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The Installation of a Digital Autoguider in Las Campanas in 2011 March

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2011 May 26

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Abstract

I upgraded the autoguider and mount control system on this visit. I installed our first digital autoguider: the mount controller. I installed a new UPS, cured the step in Ivan, installed a new waterproof cloud detector, cleaned the rain detector, replaced the cups on the anemometer, and replaced the CPU fan in the computer.

1 Introduction

I visited Las Campanas from 2011 February 19 to March 5. The primary purpose of this trip was to install our first mount controller. The autoguider system in Las Campanas was not broken. But it was felt that the new digital guiding from the mount controller could provide the most benefit to the network if it was installed here.

2 New Autoguider

I upgraded the autoguider and mount control system on this visit. The following items were changed:

1. Four modules in the main electronics crate (the autoguider module, the RA and DEC stepper modules, and the mount encoder module) were replaced by the mount controller. They are now no longer needed.
2. The RA and DEC stepper motors were replaced.
3. The cabling to the motors, limit switches, and the autoguider telescopes was replaced.

The following items were not changed:

1. The autoguider telescopes,
2. The encoders, and
3. The mount limit switches.

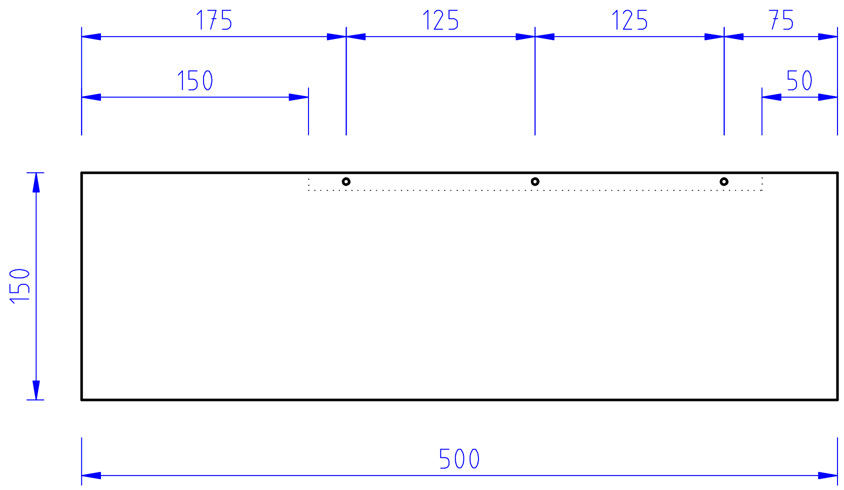

Figure 1: RA worm-wheel sun shield. 1:5 scale.

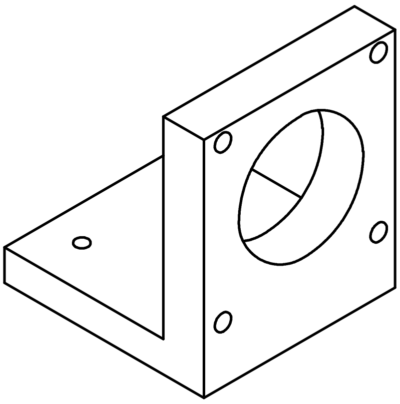

Figure 2: The motor mounting bracket.

2.1 Mount Controller

The mount controller [1] is the new electronics device that now deals with all aspects of mount control. It is a PIC-based device housed in a 2-U rack-mounting case.

The mount controller drives the stepper motors using two L297/L298 stepper motor driver combinations. It provides eight current-to-voltage converters for the quadrant photodiodes in the fine and coarse telescopes. The signals from the quadrants (not difference signals) are digitized using the 10-bit ADC on the PIC microcontroller. The mount controller provides this information, along with digital information obtained from the encoders and limit switches, to the computer.

The computer can command the mount controller to set the motor speeds and accelerations. Or the mount controller can take over and perform fine guiding based on the signals from the fine telescope. Various fine-guiding parameters are adjustable. The mount controller does not provide coarse guiding services. The computer does the coarse guiding by reading the coarse quadrants and instructing the mount controller to move the motors as appropriate.

The mount controller can drive the stepper motors directly with 5 V, or it can supply 24 V through the L297's current-limiting chopper system. Our motors can handle 0.7 A per coil. At 5 V, the current is always below the limit so no chopping is needed. At 24 V and slow motor

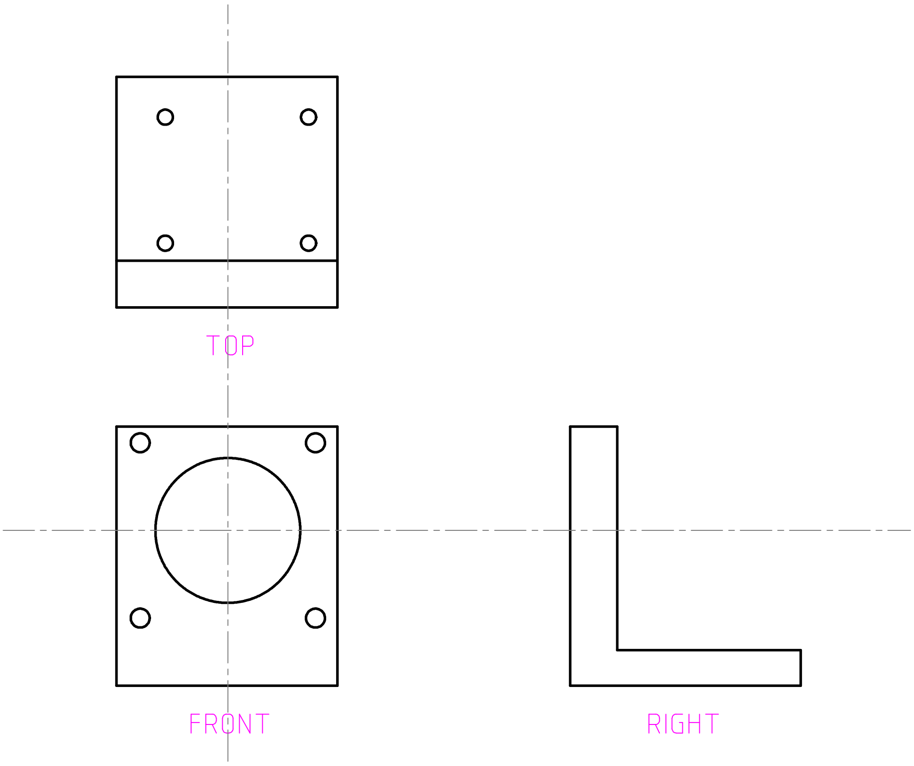

Figure 3: Views of the declination mounting bracket.

speeds, the current would exceed the limits. A stepper motor draws the most current when it is standing still. For a fixed voltage, the current drops off as the motor speed increases.

I chose to use 5 V for guiding because at 5 V the stepper motors produce less torque. In tests in Birmingham the increased torque at 24 V was causing the mount to vibrate. I was concerned this might add noise to the data.

At 24 V, chopping is required. The L297 employs a high-frequency chopper. The frequency is within the range of human hearing. At 5 V, the motors are nearly silent. At 24 V, the motors emit a loud and very annoying noise at the chopping frequency, except when they are slewing very fast, in which case they emit a not-quite-so-loud and not-quite-so-annoying tone at the high stepping frequency. These noises were loud enough that I was worried about possible adverse affects on hearing. However, we have limited exposure to the noise in the dome so this is probably not a concern.

The torque at 5 V was more than sufficient to drive Jabba on the mount in Birmingham. In Las Campanas, the RA motor stalled in early tests at 5 V. This is worrying. After I cleaned the worm and worm wheel, the motor performed well. But this indicates that the new system is less tolerant to bad grease.

