Rainbow RST - supplementary instructions

source: Rainbow User Group
editor: Chris Woodhouse FRAS

DropBox Link to this and other resources:

https://www.dropbox.com/sh/f25n7mn4yps2mkx/AAAVwlf80FzpiC56zKd0Tsdfa?dl=0

17 July 2021

just for the taste of it!

Contents

Introduction:

This is a freely-distributable instruction pamphlet that is compiled from user experiences and is designed to supplement the official user manuals, which are found at:

http://www.rainbowastro.com/manual-eng

Please feel free to suggest improvements, additions or corrections to *chris@digitalastrophotography.co.uk* and I will incorporate them in and update the PDF in the dropbox folder. You can send me text and pictures and I will lay them out.

Disclaimer

In this modern world, the best intentions sometimes go awry and some folks always want someone to blame. The information in this document is provided in good faith, with no commercial intent, and with no implied guarantee, warranty, or liability. Some operational aspects may change due to updates in the firmware, software, and drivers.

The other thing worth mentioning is that this undertaking is not endorsed or sponsored by Rainbow Robotics or any other company whose products are mentioned. Contributors are free to suggest products that they genuinely think are useful and not due to an affiliation and a conflict of interest.

Thanks

Thanks to all who helped me put this together; checking for accuracy and providing text and images.

Clear Skies!

Revision History

June 27: 1st draft - general content and layout

June 28: 2nd draft added tripods, balancing, guide rates, and scripts/drawings to dropbox folder

June 30: additional draft content and work-in-progress, corrected typos and bolt spacing error.

July 2: added content on computer connections, updated battery options

July 3: started to add alignment sections

July 4: finished draft of alignment section, just need to add TPoint values, started Alt-Az section

July 5: started autoguider section

July 6: updated alignment sections after feedback

July 9: mostly complete, just missing some miscellaneous input on asteroids, satellites and the like

July 11: tidied up and added a wishlist

July 13: added satellite section, kindly written by Carlo

July 17: added some comments about usefulness of drift correction during autoguiding

Setting Up

Handset Peculiarities

A handset is not mandatory if one is controlling the mount via its USB port, say for astrophotography. The mount supports the basic ASCOM methods and properties but, while location and guide rate can be set through ASCOM, it is not yet possible to set the mount time as the AS-COM UTCDate set property has not been implemented. (A request has been made to remedy this.) As accurate time influences the first alignment slew, for now, leave the handset in place for setting the time from the GPS receiver. It is not a good idea to plug in the handset when the mount is already on; always have the handset plugged in when the mount is turned on.

Universal Handset

The Hubo-i handset is a generic unit that is used across several products and has several menu items that are not implemented/applicable for the attached mount. It is not always clear from the handset display if the feature is disabled or not working. For instance, the following features are not implemented on the RST-135:

- balance
- PEC setup
- reticle illumination
- PEC (on/off)

Accessing Setup Menus

The handset also has several entirely separate menus for setting it up, with a not entirely logical feature grouping.

- long press of **ENT** - time, location, slew speeds, guide rate, backlash, tracking, home sensor calibration, mount type, version info
- short press **MENU** - drive, USB/WiFi setup, display backlight, display contrast, mount limits, Voltage/Temp, GPS
- short press **MSC** - parking, user objects, satellites, eclipse mode
- short press **ALGN** - drift correction on/off, tracking on/off, PEC on/off

Warning!! ==Mode Reverse==

This unexplained warning comes up if you press the **GOTO** button. A short press of the **GOTO** button starts a meridian flip. If the mount is within the flip limits (explained later on) a press of the **ENT** button will do a meridian flip. The message should read "WARNING!! Meridian Flip?".

The handset is not mandatory for imaging purposes but at present, it is the only way to set the time in the mount. An ASCOM driver improvement could fix that.

Time/Location/GPS Operation

The setting logic is not the best. There is a **UTC** time and location menu item within the **ENT** menu and a further GPS menu item within the **MENU** menu. They work exclusively. You can either set up time / location in the **ENT** menu, or accept the GPS values. The GPS receiver needs a strong signal and compared to my bike computer, only sees about half of the available satellites. It seems that the antenna is on the back of the handset and it works better face down. This is only needed until the signal is found and you have accepted the results with a long press of the **ENT** button. This appears to override any time/location information that has been put in manually.
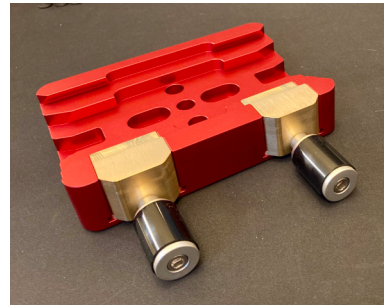
ASIAIR Polar Alignment Gotcha!

This great little one-stop imaging computer has a useful polar alignment feature. It does a 60°slew in RA to work out the center of rotation by using a timed slew. This only works properly if slew speed 2 and 3 are set to factory defaults in the handset (100x and 1,500x respectively). If the slew rates set in the handset are too high, it potentially could cause a leg clash.

Alternative Dovetail Saddles

Depending on the size of the optical configuration, several saddle plates fit onto the Rainbow. They mount has two M8 bolts (10-mm deep) and 35 mm apart. This is the same specification that Takahashi use on their Temma mounts and their telescope saddles will bolt directly to the Rainbow. Make sure you do not use overly long bolts to avoid damaging the mount. In addition to the Rainbow Vixen saddle, two dual Losmandy/Vixen plates find favor in a variety of setups. ADM do two models with different saddle lengths. I prefer their smaller one for lightweight setups and in common with some others, use a Chinese model (available from eBay and some retailers) for heavier loads. Both are well-made units and I prefer the independent brass plungers of the red Chinese model to grip heavier loads. Rowan astronomy make some beautiful alternatives too.

A range of saddles, the top two can do both Vixen and Losmandy. Be careful to ensure the knobs do not protrude and hit the mount at some orientations.

Tripod Alternatives

There are many options for supporting the diminutive RST-135. It's small size does pose some problems thought as its slim profile means there is only a small offset from the center line to the saddle plate. On long telescopes or those with protruding filter wheels or cameras the back end may easily collide with the tripod legs at some RA positions. The torque of the RST-135 is sufficient to cause damage to delicate equipment (it sheared off an eyepiece fixing screw). The very lightest systems use carbon fiber photo tripods. The best models have a flat simple top plate, with a 3/8-inch bolt and do not have flimsy center columns. This is often in the form of a circular insert. The Gitzo model opposite has a 70-mm circular flange, other larger ones have 85 mm. Popular models include the RT90C. Those with flimsy extending center columns and more than three leg-sections are more likely to wobble/flex. Photo tripods, in general, are fine for small optical systems but with heavier unbalanced loads, the leg spread is possibly insufficient for stability at all orientations and, if the legs are splayed out, may cause leg clashes.

Moving up, many others have discovered the StarField 1000 and its numerous re-badged versions. This hybrid design is called a tri-pier, with a long narrow central pillar. This provides the best clearance for imaging. The tri-pier's feet have "lunar pads" with long adjuster bolts. These are useful for precise leveling but the feet are still small enough to sink into soft ground and may slide about on smooth surfaces. It is a simple matter to remove the feet and replace with spiked M12 bolts/nuts/washers (see picture), which is more secure on a hard surface. On soft ground, a neat idea is to hammer in three long cap-head bolts (6-inches or longer) and place the spiked feet into the bolt heads. There are some specialist carbon fiber astro tripods with substantial center columns. The CYG48P and CYG54g astro tripods are two examples of premium tripods. For more substantial loads, the Avalon TPod is another option which finds favor with many. It is also suitable for more substantial mounts, and usefully has multiple fixing holes in its top plate to accommodate different adaptors. The tripod is wider though and, for longer telescopes, it is a good idea to use a pier extension of about 8-12 inches. It is supplied with rubber feet. Avalon sell spiked feet and a mount adaptor. Accessory locking/leveling feet, similar to that of the StarField 1000, are available from TPI astro (see image). The base fixings for the mount are 2, 45-mm spaced M8 holes (10-mm deep).

