Triaxial Tourbillon Clock Make

1 Parts list

Here are the parts that I used. You can use hex socket or Philips head screws, your choice. I used hex socket head cap screws for the balance wheel weights because they were heavy. I paid about $1 a piece for all the ball bearings on ebay or Amazon.

Some of the “2mm” and “3mm” shafts that I’ve picked up on ebay or Amazon have been slightly oversized, just enough so the bearings won’t fit on to them. Look for a slip fit of the shaft in the bearing. DON’T force the bearings on the shaft. I tried and jammed the bearings, making them useless. My solution was to order from another vendor. Maybe you will get lucky the first time.

1.1 Summary

(4) 3x6x2.5 ball bearings

(4) 2x5x2.5mm ball bearings

(9) 8x22x7mm ball bearings

(3) 12x28x8mm (6001) ball bearings

(~200mm) 2mm shaft

(~100mm) 3mm shaft

(18) M2x8 flat head screw

(10) M2x8 cap screw

(2) M2x10 cap screw

(3) M2x20mm flat head screw

(8) M2.5x8 cap screw

(2) M3x8 hex socket head cap screw

1.2 Details

3x6x2.5 ball bearings

- 2 for the Balance Wheel

2x5x2.5mm ball bearings

- 2 for the Fork
- 2 for the Escape Wheel

8x22x7mm ball bearings

- 1 for the Moon

- 1 for the Earth
- 2 for the Main Frame-32Crowngear and the Forkframe-forkframeconnector-1
- 1 for the Main Frame-24tgearplusshaft and the Main Frame-carriertop
- 1 for the Clock Face-72tminute shaft halfs and the Main Frame-carriertop
- 1 for the Clock Face-72tminute shaft halfs and the Clock Face-Face Plate
- 2 for holding the Main Frame-carriertop center shaft in the Mainframebottom-mainframetop a. *Note that I used A26's bearingadapter.STL as spacer between them.*
- 1 for holding the Mainframebottom-18tgearplusshaft 2 in the Mainframebottom-mainframetop c

12x28x8mm (6001) ball bearings

- 1 for the lower 30tbevel gear
- 1 for the lower drum
- 1 for the upper 30tbevel gear

2mm shaft

- 16mm long for the Tourbillon-15Tanchor2 (Fork)
- 13mm long for the Tourbillon-15Tesc (Balance Wheel)
- 13mm long (x3) to hold the three 10tbevel gears in the drum.
- 12mm long for the Forkframe-40Tgear 2
- 18mm long for the hourgear2
- 14mm long between the Clock Face-72tminute shaft halfs and the Main Frame-carrierbottom
- 13mm long between the Main Frame-24tgearplusshaft and the Main Frame-carrierbottom
- 10mm long between the Main Frame-Earth North and the Main Frame-carriertop
- 10mm long between the moon and the Main Frame-carriertop
- 46mm long between the Mainframebottom-Mainframebottom2 and the Mainframebottom-18tgearplusshaft 2

3mm shaft

- 51mm long between Forkframe-forkframe back 2 and Forkframe-forkframe1

M2x8 flat head screw

- 3 to hold Tourbillon-tourbframeback2 to the Tourbillon-tourbframemiddle2.
- 3 to hold the Tourbillon-tourbframemiddle2b to Tourbillon-tourbframemiddle2.
- 4 to hold the Clock Face-Face Face to the Clock Face-Face Plate.
- 2 to hold the Clock Face-Face Bridge to the Clock Face-Face Plate.
- 2 to hold the Main Frame-carrierbottom to the Main Frame-carriertop.M2x10 flat head screw
- 2 to hold Tourbillon-Tourbframetop2 to Tourbillon-tourbframemiddle2.
- 2 to hold Forkframe-forkframe 2 2a to Forkframe-forkframe back 2.

M2x8 cap screw

- 4 to hold Forkframe-forkframe 2 2a to Forkframe-forkframeconnector-1.
- 4 to hold Forkframe-forkframe1 to Forkframe-forkframeconnector-1.

- 1 to hold the Main Frame-39tgear cap to the Forkframe-forkframeconnector-1.
- 1 to hold the Main Frame-39tgear cap to the Main Frame-carriertop.

M2x10 cap screw

- 2 for the Main Frame-32Crowngear to the Main Frame-carriertop

M2x20mm flat head screw

- 3 for connecting the Mainframebottom-mainframetop a to the Mainframebottom-mainframetop

M2.5x8 cap screw

- 8 to the Mainframebottom-Mainframebottom2 to Mainframebottom-mainframetop c. Had to drill this out a little to get them to fit.

M3x8 hex socket head cap screw

- 2 for the Tourbillon-balancewheel to add weight

1.3 Some sources I've used

10pcs 2x5x2.5mm MR52-ZZ Precision Ball Bearings Chrome Steel, Metal Shield
https://www.amazon.com/gp/product/B00TVPSCVO/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1

3x6x2.5 mm Miniature Steel Bearings MR63ZZ L-630 673ZZ Deep Groove Ball bearing 10 PCS Skateboard Bearings
https://www.amazon.com/gp/product/B06X98386T/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1

M4x8 hex socket head cap screw

https://www.amazon.com/Adiyer-280-Pack-Metric-Screws-Assortment/dp/B072HXMDTV/ref=sr_1_fkmrnull_5_sspa?keywords=Hex+Cap+3m&qid=1550952813&s=gateway&sr=8-5-fkmrnull-spons&psc=1

1.4 Parts sources for Germany and Europe:

Based on the parts list, jay999 assemble this list of sources from www.ebay.de. At a total cost of 42.19€.

(2) 3x6x2.5 ball bearings

https://www.ebay.de/itm/2-Kugellager-MR-63-ZZ-3-x-6-x-2-5-mm/261757876750?hash=item3cf1fc3a0e:g:E4EAAOSw2s1U0L1M:rk:4:pf:0

(4) 2x5x2.5mm ball bearings

https://www.ebay.de/itm/4-Kugellager-MR-52-ZZ-2-x-5-x-2-5-mm/251431041159?hash=item3a8a753887:g:sG8AAOSwBahU0LnK:rk:2:pf:0

(9) 8x22x7mm ball bearings

https://www.ebay.de/itm/10-Kugellager-608-ZZ-8-x-22-x-7-mm/252276292922?hash=item3abcd6bd3a:g:IM0AAOSw7ThUmBqC:rk:31:pf:0

(3) 12x28x8mm (6001) ball bearings

https://www.ebay.de/itm/4-Kugellager-6001-ZZ-12-x-28-x-8-mm/252474545459?hash=item3ac8a7d533:g:fyAAAOSwstxVbC9m:rk:15:pf:0

(~200mm) 2mm shaft

https://www.ebay.de/itm/5stk-Edelstahl-Rundstange-Rundstahl-Welle-Werkzeug-Teile160x2mm-fur-RC-Modell/362497661813?hash=item54668b5b75:g:BNIAAOSwOGFcR-2c:rk:7:pf:0

(~100mm) 3mm shaft

https://www.ebay.de/itm/Edelstahl-Rundstange-Rundstahl-Welle-Stange-Achsen-3mm-x160mm-fur-RC-Modell-Auto/153282926742?hash=item23b05fd896:g:2xwAAOSwcOZcSQRL:rk:18:pf:0

(18) M2x8 flat head screw

https://www.ebay.de/itm/Senkkopfschrauben-TX-DIN-965-Edelstahl-VA-Senkschrauben-M2-M2-5-M3-M4-M5-M6-M8/271269854380?var=570184181484

