Section 1: **A Simplified Ball Bearing Mendel**

My start at 3D printing occurred about a year and a half ago, when I purchased one of the first Techzone laser cut kits. At the time, all the printed parts were way too expensive. That kit turned out to be a very frustrating experience, with a host of design and assembly issues. Nevertheless, I finally got it producing good parts. The experience gave me a clear understanding of what I wanted to see in a new Mendel design, both in initial assembly sequence, ease of adjustment, use, servicing and documentation. I do not have direct experience with the Sells Mendel, but I think it has many similar issues. About 6 months ago, I decided that a new and improved Mendel design would be a good project. Sort of like building the better mousetrap, the world might beat a path to my door… After many late nights at the drawing board, this Mendel was brought to life. It is a combination of all the features I would like to see in a Mendel based printer.

I basically wanted to design a Mendel along the lines of a Prusa, but using ball bearings. I was always uncomfortable with glued-on printed bushings. Linear bearings are not easily sourced and it takes very careful adjustment to not over-constrain their motion. I also did not want a multitude of different ways to hold a bearing as in the Sells Mendel. Instead, I wanted a "universal ball bearing assembly" that was simple to produce and could be used everywhere a bearing was used in the design. Although the ball bearings would not wear out, the assemblies should to be screwed together (not glued), for repair if necessary. Kind of like the Frankenstein monster, a bunch of standard parts to pull off the shelf and bolt together as necessary.

The Sells Mendel has a high distinct parts count, which I did not like. It often takes me a try or two to get an acceptable print, so a low number of distinct parts is desirable (then many copies can be safely made). However, simply merging multiple parts into one is bad for ABS, as I created many twisted and warped creations that more resembled modern art than engineering. Minimum parts count along with thin, relatively planar parts lying on the print bed turned out to be best. I made every effort to minimize parts count, and ended up with 15 distinct parts. Another difficulty is the multitude of fasteners in many designs. Here in the backward US, we have to order 100 screws to get one metric screw at a reasonable price. So I considered it a must to reduce it to only one fastener type, an M3 X 12 SHCS. The only thing that really worked well in my Techzone one was the z belt drive, so I kept that, but reduced the parts count. Lastly, I had endless trouble with adjusting the horizontal x belt, so it had to go. Finally, adjustment for squareness and good running was a trying (to say the least) experience. By design and assembly sequence, I tried to eliminate much of this…

In fairly exhaustive summation, this Mendel had the following features:

1. Low printed parts count (15).
2, Printable in ABS with heated bed (no tall parts, all thin and flat on the bed).
3. All ball bearings are held in 2 standard housings, a 3 bearing and a 2 bearing housing.
4. Only one fastener, M3x12!!!!

5. Ball bearing design.
6. 623 bearings, same as Huxley.
7. Very easy to adjust.
8. Vertical x belt to eliminate sag under gravity against washers.
9. All basic dimensions same as Sells Mendel (rod length, spacing, jigging; except 2 shorter smooth rods.)
10. Belt in z, but very much simplified.
11. Able to adjust y belt tension without disassembly of heated bed!!!!
12. English/Metric dual dimensions (mostly): T5 or XL belts, 5/16 or M8 frame, 5/16 or M8 rod.
13. X axis belt returns under extruder, allows Wades extruder with vertical x belt (unlike Prusa).
14. Wade's or Adrian's extruder in their proper orientations.
15. Heated bed support at 4 or 3 points for flexible or rigid bed.
16. Simple hand cut frog.
17. Anti-backlash nuts on z (as on Prusa).
18. Uses printed (8 tooth) or purchased (10 tooth) pulleys (adjust code) and motor position. Strongly suggest use of purchased 10 tooth pulleys.
19. Well integrated support for optoswitches.
20. Optoswitch flags mount with 2 screws, no rotation and hitting the switch housing.
21. All belts travel over 608 bearings to minimize bumps from belt teeth on prints.
22. Uses less than 1.5lb of ABS for a complete set (25% infill).
23. Z axis threaded rod must be M8, all SHCS must be M3X12.

