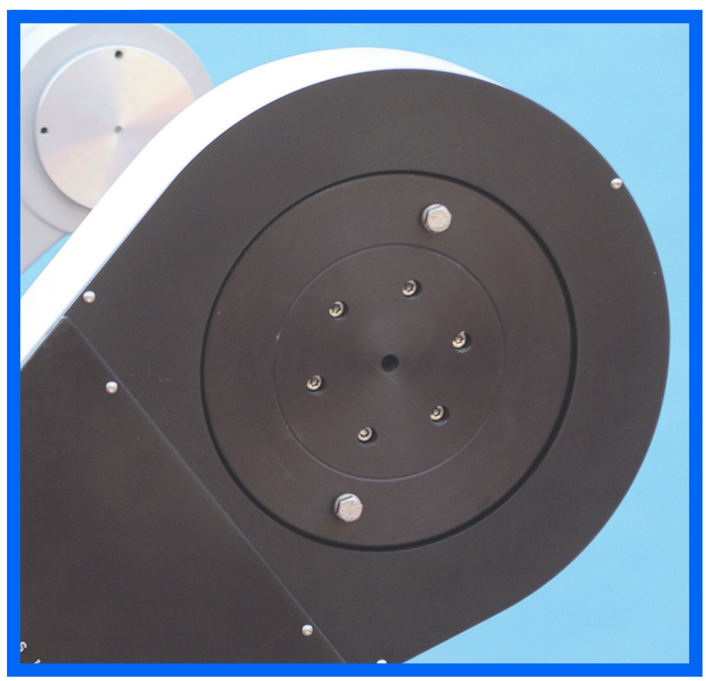


Clutch Bolts on Right Ascension Axis

When you tighten these bolts, the clutch plate presses up against the bottom face of gear and creates a noticeable drag.

With the telescope installed in the fork, adjust the slip clutch on each axis. When the clutches are loose, the telescope can be moved easily. As you tighten the clutch, you will feel increasing drag when moving the telescope. When the clutch is tight, the telescope is essentially locked, and it can only be moved under motor control.

The declination (or altitude) axis also has two clutch bolts, which are located on the outside face of the declination drive. To adjust the clutch, tighten or loosen these two bolts.



Clutch Bolts on Declination Axis

Unless the clutches are somewhat loose, you should not attempt to manually move the telescope. If you feel considerable resistance when moving the telescope, stop and loosen the clutches. If you force the telescope to move when the clutch is very tight, you risk damaging the worm and worm gear.

You can use the slip clutches on the mount to balance the telescope, check the limits of motion on each axis, "sync" the telescope on a known star, or use the telescope in a manual mode for student use. When the telescope is used under computer control, the clutches should be tight. In this case, all telescope motion is provided by the DC servomotors.

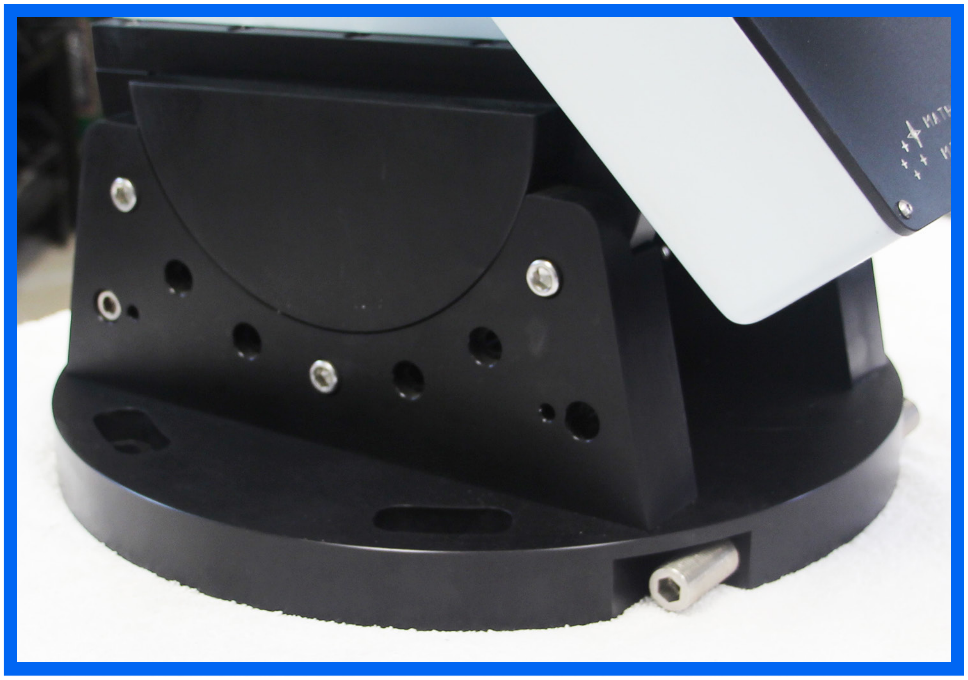
Tighten the clutches no more than to make the telescope stiff, i.e. it maintains sky position even when modestly bumped, yet the clutch will slip if you slew the telescope into a "brick wall". Leave the clutch tension on the loose side, and then tighten as needed.

Also, when you tighten the clutch, do not use excessive force on the adjustment bolts. Excessive pressure can damage the internal clutch plate. Make the clutches firm, but do not overtighten.

Adjustments

Azimuth Adjustment

Your observatory pier should be aligned such that the telescope mount is approximately on the north-south line. When the polar assembly is attached to the pier, check that the north-south line points reasonably close to the north celestial pole, at least within a few degrees. At night in the Northern Hemisphere, one can conveniently use Polaris to determine if the mount is pointed accurately to the north.

