Instructions on improving the Losmandy OPW PE behavior and Two Piece Worm Block behavior

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revised June 15, 2016 with comments about using 2 Belleville spring washers in 2 block systems

revised Aug 7, 2016 with comments about the Oldham Coupler adjustment

revised Mar 18, 2019 with possible way to put in 2 Belleville washers outside the far bearing block

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I. Overview: getting the best PE from the Losmandy OPW and precision brass worm

Online reports by other owners suggest that the OPW can typically give about 2 to 4 RMS arcsec PE. I was able to get below 1 arcsec RMS PE by making several modifications to the OPW, described below. The steps were:
(1) replace the 2 stock worm thread facing bearings with ABEC-7 stainless steel bearings (Boca bearings).
(2) Install a special Belleville spring washer on one end of the worm.
(3) Adjust the gearbox so its output axis is in line with the axis of the RA worm.
(4) Put shims around the bolts holding down the gearbox.
(5) Adjust the Oldham coupler metal ends to tighten the plastic center part of the coupler.
(6) Adjust the worm to ring gear spacing to avoid stalling the RA motor.

Parts:

Bearings were:
SR4-ZZC #7, 1/4 x 5/8 x 10/51 inch, Stainless Steel Radial Bearing
$12.95 each on eBay
http://www.ebay.com/itm/350886411467?_trksid=p2060778.m2749.l2649&ssPageName=STRK%3AMEBIDX%3AIT
(There are ABEC-7 bearings available at lower cost from McMaster-Carr (www.mcmaster.com, but I have not tried them.)
The ones I used are not on eBay any longer, but are available directly from: BocaBearings.com as R4ZZ, ABEC-7 quality. They are about $9 each (Mar 18 2019). Here is the link:
https://www.bocabearings.com/products/sr4-zzc-7-ps2-599

Belleville washers were:
http://www.mcmaster.com/#belleville-disc-springs/=v70176
Belleville Disc Spring for Ball Bearings, Bearing #R4, .406" ID, .618" OD, .0216" High

R4	0.406"	0.618"	0.0216"	0.0089"	7	10	**94065K32**	2.76

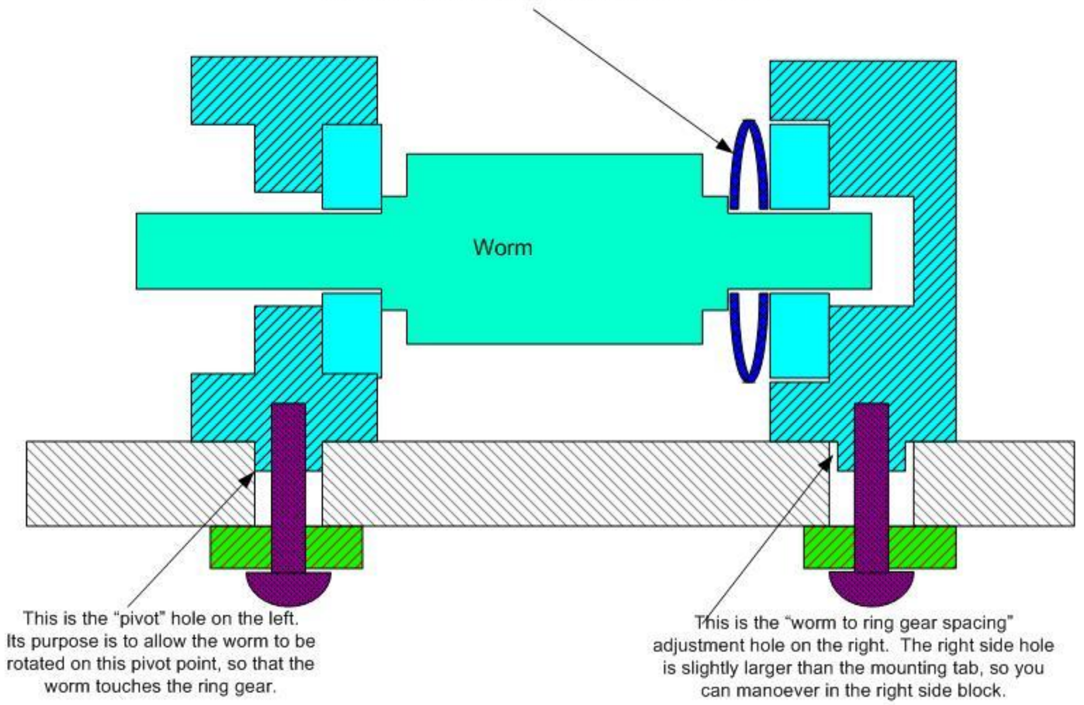
New idea: putting in Belleville washers with existing bearing.

The problem with the Losmandy worm drive design is that it does not constrain the worm from left-right movement along its axis. It needs a spring or springs to do that. Here is a simple way that might work… it has not yet been tried but should work. The diagram below shows the scheme of using 2 face-to-face Belleville washers on the worm itself to push into the center of the far worm bearing. That will push out on both bearings and eliminate side to side movement.

Two Piece Worm Blocks with a pair of R4 Belleville Washer fitted OUTSIDE the far bearing block, OUTSIDE the bearing. You compress the right bearing block while bolting the bearing block to the (black color here) DEC or RA mounting flange.

This keeps pressure on the bearing, and keeps the bearing balls of both bearings in compression.