(10) M2x8 cap screw

https://www.ebay.de/itm/Zylinderschrauben-ISO-14579-A2-TX-Edelstahl-VA-TORX-M2-M2-5-M3-M4-Vollgewinde/272021562228?var=570836115664

(2) M2x10 cap screw

https://www.ebay.de/itm/Zylinderschrauben-ISO-14579-A2-TX-Edelstahl-VA-TORX-M2-M2-5-M3-M4-Vollgewinde/272021562228?var=570836115667

(8) M2.5x8 cap screw

https://www.ebay.de/itm/Zylinderschrauben-ISO-14579-A2-TX-Edelstahl-VA-TORX-M2-M2-5-M3-M4-Vollgewinde/272021562228?var=570836117882

(2) M3x8 hex socket head cap screw

https://www.ebay.de/itm/Zylinderschrauben-DIN-912-Edelstahl-VA-ISK-Zylinderkopf-M3-M4-M5-M6-M8-M10-M12/271853628042?var=570689030299

2 Notes

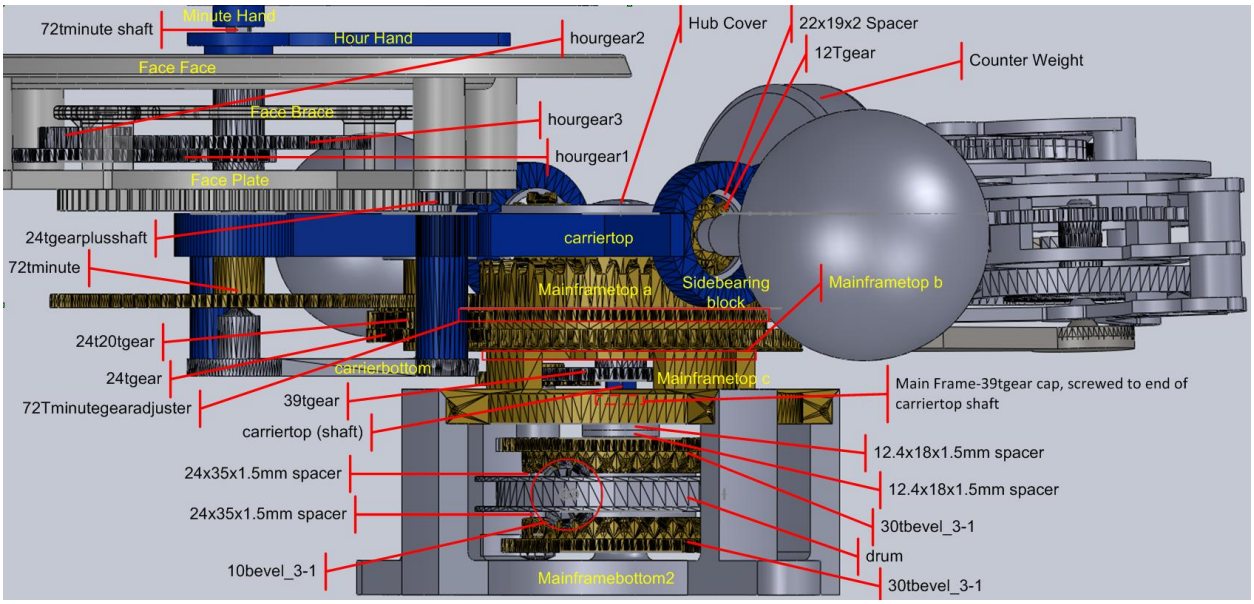
The Astronomia was on my list of clockworks to model too, but since A26 did so much work on his design, I thought that I would start with it. He put an impressive amount of work into it.

The assembly instructions were a little lean, and I haven't found an easy way of documenting a complex design either. So I took an easy way, I imported all the STLs and created some assemblies so that I could

see how all the parts fit together. My posted 'Assy' STL files show the whole assembly, and several sub-assemblies, which can be viewed with Meshmixer to get an idea of what goes where.

I made several modifications and additions to the original design, hopefully to improve its accuracy and the reliability. And a couple of the changes were just to make it look a little more like the actual Astronomia. (Note, Jaeger-LeCoutre has created many variations of their watch, my changes were of a particular instance that I had found.) With these changes it runs a couple hours with about 5 feet of nylon 30 pound test fishing line. It is hard to see in the time lapse mpeg movie file.

Figure 1: Parts Breakdown



2.1.1 Balancing the Carrier

As A26 said, the clockface was much heavier than the tourbillon. I found that when mounted on a wall, it would run fine as the clockface dropped, but would stop on the upswing. So I redesigned the clock face to be lighter (and to look more like that of the original Astronomia watch), and added a counter weight (packed with #4 lead shot) that clips onto the 32crowngear It weighs about 150 gm. The result doesn't perfectly balance the assembly, but now it will reliably run through a full revolution.

2.1.2 Ball Bearings

I changed many 'bearings' from plastic on steel shaft to ball bearings. The ball bearings are cheap, (typically, $1 each on ebay or Amazon), they made all the tolerances more accurate, and I figured that for all the time I was taking to put it together, it was small price to pay for a reliable design. I don't know what they use to lubricate those cheap ball bearings, but many of them were pretty stiff out of the package. However I found that it was nothing a drop of Mystery oil couldn't fix.

- I modified the escape wheel (15Tesc) and the fork (15anchor) to use 2x5x2.5mm ball bearings.

- I modified all the components that rotated on the main tourbillon shaft (tourbframetop, tourbframemiddle, and the balancewheel), to use a 3mm shaft and 3x6x2.5 ball bearings.

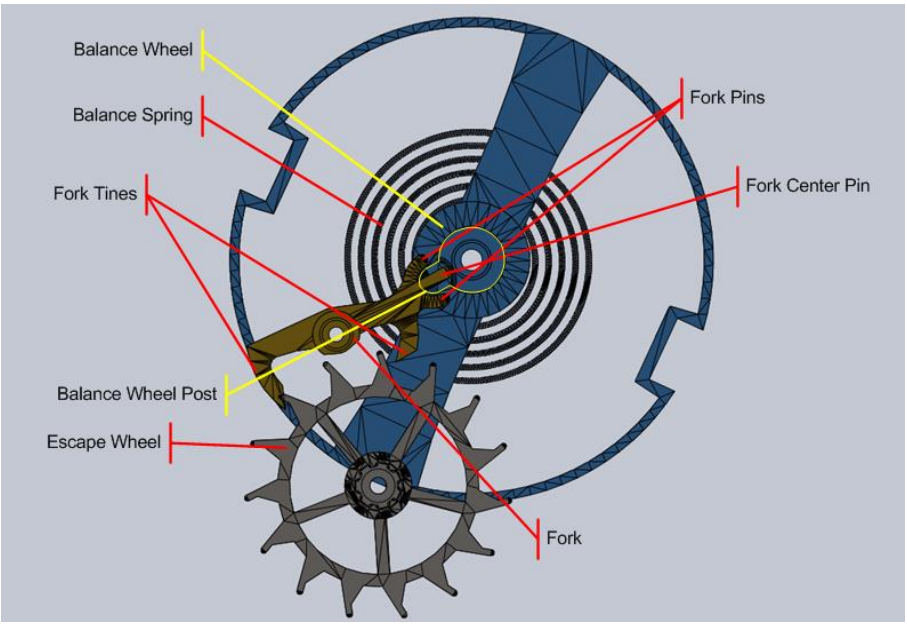
- The 8x22x7mm ball bearings that were used for the earth, the moon, the crowngear, the clockface and other places, were not particularly tight fits. Some bearings would slide right out. So I printed some 19x22x1 rings that I glued in place, to keep the bearings from moving.