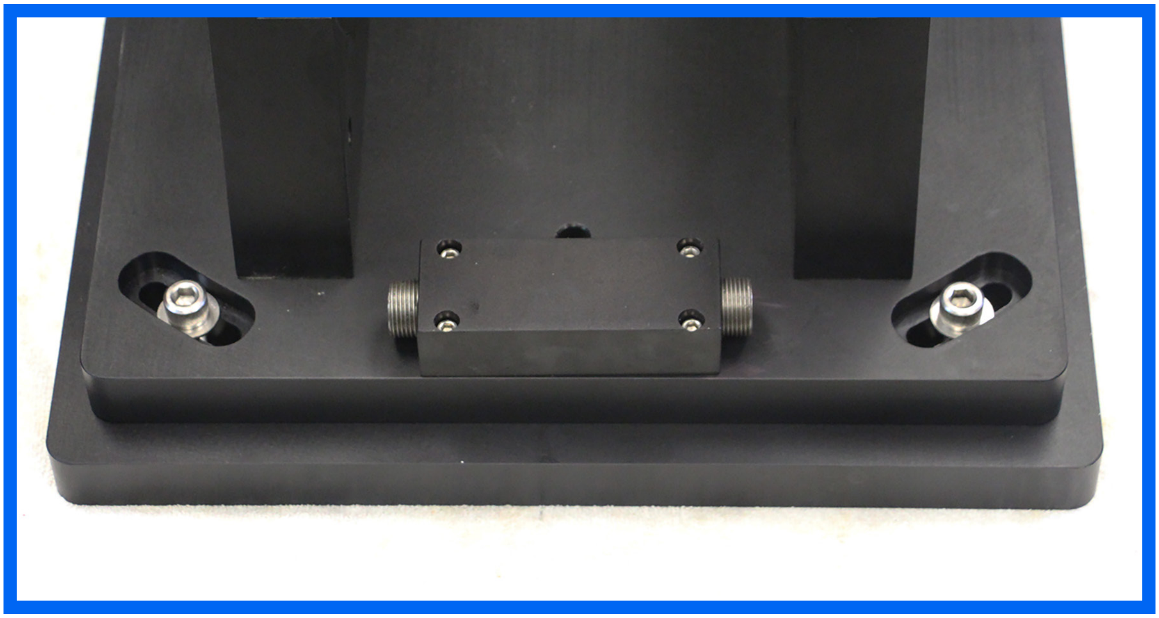

MI-750 Azimuth Adjustment

There are two recessed holes along the north edge of the Base Plate. The set screws in these holes push against a block on the Pier Plate and provide about ±5 degrees of azimuth adjustment.

To change the azimuth of the mount, first loosen (about one quarter turn) the five hex head bolts that attach the Base Plate to the Pier Plate. Do not remove these bolts, since they secure the Base Plate on the mount.

With these hex head bolts slightly loose, loosen the azimuth set screw on one side and tighten the azimuth set screw on the other side. This will slowly rotate the rocker base. Continue changing the azimuth angle in small steps, until you achieve good azimuth alignment to the celestial pole. After making your adjustments, remember to tighten the five rocker base bolts.

Note that for the MI-500 mount, one turn of the azimuth screws changes the azimuth angle by about 50 arc minutes, 40 arc minutes on a MI-750 mount, and 41 arc minutes on a MI-1000 & a MI-1250 mount.



MI-1250 Azimuth Adjustment

Altitude Adjustment

When the mount is shipped, the altitude of the Polar Assembly is set to the approximate latitude of your observatory. If you have angular measuring tools, you can refine the altitude of the mount to closely match your latitude. Do this before mounting the telescope in the fork.

The most accurate determination of altitude is made under the stars, when you are polar aligning the telescope. On the back edge of the Polar Assembly there is a large set screw. This screw pushes against the Polar Assembly to change the altitude of the mount.

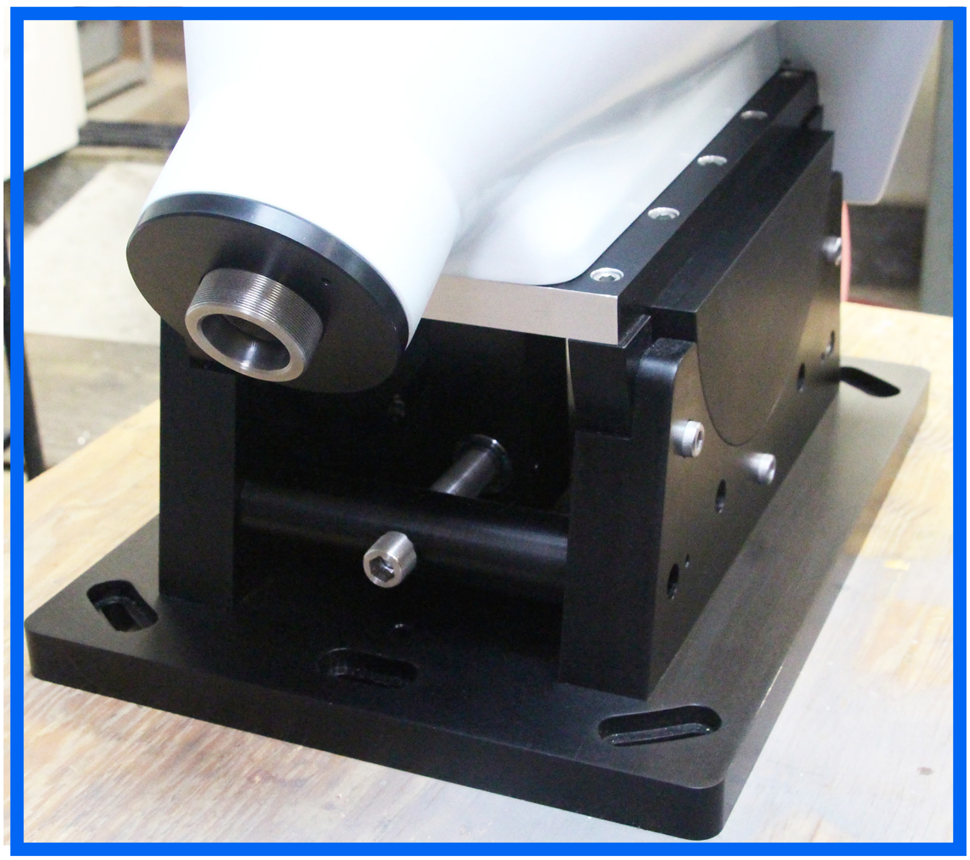
First, slightly loosen the side bolts that attach the Polar Cone cone to the Side Plates (one quarter turn is about right). This will allow the Polar Assembly to move when you turn the altitude screw. Loosen these bolts but do not remove them.