Here in the US, I built a hybrid version, listed below. The bearings are metric, as in the Sells and Huxley Mendel. It uses cheap SAE parts where they will fit (like the frame). Other parts like the washers are too big in SAE, so metric ones are used. Here in the US T5 belts are hard to find, so I designed it for XL Belts. Alternate parts are given if you want T5. (Note that the choice of pulley tooth count and type influences the calibration values in the firmware.) Recesses for nuts are specific to the thread size, and having the z axis travel agree with the metric pitch standard dictated the use of M8 threaded rod for the z threaded rod. Finally, M8 drill rod was so cheap, I did not bother to use 5/16", but you could with no modifications…

The bill of materials for the hybrid SAE-metric version Mendel is:

Description	Printed/Purchased	Quantity
ja_bearing_360	Printed	6
ja_bearing_180	Printed	6
Frame-vertex_6off	Printed (from Sells Mendel)	6
ja_z_rod_clamp	Printed	2
ja_x_carriage	Printed	1
ja_z_bearing_mount	Printed	2
ja_x_rod_clamp	Printed	4
ja_z_drive_nut_holder	Printed	2
ja_x_motor_mount	Printed	1
ja_y_motor_mount	Printed	1

ja_right_z_mount	Printed	1
ja_left_z_mount	Printed	1
ja_y_rod_support	Printed	4
ja_xl_20t_pulley	Printed (Note A)	2
ja_z_opto_mount	Printed	1
ja_frog	Fabricated	1
M3 X 12 SHCS	Purchased (1)	2 bags of 100
M3 Washer	Purchased (2)	2 bags of 100
M3 Nut	Purchased (3)	2 bags of 100
623 Bearing	Purchased (4)	30
M8 stainless threaded rod	Purchased (5)	1 of 1m or 3’
M8 steel nuts	Purchased (6)	8
M8 brass nut	Purchased (7)	4
M8 washers	Purchased (8)	2 packs of 100 (must use)
5/16 plated steel threaded rod	Purchased (9)	7 at 3’
5/16 plated steel nuts	Purchased (10)	1 pack of 100
M8 or 5/16 ground rod	Purchased (11)	3 of 3’ or 1m
xl 10 tooth pulley	Purchased (12)	3
xl_belting	Purchased (13)	8’
xl_belt	Purchased (14)	1, industry number 340 (34”)
Stepper motor	Purchased	3
Opto switch	Purchased	3
Spring	Purchased (15)	2
M3 insulating washer	Purchased	6
608 Bearing	Purchased (16)	6

Note A. This Mendel uses a printed XL 20 tooth pulley and rims. If a T5 belt is used, then use the alternate part “ja_t5_20t_pulley” (see below).