2.1.3 Escape Wheel

I was showing a print of the original escape (15Tesc) wheel design to a friend, and he accidently snapped one off a tooth handling it. The teeth were only a couple fuses thick, so I beefed them up by adding chamfers to them.

The trick to aligning the balance spring is to position the balance wheel so the tab that engages with the fork is pointing directly at the fork. Them with the balance spring rotated to the position where it drops into the mount on the tourbillon frame, push the hex center of the balance spring onto the hex of the balance wheel. After connecting the balance spring to the balance wheel and the tourbillon frame, the balance wheel tab should point directly at the fork, when the balance wheel is at rest. See the attached photo.

Figure 2: Balance Wheel to Fork Alignment



2.1.4 Getting it to Tick

This is the most critical part of the design. It is made easier if you have printer that generates accurate prints. With my printer, I needed to drill out the all parts so the shafts spun freely, but I did not need to file any of the parts.

There are 4 parts involved, the Balance Wheel, the Balance Wheel Spring, the Fork, and the Escape Wheel. The names in this section refer to Figure 2.

- Make sure that any surfaces that contact between the Balance Wheel, Fork, and Escape Wheel are free of burrs, bumps, or any other printing artifacts that may cause a surface not to be smooth. If not, then some filing or scraping with a knife may be necessary to smooth the parts.

- Make sure that the Balance Wheel, Fork, and Escape Wheel each rotate freely when installed by themselves. The Wheels should spin easily, and the Fork should flop back and forth as the assembly is rotated.
  I ran a 2.5mm drill through the Fork and Escape Wheel shaft holes, and a 3.5mm drill through the Escape Wheel shaft hole to ensure that any printing artifacts were cleared out of the cavities.
  - Note: Run the drill backwards in plastic at first, otherwise it may auger in at some weird angle and ruin the part. Once the drill is running smoothly backwards, reverse it to clear out the plastic shards.
- All bearings need to fully seated, so that their top surface is flush with the respective part. You may need to pop them out and scratch out underneath them with a knife.
- With just the Fork and Escape Wheel installed:
  - Turning the Escape Wheel backwards (clockwise in Figure 2), should cause the Fork to snap back and forth easily.
  - And turning it counterclockwise should cause it snag against a Fork Tine. If the Fork snaps back and forth a little, it is OK. But if it never snags the Balance wheel when rotated counterclockwise, then the Fork Tines may be too short.
- With just the Balance Wheel and Fork installed (No balance Spring), spinning the Balance Wheel back and forth should cleanly engage the Fork. If there is any sign of a snag, or slowing down, then inspect where the two parts are rubbing, and file the offending part lightly. It is easy to take off too much. If you do, just print another part, and start again.
- Depending on the direction the Balance Wheel is spinning, one of the Fork Pins and the Fork Center Pin should slide along the surface of the Balance Wheel shaft, but not touch so much that they slow the Balance Wheel down. The two contact points formed by the Fork Pin and the Fork Center Pin act to hold the Fork at an angle where its Tines can snag/block an Escape Wheel tooth.
  - When the Balance wheel is rotated in the opposite direction, the Balance Spring Post engages with the Fork Pins to swing the Fork in to its opposite position. The swinging action of the Fork causes the Escape Wheel to advance one tooth, and engage with the opposite Fork Tine.
  - If there is any binding when the Fork swings, you will need to file the Center Pin a little shorter.
- When all the parts are assembled, a *very light amount of torque* on the Escape Wheel in the counterclockwise direction should cause the fork to swing, and the Balance wheel to rotate. Continuing to put torque on the Escape Wheel will cause the Fork to move to its opposite position when the Balance Wheel swings back, due to the Balance Spring. As long as you put consistent, light torque on the Escape Wheel, the assembly should continue to tick.

2.1.5 Forkframe

I split forkframe2 into 2 parts, the forkframe and the gear that engages the escape wheel. I did this for 2 reasons; now both parts to be printed without supports and glued together. And I made the standoffs for the gear 1mm longer to better align with the escape wheel gear that it engages with.

I cut my main tourbillon 3mm shaft a little short (which I have since fixed), so I was also having problems with the tourbillon forkframes (1 and 2) spreading and the shaft popping out, so I beefed them up.

Making forkframe 1 a mm thicker, and forkframe 2 wider. And adding chamfers that rest against the forkframeconnector. I also changed the design of forkframe 2 and forkframe back, so that the forkframe back is now attached with screws, rather than glue.

2.1.6 Tourbframe

Since I was tweaking the design a lot, I changed most of the parts that were originally to be glued together, to be screwed together instead. Now the tourbframetop, tourbframemiddle, and tourbframeback can be disassembled.

2.1.7 Crown Gear

I was having problems with the teeth of the 40Tgear walking out of the teeth of the crowngear as the tourbillon rotated, causing the whole clock to jump in time. Instead of rotating in the plane that it was supposed to, the 40Tgear would bend/flex a little, and work its way up and out of the crowngear teeth. And if the gears didn't separate so much that they would disengage, then you would hear pop (and the whole assembly would shudder) when the 40Tgear popped back into alignment. So I tapered the teeth on the crowngear and the 40Tgear, and made the 40Tgear teeth thicker so if it did walk up, there was still enough 'tooth' left to remain engaged.

To allow the tourbillon to be removed from the crown gear, I printed a plastic washer, and modified the end of the forkframe connector to accept a 2mm screw, so the 12Tgear could be secured with a screw, rather than being glued on.

2.1.8 Carriertop

The design worked fine when resting on a table, but when I hug it on the wall the carriertop and everything attached to it would pop out. This was because I had not glued the 36tgear to the carriertop shaft. To allow the thing to be disassembled, I printed a washer (39tgear cap), and used a 2mm screw in the hole that was supposed to be used for a 2mm alignment shaft between the carriertop and mainframebottom, to secure the 39tgear to the carriertop shaft. This also meant that I had to shave 2mm off the top of the mainframebottom center shaft, to make clearance for the washer and screw.

2.1.9 Mainframetop

To make it easier to see what I was doing in the previous step easier, and to allow the mainframetop to be printed without supports, I split it into 3 pieces. After printing, the middle part of the mainframetop is glued to the top part, and the bottom part (that attaches to the mainframe bottom), is then screwed to the top/middle parts.

2.1.10 Mainframebottom

The torque generated by the 5lb weight that I was using, caused the two 30Tbevel gears to spread apart and I was afraid that they would slip, because only the tips of the teeth were engaged with the three 10tbevel gears. Also the bearings were not a particularly tight press fit into the 30Tbevel gears and I was afraid that they might pop out from the stress, so I printed some 24x35x1.5 washers, and glued them to the 30Tbevel gears to keep the 30Tbevel gears from pushing themselves off the bearings. Using the 1.5mm thick washer, rather than the 2mm thick spaces, brought the two 30Tbevel gears closer together, requiring moving the two 2mm spaces so they were between the upper 30Tbevel gear and the bottom of the mainframetop.

- The mainframebottom has a chamfer in one leg. If I positioned that leg on the bottom when I hung it on the wall, gravity would cause the pawl to drop and not engage, so I added a spring to the pawl so it always positively engaged the 30Tbevel gear.