I believe there was too much grease on the worm wheel and that the grease was too heavy. I will order some more of the lighter, spray-on grease that we have recently been using in Birmingham. I think this will work better. I have also added a sun shield to the front of the mount. It shadows the RA worm wheel. Previously, the worm wheel has been exposed to the sun all day. I am sure that this exposure quickens the deterioration of the grease. The shield that I made is shown in Figure 1 on the facing page. We should install these shields at the other stations too.

Hopefully these measures will make the system reliable at 5 V. But just in case there are problems, I tested the system at 24 V. To my surprise, I did not observe any mount vibration and

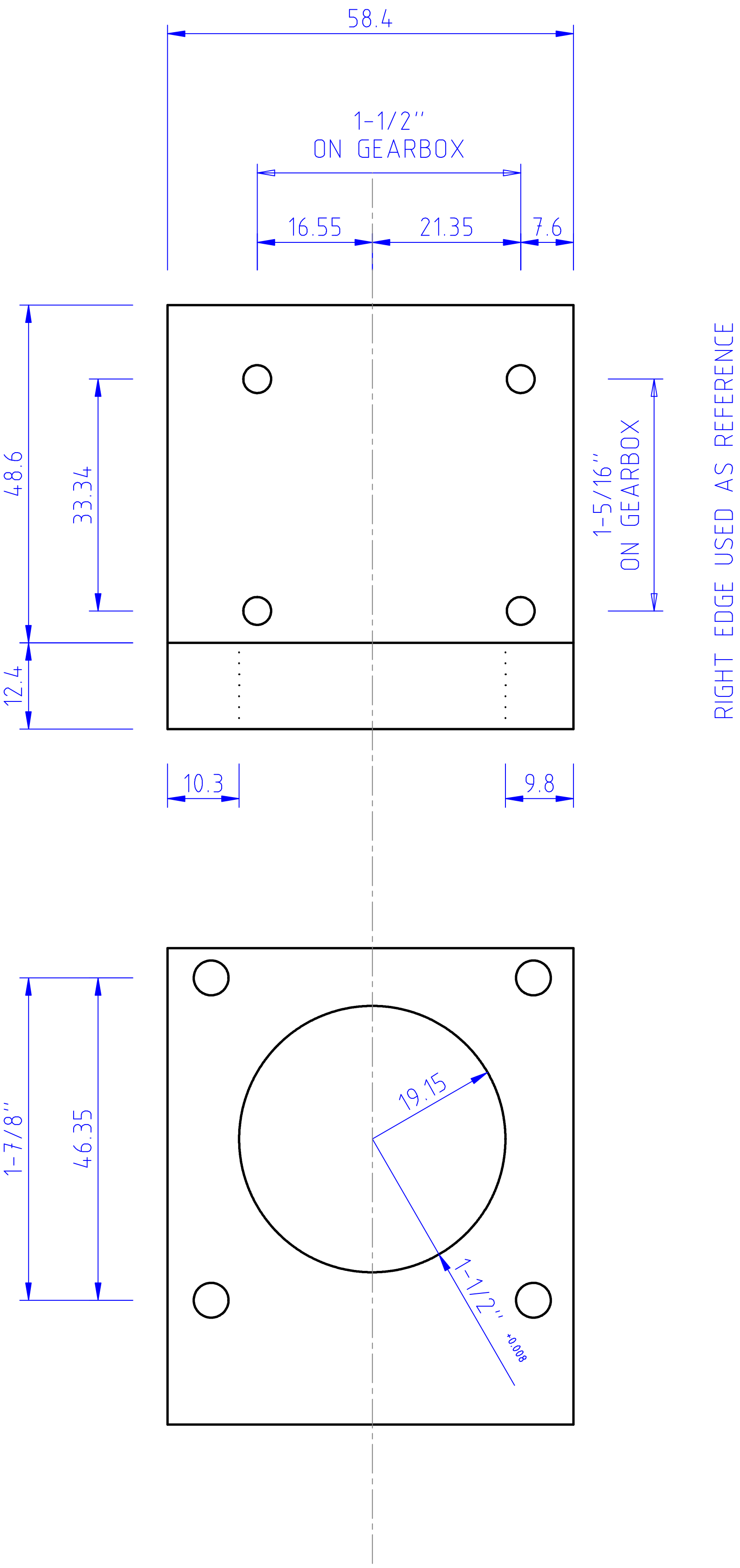

Figure 4: Declination mounting bracket. Front and top views. 1:1 scale.

the data do not appear to be any different. The tests in Birmingham were done with an empty mount and a prototype stepper driver. In Las Campanas, there are two heavy spectrometers on the mount. Perhaps the increased mass absorbs the vibrations. Perhaps the newer stepper driver circuit has improved current detection (the ground was improved) which makes the chopper

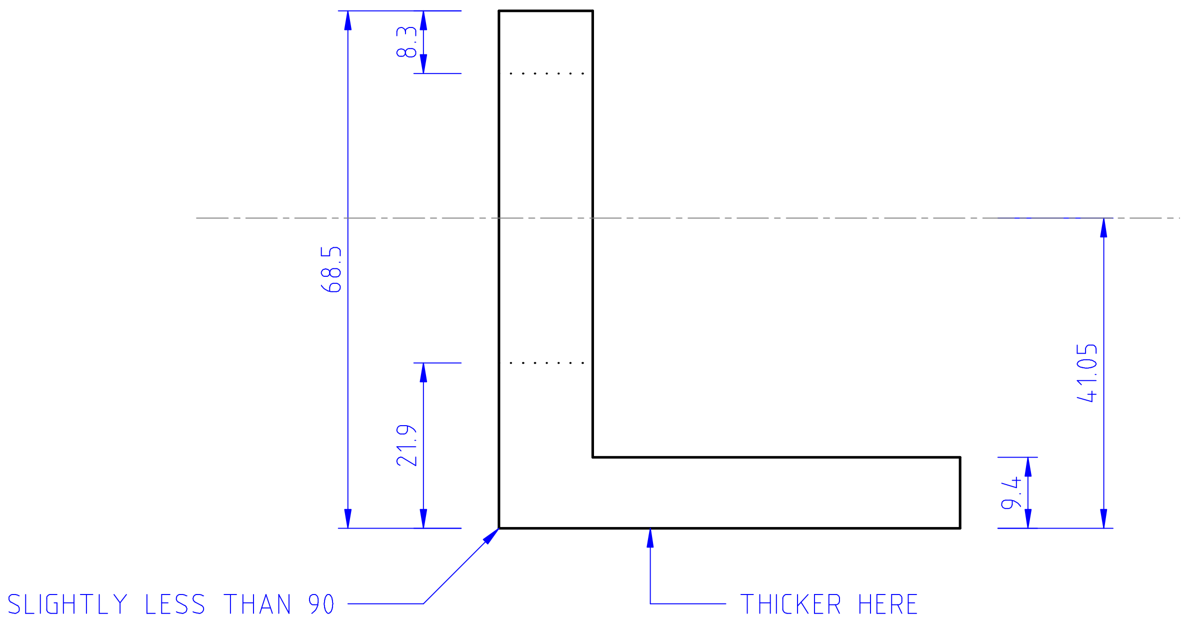

Figure 5: Declination mounting bracket. Right view. 1:1 scale.

circuit behave better. The motors seem to run smoother, even at 24 V. Also, the motor noise was much, much less annoying. Perhaps it is more noisy in general in the dome at Las Campanas making the motor noise stand out less. In any case, if the grease on the RA worm wheel deteriorates and the motor starts to stall, we can change to 24 V.

2.2 Fine-Lock Photodiode

The mount controller does not monitor the fine-lock photodiode signal. This signal is derived from a sensor that monitors the amount of light scattered from the occulting disc in the fine telescope. The old analog guider electronics used a simple threshold test to decide whether or not the fine telescope could see the sun. Occasionally when the mount is pointed directly at the sun, the fine quadrant signals are low enough (because most of the light is occulted) to confuse this simple circuit.