MI-750 Altitude Adjustment Screw

It is best to start with the polar axis of the mount pointing above the celestial pole. In this way, when you loosen the altitude screw, you will decrease the altitude of the polar assembly. It is easy to decrease the altitude, since the Polar Assembly slides downward under gravity. But if you lower the altitude of the Polar Assembly too much, you will be below the celestial pole.

If this happens, start again slightly above the celestial pole, and slowly decrease the altitude in small steps. On the first night, plan to get the correct altitude within a fraction of a degree or better. On subsequent nights, refine the alignment until you are satisfied with the results. Each time after making your adjustments, remember to tighten the side bolts.

For our larger MI-750 and MI-1000 fork mounts, it takes considerable force on the altitude screw to lift the entire fork and telescope. We recommend that you have an assistant (perhaps one on each arm) to lift upward on the fork arms so that you can increase the altitude.



MI-1250 Altitude Adjustment

On a MI-500 mount, one turn of the altitude screw changes the altitude of the mount by about 24 arc minutes. On the MI-750 mount, the change is 20 arc minutes for each turn of the screw And on the MI-1000 & MI-1250 mounts, each turn of the screw changes the altitude by 19 arc minutes. You do not need perfect polar alignment, since mount modeling software will correct for modest errors in your polar aligment.

Balancing the Mount

Fork Arm Weights

One advantage of a telescope mount with slip clutches is the ability to loosen the clutches to balance the mount. A good balance will improve the overall performance of the mount. Conversely, poor balance can adversely effect tracking and degrade pointing accuracy.

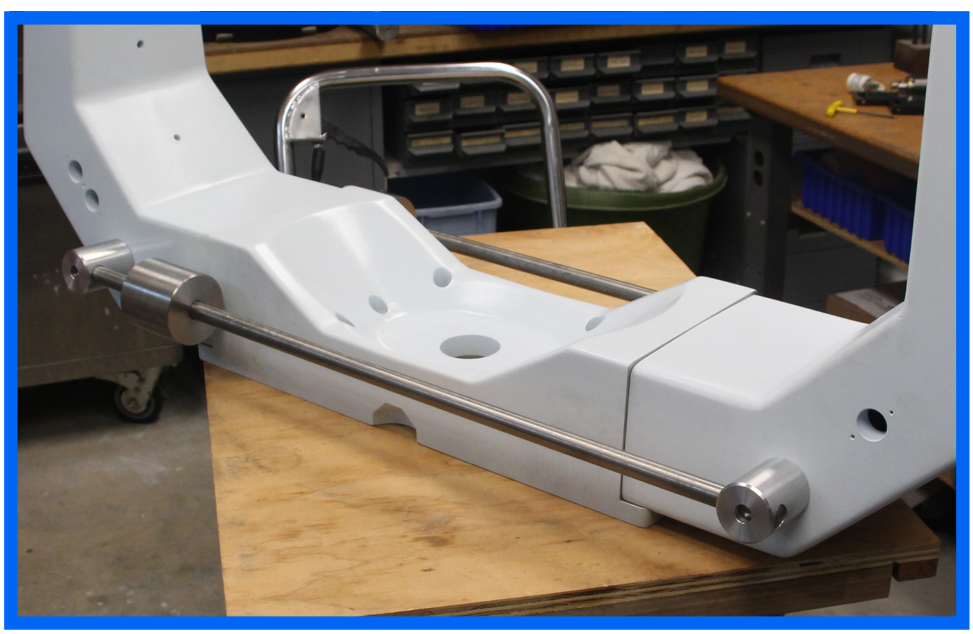
Fork mounts usually require little adjustment in right ascension, since the arms are balanced using machined counter-weights. Counter-weights are added to the fork arm that is opposite the arm with the gear drive.

A long rectangular weight is usually inserted inside the fork arm. If your mount does not include Renishaw encoders, a circular weight is also attached to the outer face of the arm.

Loosen the RA clutch and check that the fork does not rotate. If the fork rotates to the east or to the west, you need to add a small amount of weight to achieve a good balance.

Near the 45 degree bend in each fork arm, there is a hole for adding small amounts of weight. Each mount we ship includes a small "elbow" weight. As needed, install this weight inside either fork arm at the bend to adjust the fork balance.

For the MI-1000 and the MI-1250 fork, we provide a pair of sliding weights. These weights span the fork arms and allow for fine tuning the fork balance.



Fork Sliding Weights

It is best to leave the east fork arm slightly heavier than the west arm. In this way, when tracking, the worm gear drive is always working uphill against a modest load.

To balance the declination axis, you must shift the position of the telescope in the fork assembly. If the telescope attaches to the fork arms using dovetail plates, this is easy to do. Loosen the dovetails and slide the telescope to a position such that the tube assembly is well balanced.

If the telescope is fixed in the fork assmbly, you may need to add small balancing weights to the front or rear end of the telescope assembly.

Orthogonality of the Telescope

It is important that the optical axis of your telescope is perpendicular or orthogonal to the declination (or altitude) axis of the mount. Non-orthogonality will reduce the pointing accuracy of the mount. For best performance, you should test the mount and adjust the orthogonality as needed.

The technique described here can be done before you polar align your telescope. If your mount is already polar aligned, you can use this method when Polaris is directly above or below the north celestial pole (NCP), i.e. it is on the meridian at upper or lower transit.

The right ascension of Polaris is about 2 hours, 50 minutes. The means that when the local sidereal time is 2 hours, 50 minutes or 14 hours, 50 minutes (12 hours later) Polaris will be on the meridian. Use any planetarium software to determine your local sidereal time.

An easy way to check orthogonality is to manually swing the telescope through Polaris from opposite sides of the polar axis. Use Polaris since it is near the north celestial pole, and it moves very little in the time span of the test.

Loosen the clutches of the mount. Position the fork arms so that they are approximately horizontal to the ground. Move the telescope slowly in declination toward the north. Assuming that you have aligned the finder with the main telescope, locate Polaris in the finder scope A cross-hair eyepiece is very helpful here.

If the mount is reasonably well aligned to the pole, as you move the telescope in declination, Polaris will pass through the field of the eyepiece near the center.