2.1.11 Clock Face

During assembly I bumped the clock, and when it fell off my desk, the main clockface shaft on the 72minute gear broke. To make the shaft a little stronger (and to shorten it a little to take out some of the slop), I split the 72minute gear from its shaft, then split the shaft into two halves, so it could be printed parallel to the print bed, and not use supports. My theory is that laying down a shaft for printing means that the plastic fuses are extruded the length of the shaft, vs radially if the shaft was printed standing up, making it stronger. I glued the two halves of the shaft together, stuck it in a drill and used a file to smooth it, and to take it down so that it was a tight fit in the 9mm hole that I had put in the 72minute gear, then glued them together.

2.1.12 Earth

The posted STLs for the earth had different underlying grids for the North and South hemispheres, which looked a little goofy. So created a simple hemisphere, and used Meshmixer to merge A26's north and south earth STLs with my simple hemisphere STLs, and hide the grids.

2.1.12.1 Experiments with Meshmixer

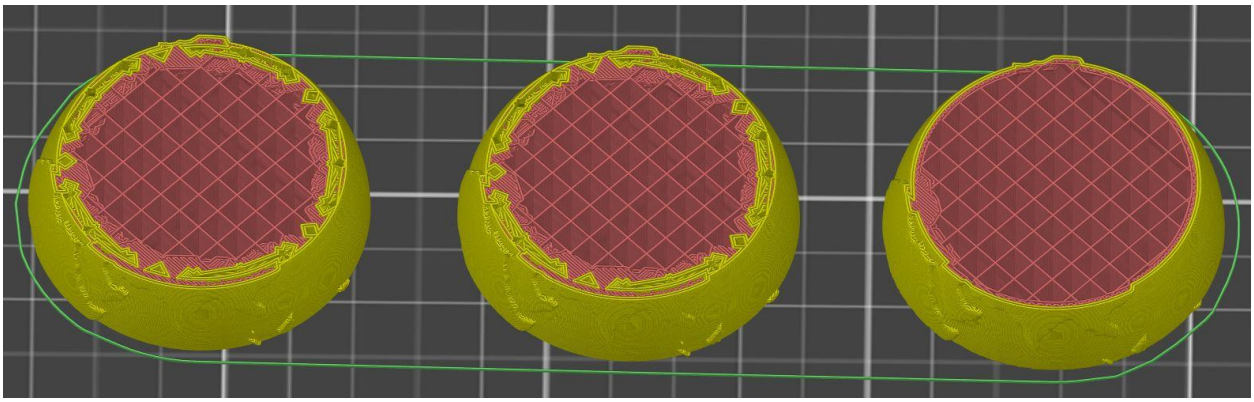
I probably spent more time mucking with the globe in Meshmixer than any other single part. The trellises that support the continents in A26s STLs are different, which I didn't like the look of, so I created the Earth_Fill mesh to hide the trellises. My idea was that I could merge together A26's original STL and my Fill STL to get the result that I wanted.

In Meshmixer, I Imported A26's original globenoth2 STL, and used Edit/Align to center it. Then used Import/Append to bring in my Main_Frame-Earth_Fill.STL. When the Import said "Auto repair', I said Yes. With the Fill selected, I used Edit/Align to home it (because where ever its home position was, it was WAY off the screen). I then used Edit/Transform to rotate it 90 degrees, and Edit/Align again so it sat flat.

At this point, I could see little bits of the trellis showing through the Fill. I needed to uncheck View/Printer Bed to be able to see the bottoms of both parts. I rotated it around so I was looking squarely at the bottom of both parts, where you can see that some of the continents are not sticking through the Fill. Using Edit/Transform again, I moved the Fill around until it looked like the continents were consistently projecting from the Fill. Rolling it over and spinning it around, it looked pretty good, I could see the continents and islands sticking through nicely. Part of the North America to South America isthmus (e.g. Mexico) didn't show, but it was close enough.

Now we get to the part that I struggled with. At this point there are two superimposed STL files on the Meshmixer screen. But they looked good, I couldn't see any of the trellis when I spun it around. If I select both files in the Object Browser, and Export the combined files as an STL, I get a 'Complex object in scene' message, which says "The resulting mesh may have errors", because one of the objects is 'complex'. If I Continue, and import it into my slicer it I can see artifacts of the trellis in the sliced view. And looking at the various slices, It appeared that the slicer decided to subtract the trellis from the Fill, so there were trellis shaped holes inside the sliced model, which caused the artifacts that I could see on the outside (Figure 3 left).

Figure 3: Trellis Artifacts



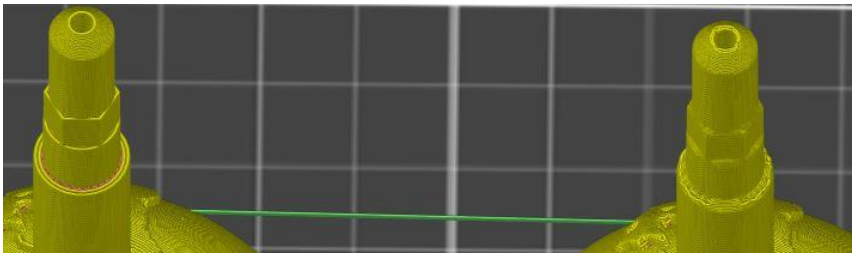
Looking back, if you paint it, like a_sarvan did, then the trellis artifacts would probably disappear.

But I decided to go back to Meshmixer and try selecting and Combining the two models. Exporting this I got the same 'Complex object in scene' message, and the same result from my slicer (Figure 3 middle).

So back in Meshmixer, I tried Boolean Union, which generated a Fatal error a when I tried to accept the result.

I then selected each of the STLs in Meshmixer, and used Edit/Make Solid on them. Selecting both and Exporting the STL, didn't generate any warning messages, and the result relative to getting rid of the mesh was correct (Figure 3 right). But the Make Solid, introduced some artifacts to the edges on the shaft where it stepped down in size (Figure 4 right).

Figure 4: Make Solid Artifacts



These artifacts could probably been cleaned up with a file, but I imported the STL into my modeler, and replaced the deformed shaft with a Hole, that the Main_Frame-Earth_Shaft fits into.

But there must be an easier way to do this.

I posted my intermediate Earth_North STLs show in Figure 3 as (left to right) Earth North 2 Mix.stl, Earth North 2 Mix Combined.stl, and Earth North 2 Mix Not Combined, both Solid.stl, respectively.

2.1.13 Hub Cover

I also added the Hub Cover to the carriertop, which the original Astronomia has just for looks.

2.1.14 Weight

I made some parts that can be used to make a weight for the clock. It weighs about 5 pounds when filled with #4 lead shot.

My original weight design had only 4 screws holding the top on. I was worried about the weight so I went to 8. The top seems pretty secure with the 8 screws, but now I worry about the strength of the cylinder walls. I went with thin (2mm) walls to save plastic and speed up the print, but it might not have been a good idea. I suspect that not much of a drop will break it open, and I'll have tiny lead balls everywhere... So I have been very careful with it. The lead came in a heavy cloth bag. I was thinking of using one inside the cylinder to act as a backup if I drop it, or the line breaks.

Glue the Weight Hook to the Weight Cap! I didn't and had lead BBs everywere.

