DISASSEMBLY OF A NEXSTAR GPS-11 MOUNT

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1. **What:** In my backyard observatory, I have a stock-out-of-the box Celestron 11-inch NexStar GPS, on its standard fork mount, permanently mounted on a steel pier. A 4-inch StellarVue refractor is mounted on Losmandy rings and mounting plate, for use as a guide scope or visual 'scope. The system includes the sliding counterweight system from Starizona. Because of the mass of the guide scope, I use 6 pounds of bar-bell weights to balance the system

2. **Why:** I had begun to hear a subtle grumbling sound when I manually rotated the scope in RA, but I was fearful about digging into it because I had no idea what was inside the mount. Then I heard Tom Krajci gave a talk at the SAS-2009 symposium describing some useful performance-enhancing modifications for schmidt-cassegrain telescopes. Even though I wasn't plagued by any of the specific problems that he covered, his talk motivated me to learn about the guts of my 'scope.

Disclaimer: In this report I will describe what I did, and how I did it. It worked for me. However, I'm not a qualified telescope mechanic, and I recognized the risk that if things went badly, I'd be sending a box of parts and a fair amount of money back to Celestron for them to re-assemble. If you do any of this to your telescope, you are definitely breaking the warranty, and you are doing so at your own risk – I'm not responsible for any bad things that happen to your telescope or to you!

3. **References:** Two references describing the the NexStar's Right Ascension (RA) axis are available on the web:

- Lenny Shaffer has written a nicely-documented description of his experiences in taking the RA axis apart. It is available at http://www.lenny-shaffer.com/az_axis_disassembly.html .
- Matthias Bopp has prepared a nice report and set of photos from his experience of replacing a key component of the RA clutch mechanism – which is apparently a common weak point in the design of this mount (although I haven't had any trouble with mine). His report is available at

http://www.dd1us.de/Downloads/replace%20or%20adjust%20altitude%20clutch%201_3.pdf .
Both of these are very handy references!

4. **How – Disassembly:** Almost all of the tools that I used are common in most home garages – a set of hex wrenches (English, not metric), Phillips-head screwdrivers (small, medium, and very large), and a couple of crescent wrenches. Supplies needed are some 90% isopropyl alcohol, a small tube of LocTite or ThreadLocker, some white general-purpose automotive grease, and some small self-stick labels. The only tool that I had to buy was a 1-1/8 inch combination wrench.

Turn off the power supply, and remove the electrical power plug from the telescope before removing any of the covers.

4.1 Removing the Optical Tube Assembly (OTA): I decided to remove the optical tube assembly from the fork arms of the mount, and to do most of the disassembly of the RA axis while the mount was still attached to the pier. Partly this was motivated by curiosity – I wondered how complicated it was to remove the optical tube – and partly to make the fork assembly lighter and easier to manipulate when time came to remove it from the pier. Removing the OTA isn't really required in order to do the rest of the disassembly, but it having the OTA out of the way does make it easier to disassemble the RA axis.

First, of course, the dew shield, guide scope, finder scope, and counterweights all came off, leaving a "bare" OTA. Then, I removed the plastic covers on both the East and West fork arms, to access some important screws. There is a correct order to removing the plastic covers. On the East fork arm, there are three pieces to remove, as shown in Figure 1 – a lower piece, an upper piece, and the lifting handle. First take out the two screws from the lifting handle, and lift

the handle off. Second, remove the 4 screws holding the (long) upper plastic cover, and finally, remove the (smaller) lower plastic cover.

At this point, I started labeling envelopes to hold all of the screws that I was removing with each part, since they weren't all the same. That was probably excessively meticulous, but at least I didn't have to worry about whether I'd be able to get things back in the correct places.

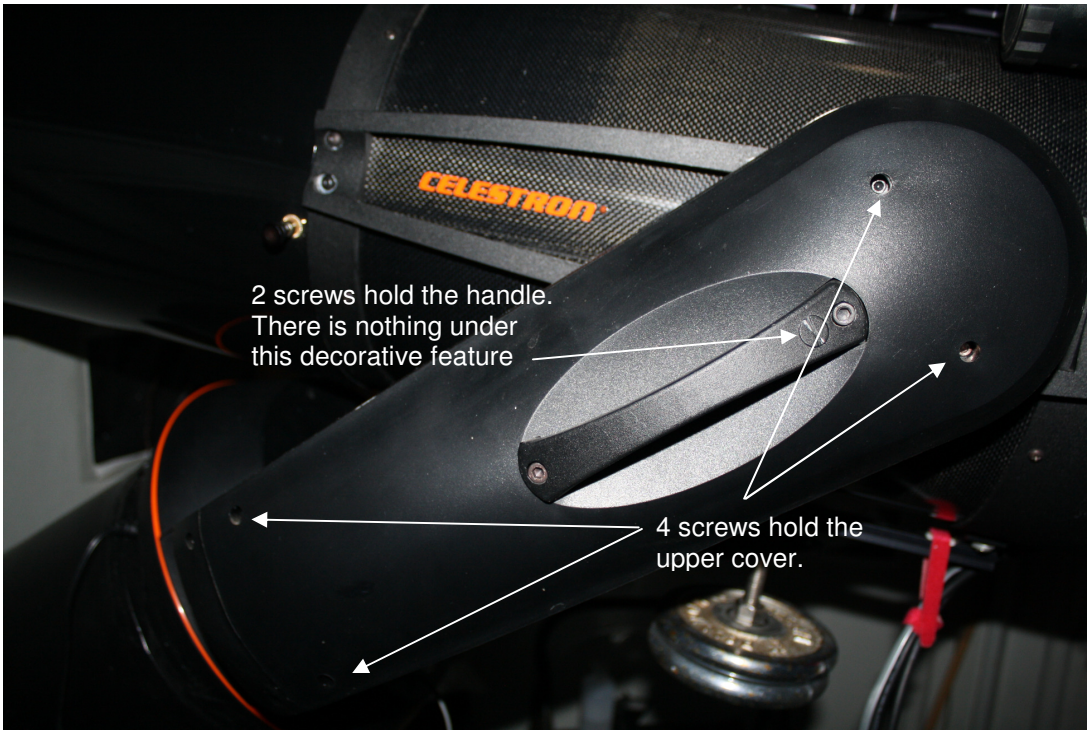

Figure 1: East fork arm

Figure 2 shows what is underneath the plastic covers on the East side fork arm. Those four large Phillips-head screws near the bottom (left in the photo) seem to attach the fork arm to the RA axis. It's worth giving them a little CCW torque at this point – not to actually loosen them, but just to break free their stiction so that they'll be easy to loosen when the time comes. I gave each one a quarter turn, then re-tightened it, and moved on to the next.