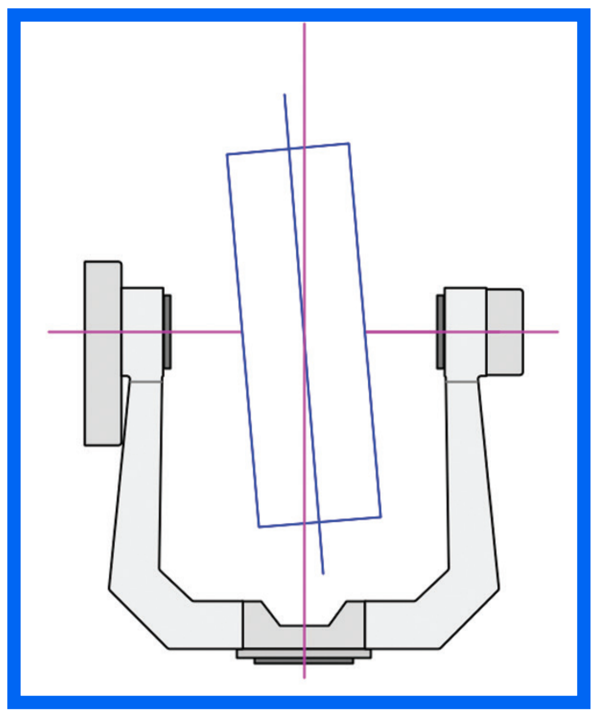
Now slowly rotate the fork in right ascension approximately 180 degrees so that the fork arms are again horizontal to the ground. Once again move the telescope in declination toward the north. Locate Polaris in the finder scope If the optical axis is orthogonal, Polaris will again pass through the field of the finder and the field of the telescope eyepiece. If this occurs, even approximately, the telecope's optical axis is reasonably orthogonal to the declination axis.

If Polaris does not pass near the center of the eyepiece, you need to adjust the optical tube assembly. Make adjustments so that Polaris is about halfway back to the center of the eyepiece field when viewed from the second side of the mount. Then repeat the process until Polaris passes near the center of the finder and eyepiece fields, when viewed from either side of the mount.

Making small shifts in the orientation of the telescope in the fork is fairly easy if the telescope is held with dovetail plates. Otherwise, you may need to use shims to make changes in the telescope orientation.

The test described here can be done in the Southern Hemisphere using the star Sigma Octantis. Known as Polaris Australis, it has right ascension of 21h 09m, and it is about one degree from the South Celestial Pole.

Do not assume that the optical axis is exactly the same as the mechanical axis of the telescope tube. This is especially true with long Newtonian telescopes and Schmidt Cassegrains with excessive mirror flop.



Misaligned Telescope Axis

If you have difficulty achieving orthogonality, there are many possible causes. The most common are bad collimation, improper placement of the secondary mirror in a Newtonian, and mirror flop in a Schmidt Cassegrain. If you can reduce the orthogonality error to a small fraction of a degree, you can get good pointing accuracy for most applications.

Software modeling can compensate for modest errors in orthogonality

Polar Alignment Using Polaris

For observers in the northern hemisphere, the star Polaris provides a reasonable approximation to the position of the north celestial pole. The current position of Polaris is about two thirds of a degree from the pole. This angle is slowly deceasing and will be less than one half degree in coming centuries.

When doing polar alignment, a very useful accessory is a small telescope with a reticle that marks the position of the celestial pole in relation to Polaris.

These polar alignment scopes allow you to measure how far your telescope mount points away from the celestial pole. With this information, you can make the required changes in the altitude and azimuth of the mount to achieve good polar alignment.

Polar alignment can be done in the Southern Hemisphere using the star Sigma Octantis, which is about one degree from the South Celestial Pole.

In general, polar alignment is easier with an equatorial fork mount. Unlike a German mount, there is no issue of "roll-over". A fork has one coordinate system since the mount passes continuously through the meridian.

Polar Alignment by Star Drift

Accurate polar alignment takes time and patience. It is a process of iteration. The accuracy of the alignment required for imaging is much higher than for visual use.

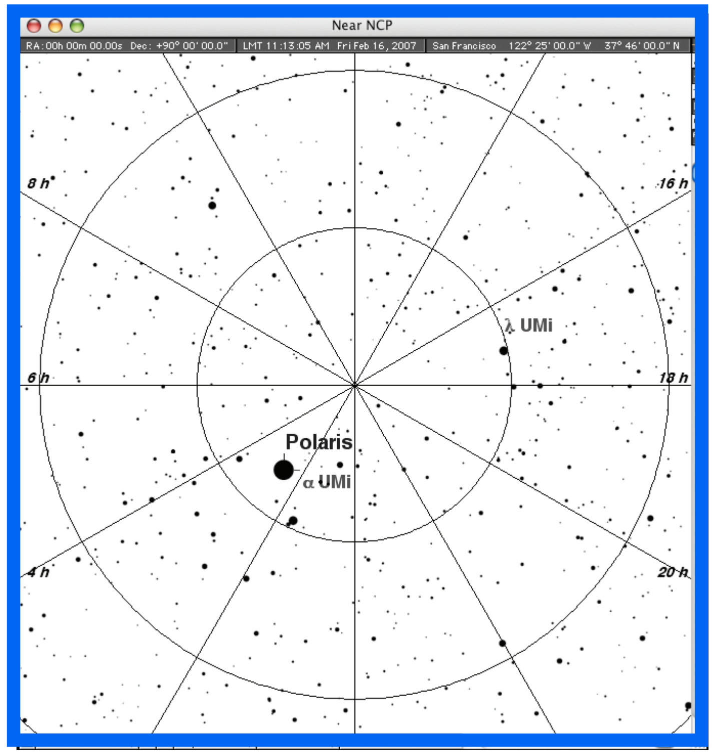
In a permanent observatory, you can improve polar alignment by the star drift method. With the drift method, you select two stars and watch their drift in the eyepiece making corrections as needed.

First, choose a star near the celestial equator and the meridian. Center the star in a cross-hair eyepiece. Make sure the cross-hairs are oriented N-E-S-W. Let your mount track and observe the drift of the star. If the star drifts south, your mount is pointing too far east. If the star drifts north, your mount is pointing too far west. Make small adjustments in the azimuth of the mount and repeat the process until there is no drift for a period of 5 minutes or more.