Balancing Considerations

One of the advertised advantages of the Rainbow mounts is that they work well without counterweights. Certainly the typical industrial robots, which use the same drive technology, are not cantilevered. There is some agreement that balancing is not essential but can be useful. For starters, the gearing is always engaged, so it is not trivial to fine-balance the mount anyway. On tripods with a small footprint, approximate balancing will prevent toppling with a heavy payload. There is also the general principal of flexure and stability on soft ground; a balanced system on the tripod always sees the same load at every orientation and is less likely to flex or sink in to soft ground on one foot or another (and ruin tracking). It is also slightly easier to alter the altitude adjuster in both directions if the mount is more evenly loaded.

The Tri-pier (top) is supplied with adjustable feet, which may slide about on some surfaces. The modified spiked foot is made from a stainless bolt, two nuts and a wide washer. Precise leveling is more essential for Alt-Az operation and third-party leveling feet are available for the Avalon Tpod (bottom).

Using counterweights reduces the peak motor load and, according to the specification, increases the maximum payload up to 18 kg. The accessory counterweight bar is quite short and to keep the overall weight down, one could use a longer bar with less weight. The counterweight bar is 18 mm in diameter and is terminated by male/female M8 threads. It has a small shoulder on the mount end, to avoid scratching the mount body. (It is a good idea to keep dust out and screw the M8 cover back in when the counterweight is removed.) A design for a longer version is in the dropbox folder. Some small Fornax and iOptron mounts use the same diameter shaft and their counterweights should be compatible.

It appears these mounts track better in an unbalanced state. There is no empirical evidence on how much imbalance and what effect it has on tracking errors. It is tempting to only consider the RA balance but it may also be the case that an deliberate imbalance around DEC may improve guiding performance and is worthy of more experimentation (sliding forward would also improve leg clearance).

The keen-eyed will notice the handset has a balancing menu item. It is disabled for the RST-135 but it is entirely feasible as the Rainbow mount measures its motors' current and electronic balance algorithms compare motor currents in opposing directions.

Setting Guide Rates

There are two ways of setting the guide rates for the Rainbow. One is through the **ENT/Speed setup** menu in the keypad and the other is through ASCOM. The Rainbow ASCOM control panel does not have a facility to set guide speeds but it is possible through AS-COM commands. It is not possible to set RA and DEC guide rates to different values (which ASCOM allows for and would be useful to improve DEC guiding behavior) but the latest Hubo-i ASCOM driver does have the correct setting format.

In ASCOM, you use the *GuideRateRightAscension* property. Most imaging applications cannot set guide rates but you can do this through a Windows form application or a Visual Basic Script, like the one shown below and also included in the Dropbox folder:

```
'Utility to set guide rates through ASCOM interface
'V2.1
Dim vbYes: vbYes=6
Dim vbNo: vbNo=7
Dim vbCancel: vbCancel=2
Dim srate: srate = 0.00416666666666667  ' sidereal rate
Dim xrate: xrate = 0.25  ' default guide rate multiplier
Dim grate: grate = srate * xrate  ' guide rate in deg/sec

'comment the following four lines for a specific mount chooser
'Set c = CreateObject("ASCOM.Utilities.Chooser")
'c.DeviceType="Telescope"
'id = c.Choose("")
'set scope = CreateObject(id)

'comment the following line for a general chooser
set scope = CreateObject("ASCOM.HUBOI.Telescope")

scope.Connected = true   ' connect mount

' set up time to PC time (not implemented in Rainbow ASCOM)
'decision = MsgBox ("Is it Daylight Saving Time?", vbYesNoCancel)
'if decision = vbYes Then
'          scope.UTCDate = Now - 1.0/24.0
'          MsgBox "UTCDate set to " & scope.UTCDate
'elseif decision = vbNo Then
'          scope.UTCDate = Now
'          MsgBox "UTCDate set to " & scope.UTCDate
'else
'          MsgBox "No Change"
'end if

' uncomment next line to home mount
'scope.FindHome

' set up guide rates - 0.1x to 1.0x
scope.Tracking = true
if scope.CanSetGuideRates then
          decision = msgbox ("set guide rate?", vbYesNo)
          if decision = vbYes Then
                    xrate = InputBox("Please enter rate 1-10
(0.1x-1x):","Guide Rate")
                    if xrate > 10 then
                              xrate = 10  ' keep in range
                    end if
                    if xrate < 1 then
                              xrate = 1    ' keep in range
                    end if
                    xrate = (xrate / 10)
                    grate = srate * xrate     ' calculate guide rate
in deg/sec
                    scope.GuideRateRightAscension = grate ' set
rate
                    scope.GuideRateDeclination = grate ' set
same rate
          end If
          'confirm guide rate by reading it from mount
          xrate = (scope.GuideRateDeclination / srate)
          MsgBox "Guide Rate Set to " & Round(xrate,2) & "x"
end If
scope.Connected = False
WScript.Quit
```

The Rainbow mount has significant cyclical tracking errors, similar to classical periodic error in a worm-driven mount. For imagers, at times in its ~7 minute cycle, the tracking error changes quickly, demanding short guide exposures and quick elimination of tracking errors to keep stars circular. Many users find a 1.0x guide rate works well, which is unusual in a mount (for example, Paramounts work well at 0.5x and Avalon mounts prefer a less aggressive 0.05-0.1x rate). That means the motor is start/stopping for brief periods.

An alternative electro-mechanical engineering viewpoint would propose a lower rate (as long as it is sufficient to keep up with the tracking error) as it imparts less inertial trauma into the system, especially with heavy payloads. Since it is now easy to change

The Pegasus Power box makes for a simple one-wire connection from the mount to the ground (above). Below that, a conventional setup requires a cable bundle to prevent snagging and improve tracking consistency.

Many find the DC plug style on the right has better reliability for a stable connection.

values over a PC connection, it is something worth experimenting with, noting the best setting may change with payload.

Cable Management

While this mount has high torque, cable management is still an important consideration; intermittent connections and catching cables may still affect operation and tracking performance. The Rainbow mount is too small to even consider through-mount cabling and perhaps one of the poorer aspects of the design is the location and design of the power and USB connectors on either side and which move with the RA axis. Best practice ensures that plugs are secure in sockets and cables are supported somehow, near the axis of rotation, to minimize strain and drag. Neither the USB or power connectors lock and there are a few strategies to reduce the likelihood of performance issues:

Power Control Box

A power control box, or an imaging computer, mounted on the telescope relieves many issues in one go. In the picture opposite, there is just one solitary power cable from a Pegasus power box to the ground (shrouded in a red satin sleeve to ride over obstacles). All the other cables move with the telescope and a coiled USB cable is used for the mount connection. Similar setups may use an ASIAir and other imaging computers with distributed power and USB connections.

Cable Bundle

A second approach bundles the cable package and supports it to minimize cable issues. In the photo opposite, the USB, power, dew heater, and focus cables are bundled in a mesh sleeve. One end is fixed the the top of the counterweight bar with a Velcro tie and the other is supported at the top of the tripod leg. The loop is sufficient to permit a 180 swing in RA. If one considers a meridian flip, the bundle moves less if it fixed to the counterweight bar (or an M8 bolt put into the hole) than if it secured to an adhesive tie mount on the saddle plate and, as a result, is less likely to cause issues. In both cases, the cable routing and lengths need to work in all orientations and may require further attachments to ensure they move freely without catching.

Power Connectors

On the subject of power connectors, there are several designs, some of which are better than others. Some criticism is leveled at Rainbow Robotics on account of the supplied cable. It is a no-win situation; there are so many power sources (automotive, power pole, spades, alligator clips, XT60 and so on) that they cannot reasonably second-guess what the customer requires at the other end. The Rainbow's power socket is recessed and it requires a long 5.1 x 2.1-mm DC connector to fully engage. There are two common DC plug styles; a plain cylinder with a central hole and one with an inner sprung connection. The sprung one appears to be more reliable and resilient to cable movement and Pegasus Astro use that style for the DC power cables they supply with their products.