I called the signal from this sensor the *fine-lock photodiode* signal because I thought the sensor was a photodiode. The autoguider telescope in the 2D Gradient monitor uses a photodiode. However, Clive McLeod called this signal the *Fine Lock P/Cell* signal. I later discovered that the sensor is not a photodiode but, instead, looks like a simple LED.

This signal has been disabled in Sutherland because it was unreliable; yet the autoguider there performs well. The decision to changeover from coarse to fine guiding in the new system is made by the computer, which can make its decision using a more complicated algorithm based on the values of all eight quadrants. The fine-lock photodiode signal is no longer needed. It was omitted from the new system because its connection would have required another cable. We are using two four-pair cables for the two quadrant photodiodes. There were no spare wires for the fine-lock photodiode signal. Because the signal has limited or no value, there is no justification for adding another cable to the bundle. Also, the PIC contains eight ADC channels. In order to accommodate a ninth signal, an external ADC IC would have been needed.

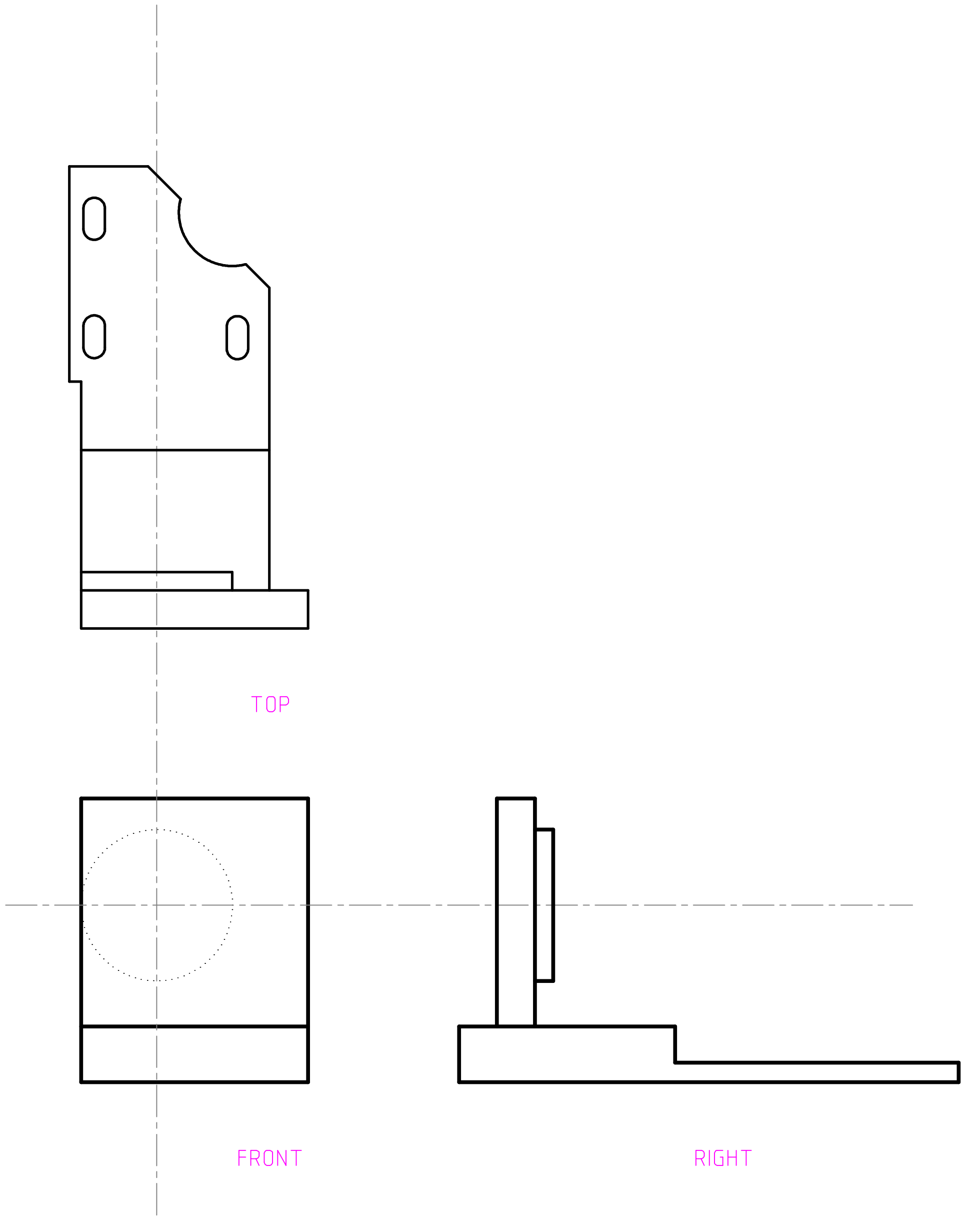

Figure 6: Views of the motor assembly.

2.3 Performance

The performance of the new system will be tested from Birmingham over the next several months and a report published in due course.

2.4 Why New Stepper Motors?

I replaced both stepper motors on this visit. We wanted to eliminate the troublesome slew motor and clutch from the system; yet we still wanted to be able to slew the mount from sunset to sunrise in thirty minutes or less. To do this, we would need a faster stepper motor.

I don't know from where we purchased our original stepper motors. They say "Step Angle $7°30'$" on them. We use that same stepper motor for both RA and declination in Las Campanas, Sutherland, and Narrabri, with one exception: the declination stepper in Las Campanas was replaced by Peter Monks in 1994 when he installed the Automated Stellar Photometer.

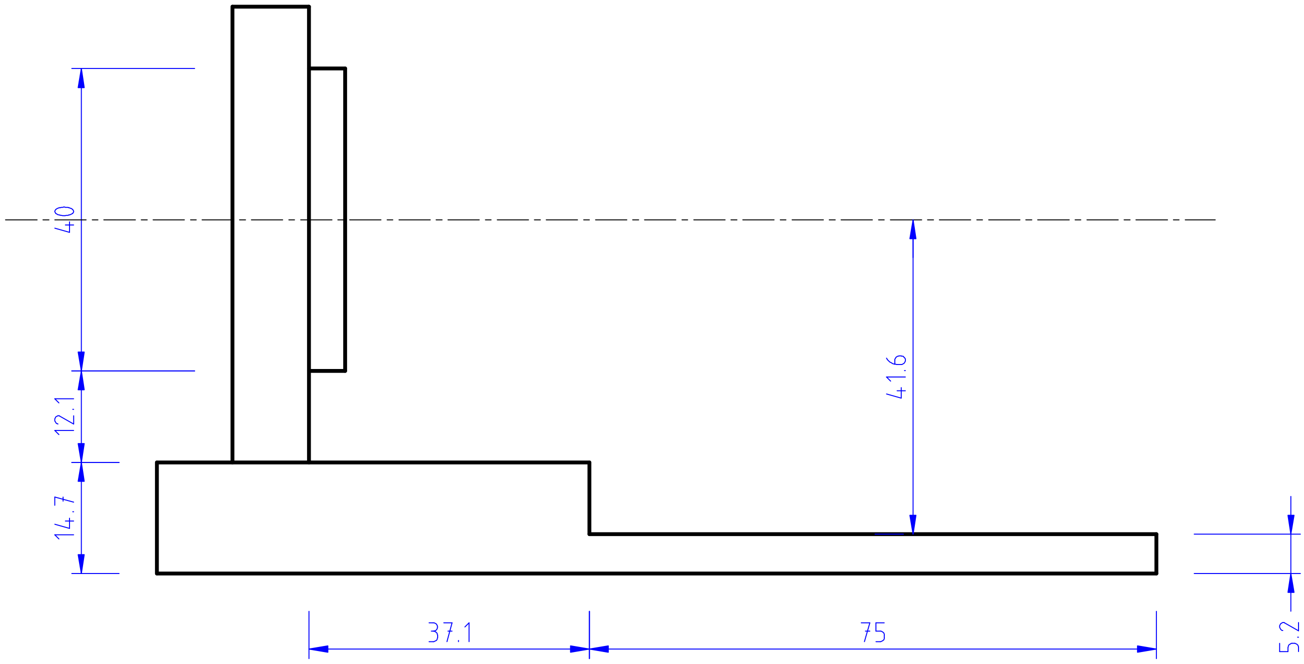

Figure 7: Motor assembly. Right view. 1:1 scale.