3 Files

This is a list of the STL files that I used to do my make. For the files that I generated, I used a file prefix that identifies the sub-assembly that the STL was part of. For A26's files I used the same file name that he used and they are marked as 'Unchanged'. In a couple of case, the same STL is used by different sub-assemblies.

List of parts that I didn't change and must be downloaded from A26's design:

- balancespring
- hands
- moon
- hourgear1
- hourgear2
- hourgear3
- sidebearingblock (print 2)
- 12Tgear (print 2)
- 24t20tgear
- 24tgear
- 39tgear
- 10tbevel_3-1 (print 3)
- 30tbevel_3-1 (print 2)

Generally you only need to print one copy of each file, but the file descriptions below will tell you if you need more.

3.1 Sub-assemblies

These are STL of all the components of the Full Triaxial, or a sub-assembly of it. The program that I used to generate these appears to have dropped some of the components when it generated the STLs. Sorry about that, but the respective file lists for each sub-assembly should be correct.

Assy Clock Face.STL

Assy Full Triaxial.STL

Assy Mainframebottom.STL

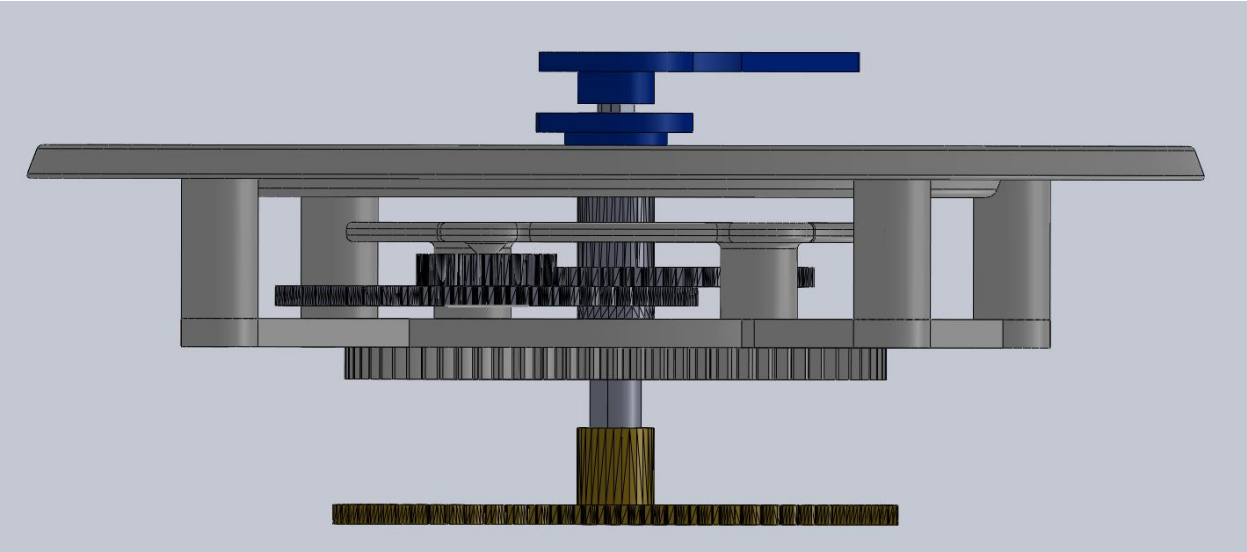
Assy Tourbillon.STL

3.2 Clock Face

Uses one 8x22x7mm ball bearing to support the Clock Face-Face Plate on the main clock dial shaft (Clock Face-72tminute shaft half), which presses into the Clock Face-Face Plate.

hourgear2 turns on an 18mm long, 2mm dia shaft.

All screws are 2mm flat head of various lengths.



3.2.1 Files

The files/components that I used for the Clock Face assembly

Clock Face-72tminute shaft half.STL - Print 2 of these, glue them together, then turn them in a drill and use a flat file to take them down so they fit snuggly in the 8x22x7mm ball bearings and the Clock Face-72tminute gear. Then glue the shaft to the 72tminute gear. Also made the shaft 2mm shorter so there was not so much slop in the assembly.

Clock Face-72tminute.STL – Redesiged so the shaft was separate.

Clock Face-Face Bridge.STL - Redesigned to make look more like the original watch

Clock Face-Face Face.STL – Redesigned to make it lighter and to look more like the original watch.

Clock Face-Face Plate.STL - Redesigned to make it lighter.

hourgear1.STL – Unchanged. Download from A26's design.

hourgear2.STL – Unchanged. Download from A26's design.

hourgear3.STL – Unchanged. Download from A26's design.

Minute hand.STL – Unchanged. Download from A26's design.

Hour hand.STL – Unchanged. Download from A26's design.

3.3 Forkframe

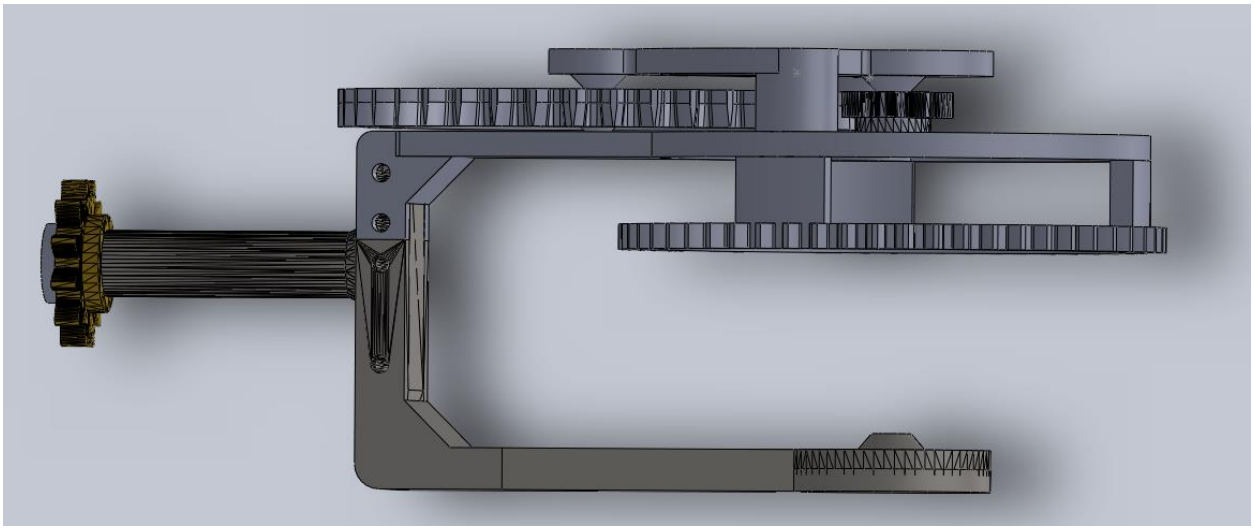
No ball bearings are used in this sub-assembly.

A 51mm x 3mm dia shaft goes between forkframe back 2 and forkframe1, to support the Tourbillon assembly.

Eight 2.5x8mm cap head screws that hold the Forkframes to the forkframeconnector.

Two 2x10mm flat head screws hold the forkframe back 2 to the forkframe 2 2a.

And 1 2x8mm flat head screws holds the 12tgear cap to the forkframeconnector to secure the 12tgear.



3.3.1 Files

Forkframe-12tgear cap.STL – Used to hold the 12tgear to the forkframeconnector, this allows the Tourbillion assembly to be removed from the 32Crowngear.

Forkframe-40Tgear 2.STL – Redesigned to have thicker teeth and to taper them.