Power Requirements

The Rainbow RST 135 consumes very little power and, depending on load and balance, tracking may consume just 200 mA and up to 3 A during high-speed slews. The voltage input can be in the range of 12–16 volts. There are many power options including many different battery models, including lead-acid and lithium derivatives. For observing, a smaller battery will suffice for the mount alone, whereas imagers will likely have a larger capacity (or multiple) models to run all the equipment. When choosing a battery one should note there is a difference between capacity and usable capacity. Many lead-acid cells should not be discharged below 50% of their stated capacity.

The ASCOM driver for the Rainbow pops up a Windows form to display mount information and has controls for slewing, parking, homing, tracking, and enabling sync commands.

Although quickly going out of favor, a fully charged lead-acid hobby battery outputs ~13.7 volts, gradually reducing with discharge, to less than 12 volts at ~50% discharge. Lithium cells fare better, maintaining a more constant output voltage up to about 80% discharge but many lithium batteries are nominally rated "12 volts" but never achieve that voltage and will not drive many devices (an Intel NUC shuts down if the supply dips below 12 volts). Several users have re-purposed higher-voltage radio-controlled hobby batteries, using a step-down DC voltage converter to ensure a stable supply voltage. If you are making your own power system, however, using a Lithium battery pack, be sure to use a battery monitor/controller to prevent over-discharging the cells and causing damage, or alternatively consider a high-capacity LiPo leisure battery which wholly manage the state of charge and have several output options. With any battery, always use the correct charger and follow the instructions carefully. At best, poor handling will reduce capacity, at worse, cause a thermal event. Here are some examples:

- small 12 volt lead-acid battery (10–20 Ah)
- counterweight mounted battery (Celestron)
- Power Bank (10,000 mAh, 5 volt) - supporting USB PD and a 15V decoy trigger cable
- RC LiPo battery (5,000 mAh, 22.2 volt) with DC-DC step down converter to 12–13 volts
- controlled ouput from Pegasus PowerBox, itself supplied from large capacity battery
- a LiPo leisure battery pack (e.g. portable powerstations); these fully integrate charging and discharge management with a wide range of capacities and output options, including AC, 12 volts and 5 volts.

Computer Control

The Rainbow mount has both USB and WiFi connectivity but only one can be active at any one time. Each one only works with one of the two protocols, "Rainbow" or "LX200" but the protocol has to be independently set in the handset's **Menu/Communication** menu.

In that menu, pressing **ENT** when the cursor is on "USB mode", sets USB and disables WiFi mode and vice versa. Scrolling down the menu finds the Protocol entry and pressing **ENT** toggles between Rainbow and LX200 protocols. Set the Rainbow protocol when using USB communication as it has a feature-rich set of commands, including setting location, guider parameters and pulse guiding. In WiFi mode, set the venerable LX200 protocol. It is the nearest thing to a universal standard but only has basic controls, though these are sufficient for visual imaging and directing the mount with mobile applications like SkySafari, Luminos, and others.

USB Operation

The USB port uses serial commands, and it shows up in Window's Device Manager as a virtual COM port. To use with a Windows PC, the PC first requires in-

SkySafari setup

stalling the Rainbow ASCOM driver (called Hubo-i in the drop-down driver selection list) and on the first connection, choosing the virtual COM port in the pop up properties window. The ASCOM driver is incorporated into a utility application, with slew controls, which is expanded to show more information and controls by pressing the triangle icon. This application only exits when the application that opened the ASCOM connection, disconnects and closes.

Multiple Connections

Those ASCOM drivers that can link to multiple applications are called hubs. The Rainbow ASCOM driver is a hub, as are applications such as TheSkyX, which can link to the mount and on to guiding and capture applications. There are many possible combinations of what links to what in a communication pipeline. For the most reliable setup, several users discovered that it was better to link TheSkyX, guiding, and image capture applications directly to the Rainbow ASCOM driver, rather than link TheSkyX to the Rainbow and then the guiding/imaging apps to TheSkyX.

WiFi Operation

In the WiFi mode, the mount sets up a WiFi network, which is joined from a smartphone, computer or tablet. To join the network, select the Rainbow SSID on your mobile device's WiFi setup menu and enter the password that is displayed on the handset's **MENU/Communication/WiFi information** menu. In the mobile app, select LX200 as the telescope protocol and enter the IP address and port number in the apps setup dialog to the values shown on the handset. If you now connect to the telescope within the app, the cursor then aligns with the telescope position and its goto and slew controls work.

Linux

The equivalent of ASCOM on the Linux OS is INDI (and INDIGO). It consists of several distinct program types, clients, servers and device rivers. A client is typically the high-level imaging application or planetarium and communicates through an INDI server which is the central hub for communi-
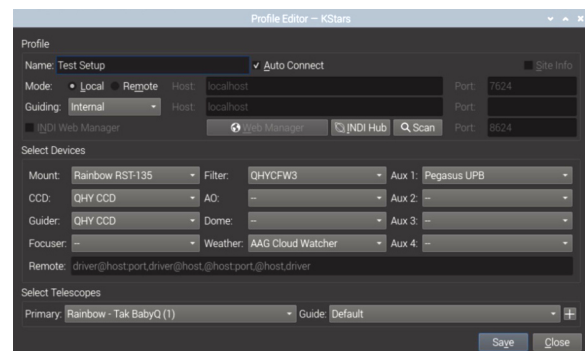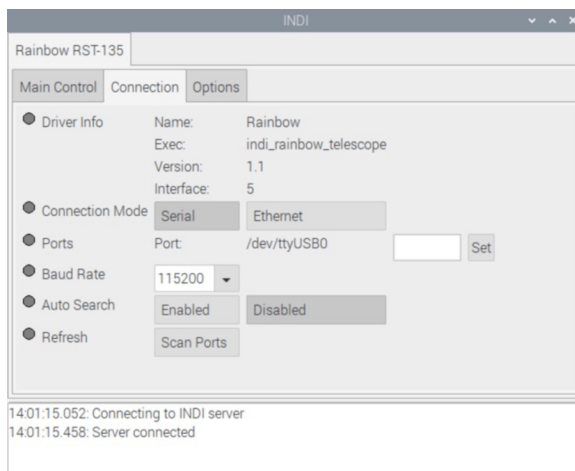
Linux setup (INDI) requires devices to be set up on INDIserver and then the applications connect to INDIserver and pick up on the connected devices.

cation between clients and device drivers and which permits local or remote operation. For the Rainbow mount, the INDI library, installed with Astroberry and StellarMate distros, include most of the known drivers including ones for the Rainbow RST models. These distros are for the Raspberry Pi but it is entirely possible to install the clients onto any common mainstream Linux system.

The Astroberry and StellarMate OS for the Raspberry Pi include KStars and EKOS as the imaging client applications. Other popular INDI clients are PHD2, CDC, CCDCiel, TheSkyX, ASTAP, HNSky, and Stellarium. To set up the Rainbow mount, you need to select the driver in the INDI server utility, start the server and then connect to it from your client app(s).

For example, to start INDI server to run the a Rainbow mount (confusingly called telescopes) on localhost and listening on default port 7624, type:

$ indiserver indi_rainbow_telescope

Alternatively, run the graphical application INDIstarter to bring up the INDI server control panel and "Add driver", selecting one of the Rainbow mounts.

Then press start and wait for the indicator to turn green. You can then click on INDI client and select the Rainbow tab and adjust the connection details and options (which details telescope and dome information). In the client application, you connect to the server and it should populate the appropriate device in the selection box. With the sever running, you can alternatively run the imaging applications on a tablet or PC and connect remotely, which boosts the overall performance and reduces lag when running on RPi computers.

The EKOS/KStars applications are not the easiest on a small screen. If imaging is your thing, it is worth trying out the established CdC planetarium and the more recent CCDCiel, from the same author (and both shareware). These now work on multiple platforms (including Macs) and can then connect to the physical devices over Ethernet.