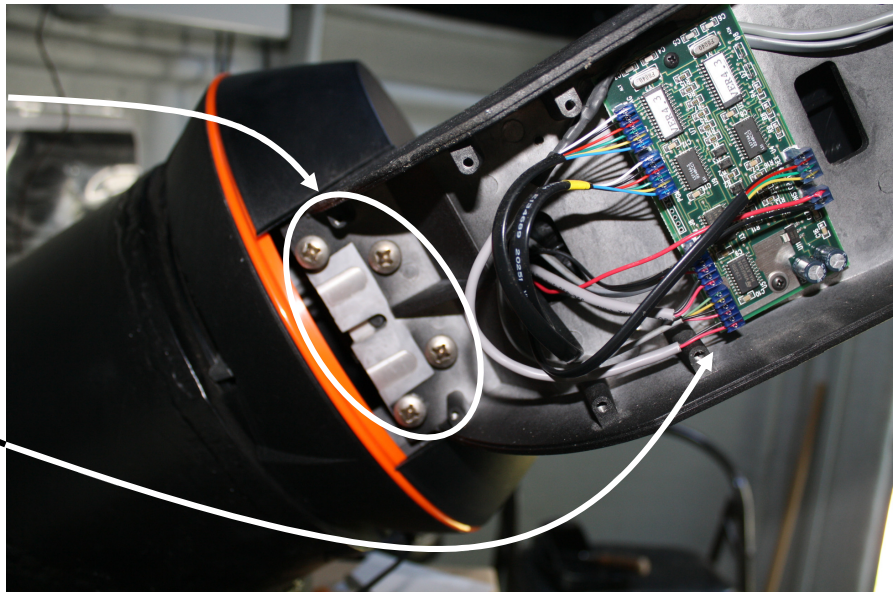

Figure 2: East fork arm (after covers are removed)

At a later step, I had to remove one of the connectors from this circuit card, but don't do so now.

Not shown, off the top right of Figure 2, is the Declination motor mechanism. You can remove the Optical tube without touching the Dec motor assembly at all.

The West fork arm is shown in Figure 3. I removed its plastic covers in the following order: first the top (long) cover, then the lifting hand grip, and finally the lower plastic cover (a U-shaped plastic piece that fits around the hand grip. The lifting hand grip is metal, and it uses button-head screws instead of the socket-cap screws that are used on all of the plastic covers.

Figure 3: West fork arm

Figure 4 shows what the West fork arm looks like with the covers removed. Note the four large Phillips-head screws at the base of the arm (lower right in the photo). As on the East arm, I gave each in turn a little CCW torque, and then re-tightened it. Breaking the stiction at this point will make it easier to loosen them when the time comes. But don't loosen them yet!

Figure 4: West fork arm after covers are removed

The Optical Tube Assembly (OTA) is attached to the Declination axis brackets by four screws on each side, as shown in Figure 5.

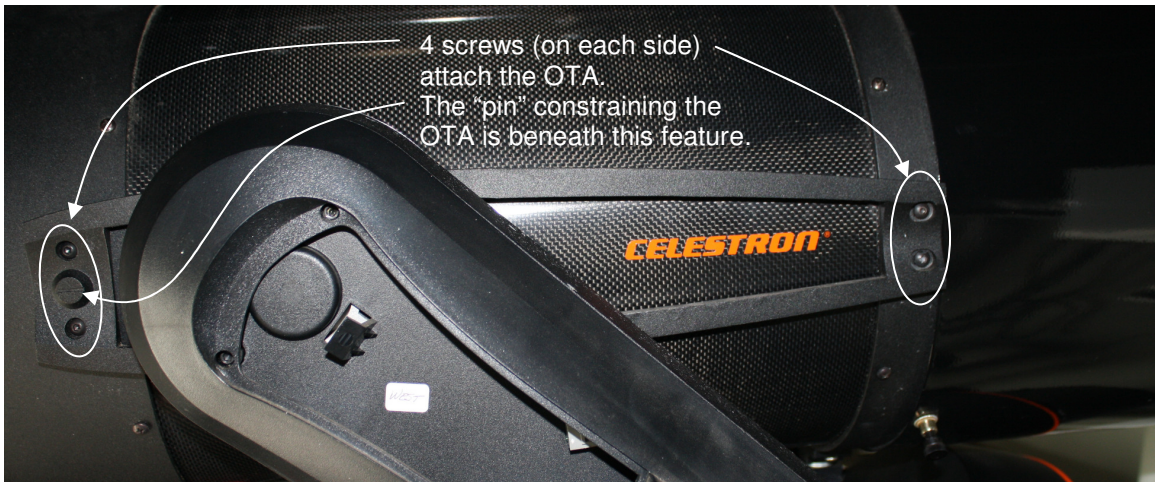

Figure 5: Bracket holds the Optical Tube Assembly

Not visible, hidden beneath the notched boss on the Declination axis bracket, is an insert that accepts an alignment pin on the OTA. Figure 6 shows one of these pins on the OTA, and the insert on the inside of the Declination bracket that accepts the pin. Each pin (one on each side of the OTA) is engaged by about ¼ inch.

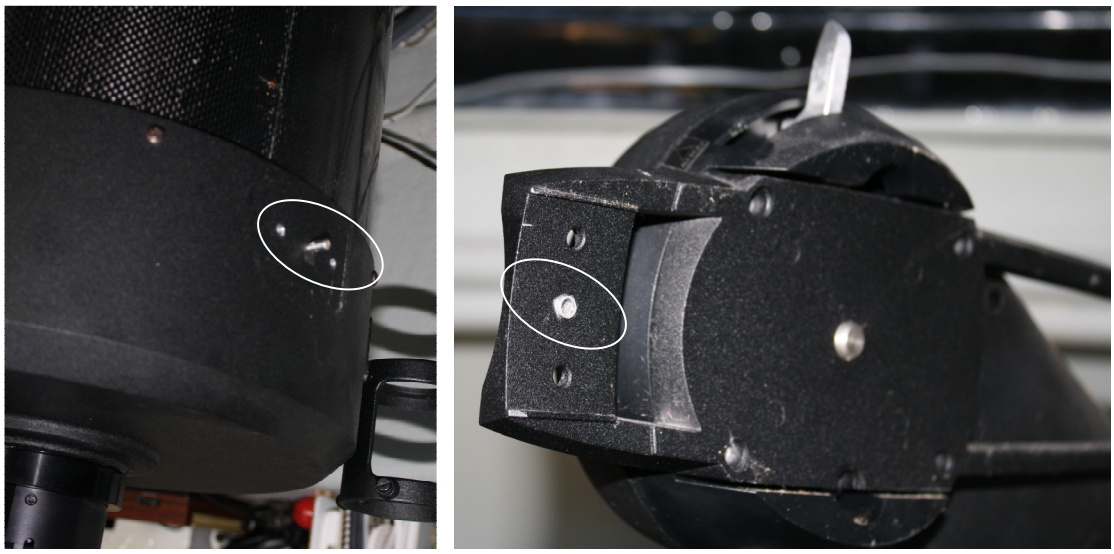

Figure 6: Locating pin on OTA and Corresponding insert on Bracket

This means that when you remove the 8 screws holding the OTA (4 on each side), the OTA won't come loose – it is still captured by the pins (one on each side). In order to disengage the pins, you loosen the 8 big Phillips-head screws shown previously in Figures 3 and 4. The idea is to spread the fork arms sufficiently (about ¼ - ½ inch on each side), that you can slip the OTA pins out of the Declination brackets. This is a two- or three-person job. With three people, it's pretty easy: I held the OTA, neighbor #1 loosened the big screws at the base of the East arm and pulled it a bit, while neighbor #2 loosened the screws on the West fork arm to spread it. Since you're trying to spread the fork arms, you need to loosen the upper screws more than the lower screws. I didn't completely remove them, so I don't know what happens if you do – I

assume that the fork arms come off, which could be a mess with all of the electronics cables that go through them (especially the East fork arm). I found that two or three complete turns each was sufficient to spread the arms enough to remove the OTA. Then I re-tightened all 8 big screws, so that the fork arms wouldn't be loose while I disassembled the RA axis.

Just for the record, the view looking at the West fork arm after the OTA has been removed is shown in Figure 7. Note that the West bracket rotates freely, while the East bracket (which is attached to the Declination motor assembly) will only rotate if the clutch is loosened. There is an inner plastic cover on the west fork arm (shown in this figure), which I didn't have any reason to remove.