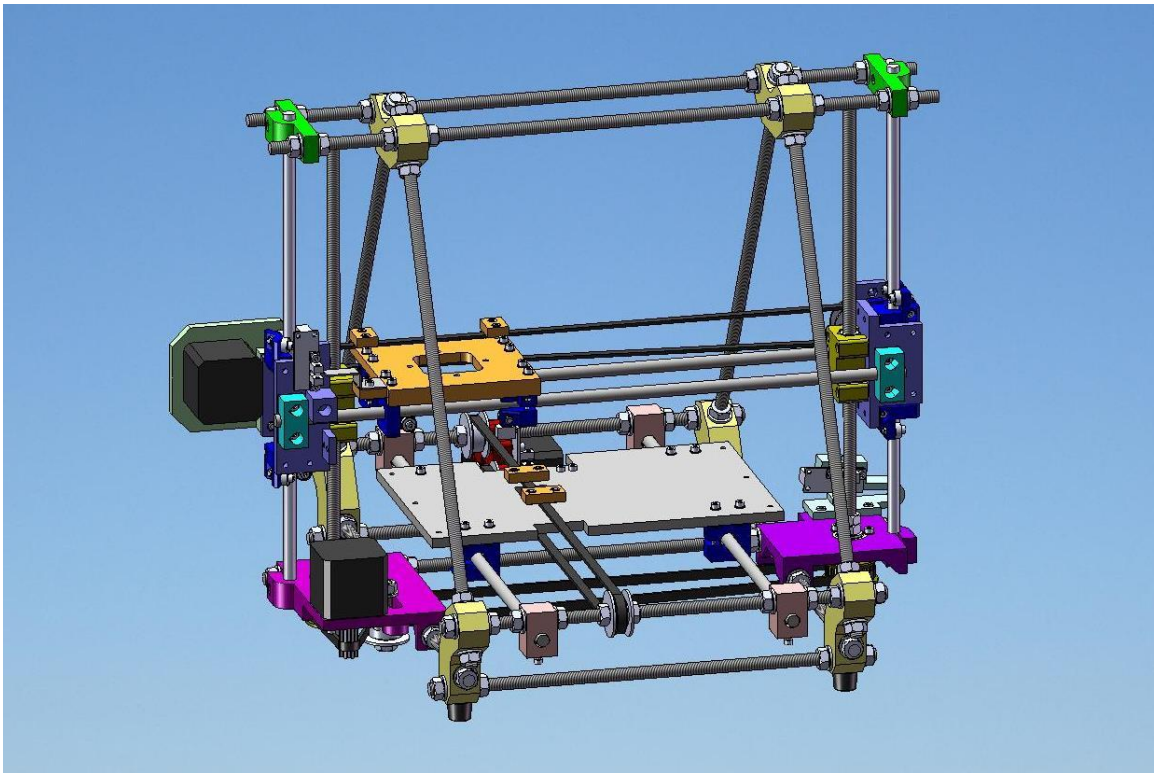
Sources (cheapest I have found):

(1) McMaster Carr 91292A114, $3.15/bag
(2) McMaster Carr 93475A210, $1.56/bag
(3) McMaster Carr 90591A121 , $1.39/bag
(4) VBX Bearing KIT623ZZ10 $9.77/(10 pack)
(5) McMaster Carr 90024A080, $8.31/3’
(6) Hardware or auto parts store, only 8 needed
(7) Auto parts store, since only 4 needed (used on exhaust systems)
(8) McMaster Carr 90024A080, $3.15/bag (must use M8, 5/16” washers too big OD)
(9) Enco 990-3211, $1.48/3’ zinc plated steel threaded rod
(10) Enco 325-3840, 2.27/bag
(11) Enco 505-0240, $4.59/3’ (oil hardening drill rod)
(12) McMaster Carr 6495K711, $10.13 ea
(13) McMaster Carr 7959K24, $2.01/ft
(14) McMaster Carr 6484K507, $5.54 ea