Clive McLeod recommended that the original stepper motors be driven at 300 Hz. With our 90:1 gearboxes, that would produce a slew rate of $187^\circ\,\mathrm{hr}^{-1}$. In BTR-34, Clive says it would be $90^\circ\,\mathrm{hr}^{-1}$. I think there was some confusion about full stepping and half stepping. The old stepper modules used SAA 1027 stepper drivers which could only do full stepping. So $187^\circ\,\mathrm{hr}^{-1}$ is the correct value.

We often slew the mount back to the sunrise position using the stepper motor. The log files show that in Las Campanas the old motors achieved $41^\circ\,\mathrm{hr}^{-1}$. It used to take over four hours to slew the mount from sunset to sunrise. From this I conclude that the motors don't really run at 300 Hz.

In 1994, Peter Monks replaced [3] the declination stepper with RS 440-458 — a 24-V, 1°.8 step-angle motor. The 90:1 gearbox was replaced by a 10:1 gearbox at the same time. At 300 Hz this should achieve $405^\circ\,\mathrm{hr}^{-1}$. However, Pete's notes say that he turned the speed down. So if it was driven at the same low rate as the RA motor, we would have actually got about $90^\circ\,\mathrm{hr}^{-1}$.

Peter's new motor doesn't step any faster. On top of that, the step size is smaller. So, in actual fact, the motor axle turns more slowly. But being a 24-V motor, it can generate much more torque. This allowed Peter to change the gearbox from 90:1 to 10:1, thus achieving the desired slew speed increase.

We occasionally have problems with the 90:1 gearboxes. The 10:1 gearbox was much, much smaller. So Peter's declination system had higher torque and a smaller gearbox. It is not surprising that the 10:1 gearbox failed on a couple of occasions.

The new motors that I installed on this trip have a 1°.8 step angle and are supplied with high-quality 50:1 gearboxes. They are being driven in half-step mode at 5V and can slew at 500 Hz. This produces a slew rate of $68^\circ\,\mathrm{hr}^{-1}$. It takes a little over two and a half hours to slew from sunset to sunrise.

If necessary, the mount controller change to 24 V and drive the motors at 3.2 kHz. This results in a slew rate of $432^\circ\,\mathrm{hr}^{-1}$ which would get the mount from sunset to sunrise in about twenty-five minutes.

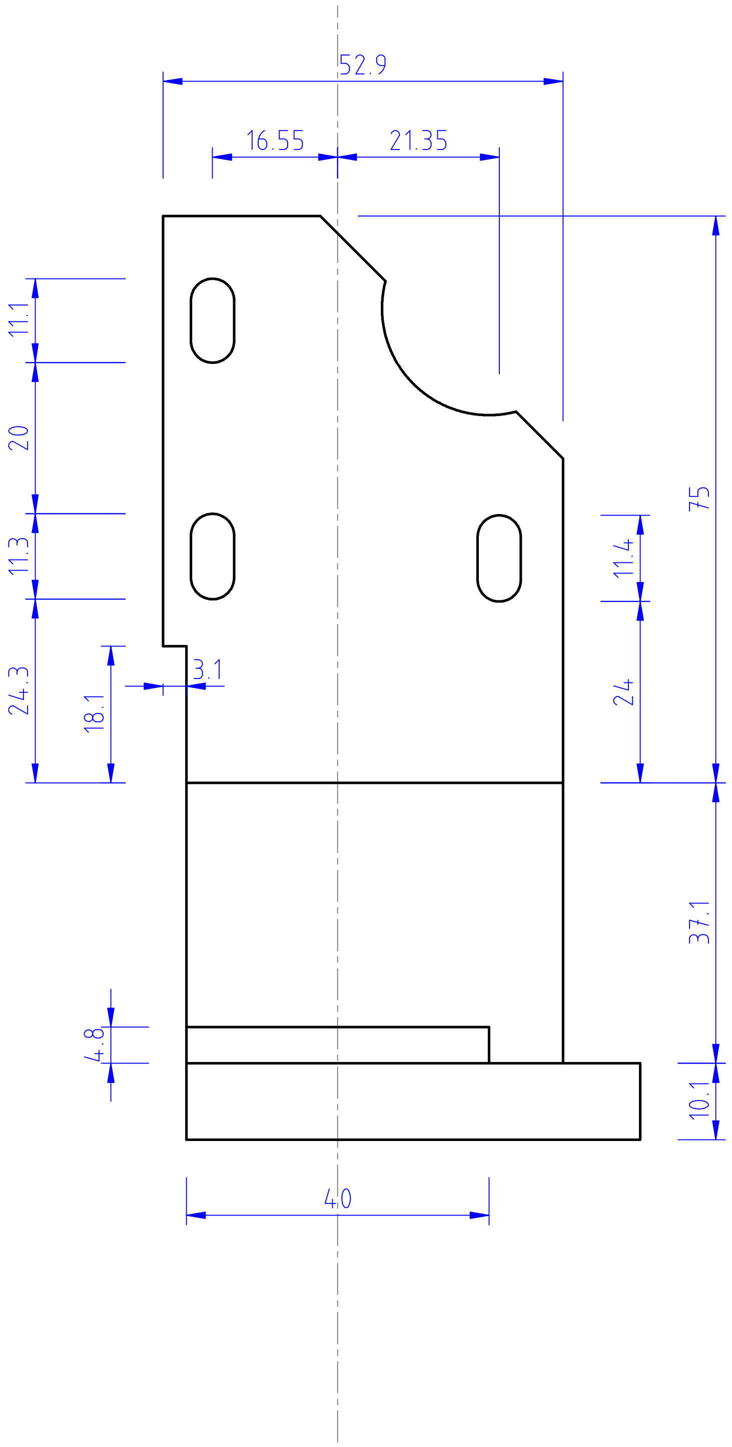

Figure 8: Motor assembly. Top view. 1:1 scale.

Peter Monk's motor and gearbox could, on paper, get near this speed. But to do so it sacrificed resolution. The step resolution of the old motors is $0.''625$. That is, for each step that the motor takes, the mount moves by $0.''625$. In contrast, the resolution of Peter's fast declination stepper was $1.''35$. The step resolution of the new motors is $0.''135$.

To summarize, here are the advantages of the new motors and gearboxes:

1. The clutch and slew motor have been eliminated. The clutch has always been problematic for us. The new system can slew at high speed without the need for a clutch.

2. The tracking motor has been eliminated. The old system used to use the tracking motor to roughly follow the sun in RA while the stepper motor was used to guide back and forth.