Forkframe-forkframe 2 2a.STL – The original forkframe 2 was split into two parts (forkframe 2 2a and forkframe 2 2b) so they could be printed without supports. Also widened the frame to make it stiffer.

Forkframe-forkframe 2 2b.STL – 1mm longer standoffs to better align the forkframe gear with the escape wheel gear.

Forkframe-forkframe back 2.STL - Changed it to support a 3mm Tourbillion assembly shaft and to add screw support for attaching to forkframe 2 2a.

Forkframe-forkframe1.STL – Made the frame thicker to make it stiffer.

Forkframe-forkframeconnector-1.STL – Made the hole in the shaft smaller so it would accommodate a 2mm screw.

12tgear – Unchanged. Download from A26's design.

3.4 Main Frame

There are six 8x22x7 ball bearings used.

Two bearings go in the 32Crowngear to hold the Tourbillon – forkframeconnector.

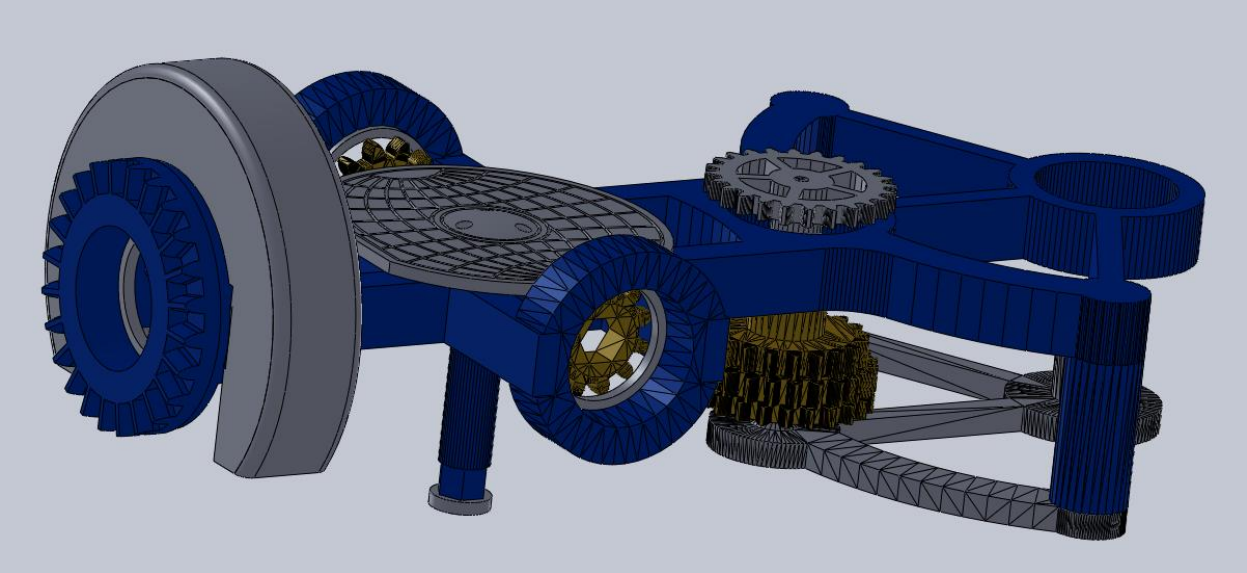
Two bearing are used for the earth and the moon, one each.

One bearing is used for the 24tgearplusshaft.

And one is used for the Clock Face-72tminute shaft.

The bearings were very lose fits, sliding out easily, so I made the 22x19x2 Spacer, which I slipped into the hole that a bearing would go in, then pressed the bearing on top of it, so that the surface of the bearing was flush with the surface of the hole that it fit in, then glued the spacer in place. You can see three of the spacers as the silver rings in the figure below, where one shows for one of the 32Crowngear bearings (on the left), and 2 show where the moon and the earth bearings go. Note, when the bearing is pressed flush, the spacer sticks out a little on the far side.

There is a fourth spacer used for the second 32Crowngear bearing, a fifth for the 24tgearplusshaft bearing, and the sixth for the Clock Face-72tminute shaft bearing.



3.4.1 Files

Main Frame-22x19x2 Spacer – Need 6 to hold the 8x22x7 ball bearings on place.

Main Frame-24tgearplusshaft – Made the shaft a little shorter to better align the gears.

Main Frame-32Crowngear.STL – Redesigned to have more tapered teeth.

Main Frame-39tgear cap.STL – Designed to keep the carriertop from falling out of the Mainframe Bottom when the clock was turned upside down, or mounted on a wall.

Main Frame-carrierbottom.STL – Redesiged to be removed from the carriertop. Now it is held on with 2 2mm flat head screws.

Main Frame-carriertop.STL – Redesiged to allow the carrierbottom to be removed.

Main Frame-Counter Weight Cover-1.STL – Glued to the counter weight after being packed with #4 lead shot.

Main Frame-Counter Weight-1.STL – Designed to provide a counter weight for the clock face. Without it, the clock would stop when mounted to a wall and the clock face was on the upswing.

Main Frame-Earth North .STL – Redesiged to get rid of the trellis support (not shown).

Main Frame-Earth Shaft.STL – Redesiged to be glued into the Earth North part after the Earth North and Earth South are glued together (not shown).

Main Frame-Earth South.STL – Redesiged to get rid of the trellis support (not shown).

Main Frame-Hub Cover.STL – Bling to make it look more like the original watch. Just eyeballed to glue in place. Center it on the main carriertop shaft. The flat side goes towards the 32Crowngear.

12Tgear – Unchanged. Need 2 to turn the Earth and the Moon. Download from A26's design.

24t20tgear – Unchanged. Slips on the 24tgearplusshaft. Download from A26's design.

24tgear – Unchanged. Fits on the 24tgearplusshaft and glued. Download from A26's design.

sidebearingblock – Unchanged. Need 2 to hold the Earth and Moon ball bearings. Glued. Download from A26's design.

3.5 Main Frame Bottom

The Mainframe Bottom uses four 12x28x8 (6001) ball bearings.

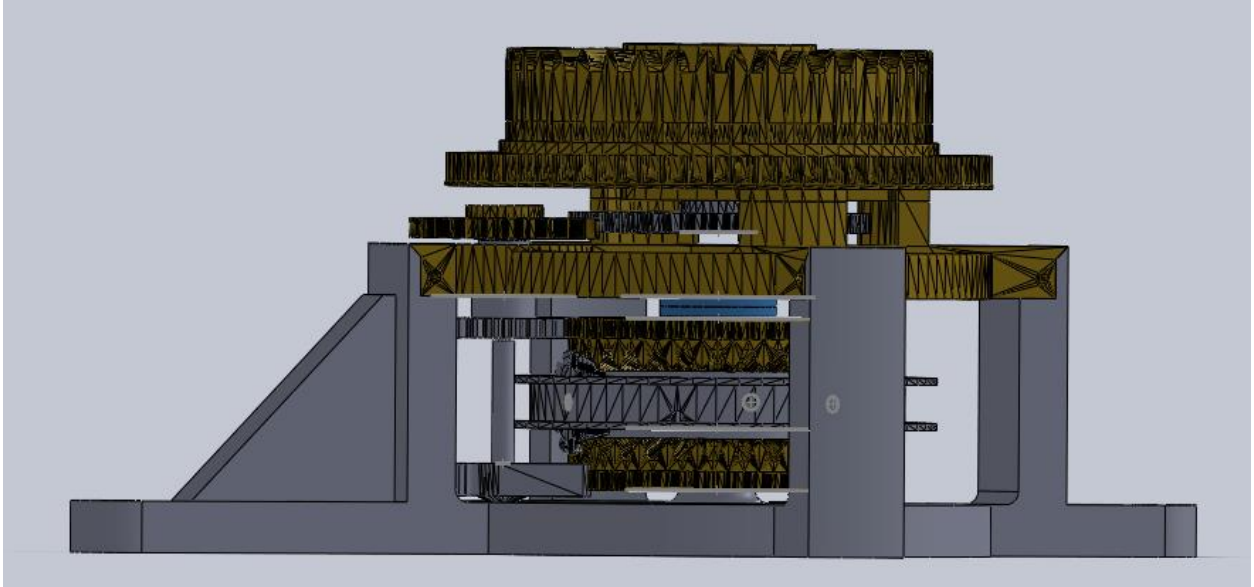
One ball bearing is inserted into each 30tbevel gear and two are inserted into mainframetop a.