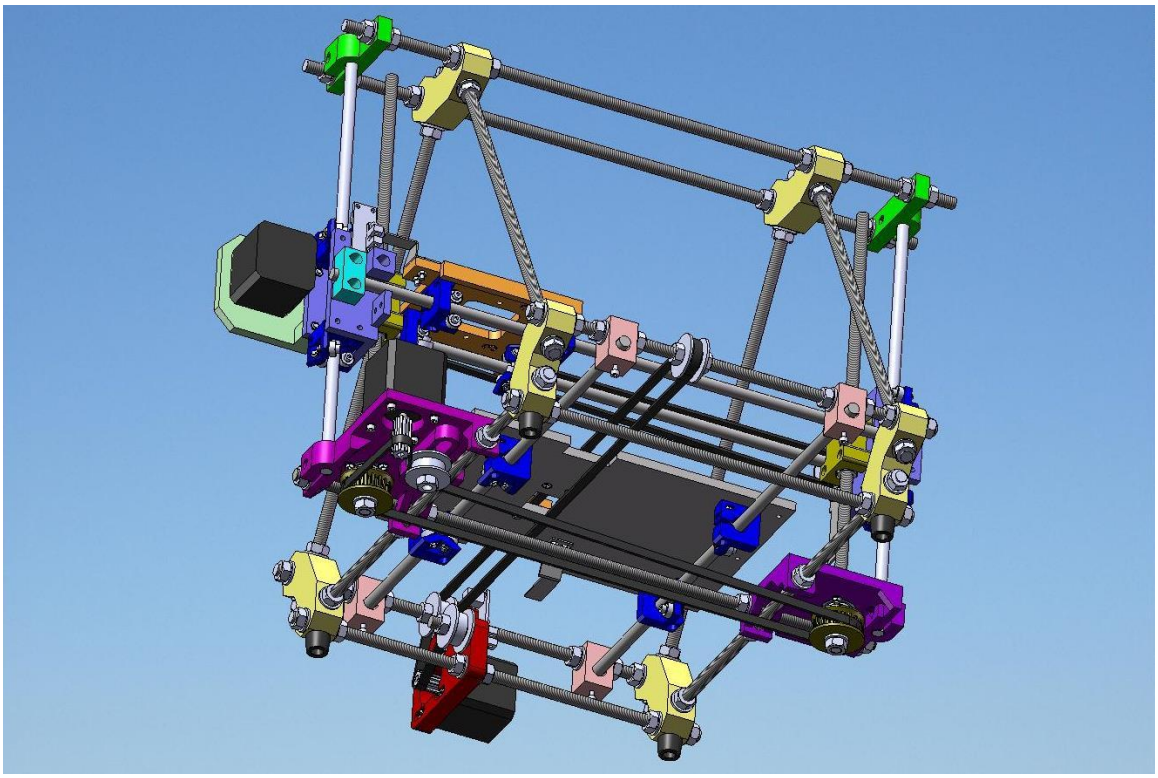
(15) Hardware Store
(16) VBX Bearing KIT608ZZ10 $4.95/(10 pack)

The bill of materials for the complete pure metric version Mendel is:

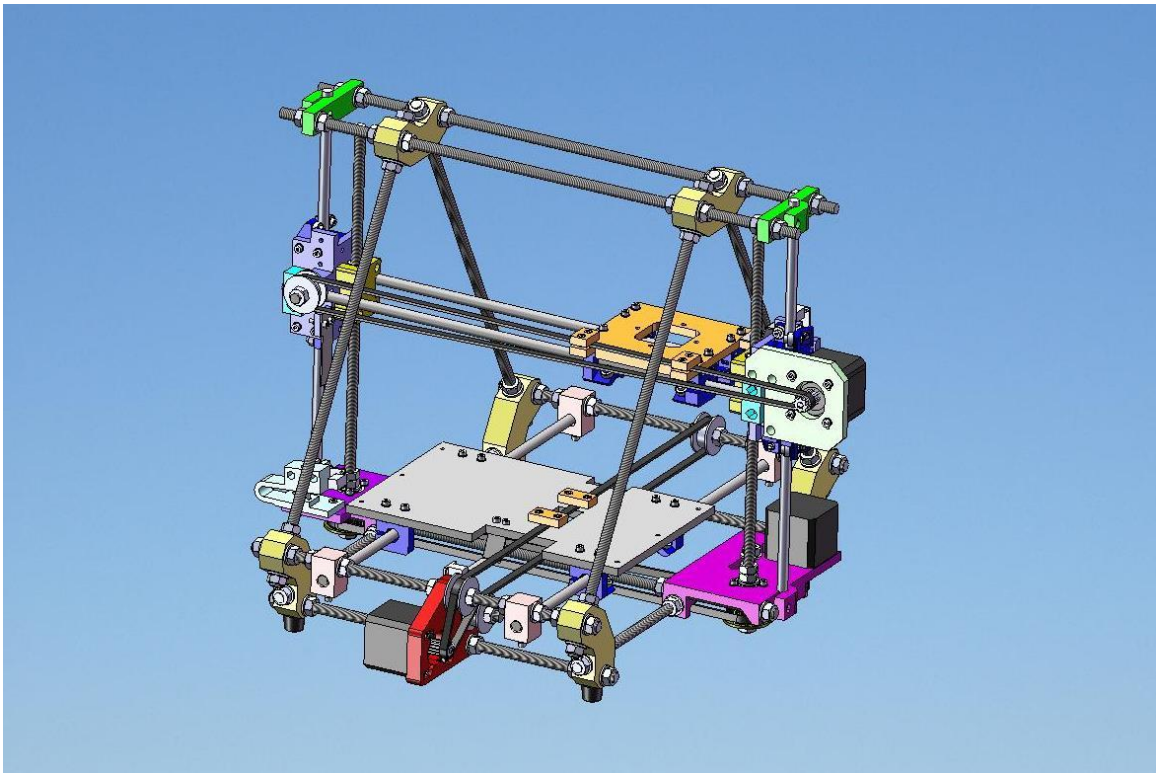
Description	Printed/Purchased	Quantity
ja_bearing_360	Printed	6
ja_bearing_180	Printed	6
Frame-vertex_6off	Printed (from Sells Mendel)	6
ja_z_rod_clamp	Printed	2
ja_x_carriage	Printed	1
ja_z_bearing_mount	Printed	2
ja_x_rod_clamp	Printed	4
ja_z_drive_nut_holder	Printed	2
ja_x_motor_mount	Printed	1
ja_y_motor_mount	Printed	1
ja_right_z_mount	Printed	1
ja_left_z_mount	Printed	1
ja_y_rod_support	Printed	4
ja_t5_20t_pulley	Printed	2
ja_z_opto_mount	Printed	1
ja_frog	Fabricated	1
M3 X 12 SHCS	Purchased	2 bags of 100
M3 Washer	Purchased	2 bags of 100
M3 Nut	Purchased	2 bags of 100
623 Bearing	Purchased	30
M8 stainless threaded rod	Purchased	1 of 1m
M8 brass nut	Purchased	4
M8 steel plated nuts	Purchased	2 packs of 100
M8 washers	Purchased	2 packs of 100 (must use!!)
M8 plated steel threaded rod	Purchased	7 at 1m
M8 ground rod	Purchased	3 of 1m
T5 8 or 10 tooth pulley	Purchased or printed (Sells)	3
T5_belting	Purchased	2.5m
T5_belt	Purchased	850 or 860mm
Stepper motor	Purchased	3
Optoswitch	Purchased	3
Spring	Purchased	2
M3 insulating washer	Purchased	6
608 Bearing	Purchased	6