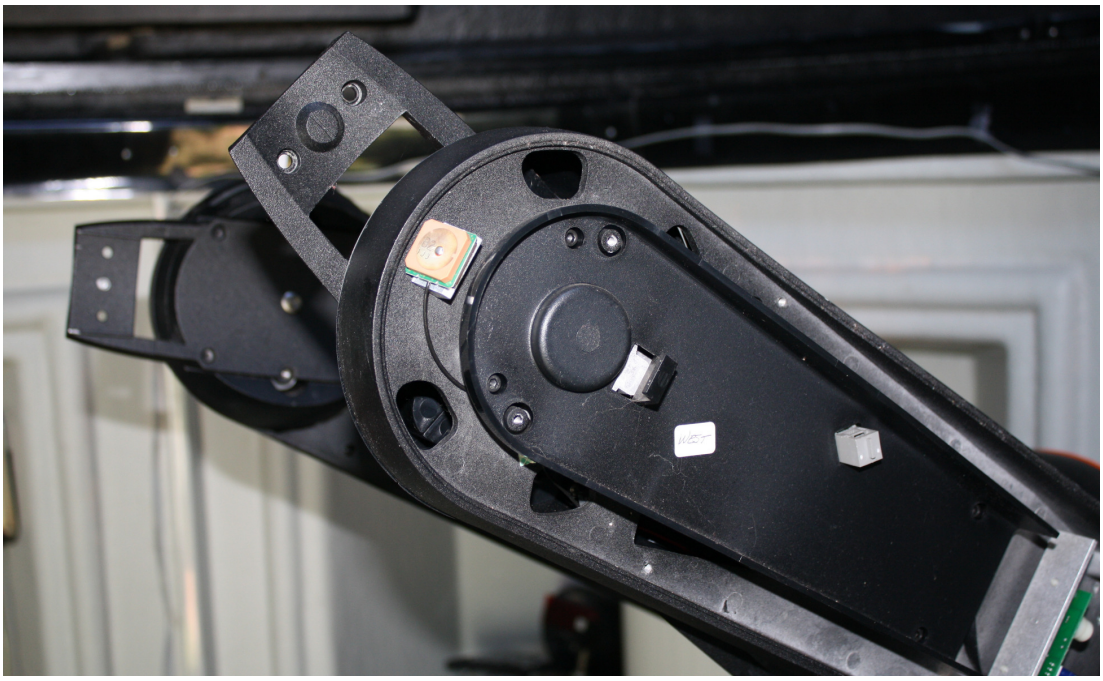

Figure 7: The OTA has been removed

4.2 Opening the control panel cover: The control panel cover is shown in Figure 8. There are five cap-head screws securing the plastic cover. Remove all of them. Note that the one at top is shorter than the other four (this will be important when you're putting it back together). With the 5 screws removed, you can lift the plastic control panel up and toward the East (left) fork arm (i.e. like a lid being opened). I watched carefully from underneath so that I wouldn't pull any wires. What you'll see at this point is shown in Figure 9.

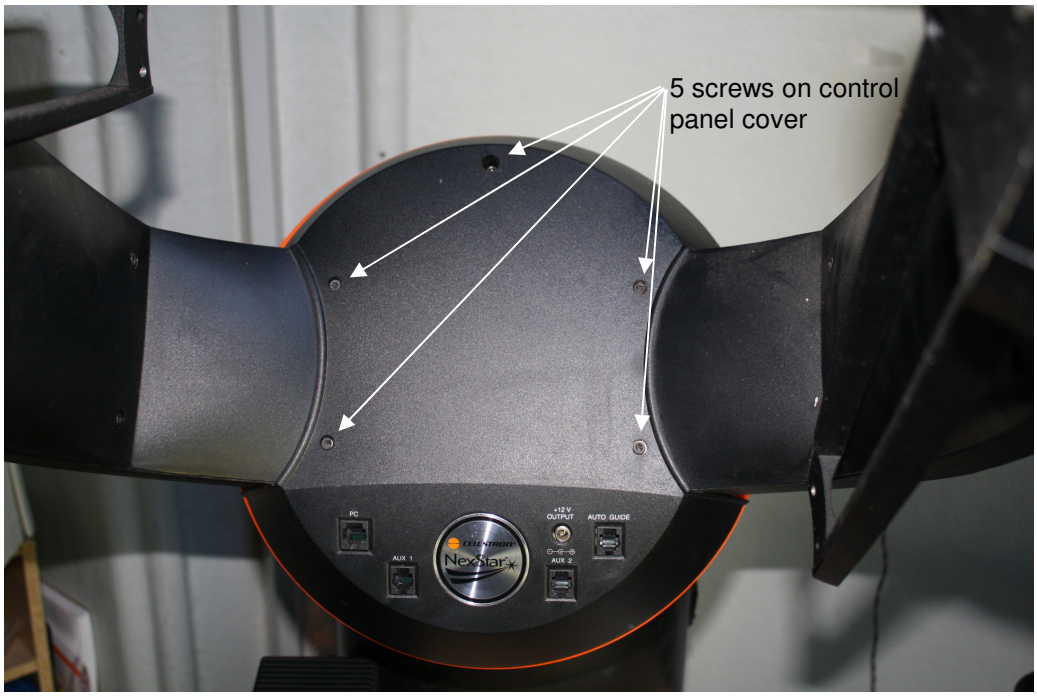

Figure 8: Control panel cover

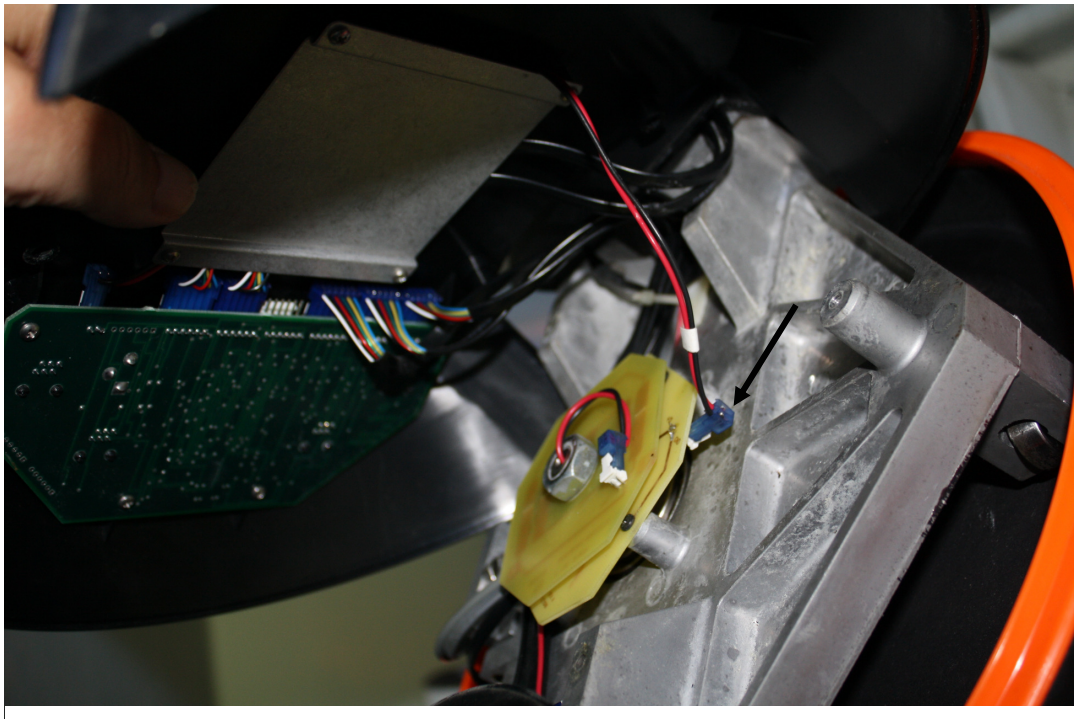

Figure 9: Underside of control panel cover

There are many cables to disconnect at this stage, so I made careful notes about which wire went where, and the orientation of each connector, *before* I removed it (i.e. which color wire was on which pin). I also labelled each cable with a sticky label.