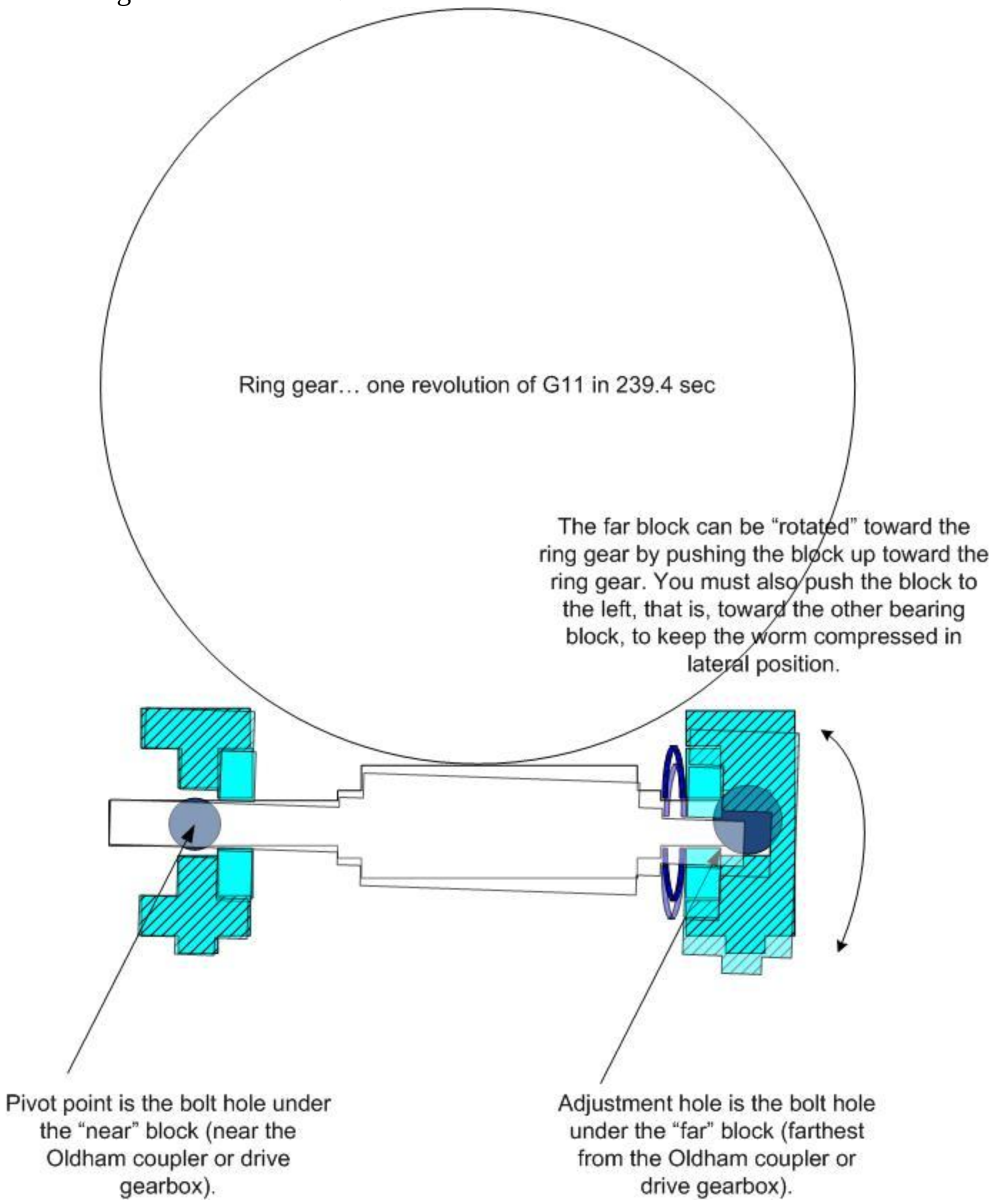
This method is a new concept, of putting a pair of face-to-face Belleville washers on the external side of the right side worm bearing. The Belleville washers push in on the center of the far right bearing, and rotate with the worm at the worm period. The Belleville washers never touch the fixed outer part of the bearing, so should not rub. This is easier to assemble because you do not have to pull out the far bearing and do not have to polish down the OD of the far bearing.



This method is a new concept, and has not yet been tried. It should work.

The only issue is this: the pair of Belleville washers must be compressed by the owner, while the owner moves the right side block both toward the ring gear, and the other bearing block. The two Belleville washers take up a little space, so the question is if there is sufficient room under the mounting bolt to move in the far bearing block, so that the worm touches the ring gear fully. – Michael Herman, Mar 18 2019

After that, you still must push in the right side worm block to have the worm engage fully with the ring gear, as the diagram below shows:

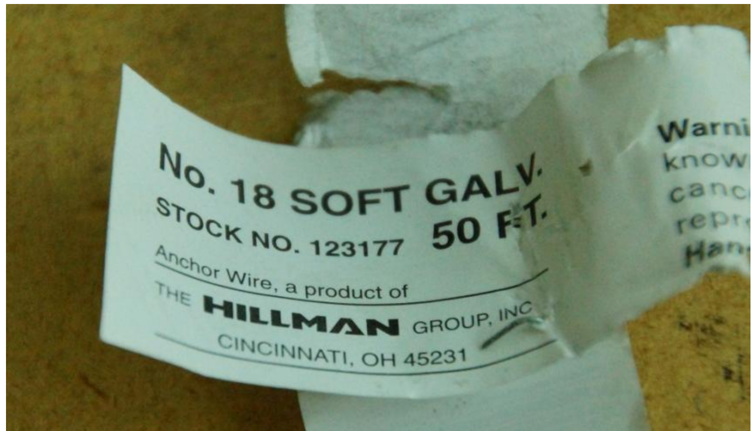


The "internal" way of putting in a Belleville washer requires some effort to remove the existing worm bearings and polish down the replacement OD so it will slide in and out of its mounting barrel. The spring is hidden inside the worm block and provides the pressure. I describe that next.

Step A: getting out the existing rear bearing (if stuck)

The front bearing block has access to push out the two bearings once the worm is removed (and removing the worm may require some filing to remove deformation from the setscrews).

If you want to lift out the back bearing from its block, here is a simple puller made from a bolt and some heavy 18 gauge steel wire. Here is the wire that I used:



I bent pieces of that wire into shape by hand, with small pliers. You put the hooked wires through the center of the bearing, then insert the bolt that keeps the wires from pulling back out. Then gently pull out the bearing. If you need this....

Step 1: take a bolt with diameter smaller than (the bearing ID + 2 wires).
Step 2: screw on a large nut (square one shown)
Step 3: wrap 2 wires around the bolt and pass the wires around the nut

Step 4: insert the 2 wire hooks through the center of the bearing

Step 5: screw down the bolt, so it prevents the hooks from being pulled back out.

Step 6: pull out the bearing from the block.