Next, select a star in the east near the celestial equator, about 30 degrees above the horizon. Center it in the eyepiece and watch the star drift. If the star drifts south, the polar axis is too low in altitude. If the star drifts north, the polar axis is too high in altitude. Make the needed adjustments to the altitude of the polar assembly. Repeat the process until there is no drift over a period about 5 minutes.

If the eastern horizon is obscured, you can select a star in the west, If the star drifts south, the polar axis is too high. If the star drifts north, the polar axis is too low. Make adjustments to the altitude of the polar assembly and then repeat the process until you detect no drift. This procedure will give you very good polar alignment.

You can use a CCD camera to help with the alignment. A CCD will usually detect movement of a star within the field more quickly than your eye. Be sure to accurately orient the camera N-E-S-W, as you would with a cross-hair eyepiece.



Star Field Near Polaris

The Internet is a great source of information. If you search using Google for “polar alignment”, you will find many artcles with examples, tips, and advice on how to accurately polar align your mount.

Maintenance

Lubrication

The mount parts that need periodic lubrication are the worm gear and the worm. The easiest way to apply new grease is to use an old toothbrush and distribute the grease along the edge of the gear. Make sure that the grease is applied to the inside of the teeth, since that is the contact surface between the worm gear and worm.

If you live in a dusty environment, you should also consider cleaning the individual teeth before applying new lubricant. To remove any dirt and any old dry grease, use a thin stiff brush. A small amount of alcohol works well as a solvent. Re-lubricate with an all weather, multi-purpose grease that works over a range of temperatures. We ship a small container of grease with each mount.

Two excellent lubricants are JET-LUBE's AP-5 multi-purpose grease and Mobil XHP 222 grease. Both of these lubricants are smooth black grease that is water resistant. They contains molybdenum disulfide, which provides a very low coefficient of friction. They can be used at temperatures as low as of 0°F (-18°C).

There are special lubricants for the extreme cold that will give good friction reduction. These can be applied to the gear and worm and also to the gearhead of the motor. This should only be needed in extreme conditions. Contact us for details.

Our gear sets include either an aluminum worm gear or a bronze worm gear, each with a stainless steel worm. The main advantage of the bronze worm gear is superior wear characteristics. In circumstances where the telescope is in continuous use, the bronze/stainless steel combination is desirable. To minimize wear, you should keep the gears well lubricated.

With nearly four decades of experience in making telescope drive gears, we have seen a few gears, in use for over 25 years, where the teeth are visibly worn thin from wear. These are usually aluminum gears. The bronze/stainless steel gear sets seldom show any significant wear.

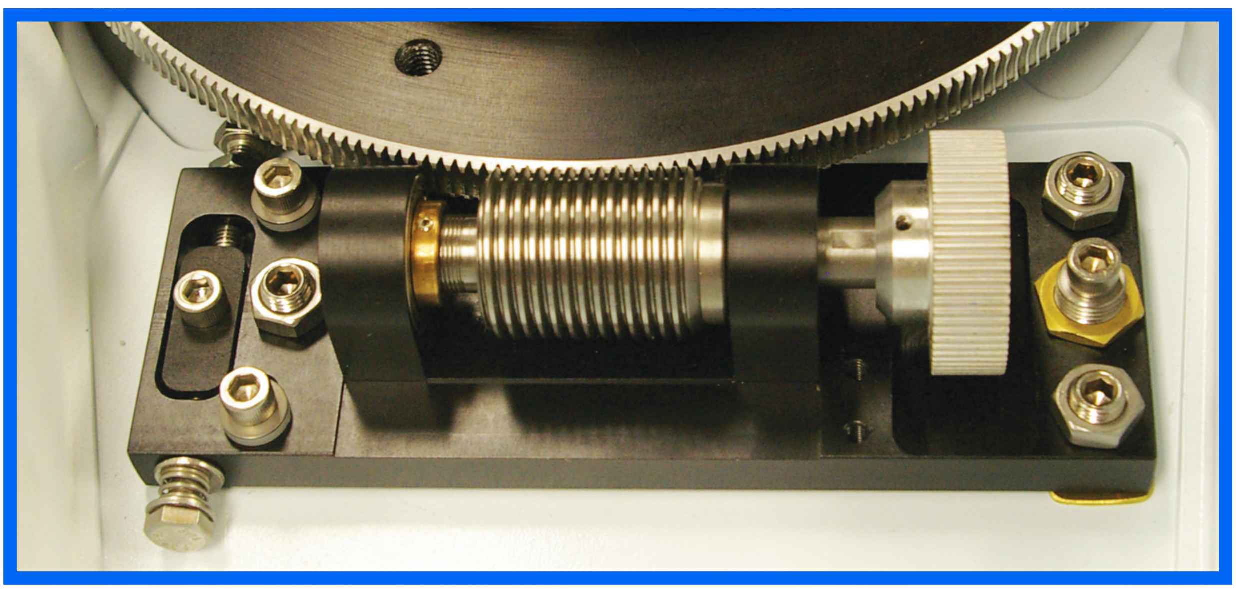
Cleaning

Cleaning the exterior of the mount is easy and routine. Use an ordinary cleaner such as 409 or Windex. You should not use paint thinner or other strong solvents, since these can penetrate the painted surface. Exterior cleaning is a matter of cosmetics and personal taste.

Each mount is shipped with a small container of touchup paint. This bluish-white paint is water soluble. If you have scratches or dings in the paint, use fine sandpaper on the damaged area and apply new paint.

Worm Plate

Each axis of the mount uses a worm gear drive. The stainless steel worm is supported on a worm plate using precision Class 7 bearings. A servomotor drives the worm shaft, which in turn engages the teeth of the worm gear causing the axis of the mount to move.