The 2-pin connector from the lower slip ring is removed first. On my scope, this connector was at the 12-o'clock-high position, and the red wire was on the left side (toward the East fork). Check yours, and take notes!

Once the 2-pin connector was removed, I could turn the control panel over enough to get a good look at the underside, as shown in Figure 10.

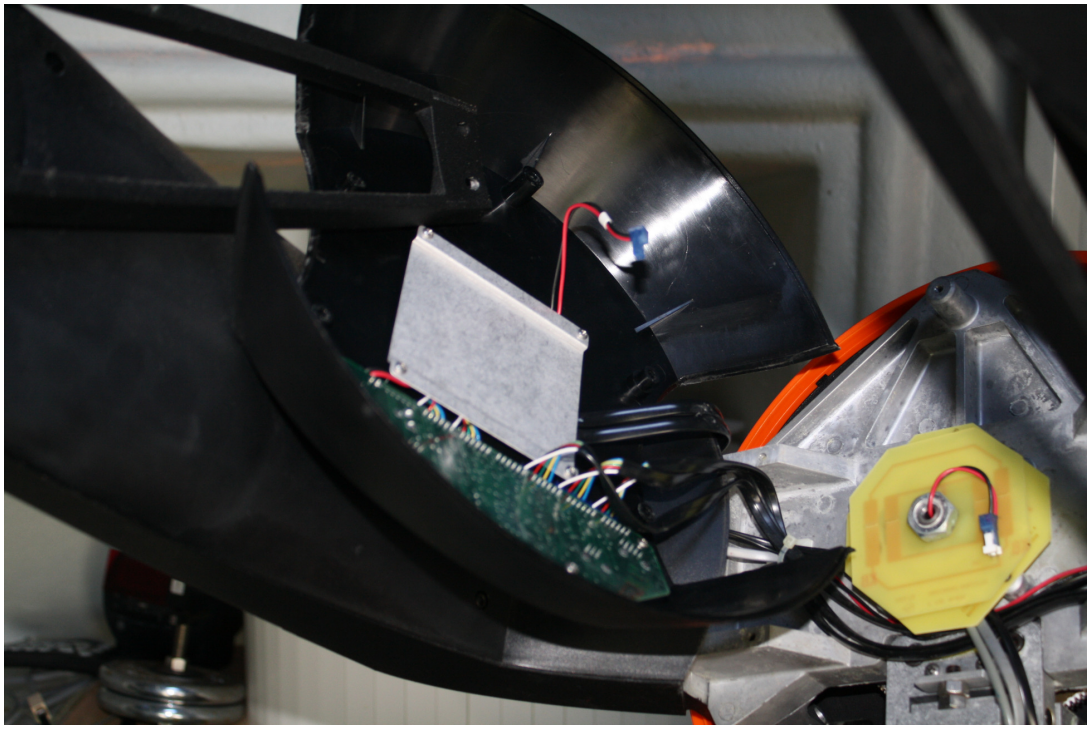

Figure 10: Control panel cover can be lifted away, after cable is disconnected from lower slip ring

A circuit board and an aluminum plate are mounted to the underside of the control panel cover. I marked each of the cables with a numbered sticky label, and made a sketch showing how each cable is mounted to the circuit board. Figure 11 shows what I saw, and Figure 12 is the corresponding sketch from my notes. Cables 6, 5, and 4 go underneath the aluminum plate. Remove this plate by extracting the 4 little Phillips-head screws, and set it and the screws aside.

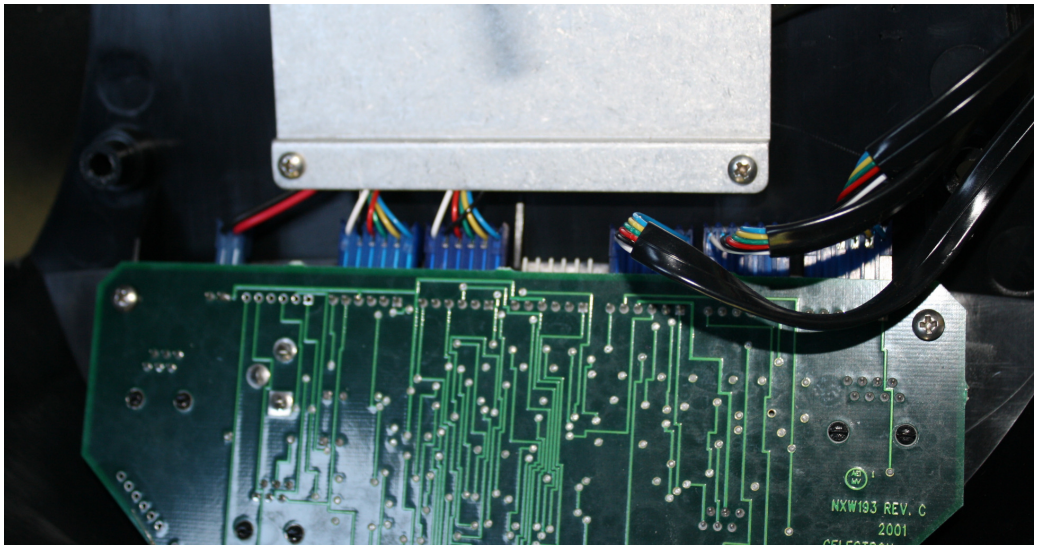

Figure 11: Connectors on circuit board (underside of control panel cover)

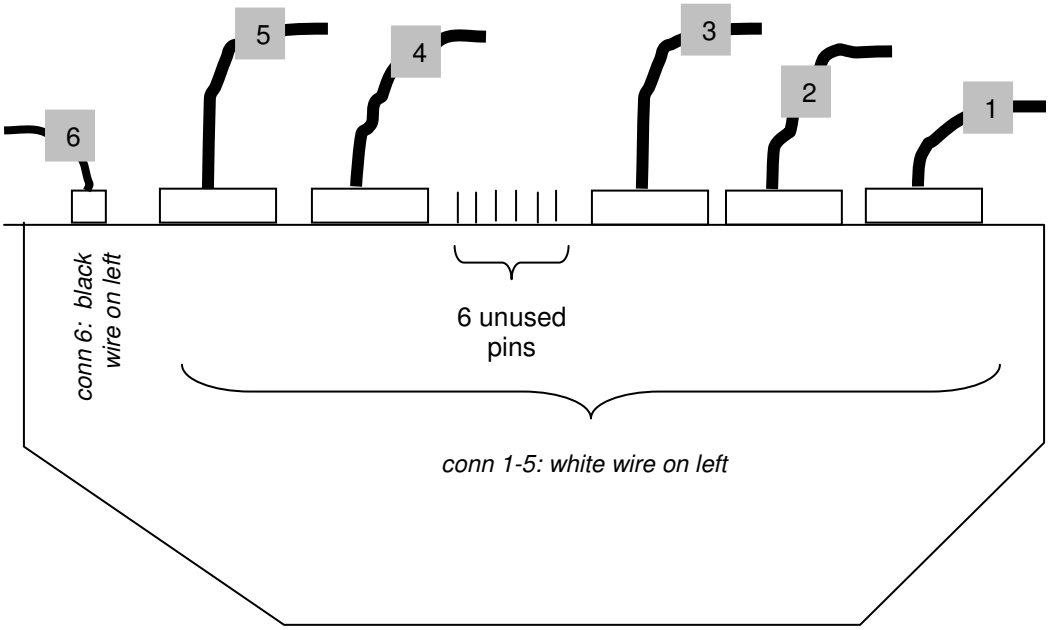

Figure 12: Add identification tags to the cables before disconnecting them!