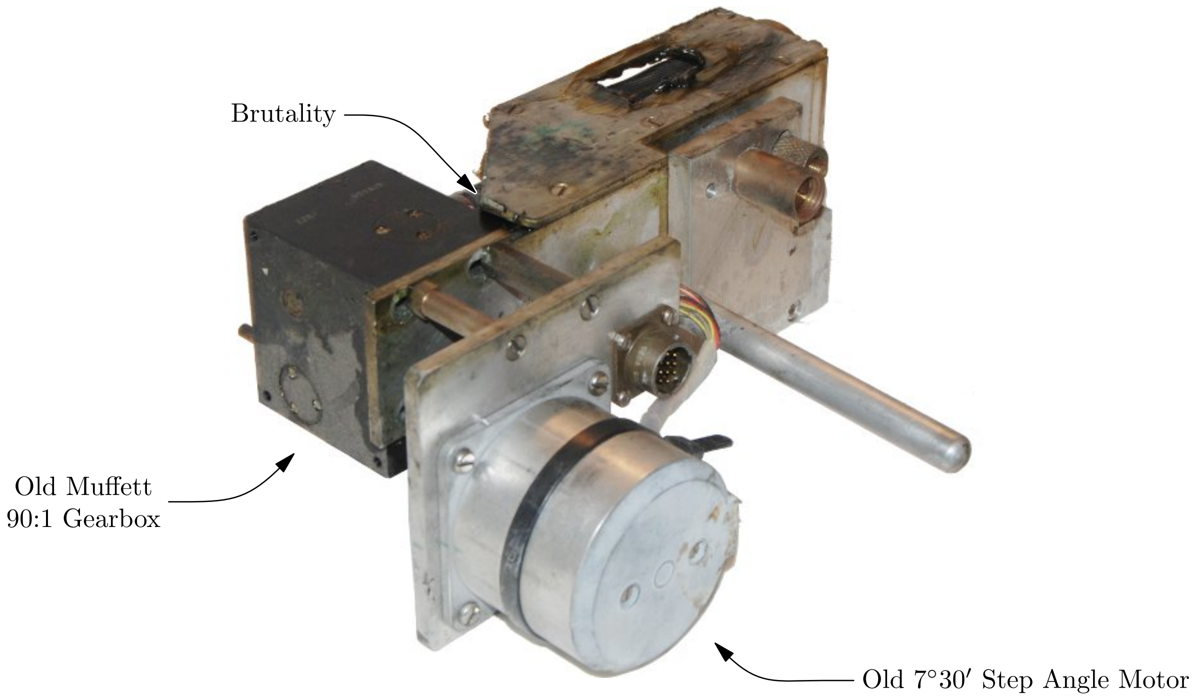

Figure 9: The worm cover was brutally bent out of the way.

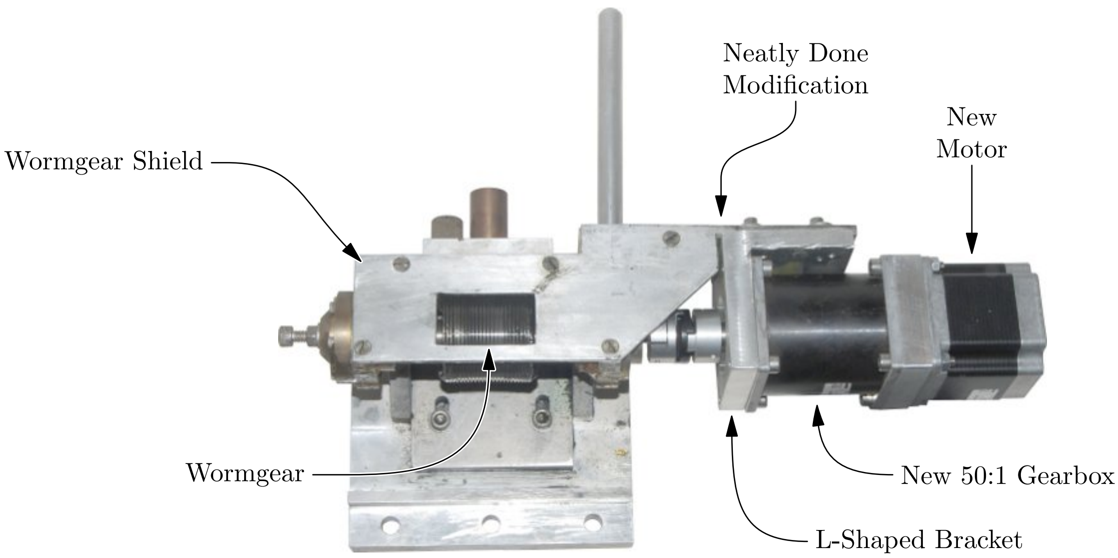

Figure 10: The new declination motor attached to the old motor assembly.

In the new system, the RA stepper moves in one direction all day so there are no backlash issues.

3. The new system has a step resolution four and a half times better than the old motors and ten times better than Peter's fast declination stepper. Hopefully this will translate into more accurate guiding.

4. The new system uses a high-quality 50:1 gearbox. We have always had problems with the grease in the old 90:1 gearboxes. The 10:1 gearbox was too small for this application.

2.5 Fitting the New Motors

The new motor is attached to the motor assembly using an L-shaped bracket made by Barry Jackson (see Figures 2 to 5). Barry consulted the master drawings and looked at the motor assemblies in the dome in Birmingham. But there was some ambiguity. He couldn't be sure the Las Campanas mount was exactly the same as the Birmingham mount. So he provided me with several L-shaped brackets.

Barry skimmed two of the brackets to what he believed to be the right thickness in order to hold the motor at the correct height above the motor assembly plate. The other two brackets he left oversized so that they could be machined to the correct thickness on site if necessary. Barry also drilled four mounting holes in the skimmed brackets. But he was worried the holes weren't in the right place. Worse still, they may even be so close to the right place that they prevent holes from being drilled in the right place.

In Las Campanas, I disassembled the motor assemblies. I removed the old motors and gearboxes. I then carefully measured the motor assembly plate and the L-brackets provided by Barry. I have drawn the Las Campanas motor assembly plates; see Figures 6 to 8.

I can now say that the motor assemblies in Las Campanas are indeed different to the ones in Birmingham. However, the important dimensions relating the mounting holes to the motor axle center line are all the same. And they do match the master drawings provided you interpret the drawings in the right way. We now know what the right way is.

Barry's skimmed L-brackets were the correct thickness. The holes were not in the right place. And, as feared, they were very close to the right place.

The motor assembly plate has slots in it so there is some room to move the holes in the L-bracket in one direction. I decided to try that. I drilled new mounting holes in the L-bracket offset slightly in the direction of the slots. The holes are now not in the ideal location. But their position is correct in the critical direction and close enough in the non-critical direction. The motor fits!

Well, almost. The L-bracket fouled the worm cover on the motor assembly. I noticed that the old 90:1 gearbox on the RA assembly also fouled the worm cover. Someone had brutally bent the worm cover out of the way in order to get the gearbox to fit (see Figure 9).

I used a hacksaw and a file to carefully and neatly modify the worm covers on both RA and declination motor assemblies. Now both motors fit and the assemblies don't look like they have been kludged (see Figure 10).

I later found out that it was Steve Hale who modified the worm cover in 2008 when he replaced [4] all the shaft couplers. It was necessary to move the 90:1 gearbox closer to the motor. The slots in the assembly plate were provided for just this purpose. However, the worm cover prevented the gearbox from moving the full length of the slots.

3 Mount Limit Switches

I rewired all the mount limit switches and connected them to the new mount controller. There are five limit switches on the RA axis and three on declination. On the RA axis we have the usual *left*, *right*, and *Armageddon* switches. There are also two other limit switches to cut power to the tracking motor and slew motor. Those two extra switches were broken; the plastic cases were cracked and broken. But the three main switches were still working. The three declination switches were also working.

Over the first few days of running, I noticed the RA limit switches flickering. The software writes a message into the log file when this happens, so you can't miss it. The declination switches worked ok. I was considering bypassing the RA limits — I didn't want the system to stop working just because the RA limit switches were bad. But first, I decided to take a closer look.

I found that if I tapped the plastic body of the RA limit switches with a screwdriver, I could make them flicker. The declination switches don't do this. I did this for a while. Afterward, the RA limit switches stopped flickering. They haven't flickered at all since then. Perhaps I knocked some dust out.

In any case, I have ordered new limit switches for both axes. I will make new assemblies and send them out on the next visit.

4 RA Encoder Shaft Coupler

While working on the RA limit switches, I had to remove the limit-switch plate. This involved removing the RA encoder. I found that the shaft coupler between the encoder and the mount has broken in half. I am pretty sure I didn't break it. This shaft coupler doesn't need to apply very much torque. I found that when I put the limit-switch plate back on, it squeezed the two halves of the shaft coupler together. This works.

I will order a new shaft coupler and send it out on the next visit.