Linux Capabilities

Linux has a different set of standardized commands and this section is missing a review of what they are and what is missing

Alignment

Polar Alignment

Polar alignment is the never-ending saga of ingenuity and endeavor! Before discussing various methods, it is an idea to put the effects of poor alignment on tracking and pointing into perspective.

Polar Alignment and Drift Rate

Drift is a consequence of the RA axis not quite being aligned with the celestial pole, and nearer the horizon, the effect of atmospheric refraction. There is also no such thing as perfect polar alignment. For instance, in TheSkyX, which has one of the best sky modeling suits available, after a 400-point TPoint model, it presents multiple alignment options, which vary in altitude by about 2 arc mins to optimize field rotation or drift in one or both axes. It is interesting to compare that with a QHY PoleMaster or SharpCap Pro (which achieve sub-arc minute accuracy) or a calibrated polar scope (which, with care should get within 2 arc minutes).

To put drift into figures, if we assume fair, good, and excellent alignment errors as 5, 2, and 0.5 arc minutes, the worse-case drift for a 5-minute exposure are 6.5, 2.6, and 0.65 arc seconds respectively. In context, the tracking error of a non-encoder RST-135 may be as high as 50 arc seconds, over the same period, and, given that it is essential to use an autoguider for imaging, the drift error is insignificant. An online calculator can be found at: *http://celestialwonders.com/tools/ driftRateCalc.html.*

Lastly, a polar alignment error that causes a slow drift in DEC may be an advantage for autoguider algorithms.

Polar Alignment and Pointing Accuracy

Polar alignment errors translate into initial slew errors, adding to those caused by time and cone angle errors. If all of these are already in the ballpark, for imagers, the required target will likely be in the camera view after a slew and accurate centering is achieved using one of the plate-solving centering methods found in nearly all image capture software. (Keeping in mind the tracking error of the non-encoder Rainbow also translates into a pointing error, if one is using a plate-solving technique to center a mount, it is best to avoid

a very small error threshold.) For imagers, after doing an initial accurate polar alignment and providing one can reproduce the mount positioning fairly accurately when it is re-assembled in the back yard, it is entirely feasible to bypass additional polar alignment and just center the target with plate solving. On Rainbow mounts, this works best if you use the two-bolt rather than the central-bolt fixing to the tripod/pier.

Polar Alignment Methods

There are several methods for polar alignment, all benefit from an initially reasonable accuracy, within a degree or two, using a compass and inclinometer. These are polar region star alignment, sky modeling, and drift alignment.

Polar region star alignment is the concept behind QHY PoleMaster and SharpCap Pro, using imaging and a polar scope. The equivalent operations align the imaging device (centering) and then matching polar region stars to either a template (PoleMaster and polar scope) or to cataloged positions (SharpCap Pro). The beauty of these methods is that they are quick and are unaffected by tracking errors. The electronic methods should guarantee an accuracy of sub 1 arc second.

Sky Models

Sky modeling is a system that compares presumed and actual slew positions and works out a number of coefficients in a complex pointing model. The model is used to make adjustments to the slew position and potentially, with enough data, control both motors during tracking too to improve overall tracking accuracy. The more points, the more comprehensive and accurate the model. One unique benefit of this method is that it does not require access to the pole.

The model can be managed within the Rainbow handset, either visually, using easily identified alignment stars or computerized, using syncs from an imaging app. Alternatively, you can use an external modeling application, like TheSkyX's TPoint or Maxim's Max-Point. These slew to multiple points in the sky, plate solve and calculate their own pointing corrections. In either case, it takes a minimum of three, well-separated calibration points to work out the polar alignment,

time, and cone-angle errors. In common with 10Micron and Paramount systems, the Rainbow mounts will suggest an alignment correction based on turning the Alt/Az adjusters. In practice, this is less than ideal, as there is considerable backlash in the mechanical adjustment (the mount does not immediately move when you change the adjuster) which is especially true of the altitude control on the Rainbow (and other mounts). A better method, used in TPoint, is to slew to an alignment star with the polar error removed and align it with the Alt/Az knobs. (See Eureka! below.)

Internal Alignment Methods

In the handbook, Rainbow Robotics states that their internal pointing model has up to 6 terms. For all 6 terms to be in play, it requires 5 or more modeling points. (Since it does not know atmospheric conditions, it is assumed that it does not correct for atmospheric refraction.)

If you are just using the handset, follow the process below. It is always best to choose alignment stars that are 40 degrees or more above the horizon to avoid atmospheric refraction errors affecting the result and widely spaced, avoiding any directly on the meridian.

From the main screen, press **STAR** and scroll to the "Align Star" or "Guide Star" catalog and press **ENT** to select. These two catalogs are uniquely listed with their altitude and azimuth next to them, to aid selection.

1. Scroll to a suitable star and press **GOTO**.
2. On the goto menu, press **ENT** to slew, or **ESC** to change your mind.
3. After the mount stops slewing, center the star (camera or eyepiece) and hold **ENT** to confirm.
4. Press **ESC** twice to select a new star.
5. Repeat 1–5 four or five more times
6. Press **ESC** several times to get to main screen.
7. Hold **ENT** button to bring up menu and scroll down to Align angle.
8. Press **ENT** to show the 6 model terms (see opposite). The last two are mechanical errors, which only show up after multiple syncs.
9. Press **ENT** again to show adjuster knob rotation instruction.
10. Press **ESC** to cancel out, or adjust knobs and press **ENT** to confirm (mount slews to corrected position on last star and zeroes the two polar alignment error terms in the model.

① +000.521   +001.094   ②
③ +001.004   +000.166   ④
⑤ +000.220   +000.090   ⑥

① Polar alignment error: Azimuth (+ is West)

② Polar alignment error: Altitude (+ is low)

③ Right ascension error, (time/longitude)

④ Declination error (DEC and the latitude error)

⑤ DEC Orthogonal error of the OTA (degrees)

⑥ RA/DEC axis orthogonal error (mount mechanics)

An explanation of the alignment model figures in the handset

11. In the case of the Azimuth knob turn instructions, the CW/CCW applies to the right-hand knob (the left-hand knob goes in the opposite direction).

Eureka!

In step 10 above, the assumption is that the polar alignment error is removed by turning the knobs by the specified amount. Each mount slew/sync benefits from an improved model and the last slew is already using the 6 model terms to improve its pointing accuracy. When you press **ENT** to confirm you have turned the knobs, it removes the polar alignment error from the model and re-slews to the last alignment star with the assumption of perfect polar alignment. The previous issue of mechanical adjuster backlash can be side-
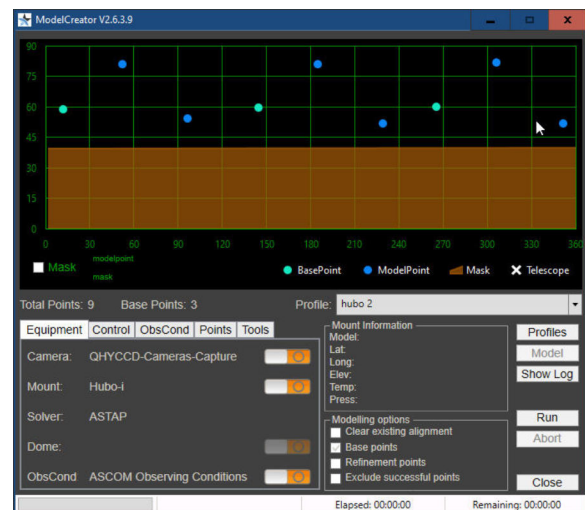
ModelCreator by Astromi.ch is a free utility that can quickly achieve multiple sync points.

stepped by then ensuring the star is centered (visually or using a looping camera exposure). If it is not, continue to adjust the Az/Alt knobs until it is centered. This is equivalent to the TPoint accurate alignment process (albeit with a less sophisticated model). It appears that this approach can also be used after a set of external syncs (see below).