It is very important to know to which connector, and in which orientation, each cable is connected (hence the "white wire on left" note on my sketch). If you use self-stick labels to mark these cables, make sure that they stick firmly – if you lose one, then it's simple to replace it; if you lose two of them, then ... well, don't let that happen!

Now you can disconnect cables 1 through 5 from the circuit card by pulling each one gently away from the circuit card. Grab each by the connector, not the wire bundle. Cable #6 is the cable from the circuit board to the lower slip ring (which was removed from the lower slip ring in a previous step). Hence, you can leave it attached to the circuit board.

With the cables (except for cable #6) disconnected, you can lift the control panel cover away and set it aside, as shown in Figure13.

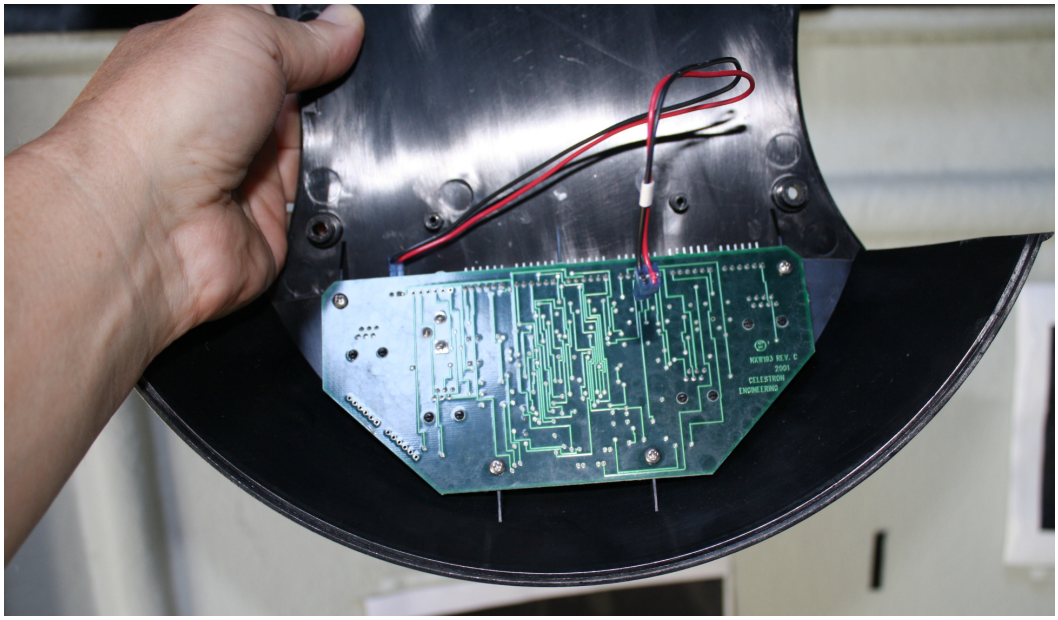

Figure 13: With cables disconnected from circuit board, control panel cover is free to be removed

4.3 Removing the Main Bearing: With the control panel removed, you have free access to the RA mechanism of the mount, as shown in Figures 14 and 15. The slip ring assembly is in the center (note the two-wire cable that passes through the center bolt and nut), and the RA drive mechanism is on the bottom of the photos.

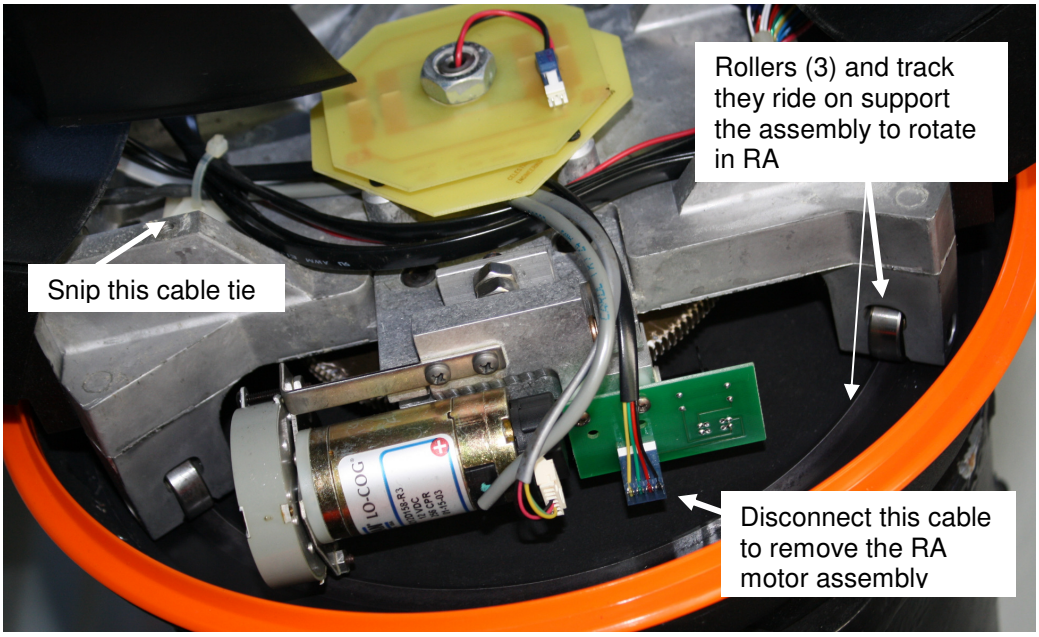

Figure 14: RA structure, showing rollers and motor assembly

Also visible in Figure 14 is a cable-tie. You'll need to snip this, to free up the cables that it holds. I didn't replace it when I put the mount back together; I just re-routed the cables so that they wouldn't get hung up anywhere as the mount rotates.