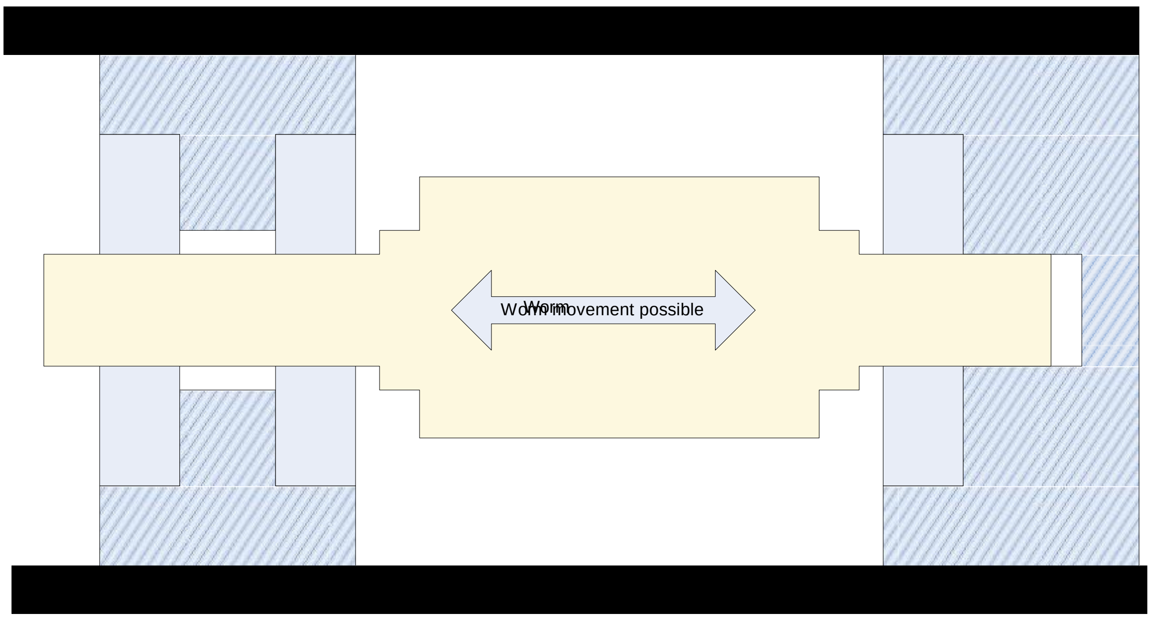
Post-script Aug 7 2016: Two owners found that this simple puller was not able to remove the bearing, and they resorted to drilling out the end of the right bearing block with a small hole, and then pushed out the bearing from there. I then made a similar puller to the one above by bending some steel nails into thicker jaws, and hooking those above the bearing with steel wire. I have sent this to Masami Yamada in Tokyo to try.

Other ways of getting out the stuck bearing are to use the ends of bent steel nails, held in a vice, and gently tapping on the block to knock it off of the held bearing.

Step B: Putting in the Belleville washer

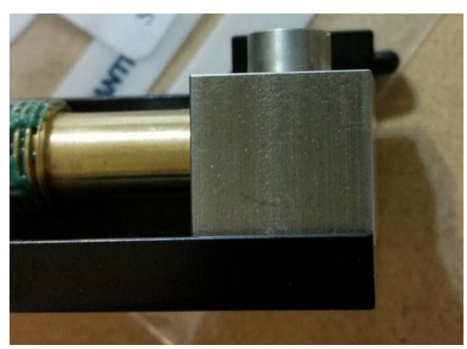
Here is the original problem (showing the Losmandy OPW One Piece Worm block), there will be a gap between the (brass or steel) worm and the facing inner bearings, due to temperature differences between the aluminum (black) and the worm (shown).

Normal OPW without a Belleville washer installed,
allows the the worm to shift along its axis, between the two facing bearings. (Drawing not to scale)



Once the bearing is out, put the Belleville washer in so that the curved out part faces the worm and bearing. This puts the larger outer edge against the worm block.

After you put in the washer, you should see the outer bearing block slightly extend past the end of the OPW:



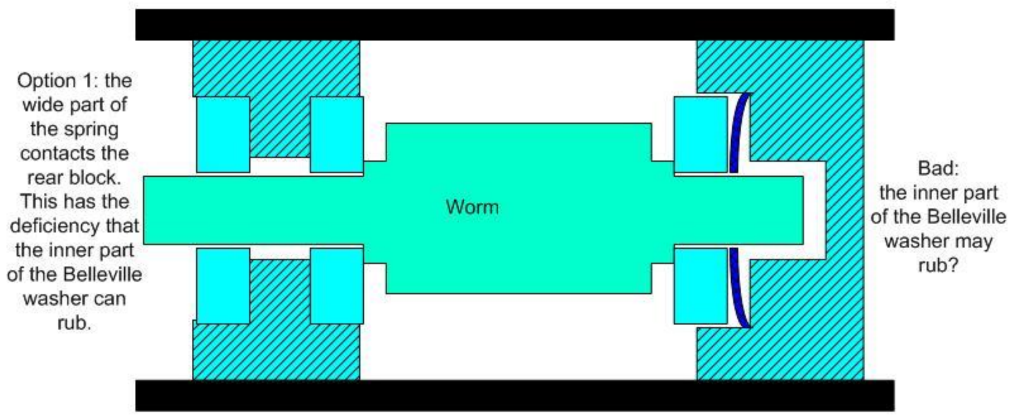
After you put in the washer and compress in the end block, you should see the outer bearing block slightly extend past the end of the OPW:

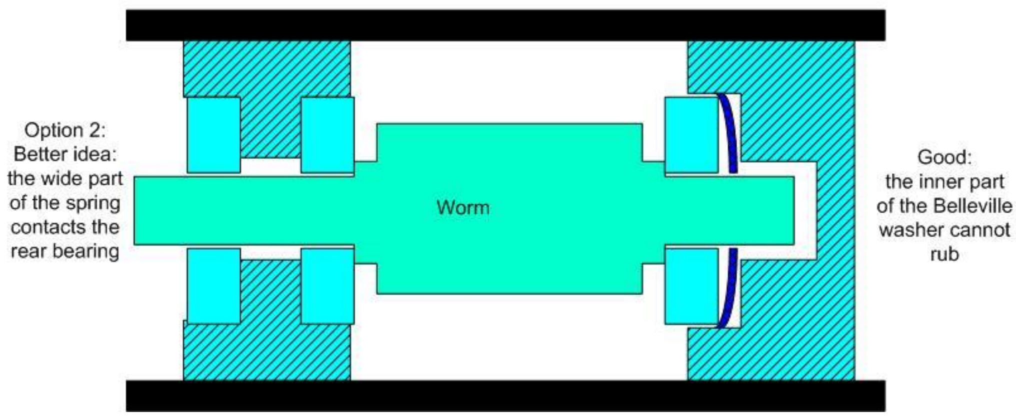
The disks are these, from McMaster-Carr

Here are the sketches of how the spring will go in:

OPW with the Belleville washer installed, before the rear bearing block is compressed.
Note that when installed with the rear bearing block not force in, the rear block will be either flush or just slightly past the end of the OPW body. (Drawing not to scale)

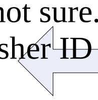
OPW One Piece Worm Block with R4 Belleville Washer fitted into rear block, behind the bearing.
You compress the right bearing block while bolting the bearing block to the (black color here) OPW mounting bracket.
This keeps pressure on the bearing, and keeps the bearing balls in compression.