5 New UPS

I installed a new UPS on this visit. We already have one UPS; but it isn't powerful enough to supply both the dome and the computer at the same time.

On my last visit [5] in 2007, I discovered the problem with the old UPS. On a power failure, the UPS would cut out. If you press the power button to turn it off and then back on again, it would start up and power both the computer and the dome and it had enough energy to close the dome. I found that after disconnecting the computer, the UPS could survive a power failure without cutting out. So I left the computer not connected to the UPS.

On this trip, I planned on connecting the computer to the new UPS. That did work. But now I discovered that the old UPS cuts out on power failures, even when the dome is the only thing connected. I tried the new UPS with the dome. It works! The new UPS is considerably lighter than the old UPS. They are both rated at 1500 VA. I assume that the new one has less battery capacity. I tested it with the dome. I had it close the shutter and blind three times. It had more than enough capacity to do this. I connected the computer to the old UPS. It works too.

So now we have two UPSs: one for the dome and one for the computer. They both work. But the dome is connected to the small one and the computer is connected to the big one.

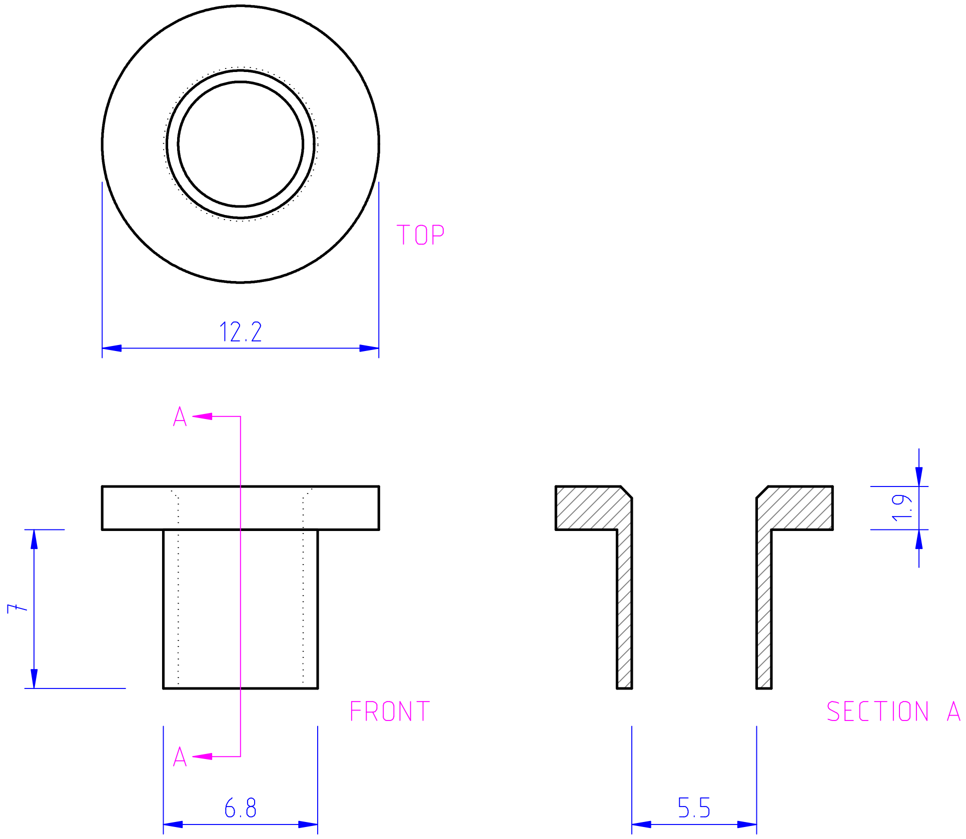

Figure 11: Old collar. 3:1 scale.

6 Waterproof Cloud Detector

I swapped the cloud detector for Barry's new waterproof cloud detector [6]. It works.

The cloud detector in Las Campanas is connected to Richard Lines's sun-monitor box [7]. The sun monitor has long since stopped working. It contained a light-dependent resistor (LDR) just like our cloud detectors. So the cloud detectors work with Richard's sun-monitor electronics box.

I first installed the cloud detector [5] back in 2007 December. I connected it to the sun-monitor box. On 2008 January 17, the cloud detector data started to look odd; so I set the software to ignore it. I blamed Richard's sun-monitor box. Everywhere else we use simple voltage dividers. On 2008 February 14, the cloud detector started behaving correctly again. It has been working ever since. But nobody had ever checked. So we have had the cloud detector on override unnecessarily for the last three years.

7 Ivan's Oven

Before this visit, there was a step in the data from Ivan. I believed that the cell was loose in Ivan's oven. On this visit, I took the oven apart to have a closer look.

The cell was loose. Ivan was originally intended to have a sodium cell. You should read BTR-66 for a description of Chris Underhill's early experiments. Chris never managed to get the sodium cell working; so he changed Ivan to a potassium cell.

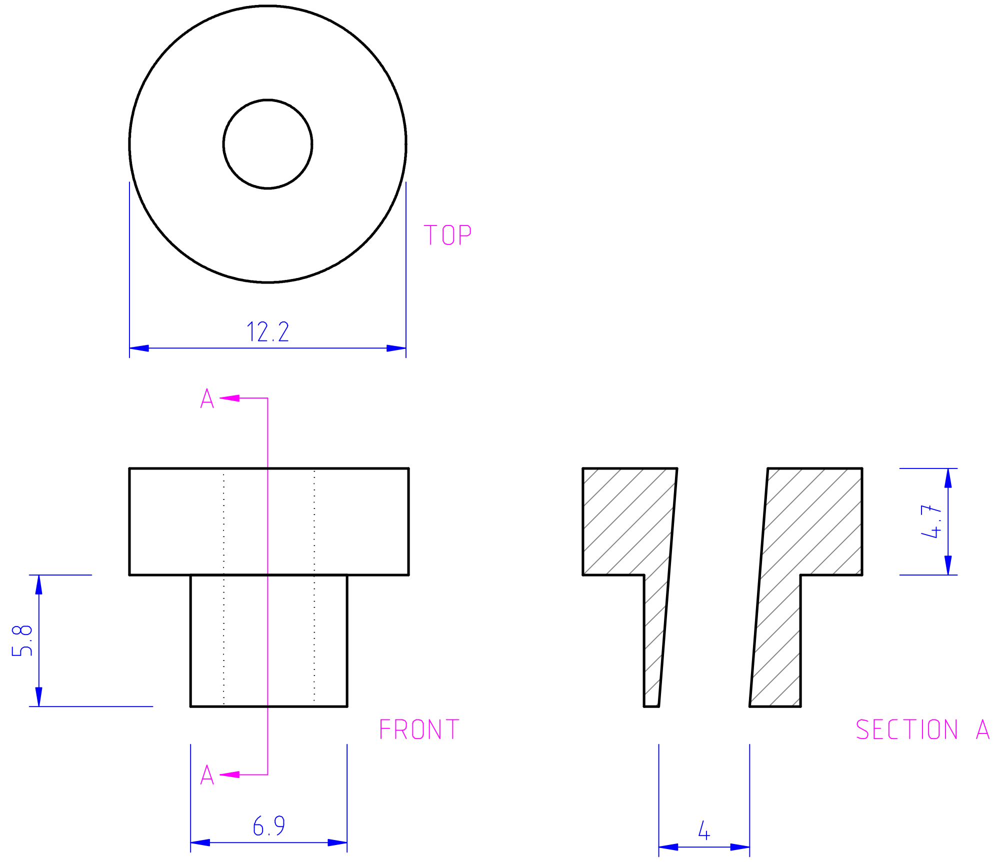

Figure 12: New collar, before changes. 3:1 scale.

There seems to be some problem with the stem sizes of the various cells. In Las Campanas, I found a sodium cell with a 4.0-mm-diameter stem. I also found two spare potassium cells: one with a 4.1-mm-diameter stem and one with a 5.1-mm-diameter stem. The potassium cell that is currently in Ivan has a 4.0-mm-diameter stem.