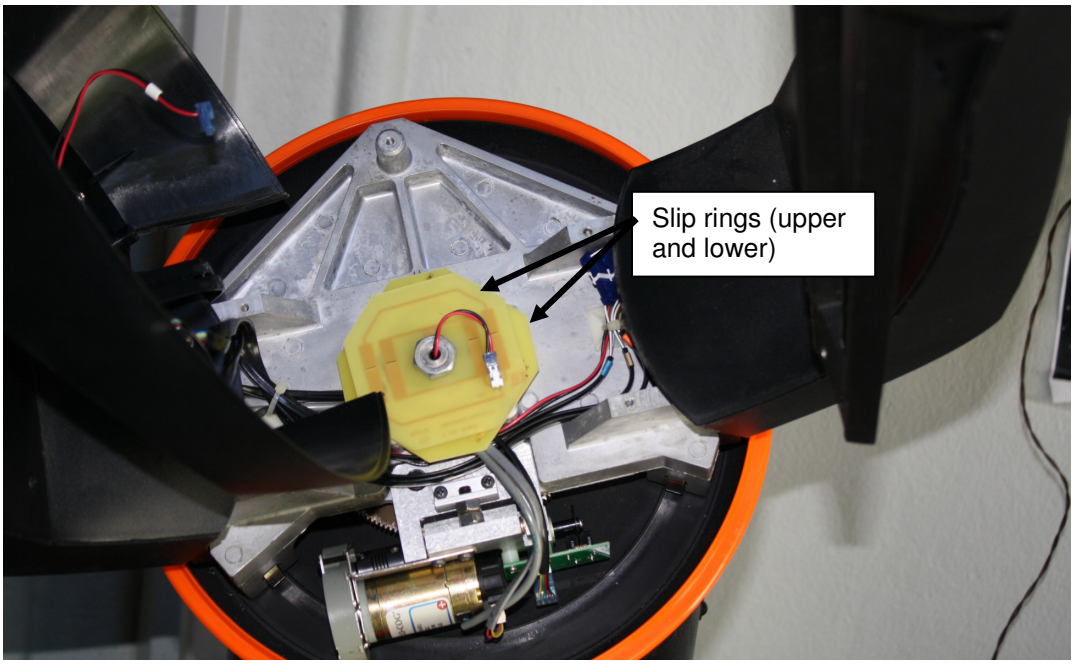

Figure 15: RA structure

I disconnected the cable from the connector on the upper slip ring (this is the wire that comes up through the center nut and bolt), as shown in Figure 15. Make a note about the orientation of the connector before you un-mate it: on my scope, the red wire is on the outside pin (i.e. radially outboard).

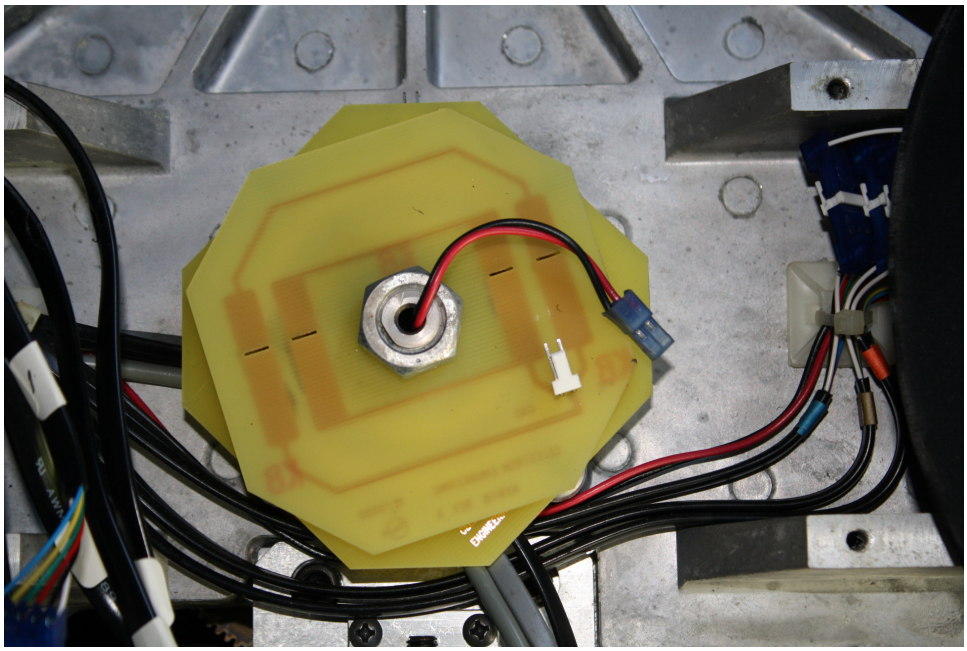

Figure 16: Disconnect cable from upper slip ring connector

I used a crescent wrench to unscrew the hex nut, being careful not to twist up the wire or scrape up the upper slip ring. There is LocTite on this nut, so it took a bit of force to loosen and remove it. I used a bath of 90% isopropyl alcohol, a toothbrush, and some toothpicks to clean the dried LocTite off of the threads of this nut, and the several other LocTited parts that were encountered in subsequent steps.

I took note of the orientation of the upper slip ring before removing it. The center bolt has a flat segment (making it C-shaped), so that there is only one way that the upper slip ring can go back on. When you remove the upper slip ring, turn it over to see the “spring” features on the copper traces that ensure electrical contact with the corresponding traces on the lower slip ring, as the mount rotates.

With the upper slip ring removed, the lower slip ring and its 4 mounting screws is visible, as shown in Figure 16. The orientation of the lower slip ring is established by the “12v” and “Gnd” labels (on my ‘scope they are on top, opposite to the RA motor assembly). After removing the four little screws (which also seem to have a little LocTite on them, hence needed a fair bit of force to loosen), I lifted off the lower slip ring. Note that the two grey wires and one black wire are routed beneath the lower slip ring – this was useful to remember when I was putting everything back together.

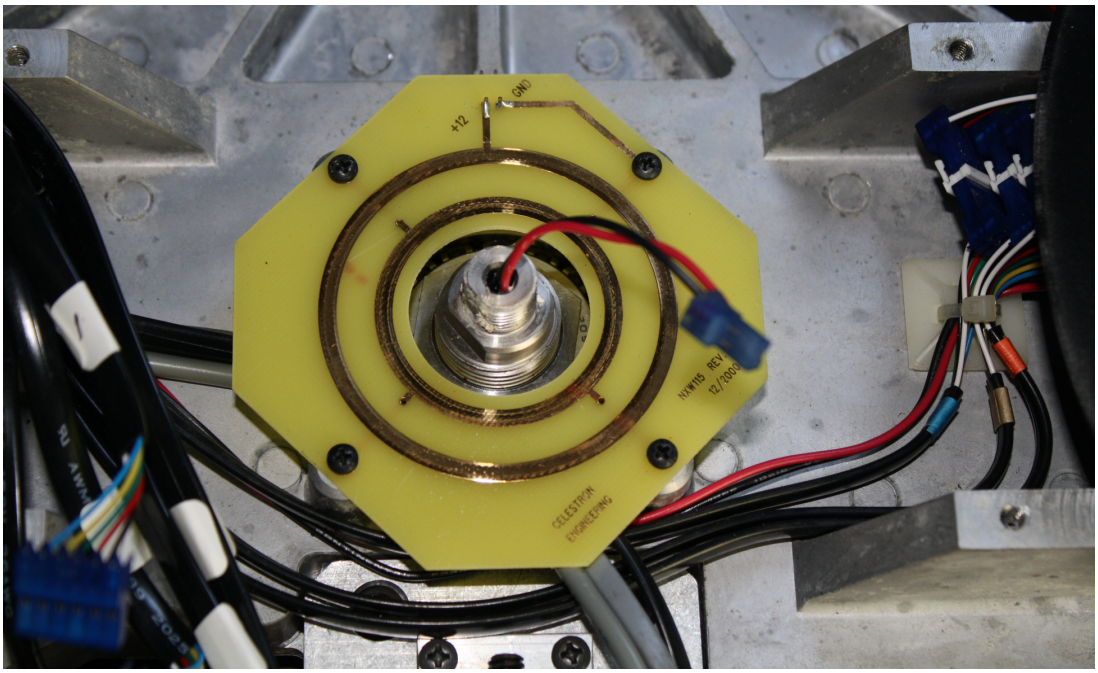

Figure 17: Lower slip ring is visible after upper slip ring has been removed

Lifting the lower slip ring off reveals the main bearing and its holding nut, as shown in Figure 17. Before attacking that nut, two preparatory steps turned out to be needed: getting some cables out of the way, and removing the RA motor drive assembly.