OPW with the Belleville washer installed, after the rear bearing block is compressed.
Note that you have to hand-compress the rear bearing block in the direction of the arrow, while tightening down the bolts that hold it to the OWP frame. (Drawing not to scale)

The Belleville washer spec says it compresses fully with 7 pounds pressure... I'd just push the thing together and see how that works. With temperature drops, the aluminum of the G11 will contract slightly faster than the brass of the worm (if your worm is brass). If your worm is stainless, then that contracts even less than brass. In either case, I don't think anything can go very wrong. Could the Belleville washer go in better in the other direction, with the larger edge facing the worm teeth? I am not sure... but my reasoning was that there is less of a lip on the back worm block to hold the inner washer ID edge.



Step C: Adjusting the Oldham Coupler to reduce its play

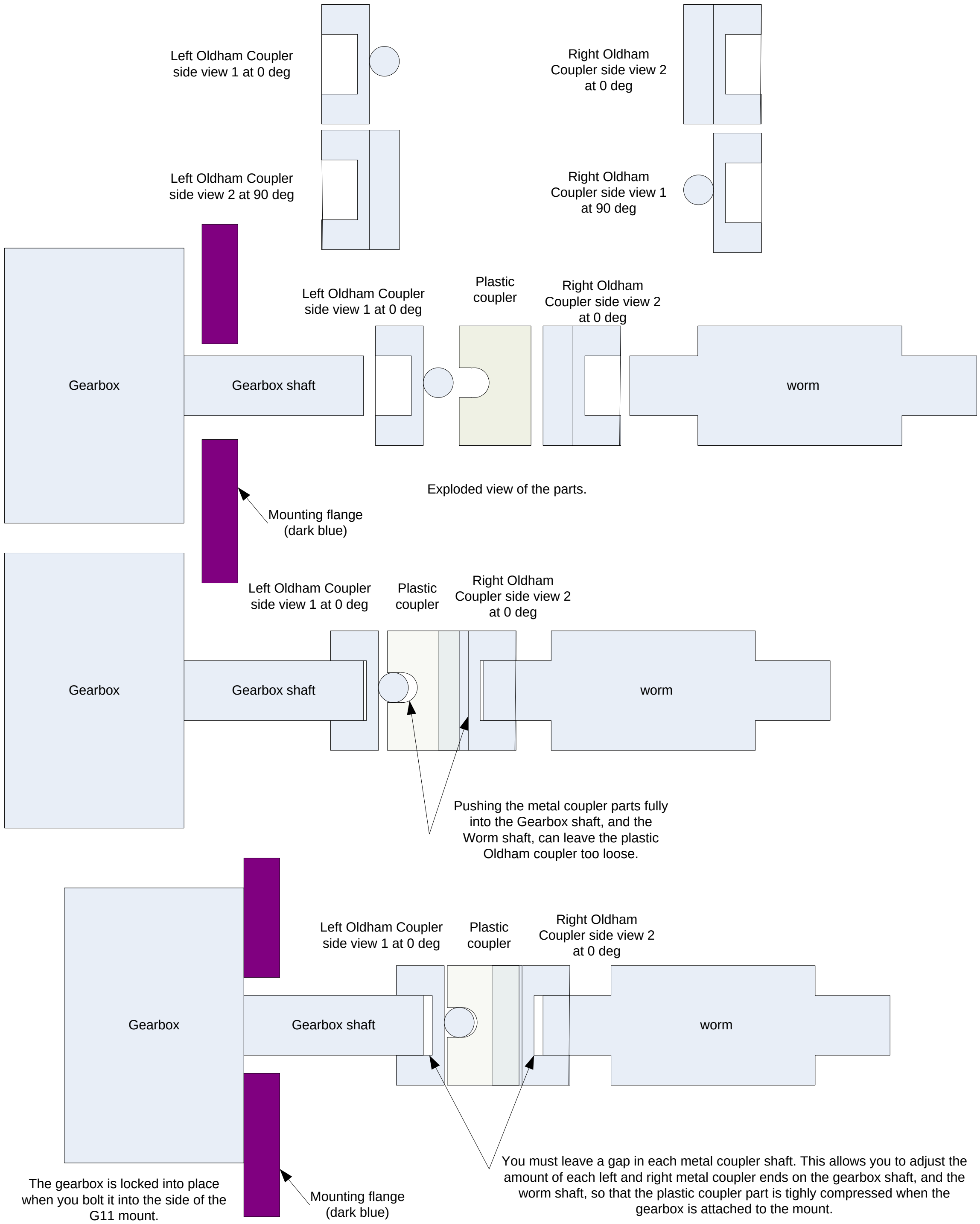
The Oldham coupler is another key to the puzzle of RA PE. The coupler allows there to be a difference in angle, and in axis parallelism, between the gearbox drive shaft, and the worm axis shaft. That sounds like a good thing, but it can also add errors to the periodic rotation of the worm - and those errors are what we are trying to eliminate.

The coupler works by having a plastic sliding part, between two metal ends that have a metal rod brazed on. The two rods can slide in one direction only, and the plastic coupling has a groove on each side to allow each side rod to slide along the groove.

If there is a difference between the axis of the worm (on the right side of the coupler) and the gearbox drive shaft (on the left side of the coupler), then this can result in a speedup and slowdown in the worm speed, as the rods slide in the coupling.

More of a problem is that the groove for each side rod can allow there to be excess movement of the coupling rods unless the plastic middle part is fairly close (not necessarily compressed) by the two metal end parts. We do not want the plastic part to be loose between the metal slide rods.

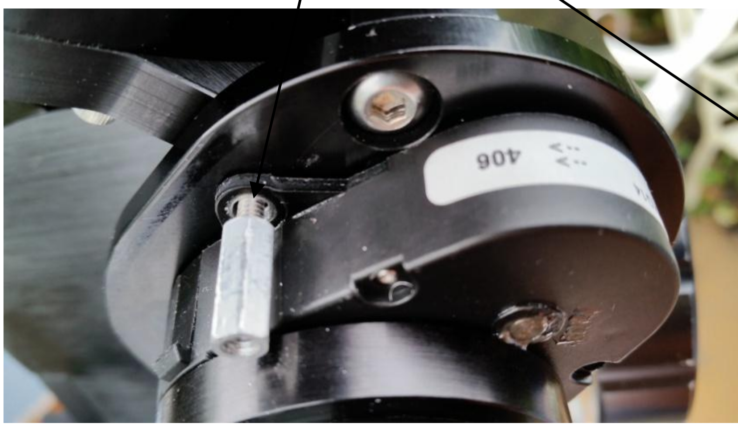
There is really no way to adjust that except after the gearbox and worm have been attached to the mount. If the Oldham coupler metal plate setscrews are observable, one can get an allen wrench in there and slide the metal parts of the coupler toward each other. In the case of the 2 separate bearing blocks, this is easy. In the case of the OPW, this is difficult.