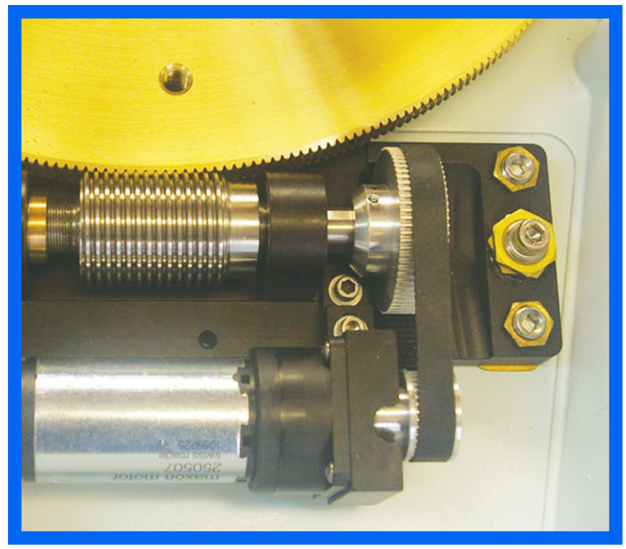


Worm Plate (motor removed)

The worm plate pivots about a pin located on the right edge of the worm plate. On the left side of the plate is a spring that pushes the worm plate into the worm gear. If needed, you can adjust the spring tension to change the pressure of the worm against the worm gear. Too much pressure will cause an unnecessary heavy load on the servomotor. Too little pressure will produce backlash in the worm drive.

Next to the pressure spring are two "hold down screws". These cap screws prevent the worm plate from lifting as the plate moves about the pivot pin. These two screws are adjusted to be finger tight. If the screws are too tight, the worm plate becomes fixed, and you defeat the spring action of the worm against the worm gear. This will likely result in some backlash.

The height of the worm central axis is carefully adjusted to the center line of the worm gear. To make this adjustment, there are three set screws in the worm plate, two on the right side, one on the left side. In general, we recommend that you not adjust these set screws.


Timing Belt and Pulleys

Between the two bearings that support the worm, there is thin brass nut on the left side of the stainless steel worm. This is a thrust nut that eliminates any end play in the worm. Normally this nut requires no adjustment.

If your mount uses pulleys and timing belts, periodically check the belt tension on each axis and make adjustments as necessary. To adjust the tension in the belt, loosen the two socket head cap screws holding the motor bracket to the worm plate. To increase the tension on the belt, push the bracket arm away from the worm axis. Re-tighten the two screws and test that the belt tension is firm, and the belt does not wander when rotating.

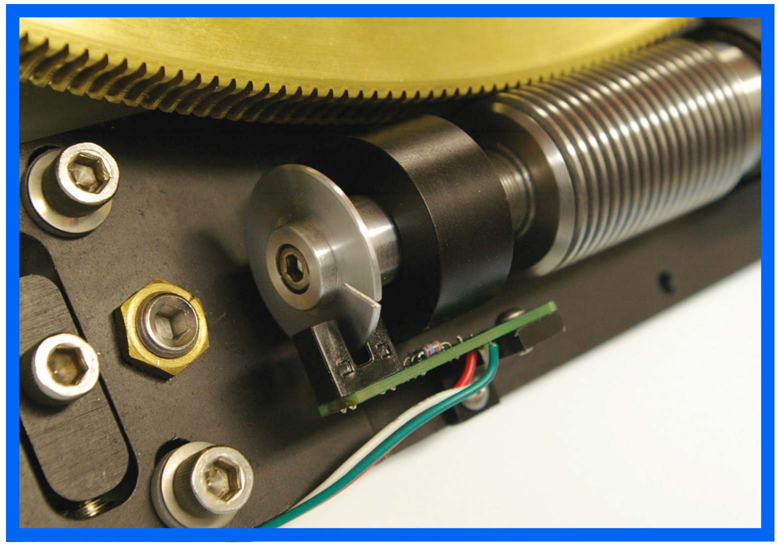
Some worm drives have spur gears instead of belts. To adjust the backlash of the gears, loosening the two small hex head screws on the end of the motor bracket. Push the bracket gently up against the gear on the worm shaft . The spur gear on the worm shaft and the brass pinion gear in the bracket need to be firmly engaged, but with a small amount of backlash to prevent any binding. Rotate the gears to see that they turn freely.

Also check the set screws that hold the pulleys (or spur gears) on the worm shaft and the motor shaft. They can loosen over time and create the effect of backlash. If a set screw comes loose, we recommend using a thread locking compound to prevent the screw from loosening again.

PEC Sensor

The Servo II control supports a hardware PEC sensor. PEC is short for "periodic error correction". As the RA worm rotates, a small disk on the end of worm shaft passes through an infrared sensor. A thin slot is cut into the edge of the disk, and when the slot passes through the small opening in the sensor, a signal is generated.

When the drive is tracking, the slot in the disk periodically passes through the sensor opening. This calibrates the position or the phase of the worm. Each time the signal appears, the control knows the worm has completed one rotation.



PEC Sensor on Worm Shaft

As the worm rotates, small residual errors in the worm gear produces tracking errors. By recording these gear irregularites, an error profile is generated. This profile is then used to make small changes in the worm rotation rate, the goal of which is to cancel out the worm gear errors. PEC models the gear error to improve tracking accuracy.

The PEC sensor is mounted on a small bracket attached to the worm plate. Check that the PEC disk passes through the center of the sensor opening, which is about .120 inches wide. If needed, loosen the bracket and make adjustments.

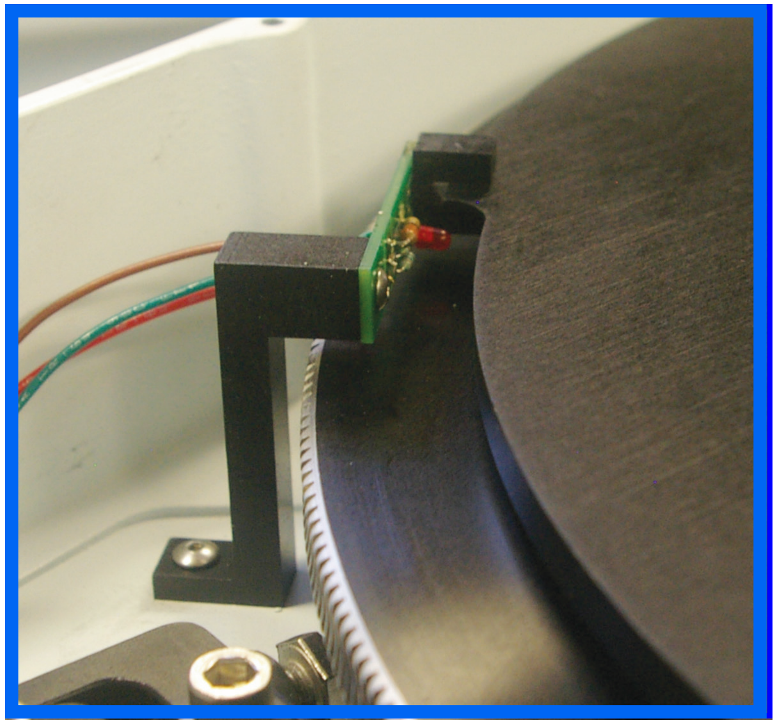
Note that the sensor circuit board includes a small LED (light emitting diode) near the sensor opening. When the slot in the disk passes through the sensor opening, the signal causes the light to briefly flash. Check this to confirm that the PEC is working properly.