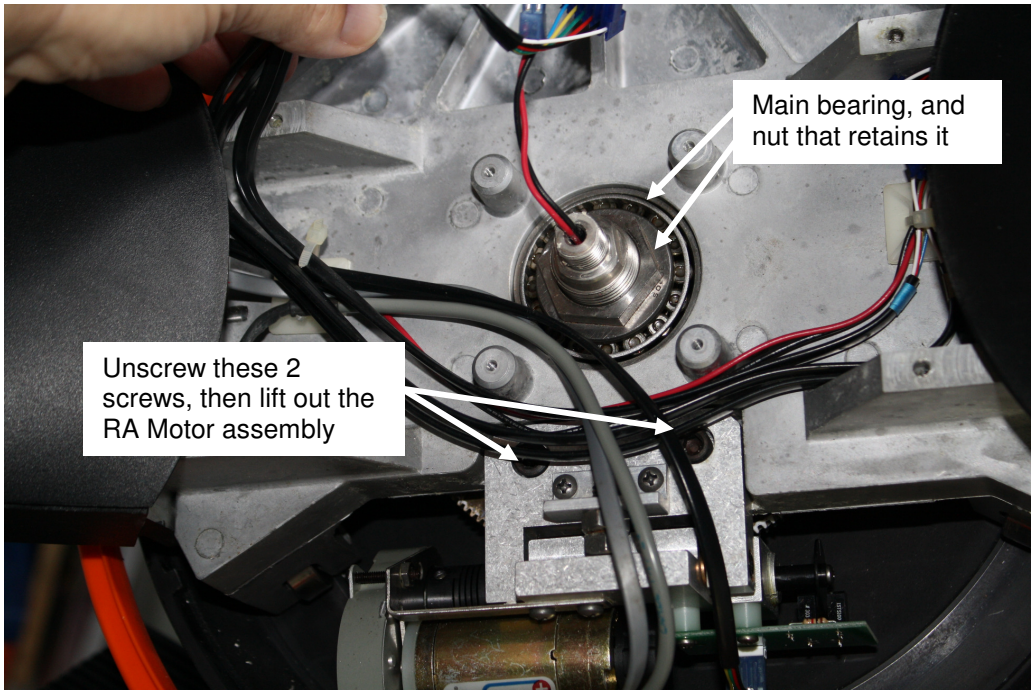

Figure 18: Slip rings removed

There is a small circuit card on the RA motor drive assembly, with a black cable on a connector. Label this cable, make a note of the orientation of the wires – on my scope the yellow

wire was on the left (i.e. closest to the motor), and the black wire on the right – then disconnect the cable from the circuit board.

There are also two grey cables connected (permanently) to the RA motor itself. These route to the circuit card on the East fork arm (refer back to Figure 2). I traced these wires to their connector on the East fork arm circuit board, and made note of its location and orientation; my notes are shown in Figure 18.

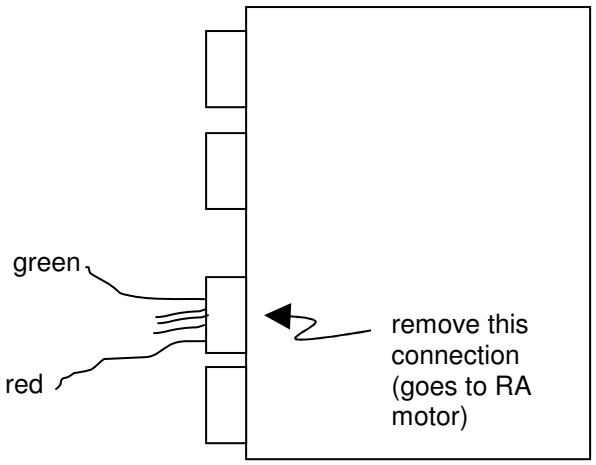

Figure 19: Connector to remove from circuit card in East fork arm

I disconnected the connector from the circuit card, and slipped the cable and connector through the gap at the base of the fork arm, so that it could follow when the RA motor assembly was removed.

The RA motor assembly is removed by extracting the two black cap-head screws indicated in Figure 17. These have LocTite on them, hence take a fair amount of effort to break free and unscrew. With the two screws removed, the entire RA motor assembly (with its grey cables) can be lifted out and set aside.

At this point, I took the mount off of the pier, so that I could place it on the floor with the fork arms pointing straight up, and no stress on the nut, bolt, or bearing.

Now it's time to remove the big hex nut that captures the main RA bearing. This is a 1-1/8 inch nut, with LocTite on it. Between the four posts surrounding it (refer to Figure 17), the delicate wire in the center of the bolt, and the fact that the assembly is now free to rotate, it was a bit tricky to unscrew. Once the bolt was removed, I could lift the whole structure straight up, out of the base of the mount. The tapered roller bearing could then be easily slipped up out of its race.

The only parts remaining on the base were the main gear (brass or bronze?) and the clutch mechanism, and the main bolt/post with the 2-wire cable through its center. On the base, there is a smooth, hard raceway for the three main rollers to ride on. (The rollers themselves are on the underside of the structure that has been lifted out of the base.)

4.4 Cleaning and Lubrication: I found that my main bearing seemed not to have any lubricant on it., I bathed and brushed the bearing in alcohol to clean away any residual lubricant or dirt. After drying, I applied a very light coat of white grease to the rollers. (This is a messy job, using fingers to put on a little grease and rotate the rollers to smear the grease around, then wiping the excess off with a paper towel).

There was some debris on the outer race (the smooth shiny surface that you can see in the structure after the bearing is removed). I used alcohol and a paper towel to clean the outer race.

I carefully cleaned the surfaces of the three rollers with alcohol and fine steel wool, being careful not to get alcohol or debris into their bearings.

I carefully examined the smooth track in the base of the mount that these rollers ride on. I noticed that on the base, the track was very slightly marbled in some areas, as if debris had been pressed into its hard surface. I tried scouring the track with fine steel wool and alcohol, but that

didn't seem to do anything useful and I wasn't ready to try anything more aggressive, so I left it as it was. When I re-assembled the mount, I rotated the base 120 degrees relative to its previous orientation, so that the two rollers that carry most of the equatorially-mounted load would ride on the smoothest portion of the track.

I noticed that both the main RA gear, and the worm gear on the RA motor assembly, had virtually no lubricant on them, so I cleaned both as well as possible (alcohol, tooth brush, and toothpicks), then smeared some white grease on each of them. I used a finger and a toothpick to get the grease into the teeth of the main gear, trying to get a little bit into each cavity between the teeth. I probably used more than the recommended "very thin film", but couldn't see how a little extra could hurt – worst case, it will drip down inside the base.

5. Re-Assembly: My plan for re-assembly was to clean all of the parts that had old LocTite on them, and then follow the disassembly procedure in reverse.

The first time I set the structure back onto the base, I torqued the main nut (holding the bearing in) pretty tightly – snug and then another half-turn or so. The mount seemed too snug, with a little roughness when turning it in RA. I took it completely back apart (which of course meant spending a half-hour to cleaning away all the newly-dried LocTite!), including lifting the structure out of the base. The second time I was more gentle: I set the base on the floor of the observatory, set the fork structure onto the base (carefully aligning it so that the rollers set down on their track), and jiggled the assembly to seat the main bearing properly. I brought the big (1-1/8 inch) nut finger-tight, and confirmed that the assembly rotated smoothly. With the nut snug, and only the weight of the fork-arm structure pressing downward, I gave the main nut less than about 1/8 of a turn – enough to firmly hold the structure against the base, but not so firm as to press overly-hard against the roller's track. At this light torque, the assembly rotated easily and smoothly, and it seemed that the "grumble" that prompted all of this disassembly was gone.

Aside from the effort to get a sufficiently light torque on the main nut, the rest of the re-assembly went very smoothly. When the cables underneath the control panel were re-connected, I didn't replace the cable-tie. Instead, I routed the cables around the available posts in the aluminum casting, to keep them away from the rotating slip ring. Reassembly was a straightforward one-person job except for (a) putting the mount back onto the pier (which is a two-person job), and (b) putting the Optical Tube Assembly back on (which definitely requires two people, and is a bit easier with a third person).