Left Oldham Coupler side view 1 at 0 deg
Right Oldham Coupler side view 2 at 0 deg
Left Oldham Coupler side view 2 at 90 deg
Right Oldham Coupler side view 1 at 90 deg
Gearbox
Gearbox shaft
Left Oldham Coupler side view 1 at 0 deg
Plastic coupler
Right Oldham Coupler side view 2 at 0 deg
worm
Exploded view of the parts.
Mounting flange (dark blue)
Gearbox
Gearbox shaft
Left Oldham Coupler side view 1 at 0 deg
Plastic coupler
Right Oldham Coupler side view 2 at 0 deg
worm
Pushing the metal coupler parts fully into the Gearbox shaft, and the Worm shaft, can leave the plastic Oldham coupler too loose.
Gearbox
Gearbox shaft
Left Oldham Coupler side view 1 at 0 deg
Plastic coupler
Right Oldham Coupler side view 2 at 0 deg
worm
The gearbox is locked into place when you bolt it into the side of the G11 mount.
Mounting flange (dark blue)
You must leave a gap in each metal coupler shaft. This allows you to adjust the amount of each left and right metal coupler ends on the gearbox shaft, and the worm shaft, so that the plastic coupler part is tighly compressed when the gearbox is attached to the mount.

Step D: Reducing gearbox play

There is another part of the puzzle, on the outside of the OPW...the mounting of the Gearbox.

The new gearbox has mounting holes that are larger than the bolt that mounts them. Here is a picture of the problem. To fix this, I made some "tube" that takes up the gap, out of brass shim stock, cut with a scissors, and wound around the bolt. This is not ideal but did work to keep the gearbox from shifting out of alignment with the OPW mounting.



A simple solution: wind some brass shim around the bolt.
In place, the shims keep the gearbox from shifting.

Step E: Measuring the PE (before and after)

Download the free program PECprep from
http://eq-mod.sourceforge.net/pecprep/index.html

When you run the program, you can select the top menu Mount / Losmandy G11 mount... the program then knows the mount and worm parameters.

Download and run the program PHD from Stark (or better, PHD2).

1. Do a drift alignment before you start to gather your PE data. This will help keep your guide star on the imager chip region.
2. Take about 4 or more worm periods. The G11 period is about 240 seconds, so you need about 20 to 30 minutes of tracking.
3. When you run PHD (or PHD2), first allow the program to Calibrate.
4. next tell PHD to make a Log file.
5. On the Losmandy G11 with Gemini, you MUST be in "G" for Guide mode, else the autoguider signals will not work. Once the PHD is calibrated, go to your Documents top level, and delete or rename the PHD log file.
6. Run the PECprep program. In the File section, import the PHD logfile.

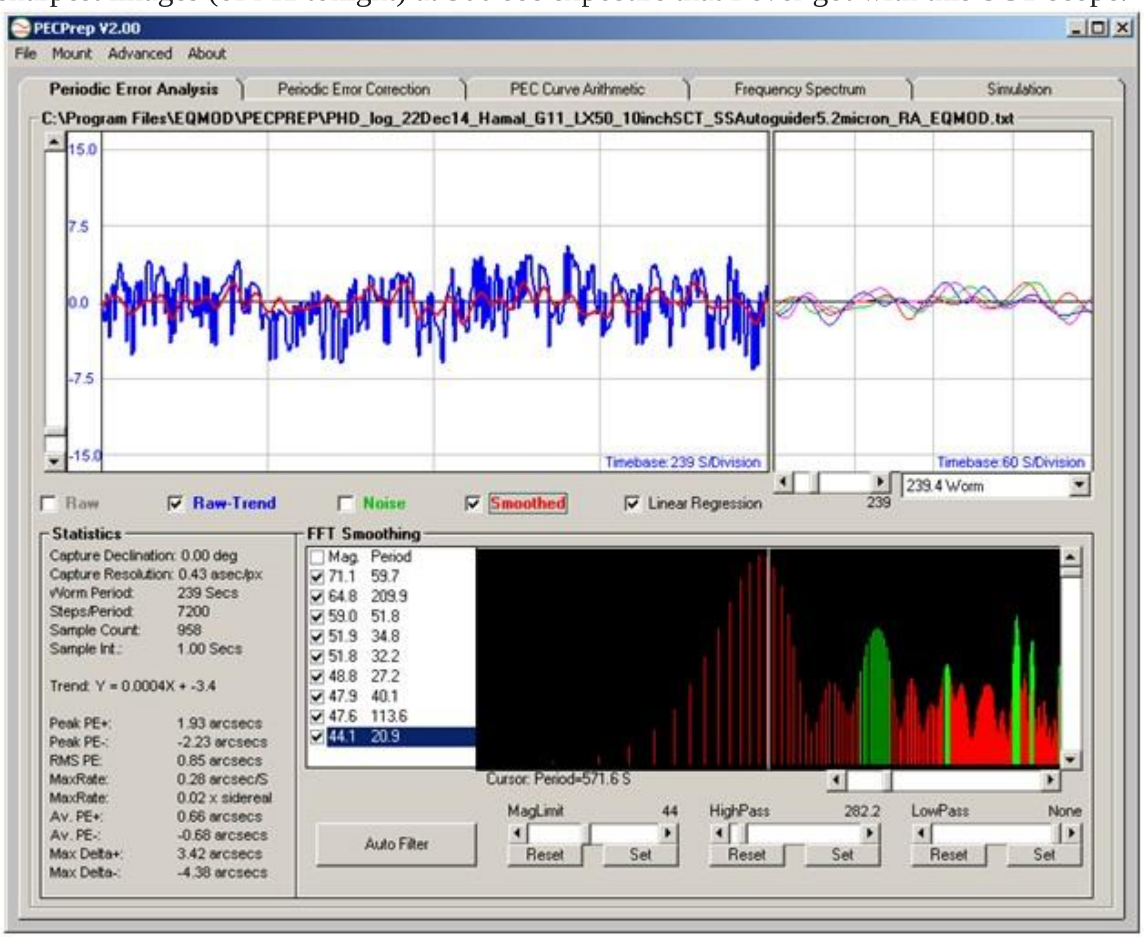
My email to the Losmandy group on Dec23 2014 was:

Hi gang,

I just measured the RMS PE measured on the upgraded G11 OPW, and it comes out at under 0.9 arcsecs. That is down from 4.8 arcsecs on the same OPW block from just a few weeks ago, but with a few different components. .