There is a plastic collar that fits around the stem and sits between the glass cell and the metal oven. Ivan's collar has a 5-mm-diameter hole in it. It looks like it was designed for the larger-diameter stem. I found lots of copper foil wrapped around the cell stem to make it fit in the collar better. But it wasn't perfect and the cell wobbled slightly.

The plastic collar was very brittle. When I tried to put more foil around the stem, the collar shattered into lots of tiny little pieces. I found another collar in with all the plastic junk in one of the drawers of the storage cabinet. I never knew what it was for. It has an inner diameter of 4mm and an outer diameter of 6.9mm. These numbers are just right. However, when you put the cell in, the collar holds the cell too high.

I filed the new collar down. The cell has a 6.5-mm shoulder around the stem. I used a 6.5-mm drill bit to counter bore the collar. I didn't really counter bore it enough. I think I filed too much off the collar for that. If I counter bore too much, the collar will fall apart.

The center hole in this new collar is very crooked. When I reassembled the cell and oven, it holds the cell stem up against the side of the temperature control collar. It may be putting lateral pressure on the cell stem. That would be bad.

I will ask Barry to make a new plastic collar to be sent out on the next visit. Figure 11 on the preceding page shows the old collar before it shattered. Figure 12 shows the new collar

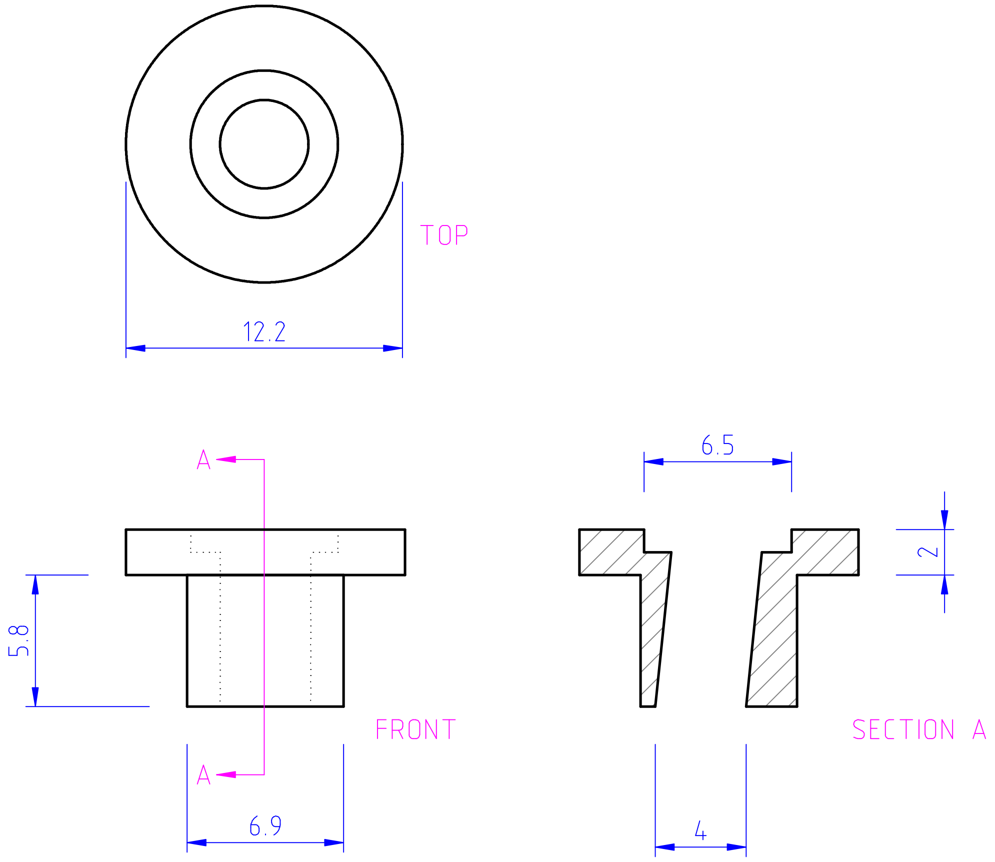

Figure 13: New collar, after changes. 3:1 scale.

before I modified it. Figure 13 shows what the collar looks like now. Notice how the hole has been drilled very badly.

Figures 14 and 15 show autoguider scans taken after Ivan's oven was repaired. They main difference between these scans and the last ones [5] that I took in 1997 December are that Ivan's ratios are somewhat lower. Ivan's sensitivity is not as good as it was before. I suspect this is because the cell is being held at an angle.

8 Ivan's V/F Power Cable

Ivan's V/F Power Cable broke while I was working on the mount. I replaced it.

9 Ivan's Detector Temperatures

I found that Ivan's detector temperatures were backwards. I changed the labels in the *zoo.conf* file. However, all of the restart records in the temperature files from 2007 December 11 to 2011 March 1 have the labels *i_star* and *i_port* backwards.

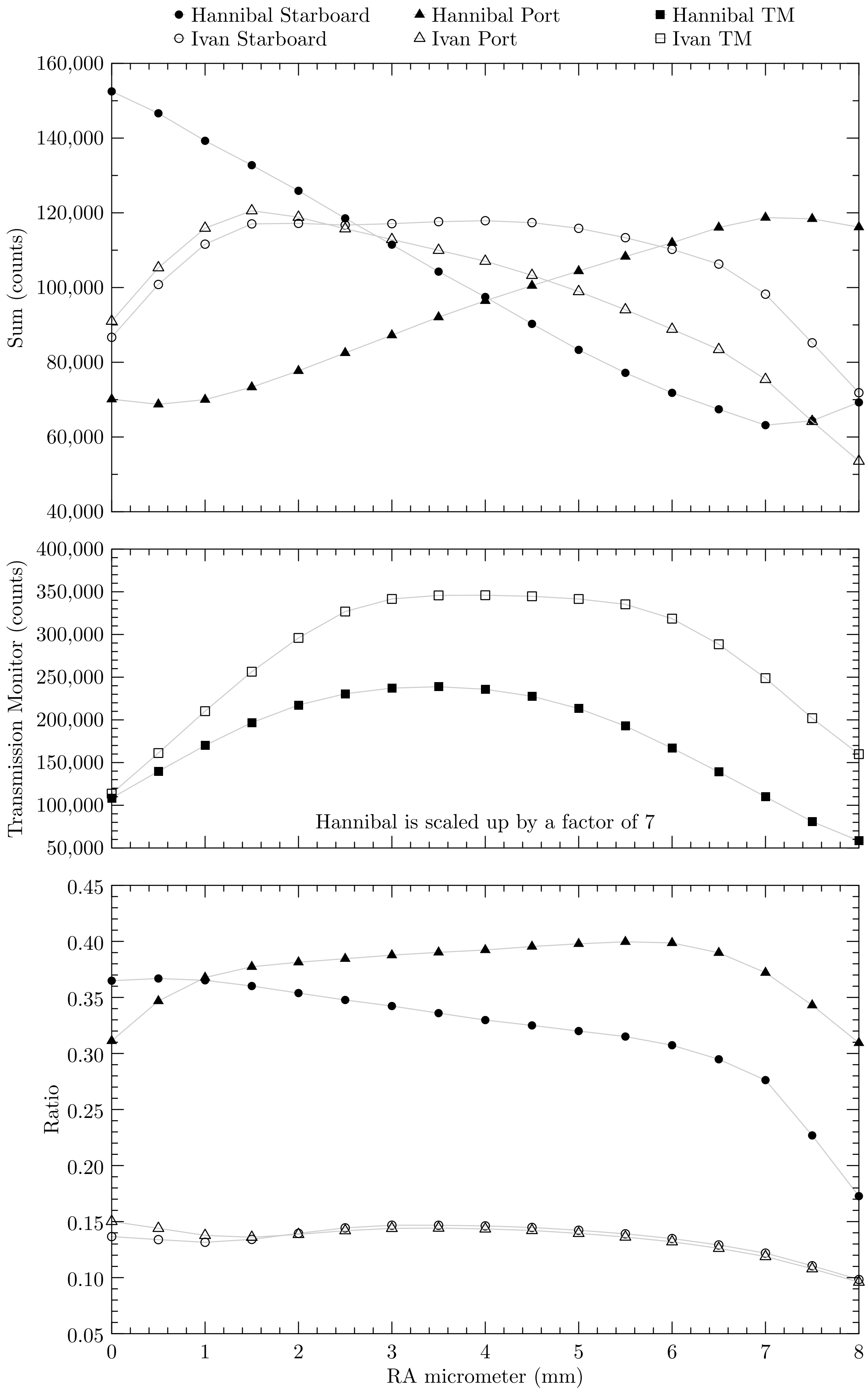

Figure 14: Right ascension scan.