6. Results: The most important "good" result was that everything still worked after I put the 'scope back together! And the faint "grumbling" noise that had bothered me was gone.

I made a series of tracking tests (unguided tracking error, tracking error with PEC active, and tracking error with guiding) to compare with previous performance. I was particularly interested in this because the only aspect of this 'scope that Ihadn't been completely satisfied with was its poor tracking. From the day I bought it, it displayed a very large (~ 20 arc-sec P-P) non-periodic error. Since this error was not synchronous with the worm rotation, PEC didn't help (in fact, it hurt).

5.1 Unguided Tracking: With the autoguider boxes un-checked (i.e. guiding "off" in both axes), and the main imager binned 2X2 (about 2 arc-sec per pixel) I put a star in the center of the FOV, and created a 20-minute autoguider log to show the inherent tracking error of the mount. The result is shown in Figure 19. Note that this graph is reported with 2X2 binning, that is about 2 arc-sec per pixel.

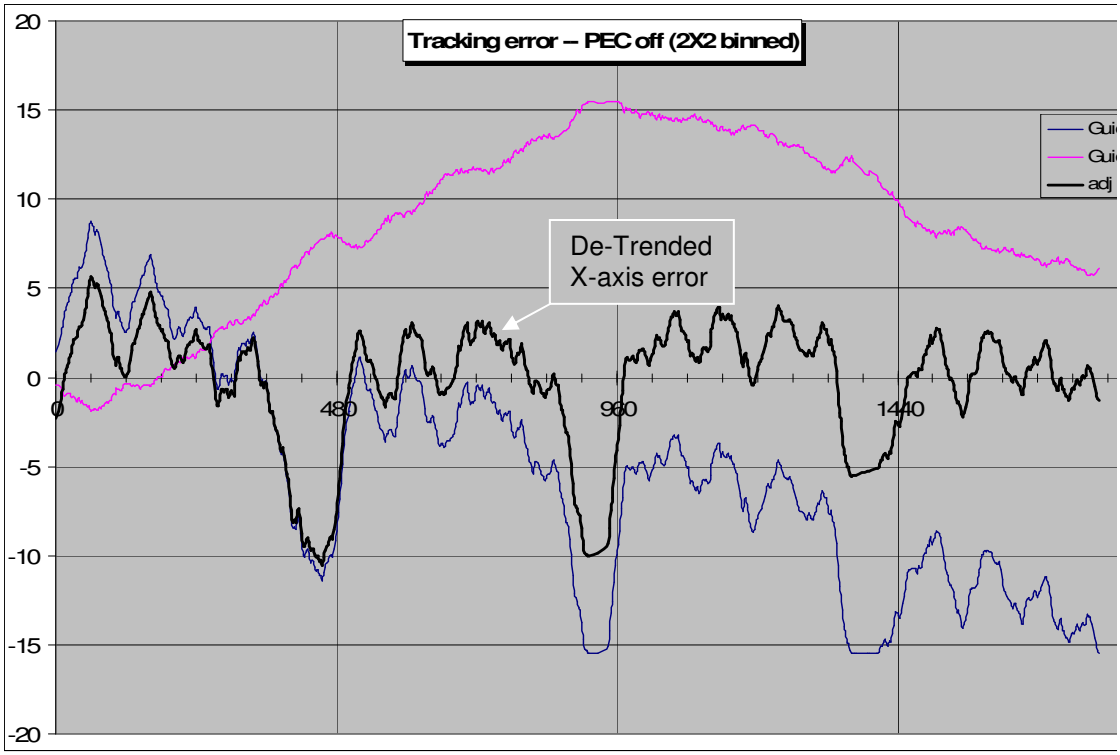

Figure 20: Tracking error (scale = 2 arc-sec per pixel)

The error is still large (about 20-30 arc-sec peak), but it is "smoother" than before, and most importantly it is periodic – synchronous with the worm gear's 8 minute period.

5.2 Tracking with PEC: I used PECTool to do a 6-run training of the Periodic Error Correction memory, then another unguided tracking test, this time with PEC playback active. The results are shown in Figure 20. (Note that this graph is done with 1X1 binning, hence 1 pixel ≈ 1 arc-sec.)

The result looks very good – peak error about 5 arc-sec, and "smooth" tracking error. A few preliminary tests indicate that the system can make acceptable 1-minute images unguided (but with PEC active), and for longer images, autoguider exposures of >5 seconds should be quite acceptable.

Overall, I am very happy with the improved tracking performance, and the educational experience of doing this work.

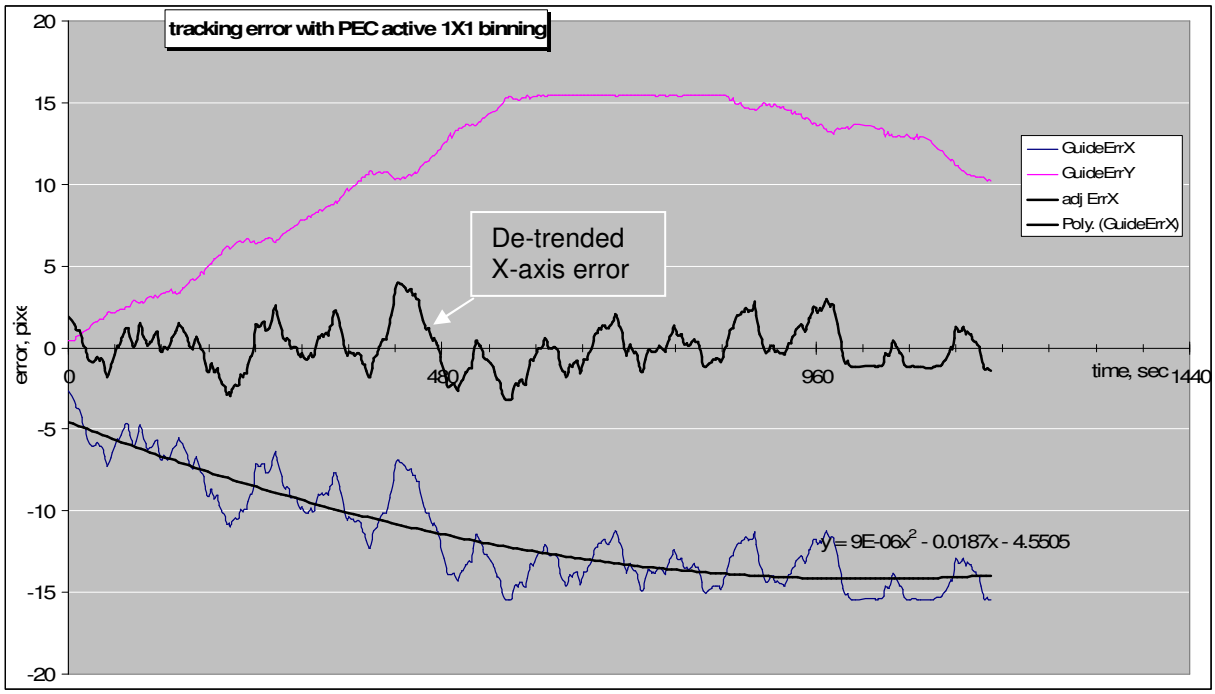

Figure 21: Tracking error with PEC playback (scale = 1 arc-sec per pixel)

[see Altimira Observatory Noteboook 6-30-2009 thru 7-10-2009 for original notes].