I used the same hardware (Orion Starshoot Autoguider with 5.2um pixels) and software (PECPrep) and scope (Meade LX50 10" SCT FL2500mm) to measure the PE in both cases. (I imaged Hamal for this measurement at about 10PM, at my location near San Francisco, it was starting out pretty close to the meridian and equator).

That PE is below the seeing conditions tonight. The program says that applying a PEC will bring the RMS PE to 0.6 arcsecs. I am running the mount tonight with a heavy 10" SCT, two 20 lb + 7lb counterweights. My camera has a 2" filterwheel and Lumicon giant off-axis guider. I am autoguiding (with no PEC installed) using the ASCOM interface, PHD with 4.5 sec exposures on an Orion Starshoot Autoguider, and getting the best sharpest images (of M1 tonight) at 500 sec exposure that I ever got with this SCT scope.



OK. details if interested:

This G11 is a vintage about 1995, badged as a Celestron G11 made by Losmandy. This is a very old mount; I bought it used a few months ago. It had the original steel worm and original bearing blocks (separate, black color). I bought a used Gemini-1 unit, and new High Torque motors and the new gearboxes for both RA and DEC.

I did not measure the PE of the original equipment, but I learned that they typically run about 8 arcsec PE. Reading that the OPW and new precision worm should deliver about 2 arcsec RMS, and at the urging of another group member, I bought a new OPW (One Piece Worm) retail. It did not come with the worm installed, but instead a worm was sent to me by Losmandy directly. The OPW came with 3 bearings installed, and a new Oldham coupler (2 stainless parts and a plastic coupler for the middle).
It also came with the external aluminum elliptical part that mounts the High Torque gearbox and High Torque motor.

I measured the PE of this set of new OPW and Losmandy precision worm. After drift aligning, I got 4.8 arcsecs RMS. I expected half that, and contacted Losmandy. They sent me another worm to try. This second worm is in the G11 tonight. However, I also upgraded other components... so it is not absolutely clear that only the worm has made the difference.

I also read very well done research by Michael Siniscalchi (http://helixgate.net/) who investigated several aspects of G11 operation. He found that the worm bearings, and their axial preloading, made a difference in his PE. He also investigated the effects of different Oldham and similar couplers.

For those reasons, and other members of our group who pointed out that the worm bearings could be found on line, I purchased new ABEC-7 bearings via eBay from Boca Bearings; they were about $13 each. The OPW takes 3, but I have only used 2: the 2 facing the worm threads. I ordered the 3rd bearing only after reassembling the OPW, and decided to see what the results might be with only 2 high quality bearings around the worm. The other bearing faces the Oldham coupler, and is not present in some other mounts (the Orion Atlas=Synta EQG has only got 2 such bearings).

Other members in emails here also mentioned recently that the Ovision worm block had a Belleville washer and a screw at the end for compressing that. I found the right Belleville washer on McMaster-Carr, and installed one of them at the end of the OPW fartest from the motor. The OPW was able to accommodate the thin washer without difficulty. The washer provides a spring between the worm block and the end bearing outward face, so the bearing is compressed on to the worm. This keeps the worm from side to side movement under any temperature conditions (as Brass contracts faster than either aluminum or stainless steel).

Anyway, I reassembled the system, and ran it in the daytime over the weekend. The RA axis worm gear was set too tightly against the ring gear, and I was getting "RA Lags" error messages on the Gemini-1 handbox. I backed out the worm using the OPW screw adjustment, until the messages went away.

Anyway... I'm surprised this story has a happy ending...maybe an early Xmas present. I really thought I'd have to buy the Ovision worm block...

I'll write up a report with photos of the assembly... but I'm very happy that I did not need to go any further to get to the PE I was seeking.

All the best,
Michael

II. Overview: getting the best operation from the Losmandy 2 worm blocks

Though I replaced my RA worm blocks with an OPW one piece worm block, I never touched the DEC worm gear. It is still the original steel worm, and the 2 separate worm blocks. I did not think about putting a Belleville spring washer into the DEC area until this week (June 15 2016).

My Gemini-1 system has been reporting "DEC Lags" errors for the last few months. As I have not been doing deep sky imaging, I mostly ignored the error reports by the Gemini-1.

However, when I would reverse DEC direction using the hand paddle or PC Gemini.net paddle buttons, the DEC image movement would have a long lag, and would show no image motion for a few seconds. This confirmed what the Gemini-1 would say: there was a DEC "lag". I still do not know how the Gemini-1 would know this, as it cannot detect the actual image movement. Perhaps it is monitoring the current drawn by the motor (the manual says it does this), and so it "knows" that the current is too low to be driving the actual mount itself…it is just turning the DEC worm around with no load.

I finally had a chance to look at the mount in the daytime and determine what might be wrong.

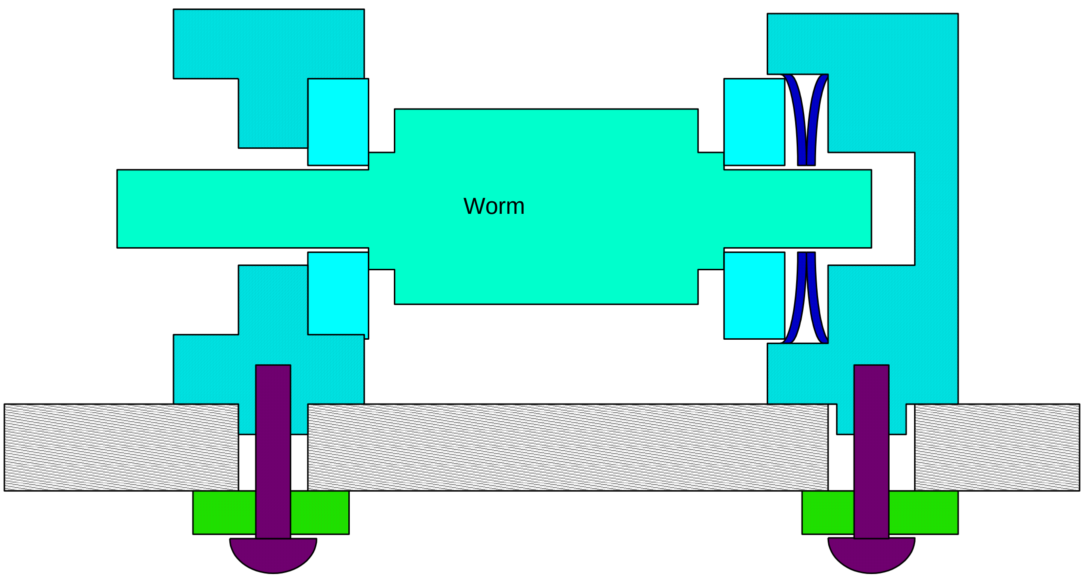
If I pushed the scope left and right on the DEC axis, I could see the worm slightly moving left to right. So this told me that the worm blocks might be close to the mounting flange, but the mounting blocks are not close enough together to compress the worm or the worm bearings.