Using External Syncs

The above slew/align/sync process can be automated to varying degrees by using a planetarium or imaging application to slew to different parts of the sky, take an image, plate solve and sync. For this to work, you need to open up the full Rainbow ASCOM utility screen and in the Sync box, select "Star Alignment". The imaging app needs to be set up to send sync commands and connected to the mount and camera. This makes the centering process much faster but you still have to manually control the slew and perform sync each time. For some years, 10Micron owners have used simple utilities to automate this and the company astromi.ch, which make a range of environmental sensors have a free utility program on their website that automates the slew and sync process with many common imaging apps and ASCOM. They have modified it to work with the Rainbow mount too. You need ModelCreator2 version 2.6.3.9 or later, now available from the astromi.ch website's download page.

This Windows app can either call upon imaging applications to supply data or directly access the camera, plate solve and slew/sync the mount to entirely automate a sequence of slew/sync commands. Again, it requires the "Star Alignment" option enabled in the Hubo-i ASCOM driver. It is also much easier to visualize and optimize the target spacing using this utility.

Accurate polar alignment may follow; having completed the syncs, slew to a prominent star using the handset (as before). Press **ESC** until you get to the main display, then hold **ENT** and select the "Align angle" menu, press **ENT** to show the knob changes, (ignore them) press **ENT** again for the mount to remove the polar error terms and re-slew to the star. Now use a camera exposure loop to center the star using the mount's adjuster knobs.

External Modeling Applications

The Rainbow mount is limited to just 6 basic modeling parameters and has a simple dual-axis tracking mode which is useful for visual astronomy and improving pointing accuracy to a fair degree. It is not necessary if you are guiding and potentially makes tracking worse. This is enabled with the "Drift Correct" option in the **ALGN** menu. External pointing models, such as those in TheSkyX and MaxPoint are more complex and precise. TheSkyX, for example, can measure 400+ points and create a very sophisticated model, with 25+ parameters and, to some degree, remove cyclical gear errors too. Its advanced polar alignment process, which is run after the model has completed, is extremely accurate and ideal for observatory setups.

With these applications, the mount does not want to receive sync commands and create its own model; to stop this from occurring, open the Hubo-i ASCOM utility and check the 1-Star Sync option. In practice, a xxx-point TPoint model in TheSkyX, achieved an RMS pointing error of ~30 arc seconds, a good result, considering the cyclical tracking error. TPoint is particularly good at modeling, as it initially uses all points with equal weighting and after sufficient points, it iteratively works out a super model, which as part of the process rejects outlier sync values. (On a Paramount MX, RMS pointing errors of 4 arc seconds are routine.)

(Multi) Star Alignment

The modeling process described above, which measures polar alignment and suggests corrections, also accounts for errors in RA and DEC, caused by cone angle errors on the telescope as well as clock inaccuracies. The corrections are automatically applied to subsequent slew/goto commands and if there are sufficient measurements to work out all 6 model parameters, the mount will also track on both axes. To enable this, press **ALGN** and scroll down to "Drift Correct". Press **ENT** to toggle on and off. In common with many other mounts, a minimum of three-star synchronizations is required for simplistic alignment.

If the mount is permanently set up, it is useful to save the alignment data and re-use it next time. By default, the mount forgets the model data when it is switched off but there is an option to store it. To do this, hold **ENT** and scroll down to "Auto Res." Press **ENT** again to toggle the option on and off. If you wish to delete the alignment data, disable Auto Res.(ume) and turn the mount off and on again.

Homing and Offset Calibration

The mount's home position is defined by two position sensors, one on each axis, and a software-applied offset,

The bubble level on this digital level has markings for 0.033°

to move the mount so it is pointing Alt 0°, Az 270° (for positive latitudes). It has nothing to do with time or location and is simply a mechanical reference point.

The Importance of Homing

When the mount switches on, it does not know where it is pointing and assumes it is in the home position. For that reason, it is a good idea to switch the mount on and off with it in the home position. That is not the whole story, however, since the axes can rotate when they are unpowered. For this reason, at the beginning of any session, it is a good idea to home the mount before doing the first slew. For info, ASCOM has a telescope home command and it is implemented in the Rainbow ASCOM driver and is scriptable too, if you do not wish to use a handset.

The physical sensor positions vary slightly between units and it appears that the manufacturing setup assumes a constant offset for each axis (i.e. the units are not calibrated.) The tolerances appear to be small, under a degree, but it will clearly affect initial pointing accuracy. They also do not account for any slight angle in the saddle-plate assembly.

It is possible to change the offset values using the handset. When the mount is exactly in the right position, hold the **ENT** key and select "Mount Setup" and then "Offset Set" and hold **ENT** again to fix. Establishing this slew position requires an accurate spirit level and the intended saddle plate. (A saddle plate with straight sides makes life easier). While digital levels have 0.1° readouts, they are insufficiently accurate for this purpose but some have an additional spirit level on top, with 0.03° markings (2 arc mins), which, when used with care, have 1 arc minute repeatability.

An example is shown in the image over. The two tiny screws on the top adjust the bubble level calibration. When it is accurately calibrated and placed on a horizontal surface, it should be perfectly centered and also when turned around by 180°. The offset calibration process is as follows:

1. Fix a saddle plate to the mount.
2. Slacken the azimuth fixing bolt and side clamps and tilt the mount into the Alt/Az configuration (90° latitude) and then lightly tighten the side clamps.
3. Rest the mount on a perfectly horizontal flat surface or fix to a perfectly horizontal and stable tripod/pier.
4. Turn the mount on and home the mount by holding the **ILL** button.
5. When the mount stops moving, place the level along a horizontal part of the dovetail plate and use the *DEC* slew controls (up and down arrows) to make it perfectly level.
6. Slacken the side clamps and tilt the mount as far as possible (~0 ° latitude).
7. Place the level along a flat part of the dovetail plate and rock the *RA* axis slightly with the slew controls (left and right arrows) until perfectly level, but **do not touch the DEC slew controls (up and down arrows)**.
8. From the main screen, hold **ENT**, scroll down to "Mount Setup", press **ENT** and **ENT** again with the selector on "Offset Set." Hold **ENT** to store the new offsets in the mount.
9. Press **ESC** to come out of the menu system.

Auto Centering in Apps

SGP, NINA and many other applications routinely have automatic centering methods, which slew to a target, plate solve, "sync", and re-slew to the corrected position to perfectly center the target. The "sync" has take several forms, including sending an ASCOM sync command to the mount, or computing a local offset value in the imaging application to compute a small slew or deliberately modified target coordinate.

If you are using an external model, e.g. TPoint , it is a good idea to disable sync commands being fed back to the mount (a setting in the imaging application) to preserve the integrity of the model. The same is true if you wish to preserve the internal 6-term model in the mount. The centering routines mostly make pointing models a nice-to-have rather than essential.

Guiding

Need to add some graphics and examples.

Mount Tracking Characteristics

The non-encoder version of the mount has significant cyclical tracking error which requires guiding out for astrophotography. This is not quite like classical periodic error as it appears to change with load and orientation. It has a principle tracking error cycle of about 430 seconds (sidereal day/200), which can be as much as 50 arc seconds pk-pk. More significantly, at times, it has periods of a high rate of change up to about 0.7 arc seconds/second in some units. This mandates rapid guider corrections, in the range of 2–5 corrections per second. Few other mounts require such rapid guiding but the good news is that the Rainbow mounts behave very well dynamically to guider commands. For instance, many users employ a 100% guide rate, effectively stop/starting the mount, to good effect. Slower guide rates, coupled with longer guide exposures will struggle to keep up with tracking errors. The mount payload is a factor. The dynamics of moving an 18-kg mass are very different from a 1-kg camera and lens.

Evaluating Mount Tracking

The evidence suggests that the tracking performance of Rainbow mounts vary with unit and loading. Before attempting any autoguiding, it is a good idea to see what it does, without guiding. One way to do this is to use an autoguider application, such as PHD2, as a measurement tool:

1. Clear out any tracking models in the Rainbow and accurately polar align the mount. Use a guide scope of about 200-300 mm focal length.
2. Open PHD2 and calibrate the guide system, near the meridian and at a low declination.
3. Choose a bright guide star and use a short guide exposure (0.2 seconds) for the calibration process, to minimize the effect of any periodic error on the calibration results.