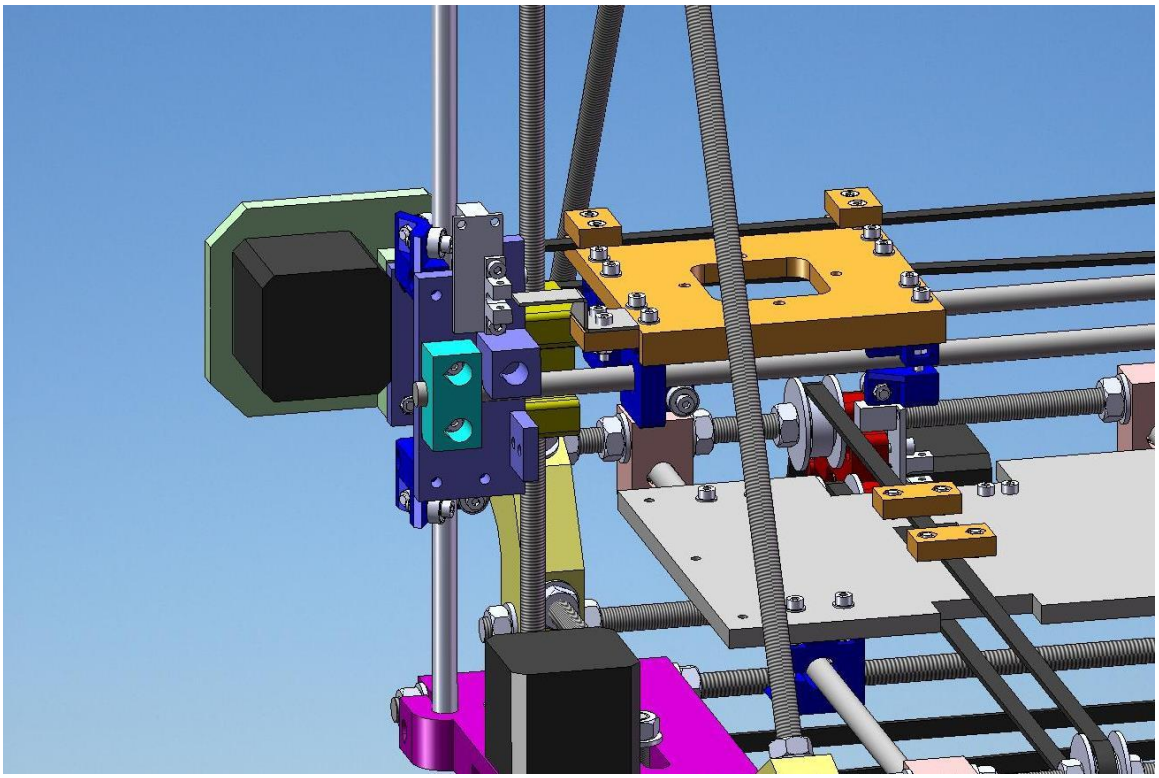
Front view, omitting bed and extruder. Note standard bearing assemblies on all rods.



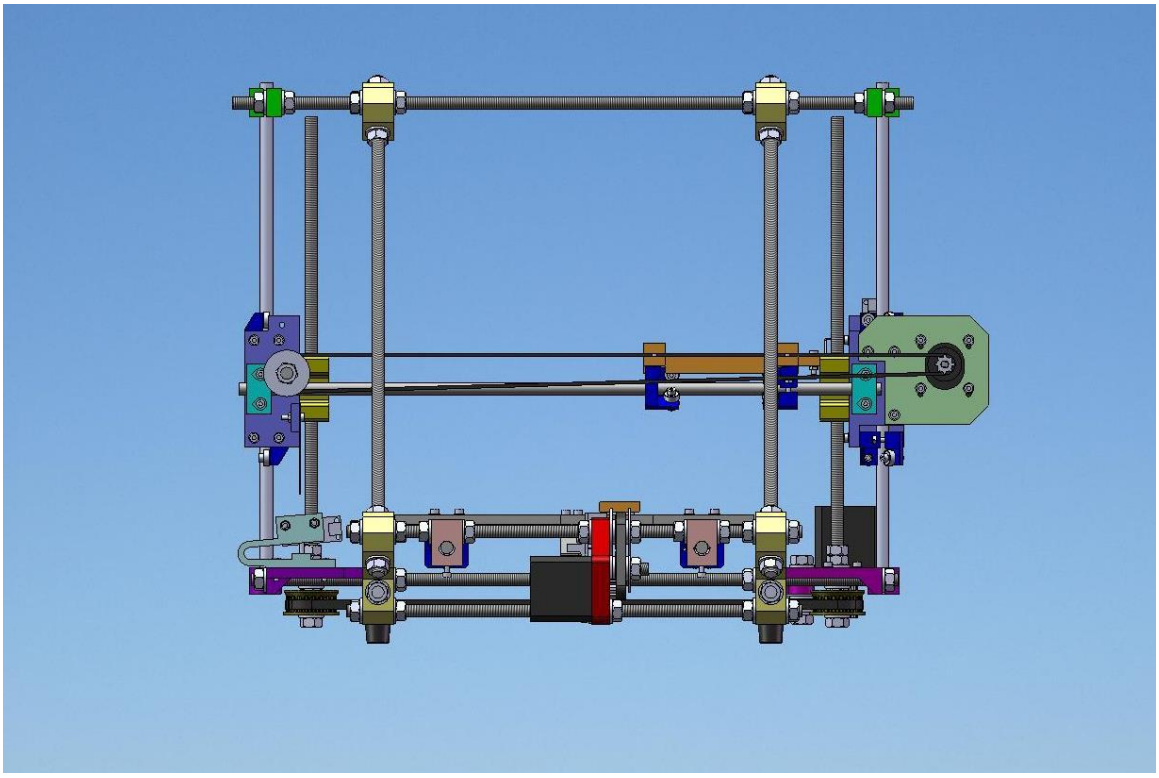
Bottom view, showing simplified z axis, belt and pulleys.