I have employed the same idea as used in the OPW to solve the DEC movement lagging problem. Here is the concept:

Concept drawing.

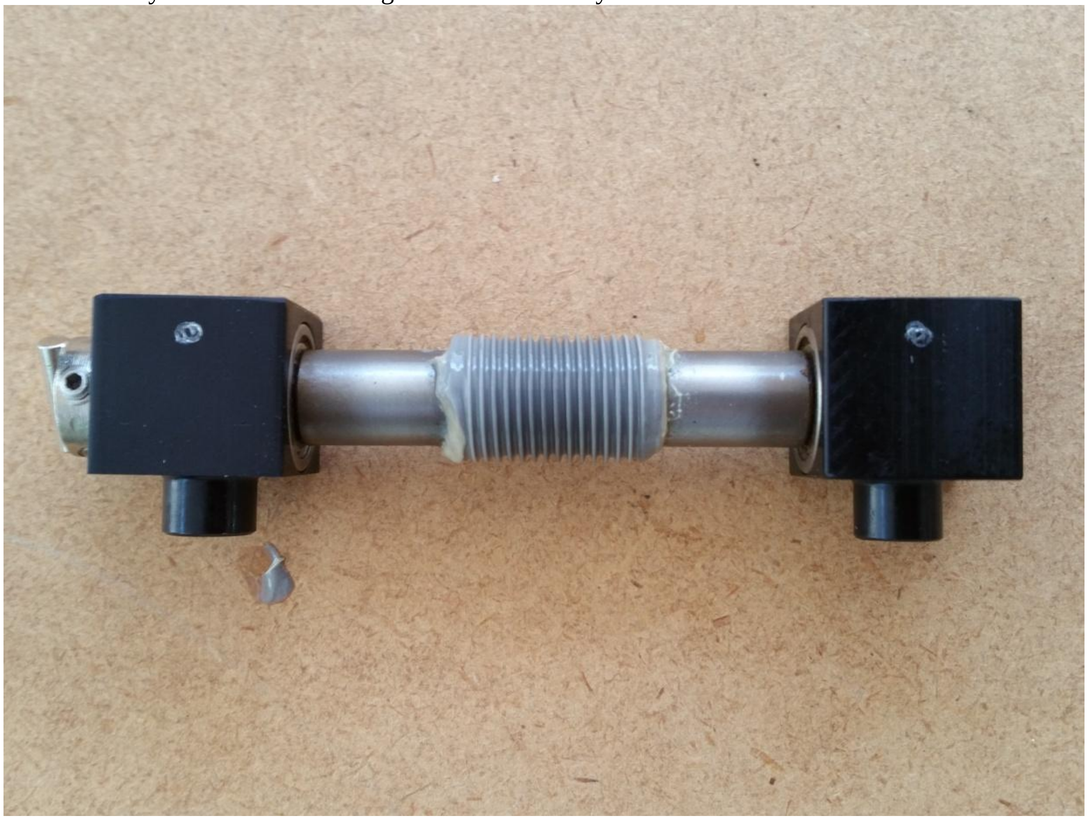
Two Piece Worm Blocks with a pair of R4 Belleville Washer fitted into rear block, behind the bearing.
You compress the right bearing block while bolting the bearing block to the (black color here) DEC or RA mounting flange.

This keeps pressure on the bearing, and keeps the bearing balls of both bearings in compression.



Photos of the assembly:

This is the way the two DEC bearing blocks look when you remove them from the G11.