4. Once complete, disable the guider outputs (in the "brain"), select a star about half an hour before the meridian, and near DEC = 0
5. Increase the guide exposure to about 2 seconds, set PHD's vertical axis to +/-16px and the horizontal axis to 400,
6. Start the autoguider and record the tracking error for 15 minutes.
7. Analyze the results, in particular, the steepest slope on the RA axis, in arc seconds/second
8. Try an autoguider exposure that is about 0.3/R to 0.15/R the arc second value, in seconds. E.g. for a maximum error rate of 0.5"/second, choose 0.6–0.3 second autoguider exposure.

Autoguiding

The Rainbow mount responds equally well to guide signals on its ST4 interface or ASCOM-based pulse guiding (Does Linux support pulse guide?). It is probably best to disable drift compensation option in the handset before trying to guide as the two "corrections" may interact in an unpredictable way. Both guide signals are based around time; that is, a guide command is a combination of the guide rate (set in the mount) and a duration, supplied by the autoguider system. A long pulse of slow guide rate is equivalent to a short
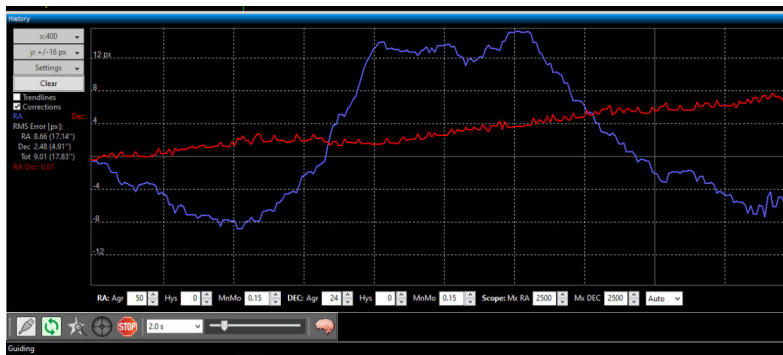
The tracking error from PHD2 (with guide outputs disabled) shows the mount's characteristics. The peak-peak value is less important than the rate of change, which influences PHD2's filtering settings and exposure duration. This mount guides well and achieves good RMS errors of about 0.5".

pulse at a high guide rate. A discussion on guiding any mount is never as simple as plug-in values, Even it did, the user would learn nothing and it is sometimes better to understand the complex interaction of hardware and software and respond to problems with an informed guess.

One approach to guiding is to start with a basic premise and then modify it to suit. Generally speaking, short guide exposures are more likely to be affected by astronomical seeing. Multi-star guiding, over a wide field, is less susceptible. Longer exposures give greater confidence of tracking error, permitting a higher aggression setting, but again, less reactive.

As with many mounts, RA and DEC guiding settings are very different on account of the fast-moving tracking error compared with slow drift. The Rainbow mount has low backlash and is very sensitive to DEC corrections. (It is apparent that the DEC guide trace is smoother without guiding than with, even with small corrections, probably a result of the issues with rapid reversals of a large mass,)

Guiding is always a compromise between over-reaction and too little, too late. Since the mount responds well to aggressive guide rates, the traditional penalty of chasing the seeing appears to be less relevant. Suggested starter values for PHD2, using hysteresis algorithm and a 0.8x guide rate are 70% aggression and 10% hysteresis (RA) and much lower aggression and higher hysteresis for DEC, depending on load. The latest PHD2 versions include a predictive PEC guide algorithm for RA. Suggested settings include the 430-second cycle time and the default settings for the contributions of PE and real-time measurement error. With these settings, the guiding performance should improve slightly after about 15 minutes (depending on the number of PE cycles it optimizes over). It is also worthwhile enabling multi-star guiding if you are using a guide scope, but less advantageous with off-axis systems, as the stars in the field of view are similarly affected by seeing.

Min Move or No Move At All

One has to be careful with the min move settings. In PHD2, the min move value is the minimum guider movement command, in guider pixels. This is not the same as the minimum error. If the value is too high, it locks in a large tracking error. For example, a min move value of 0.2 pixels, with a guide aggression setting of 50%, will not react to a computed tracking error of 0.39 pixels, but will to 0.4 pixels. The best min move value changes with the optical configuration too, both in terms of pixel scale and focal lengths. If the guide and imaging camera have similar pixel sizes, but the imaging telescope has 4x the focal length, the guider will not react until the guide error is 1.6 pixels. Generally speaking, the best min move value is smaller for a separate guide scope than it is with an off-axis system.

PHD2 can detect star centroid errors of about 1/10th pixel, and a low aggression rate may try to issue a smaller correction still. A combination of a small min move value, however, with other guiding parameters may not move the mount at all, on account of incredibly brief guider commands.

The guider pulse width T (seconds) is given by the following equation, where A = aggression, E is computed tracking error (in arc seconds) and G is the guide rate:

T=A x E / (15 x G)

For example, at a guide rate of 0.8x, an aggression setting of 0.5x and a pixel scale of 1"/pixel, a 0.2-pixel error will only trigger a 4 ms guide pulse. A 8 ms movement of a 10-kg mass is unlikely to have much effect and it may be seen that several guide pulses are issued, without any apparent effect on tracking. The old Meade LX200 mount would not react to anything less than 50 ms. The Rainbow mount is much lighter and more nimble, and suggest 15 ms as a minimum working value.

Assuming 1"/pixel imaging scale, working backward, if the min move was 0.1 pixels (equivalent to AxE), then the guide rate would need to be 0.5x or less.

It might be useful to make a spreadsheet that allows one to plug in the imaging and guider characteristics/settings to warn of over and under correction.

Comparing Guide Settings

The RMS tracking errors in PHD2 are often quoted as a measure of goodness. The RMS value, however, is affected as much by seeing conditions as it is by the underlying tracking error. A guide star's centroid position is less affected by seeing in a long exposure. As a result, it is easier to compare autoguider settings if they share the same exposure time.

Secondly, the RA tracking error (arc seconds) is affected by its declination. For example, in the system above, a 1-pixel error at DEC=0° has a 1 arc-second error in RA. At DEC=60°, the same pixel error is caused by a 0.5 arc-second error. It is best to make comparisons using the same declination in each case.

Alt-Az Operation

Need someone to check this entire section and suggest other best practices.

Alt-Az "Modes"

There are two confusing Alt-Az "modes". One assumes the mount is in a conventional GEM alignment, pointing to the celestial pole, the other with the RA axis pointing straight up and with the mount rotated 90° CCW on the tripod. In the first case, the mount converts the slew controls into a combination of RA and DEC motor movements, so it "behaves" like an Alt-Az mount. In the second configuration, the four slew controls simply move one axis, as in a conventional Alt-Az mount and tracking uses both axes. To add to the confusion, these are further compounded as the main turn-on display refers to Equatorial and Alt-Az "mode" when in it should say "config".

Alt-Az in Equatorial Configuration

This hybrid mode is an enigma. To set it up, orientate the mount in an equatorial configuration and align to the celestial pole as normal. If the main screen says the mount is in "Alt-Azimuth Mode", hold **ENT**, scroll down to "Mount Setup.", press **ENT**, select "Mount Config." and press **ENT.** Now hold **ENT** to allow you to enter "0" to replace the "#" in the menu for "Equat" configuration and press **ENT** to save. Press **ESC** to come out of the menu system, home the mount (hold **ILL**), switch the mount off and then on again.

You need to now tell the mount to behave like an Alt-Az mount. First, press **ALGN**, select "Drift Connect." and if it is set to "off", press **ENT** to turn it on, which enables two-axis tracking.