The PEC sensor is installed on mounts using the Servo II control. If you are also using Renishaw encoders, the PEC sensor is not needed and is not installed on the mount.

Home Sensors

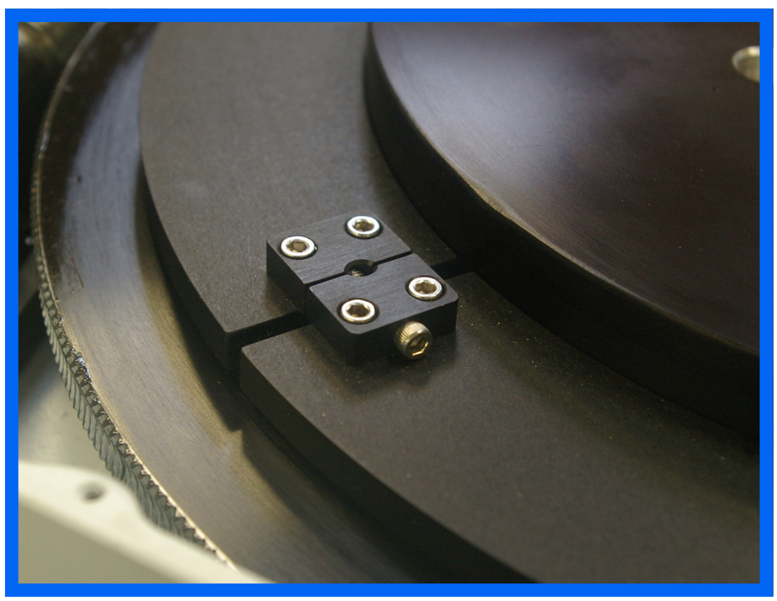
The Servo II control supports mount homing. Each axis of the mount has a circular disk or annulus that is mounted above the face of the worm gear. A small U-shaped infrared sensor is mounted on a bracket inside the gear casing.

The homing disks are attached to the axis of the telescope, so that any motion of the mount, either by the servomotor or by manual motion, is recorded by the homing sensor. The homing disk features a small clamp that allows you to adjust the zero position of the disk.



Homing Disk and Sensor

As the telescope moves, the sensor records the state of the home disk. Half of the homing disk passes through an opening in the sensor; this blocks the infrared signal that passes across the sensor opening. The other half of the homing disk has a smaller diameter, such that the homing disk does not pass through the sensor opening; the infrared signal is not blocked.



Homing Disk and Clamp

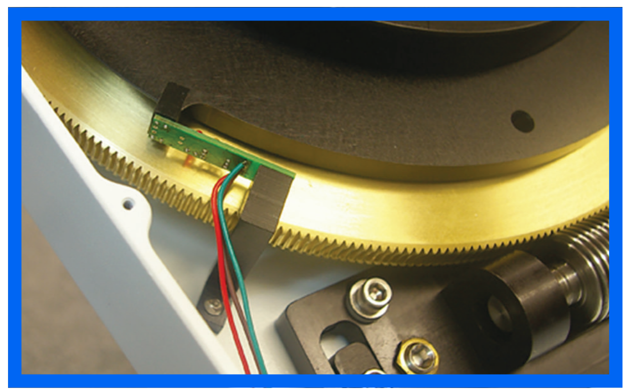
The key position is the transition edge of the homing disk when the sensor changes from signal to no signal, or from no signal to signal. These two unique positions of the mount establish repeatable mount orientations called the zero home positions. Either of these home position can be used. They enable the telescope to be controlled from a remote location.

When the mount and control are first turned on, a command is given to find the zero home position. You have a choice as to which zero position to use: signal to no signal or no signal to signal. The servomotors set the mount in to motion searching for the zero position as measured by the home sensor. Once located, the position of the telescope in local altazimuth coordinates is known.

Knowing the local sidereal time and the longitude and latitude of the observatory, the position of the telescope in equatorial coordinates can be calculated. The observer now knows where the telescope is pointed in the sky, whether the observer is at the observatory or on the other side of the world.

One needs to select a suitable home position for the mount. A good choice is to have the fork mount point to the meridian near the celestial equatorial. To set this home position, manually move the telescope to point directly south near the celestial equator.

With the telescope pointing to the new home position, loosen each clamp on the homing disks. Now rotate each home disk so that the zero home point (transition point) is aligned with the small opening of the sensor. No great precision is required. The picture to the right shows the homing disk zero point near the opening in the infrared sensor.



Homing Disk Near Transition Point

It is best to set the home position before installing the fork and telescope on the mount. In this way you have easy access to the RA/Azimuth home disk and clamp. If you need to change the home position after installation, remove the screws in the upper semi-circular cover plate. You can then rotate the cover so that the flat edge of the cover makes the home clamp visible (see picture). Then use a hex wrench to loosen the clamp and rotate the home disk to the new position. Tighten the clamp when you have the new home disk adjusted.

Home Clamp Under Cover

Renishaw Encoders

As an option, your mount may include Renishaw encoders. Using the Servo II control, these encoders are installed on the right ascension and declination axes (or azimuth and altitude axes). A Renishaw encoder consist of an encoder ring and a read-head.