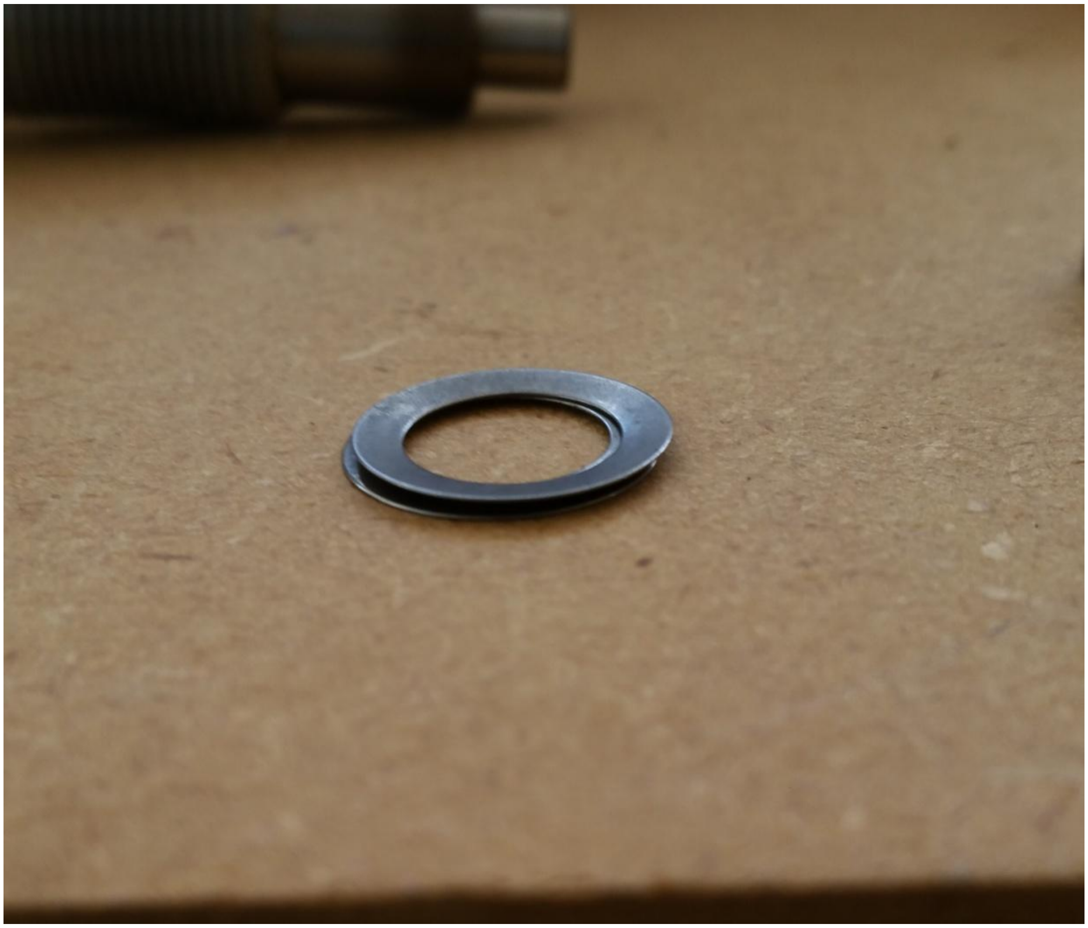


Pull the worm out of the right hand (rear) bearing block.
Then make a small "bearing puller" out of steel wire and a small bolt and nut, as shown.

Insert the 2 wire jaws into the bearing center hole, and then screw in the bolt to keep the 2 jaws from retracting back out of the hole. Pull the bearing out. The picture above shows the bearing puller, and the bearing still in the jaws of the wire puller.

Now you see down the rear bearing block:

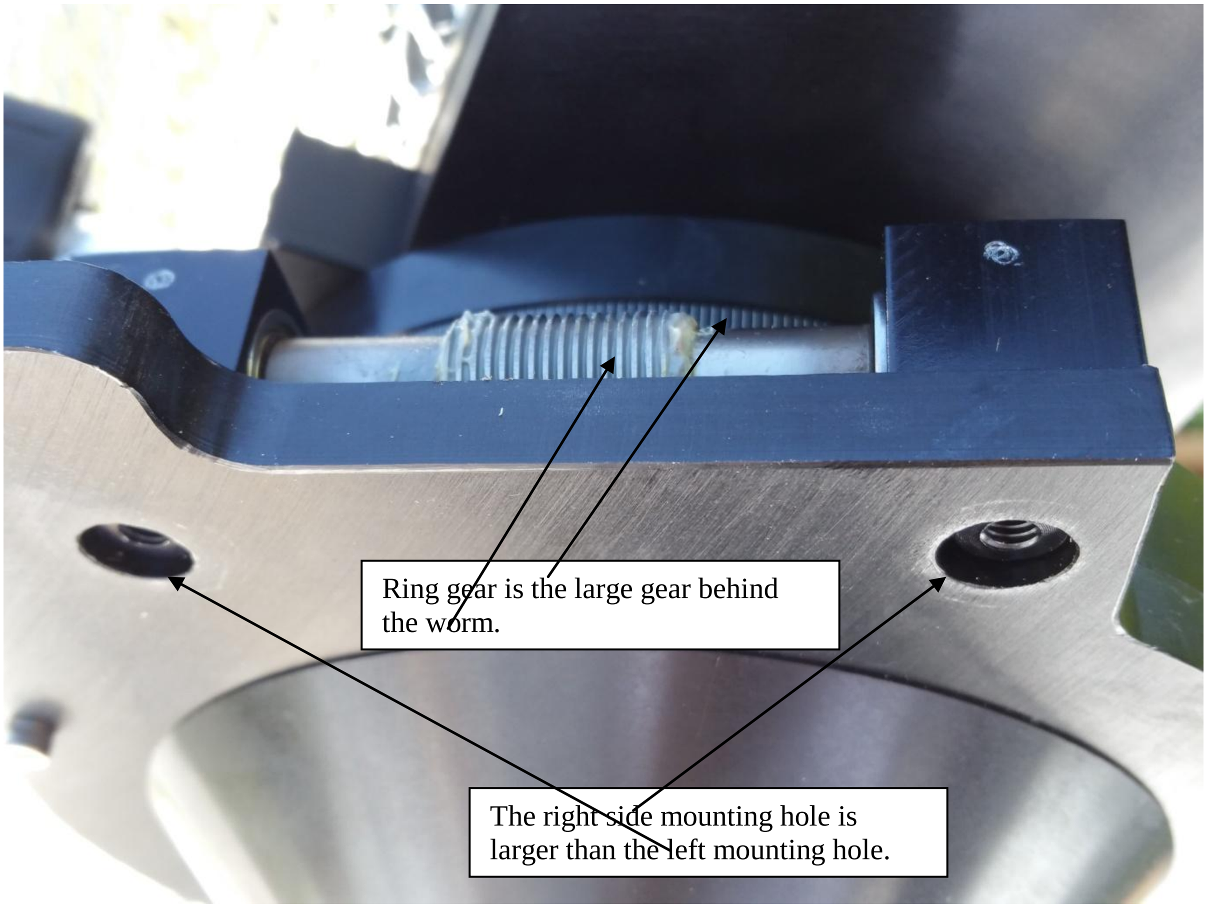
Now place 2 Belleville R4 spring washers with the small inner section facing each other as shown:



Insert the facing pair of spring washers into the rear bearing block:

Now use some 2000 grit or similar very fine grit sandpaper to polish down the outer diameter of the bearing, and put some lubricant (I used SS2000 teflon grease) around the bearing so it will slide on the sides of the block hole. I was careful to NOT overpolish the inside of the block, or outside of the bearing, to cause the bearing to have play perpendicular to the worm axis.

Now install the 2 bearing blocks back on the G11, being careful to rotate the worm or ring to be sure the teeth are engaged. You will find the right hand bearing block has a slightly larger hole to fit, which compresses the pair of spring washers during the installation.



Now complete bolting in the left underneath bolt until snug, and snug the right underneath bolt. This right side bolt position must be adjusted so that the worm is not too tight against the larger ring gear teeth.

Adjust the gap between the rightmost block and the G11 body, so that the teeth are not too tight. Test the movement in the DEC direction using the motor control. Ensure there is no binding or motor stalling.


This space is a critical adjustment. Tighten the bolt below the bearing block after you set the spacing (with a feeler gauge).
20
30
40