If you do not turn on "Drift Correct *and* Equatorial Mode, the final menu setting is blocked: Now press **ESC** to get back to the main screen and then press **Menu**, select "Drive", press **ENT**, select "AltAz Mode", press **ENT** (no beep), and **ESC** twice, to exit the menus. You do not need to turn the mount off and on again. If you use the slew buttons, both axes move, but tracking principally uses one (as the mount is still polar aligned).

Conventional Alt-Az Configuration

A second, true AltAz configuration, has the mount set at 90° latitude. In this configuration, without any celestial pole reference, the mount needs to be perfectly horizontal and aligned to the meridian. In this configuration the mount itself is rotated 90 CCW, so that in the home position, the saddle plate is on the EAST side (in the northern hemisphere), pointing South.

First, to ensure the mount is perfectly at 90° latitude, place the mount on a flat surface and use a set square or try-square to confirm the saddle-plate surface is perfectly orthogonal to the mount base. Second, level the support as accurately as possible (e.g. use the bubble level shown previously). You should be able to achieve an accuracy of 1 arc minute.

If not already, put the mount in Alt-Azimuth Mode: (a.k.a. Alt-Az configuration). From the main screen, hold **ENT**, scroll down to "Mount Setup.", press **ENT**, select "Mount Config.", press **ENT** again and then hold **ENT** to allow you to enter "1" to replace the "#" in the menu to select "AltAz" configuration. Press **ENT** to save. Press **ESC** to come out of the menu system, switch the mount off and then on again and home the mount (hold **ILL**). Set up the time and location using the internal GPS or manually, as before.

Setting Azimuth

As an optional step, to reduce the initial azimuth error to something manageable, one can adjust the azimuth knobs to align to a known object, either in daylight or at night. Whichever method you choose, first rotate the mount so the saddle plate is in line with the meridian, using a compass (or smartphone) as a guide. If you are using a compass, check that it is set up for the correct magnetic declination. (Reference: *https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml*)

Daylight Azimuth Initial Adjustment

It is possible to use the Sun as a reference to set up the azimuth. To remove all risk of something nasty happening, take everything off the saddle plate. Next, set up the mount's location and time using the GPS system (or input manually). Slew to the Sun and adjust the Az-

imuth knobs until the Sun grazes the saddle plate. It should be possible to get both Altitude and Azimuth within a degree with a little care.

### Nighttime Azimuth Initial Adjustment

More conventionally, initial alignment is performed at night. After ensuring the mount has the right time and location, and with a telescope mounted on the Rainbow, slew to a prominent star in the handset catalog and center it as best as possible using just the Azimuth knobs. If you mount is perfectly level already and you use the latitude adjuster to center the star, it probably make the altitude error worse for other stars. Both this and the daylight adjustment are optional, approximate alignments. If greater accuracy is required, a pointing model is required.

Home Position Adjustment

The home position offset calibration for Alt-Az operation is the same as for the GEM configuration, and is discussed earlier. For clarification, homing has nothing to do with time and location. Homing is simply a reference position, with a fixed offset from physical sensors on the DEC and RA axes (similar to the system used in Paramounts). For that reason, it does not matter if homing is done before or after GPS time setting (or manual time/location setting) but it is advisable to home the mount each time you turn a mount on and before the first slew.

Improving Alt-Az Alignment

With the mount roughly aligned in altitude and azimuth, to improve alignment further requires several star syncs to build up a sky model. Just as in the GEM configuration, it takes at least five well-spaced synched points around the sky. Following the same cycle of slew/center/sync, described earlier, it should be possible to build up a 6-term pointing model, as before.
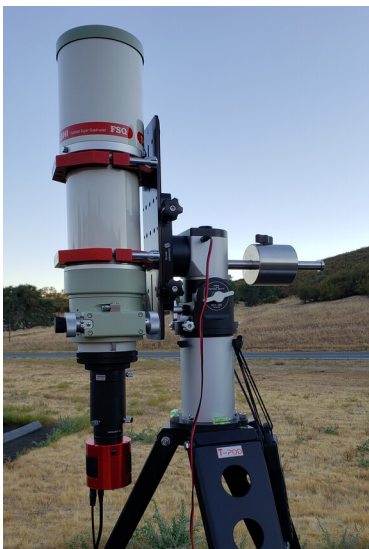
Alt-Az Best Practices

- Test that your telescope/camera setup does not run into the tripod legs when pointed at the zenith. Longer tube refractors may run into the tripod if the mini-pier extension is not used. Allow for clearance by adjusting your dovetail plate in the saddle, moving the tube assembly forward. (See image.)
- It is entirely possible to do short exposure imaging in Alt-Az. Short exposures work (15"), but avoid imaging within 15 degrees of the zenith, field rotation is the worst at the zenith and stars will show trails. Sharpcap does a very nice job aligning and stacking short exposures.
- As noted, precise level is important. Use leveling feet for your pier or tripod. This makes leveling more precise and less time consuming when fussing with tripod legs in the field.
- Use the counterweight for tripod and/or pier stability when using a heavy telescope.

Miscellany

Meridian Flips and Limits

The slim dimensions of this mount make it susceptible to telescope-leg clashes. Pier extensions help but a bulky filter wheel or an off-axis-guider can still easily hit the slimmest of piers, if the mount is allowed to go too far past the meridian. The mount can set upper and lower declination limits as well as a meridian limit. Tracking stops at these limits.

Setting Mount's Limits

The three limit settings in the handset are in integer degrees (not to be confused with the time settings found in some imaging applications). Press **MENU**, scroll down to "Limit", press **ENT** to select and hold **ENT** to modify values. Press **ENT** to confirm.

The upper and lower limit settings apply to GOTOs and tracking, whereas the meridian limit only applies to tracking. If you GOTO something slightly beyond the meridian limit, the mount will flip. The meridian limit refers to degrees in RA, not Azimuth. As a result, the azimuth value for the meridian limit changes with declination. It is normal best practice to set the limit just past the meridian and not flip before the meridian. In that way, one does not avoid a leg clash on one side only to cause one on the other. Another suggestion is to take your worse-case imaging setup (for leg clashes) and using the hand controller, find the RA limit past the meridian that allows the telescope to rotate in DEC without hitting the pier. This knowledge may persuade you to replace a bulky filter wheel with a much slimmer filter drawer! As the mount does not require balancing, it may also be possible to slide the telescope forward in the saddle plate to improve clearances. It is also a good idea to avoid making the meridian flip value exactly zero, as it may cause unexpected behavior due to variations in clock and location settings between the imaging software and the mount.

If your longest typical exposure is 10 minutes, at 4 minutes per degree, a meridian limit of 3 degrees may work for you. Whatever you choose, meridian flips can be hazardous and one should supervise the first ones to be sure everything misses everything else and be ready to hit the kill switch. The mount is very strong and it is likely to bend something if it hits a tripod.

Setting Imaging Application Meridian Flips

Meridian flips are one of the more ambiguous processes in mounts and in ASCOM. Each mount does things differently; managing a meridian flip requires knowledge of the meridian limit, where the telescope is pointing and from which side of the pier. In general, imaging apps can either trigger a meridian flip with an ASCOM SideOfPier command, or simply re-issue a slew to the current target when the mount has passed the meridian. The Rainbow mount does report SideOfPier and CanSetPierSide, but does not implement DestinationSideOfPier.

In the above example, if the meridian limit is 3 degrees, the imaging application should flip the mount before the limit is reached. For example, in SGP set the meridian limit to just less than 3 degrees at 11 minutes and enable "wait for the limit" before flipping. If a 10-minute exposure starts before the meridian, it will complete, but if SGP ends an exposure at two minutes past the meridian, it will not start the next and wait a further 9 minutes before flipping, centering and carrying on imaging.