I changed the spacing between the 30tbevel gears because when weight was applied to the drum, the torque would push the 30tbevel gears apart so only tips of the 10tbevel_3 gears were engaged with the 30tbevel teeth. Also the thrust generate by the gear teeth would cause the 12x28x8 ball bearings to slip out of the 30tbevel gears, so I made the spacers large enough to hold the bearings in place.

I split the mainframetop into 3 parts so it could be printed without supports, and to allow the it to be separated into two parts for maintence. Mainframetop a is glued to mainframetop b, and mainframetop c is then screwed to the pair.

43mm long 2mm dia shaft for the 18tgearplusshaft, ratchet spacer and ratchet to rotate on.

Three 13mm long, 2mm dia shafts to hold the 10tbevel_3 gear(s) in the drum.



3.5.1 Files

Mainframebottom-12.4x18x1.5mm spacer.STL – Two are inserted on the Mainframebottom2 center shaft, between the upper 30tbevel gear and the mainframetop c, to hold the bevel gears and drum in place. Shown in blue in the figure above.

Mainframebottom-18tgearplusshaft 2.STL – Modified to make the shaft shorter to better align the gears.

Mainframebottom-24x35x1.5mm spacer.STL – Glue it to the top side of the lower 30tbevel. Just eyeball it to center it. This will act as a spacer, and prevent the ball bearing from pressing through the gear.

Mainframebottom-24x35x1mm spacer.STL – Glue it to the bottom side of the upper 30tbevel. Just eyeball it to center it. This will act as a spacer, and prevent the ball bearing from pressing through the gear.

Mainframebottom-Mainframebottom2.STL – Modified to shorten the center shaft, so there was clearance for the Main Frame-39tgear cap and the screw that holds it.

Mainframebottom-mainframetop a.STL – The upper part of the mainframetop. This is glued to the mainframetop b part.

Mainframebottom-mainframetop b.STL – The center part of the mainframetop. This is glued to the mainframetop a part.

Mainframebottom-mainframetop c.STL – The lower part of the mainframetop. This is screwed with 2x20mm flat head screws to the mainframetop a and b parts, after they are glued together. And screwed to the Mainframebottom2 with eight 2.5x8 cap head screws.

Mainframebottom-ratchet spacer.STL – Used to hold the ratchet in position.

Mainframebottom-ratchet.stl – Added a spring so it would remain engaged when hanging on a wall.

Clock Face-24tgearplusshaft-1.STL – Shaft made shorter to better align the gears.

24tgear – Unchanged. Note this gear must be installed with the hub facing up so it doesn't block the Main Frame when it rotates. Download from A26's design.

30tbevel – Unchanged. Need two. See the details about these gears at the beginning of this section. Download from A26's design.

10tbevel_3 gear – Unchanged. Need three. Held in the drum with the 13mm long, 2mm dia shafts. Download from A26's design.

3.6 Tourbillon

Four 3x6x2.5mm and four 2x5x2.5mm ball bearings are used in this sub-assembly.

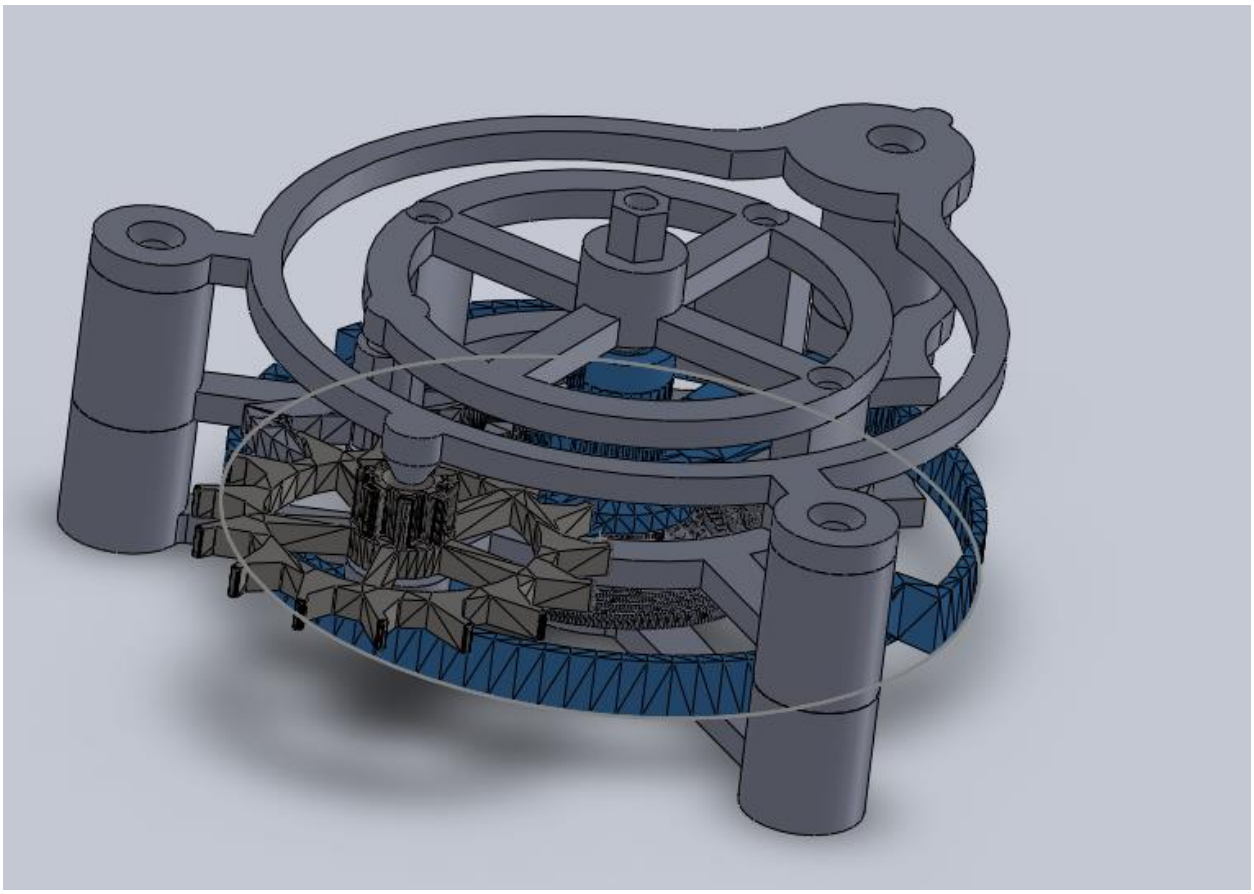
Two 3x6x2.5mm ball bearings are used in to support the frame, One presses into the tourbframemiddle2b and another into the Tourbframetop2.