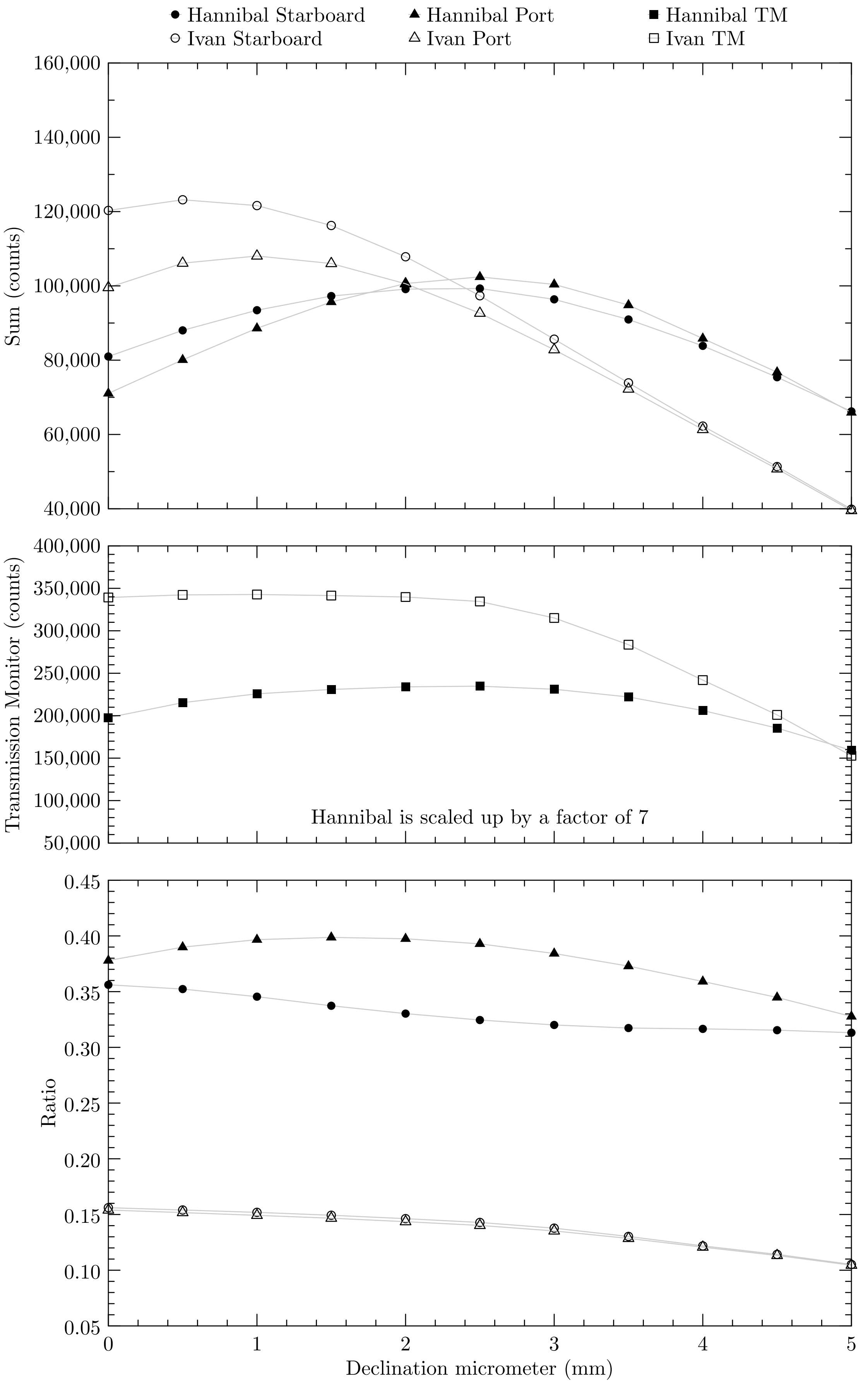

Figure 15: Declination scan.

10 Shutter Motor

Back on 2010 February 14, the connection between the shutter motor and its gearbox broke. Emilio Cerda noticed the problem. Pedro Cortes in the mechanical workshop fixed the problem. They told me the solution was temporary. But I never heard anything more about this.

On this trip, I noticed that the shutter was making a terrible scraping sound. I guessed that the track was dry. I sprayed it with WD-40. There is some spray grease here, but the can doesn't work anymore. After being sprayed with WD-40, the shutter continued to make the scraping sound. The problem was that one side of the orange Lovejoy shaft coupler between the shutter motor and the gearbox had come loose. It slid up the shaft until the back side was touching the gearbox. The bolt heads on the gearbox were grinding away the back side of the shaft coupler. 3 mm are gone. I used a screwdriver to push the coupler back together. Then I tightened the grub screw with a 4-mm Allen key. Now it seems to be ok.

11 Rain Detector Dirty

The rain detector tripped on a couple of mornings while I was in Las Campanas. There was no rain. There wasn't even any dew or condensation. I climbed up and found that there were bird droppings on the rain-detector sensor. I cleaned the sensor and the false rain trips went away.

12 Anemometer Cups

I replaced the anemometer cups. There was one cup missing from the old set.

13 Foam Adhesive

Lots of foam is coming loose in the dome. Some of the foam tiles have been stuck back on with duct tape. This normally doesn't work very well. Duct tape doesn't last long in the Las Campanas weather. Some of the duct tape had fallen on the dome track. The motor was driving the gears right over the top of it.

Also, the foam on Ivan's cover is loose. I had to cut some of the foam away to make room for the new declination motor.

I will have some adhesive sent to Las Campanas. On the next visit, the dome foam and Ivan's foam should be reattached.

14 CPU Fan

I found that the CPU fan wasn't working. I didn't have a spare 60-mm fan. Instead I attached an 80-mm case fan to the CPU heatsink. It is held with only one bolt; but it looks like it will work ok.

15 Software Upgrades

I upgraded the computer from Fedora Core 7 to Fedora 14. I installed a new hard disk. There are now three disks in Las Campanas: two are in the computer and one is on the shelf. I have made sure all three disks will boot.

The new disk is twice as large as the old one. I put two partitions on it. I will swap back and forth between those partitions each month. Whichever one is not in use at any given time contains a full backup of the system.

16 Network Camera

The network camera is not working. The power supply is ok; but no lights on the camera come on. I took it apart. There is corrosion on the inside. It looks like water accumulates in the bottom. Or rather, it accumulates at the top of the camera because we mount it upside down. I suspect that it would have been ok if we had drilled holes in the top of the case to let the water run out. I tried cleaning the camera; but there are some pins missing from one if the ICs.

A similar fate befell our network camera in Sutherland too. I will order replacement cameras.

17 Neslab Water Circulator

I tested the Neslab water circulator. It still works.

We have a 44-gallon water tank and a pump. Normally, the Neslab doesn't do anything. However, if the water temperature gets above 28°C, the computer will turn on the Neslab to cool the tank. The Neslab has been setup like this since 1999 January; yet it has never once been needed. It just doesn't get that hot in Las Campanas.

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