Renishaw Encoder Rings

Depending on the size of your mount, the encoder rings have diameters of 200mm, 150mm, 115mm, or 100mm. These Renishaw encoders provide a resolution of .10 to .20 arc seconds, and provide unmatched tracking precision and pointing accuracy.

One encoder ring is installed inside the polar cone (or azimuth base) and one encoder ring is installed on the west fork arm. The read-heads are mounted on dovetail slides that permit accurate adjustment of the separation between the read-head and encoder ring.

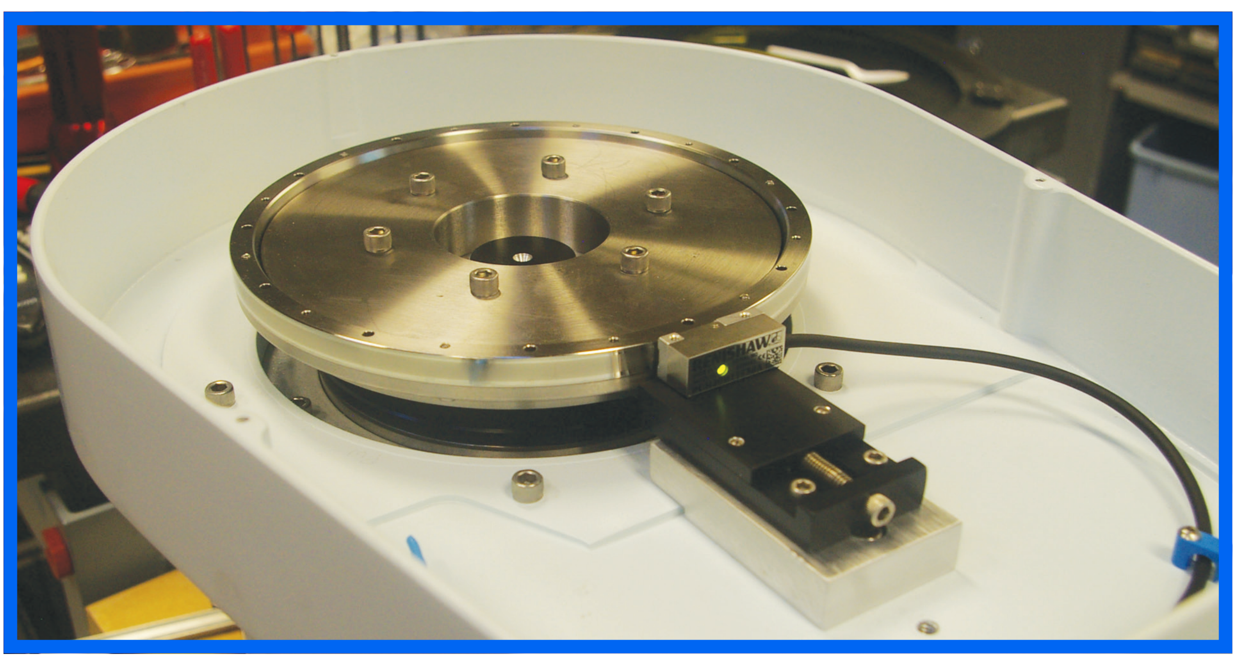
The RA read-head is mounted inside a pocket machined on the east side of the polar cone. The declination encoder read-head is mounted inside a casing on the west fork arm.

The mount moves when servomotors drive the worm and worm gear. Since there is a 2000 count encoder on the servomotor and the worm gears reductions are known, the electronic control knows the numerical change in the position of the telescope. With a good mount installation, the accuracy of the telescope position is limited mostly by the motor encoders and the drive gears in the mount.

Read-head on Right Ascension Axis

Renishaw encoders measure the true motion of the telescope, independent of the worm gears, timing belts, and servomotors. These encoders have a precision typically 10x greater than the mount drive system, so that tracking and pointing are greatly improved.

Each Renishaw encoder is carefully installed so that encoder ring is concentric with the axis bearings and the read-head is at the proper height in relation to the center line of the encoder ring. The Renishaw read-heads are mounted on dovetail slides, so that you can adjust the separation between the encoder ring and read-head. The target separation is .80mm , about .032 inches. This can vary from about from .70mm to .90mm.



Read-head on Declination Axis

There is an indicator light on the back surface of the read-head. When the separation is in range, the light will be green. When the read-head is out of range, the indicator light will be red.

When the encoders are in use, check that the indicator light is green. If the light is red, you need to adjust the separation between the encoder ring and the read-head. Turn the hex head screw on the outside of the dovetail slide using a 1/8 hex head wrench.

One turn of this screw will move the read-head by about .80 mm, or .032 inches. A clockwise turn moves the read-head outward, and a counter-clockwise turn moves the read-head inward. When the mount is shipped, we turn the dovetail slide one full turn clockwise, moving the read-head away from the ring by about .80mm.

The top surface of the dovetail has two small nylon tipped set screws. These screws serve as dovetail clamps. When the indicator light is green, slowly tighten these screws to prevent any further changes. Very little pressure is needed.When changes are needed, loosen these set screws, adjust the dovetail slider, and carefully tighten the set screws.

Proceed slowly with these adjustments. The read-heads are very sensitve. A good technique is to carefully place your finger on the dovetail slide so you can feel the motion of the slide. Make only small changes, and then check the results.

We ship a blue plastic gauge made by Renishaw to check the read-head separation. When you can insert this gauge between the read-head and encoder ring, the separation is nearly correct. If the gauge does not fit, the separation is too small.

Cold Weather Operation

The components of the mount and electronics are all made to operate at temperatures near freezing. However, if your observatory is located where temperatures get well below freezing, you may need to take some precautions. The mechanical components are all rated to about 0°F (-18°C).

We recommend that you find a way to heat the electronic control. One easy solution is to simply put the control on top of the power supply, a convenient heat source. You might also be able to use dew heater strips or some other source of low heat.

Electronic Damage

If you live in an area where lightning storms are common, sudden surges in the power supply can damage the telescope control, the servomotors, and any CCD camera. As a precaution, disconnect the electronics from the observatory power supply until the storm passes.

Technical Support

If you have any questions or problems with the setup or the operation of the mount, please feel free to contact us. Please provide details of the problem and send relevent pictures if possible.

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