ASCOM Limitations

ASCOM has an extensive list of methods and properties in the telescope class. Not all are mandatory and not all are implemented in the Rainbow mount. The following have been noted as useful and absent. Rainbow have been requested to implement them:

- DeclinationRate(set) (unique RA and DEC guide rate values)
- RightAscensionRate(set) (unique RA and DEC guide rate values)
- UTCDate(set) (permits external setting of date and time)
- SiteElevation(get, set). (permits external setting of site elevation)
- Add controls for the above settings in the Hubo-i ASCOM Windows application

Known Limitations

There are a few things that could be improved or added on the Rainbow:

- PEC - it is understood that if the tracking behavior is modified by balance and load, a permanent PEC is of limited use. A semi-permanent PEC, however, would be very useful. This has already been demonstrated with PHD2's predictive PEC algorithm (which is quite effective) and several other mounts calculate a PEC by monitoring the guide pulses of a few gear rotations (e.g. iOptron). PHD2's algorithm is compromised as it does not know the precise gear positions and any slew or interruption loses sync. A PEC feature in the mount is entirely feasible, which monitors guider inputs for a few cycles and continues to update itself could more easily keep sync with the rotation of its gears and any variations over time.
- Park position - it would be useful to be able to park the mount from the ASCOM driver with the telescope at DEC=90°, rather than DEC=0°.
- Home position - the home position is arbitrary, and is simply an offset from physical sensors. It would be good to have an optional home position with the DEC similarly at 90°, much easier for sliding in telescope dovetails.
- Balancing function - it is useful to know the degree of imbalance - it allows one to reproduce a set of conditions from one session to another and potentially prevent an overload indicator.
- Better power and USB connections - a locking connector for power would be useful and potentially relocate the USB to make cabling easier and less likely to drag.
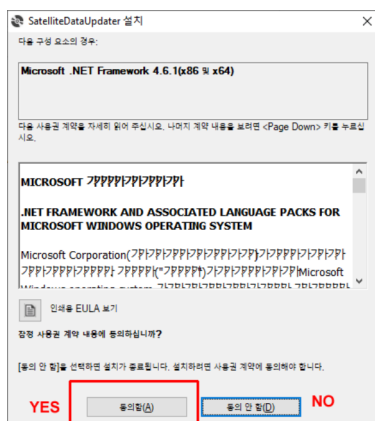
Satellites

The following is the procedure to correctly install the program for loading satellites in the keypad, and to search, select and load the data of a satellite (in the example the ISS) for automatic pointing. Please note, the update of the satellite data on the mount is possible **only** through the USB cable.

First, download the program from the RainbowAstro website: *http://www.rainbowastro.com*. At the bottom of the support/download/support page is the download link for the satellite data updater, which opens a Google drive page.

Download the ZIP file, unzip it into a folder and then run the Setup.exe program. Windows will go into panic mode, so click on "More info" and "Run Anyway" to continue. Windows will ask for authorization several times; answer yes every time. When you are shown the SatelliteDataUpdater screen opposite, press YES, as shown to continue the installation. Here, you may also have to confirm your intention to install the program several times.

The program opens up automatically. (The SatelliteDataUpdater application is found in Windows under Start/Programs/RainbowAstro/SatelliteDataUpdater and it may be useful to put this as a shortcut somewhere

for future reference.) Running the program will give you a blank screen whose operation is easier to work out:

- **Add TLE**: To add the data of one or more satellites, follow the procedure below
- **ComPort**: Select the virtual COM port to which the mount is connected via the USB cable
- **Connect:** Press Connect to activate the USB connection
- **Update Satellite Data:** Send the satellite data
- **Disconnect:** close the connection
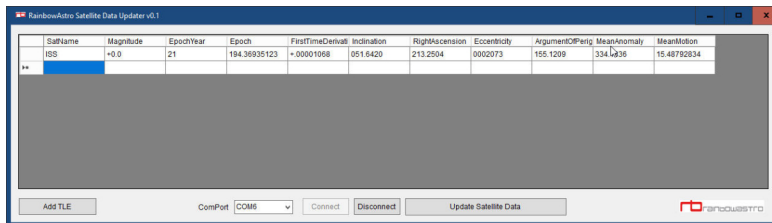
Loading Satellite Data

Loading satellite positions and trajectories on the mount requires sending a series of "numbers" which can be easily found on the website:

https://www.heavens-above.com/

Before starting it is FUNDAMENTAL to indicate your position as accurately as possible. This is made easy as the mount uses an internal GPS which can very simply provide us with the geographic coordinates: latitude and longitude, or use what.three.words.

Using the example of the ISS, first click on **ISS**, then on **ORBIT**. Look for the two lines of orbital elements under the global tracking pictures, like these below:

1 25544U 98067A   21194.36935123 .00001068 00000-0 27703-4 0 9997

2 25544 51.6420 213.2504 0002073 155.1209 334.1836 15.48792834292655

Select these two lines and copy to the clipboard (Ctrl-C). If not already running, open the satellite loading program, press **Add TLE** and paste the two lines of data (Ctrl-V).

Next, enter a mnemonic name for the satellite and preferably also today's date. (Remember, the orbital parameters of the satellites change continuously and it is therefore a good idea to download them the same day you want to do the observation.) Repeat this procedure for additional satellites, as required.

With the correct **ComPort** selected, **Connect** to the mount and press **Update Satellite Data** and then finally, **Disconnect** the mount and close the updater program.

In Operation

GOTO and satellite tracking can **only** be done in Alt-Az configuration (mode) with latitude=90°. The instructions for setting this up are in the Alt-Az section. For accurate tracking it is important to have the mount perfectly level on its tripod/pier and to do an accurate, multi-star alignment, by any of the methods mentioned in earlier sections. Next, press the **MSC** menu and select "Satellites" on the handset.

Now select the satellite by name, press **ENT** and the handset shows its position and the current (UTC?) time. Press **NEXT** to see information about each pass. Look for the azimuth for its next rise (@10°) and manually slew the telescope to zero altitude and that azimuth and wait for the satellite to rise. (Alternatively, the rise (start) times are also shown on the *https://heavens-above.com* website for each pass.) Note: The website data is in local time but the handset display may be different due to daylight saving time settings.
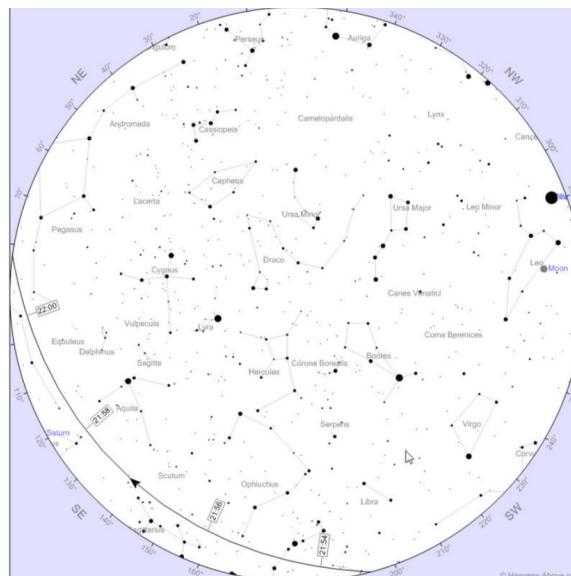
Event	Time	Altitude	Azimuth	Distance (km)	Brightness	Sun altitude
Rises	21:52:39	0°	194° (SSW)	2,358	-0.3	-5.6°
Reaches altitude 10°	21:55:45	10°	163° (SSE)	1,499	-1.5	-6.0°
Maximum altitude	21:57:10	12°	138° (SE)	1,375	-1.8	-6.1°
Drops below altitude 10°	21:58:34	10°	113° (ESE)	1,503	-1.5	-6.3°
Sets	22:01:41	0°	82° (E)	2,371	-0.3	-6.6°

When the satellite has risen above the horizon, the GOTO button will be enabled and pressing it will start tracking on the satellite. Take care as the telescope will move quickly and in an unusual way as it tracks the unique satellite orbit. If the mount was accurately leveled and aligned and if the satellite data is recent, the mount should find the satellite, center it perfectly and or track it until the satellite sets below the horizon.

At the end you can continue to use the mount as if nothing had happened, because it will not have lost the alignment caused by the movement of the tracked satellite.

Asteroids

It might be that if a source of asteroid data could be found that it might follow the satellite or comet process - work in progress.