Two more 3x6x2.5mm ball bearings are pressed in to either end of the balancewheel.

Two 2x5x2.5mm ball bearings press into the escape wheel (15Tesc) and the fork (15Tanchor2).

A 13mm x 2mm dia shaft supports the escape wheel (15Tesc), and a 16.5mm x 2mm dia shaft supports the fork (15Tanchor2).

All screws are 2mm flat head of various lengths.



3.6.1 Files

Tourbillon-15Tanchor2.STL - Modifed to add 2x5x2.5mm ball bearings.

Tourbillon-15Tesc.STL - Modifed to add 2x5x2.5mm ball bearings.

Tourbillon-Balancewheel Spacer.STL – Two of these back to back go between the tourbframemiddle2b and the balancewheel

Tourbillon-balancewheel.STL – Modifed to add 3x6x2.5mm ball bearings. Blue in the figure above.

Tourbillon-tourbframeback2.STL – Modified to screw to tourbframemiddle2.

Tourbillon-tourbframemiddle2.STL – Modified to attach to tourbframeback2 and Tourbframetop2 with screws.

Tourbillon-tourbframemiddle2b.STL – Modifed to hold a 3x6x2.5mm ball bearing.

Tourbillon-Tourbframetop2.STL – Modified to screw to tourbframemiddle2.

balancespring – Unchanged. Download from A26's design.

3.7 Weight

Weighs about 5 lbs when filled with #4 lead shot.

3.7.1 Files

Weight Base.STL

Weight Cap.STL

Weight Hook 2.STL

Weight Hook.STL

3.8 Other

Triaxial timelapse.mpeg – video.

4 File Summary

Unless noted, I used a .2mm first layer and all other layers were 1.5mm.

I also set the Perimeter Vertical Shell count to 3. I used the default settings for all the support options.

Sub-Assy	File Name	Quan.	Support material	Color	Notes
Clock Face					
	Clock Face-72tminute shaft half	1	No	Silver	
	Clock Face-72tminute	1	No	Gold	
	Clock Face-Face Bridge	1	No	White	
	Clock Face-Face Face	1	No	White	
	Clock Face-Face Plate	1	No	White	
	hourgear1	1	No	Gold	Download from A26's design.
	hourgear2	1	No	Gold	Download from A26's design.
	hourgear3	1	No	Gold	Download from A26's design.
	Minute hand	1	No	Blue	Download from A26's design.
	Hour hand	1	No	Blue	Download from A26's design.
Fork Frame					
	Forkframe-12tgear cap	1	No	Gold	
	Forkframe-40Tgear 2	1	No	Gold	
	Forkframe-forkframe 2 2a	1	No	Silver	
	Forkframe-forkframe 2 2b	1	No	Silver	
	Forkframe-forkframe back 2	1	No	Silver	
	Forkframe-forkframe1	1	No	Silver	
	Forkframe-forkframeconnector-1	1	No	Silver	
	12tgear	1	No	Gold	Download from A26's design.
Main Frame					
	Main Frame-22x19x2 Spacer	6	No	Gold	
	Main Frame-24tgearplusshaft	1	No	Gold	
	Main Frame-32Crowngear	1	No	Blue	
	Main Frame-39tgear cap	1	No	Gold	
	Main Frame-carrierbottom	1	No	Blue	
	Main Frame-carriertop	1	No	Blue	Note 1
	Main Frame-carriertop_no_shaft	1	No	Blue	Note 1
	Main_Frame-carriertop_shaft_half	2	No	Blue	Note 1
	carriertop_shaft_whole	1	NA	Blue	Note 4
	Main Frame-Counter Weight Cover-1	1	No	Silver	
	Main Frame-Counter Weight-1	1	No	Silver	
	Main Frame-Earth North	1	No	White	Note 2
	Main Frame-Earth Shaft	1	No	White	

Sub-Assy	File Name	Quan.	Support material	Color	Notes
	Main Frame-Earth South	1	No	White	
	Earth_North_2_Mix_Combined	1	No	White	Note 2
	Earth_North_2_Mix_Not_Combined_both_Solid	1	No	White	Note 2
	Earth_North_2_Mix	1	No	White	Note 2
	Whole_Earth	1	NA	White	Note 3
	Main Frame-Hub Cover	1	No	Silver	
	12Tgear	2	No	Gold	Download from A26's design.
	24t20tgear	1	No	Gold	Download from A26's design.
	24tgear	1	No	Gold	Download from A26's design.
	sidebearingblock	2	No	Blue	Download from A26's design.
Main Frame Bottom					
	Mainframebottom-12.4x18x1.5mm spacer	2	No	Silver	
	Mainframebottom-18tgearplusshaft 2	1	No	Gold	
	Mainframebottom-24x35x1.5mm spacer	1	No	Silver	
	Mainframebottom-24x35x1mm spacer	1	No	Silver	
	Mainframebottom-Mainframebottom2	1	No	Blue	
	Mainframebottom-mainframetop a	1	No	Gold	
	Mainframebottom-mainframetop b	1	No	Gold	
	Mainframebottom-mainframetop c	1	No	Blue	
	Mainframebottom-ratchet spacer	1	No	Silver	
	drum	1	Yes	Silver	Download from A26's design.
	Mainframebottom-ratchet	1	No	Silver	
	Clock Face-24tgearplusshaft-1	1	No	Gold	
	24tgear	1	No	Gold	Download from A26's design.
	30tbevel	2	No	Gold	Download from A26's design.
	10tbevel_3 gear	3	No	Gold	Download from A26's design.
Tourbillon					
	Tourbillon-15Tanchor2	1	No	Silver	
	Tourbillon-15Tesc	1	No	Silver	
	Tourbillon-Balancewheel Spacer	2	No	Silver	
	Tourbillon-balancewheel	1	Yes	Silver	
	Tourbillon-tourbframeback2	1	No	Blue	
	Tourbillon-tourbframemiddle2	1	No	Blue	
	Tourbillon-tourbframemiddle2b	1	No	Blue	
	Tourbillon-Tourbframetop2	1	No	Blue	
	balancespring	1	No	Silver	Download from A26's design.
Weight					
	Weight Base	1	No	Silver	
	Weight Cap	1	No	Silver	

Sub-Assy	File Name	Quan.	Support material	Color	Notes
	Weight Hook 2	1	Yes	Silver	
	Weight Hook	1	Yes	Silver	

Note 1: Some people were having problems with the shaft breaking off the Main Frame-carriertop STL. The Main Frame-carriertop_no_shaft STL is identical to the Main Frame-carriertop, but with no shaft. The shaft (Main_Frame-carriertop_shaft_half.STL) can be printed separately with its fuses going length wise, making it stronger. The shaft halfs can be glued together, then glued into the hole in the Main Frame-carriertop_no_shaft STL.

Note 2: There were some issues printing the Main Frame-Earth North STL. The Earth_North_2_Mix_Combined, Earth_North_2_Mix_Not_Combined_both_Solid, and Earth_North_2_Mix STLs provide some alternatives that may work better with your slicer and printer.

Note 3: A single STL with both the northern and southern Earth hemispheres for SLS printers.

Note 4: A single STL of the carriertop_shaft for SLS printers.