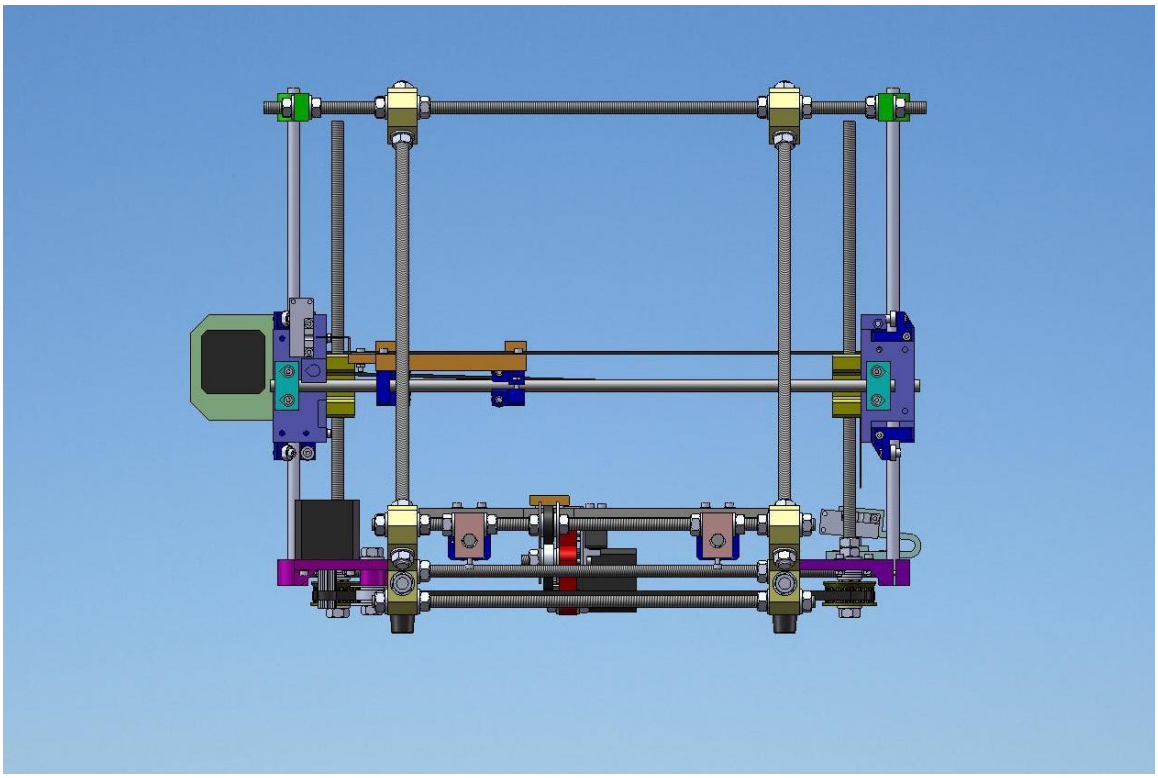
Back view, showing X belt and carriage and simplified Y motor mount.



Close-up view of x optoswitches and 360 Z axis bearings.

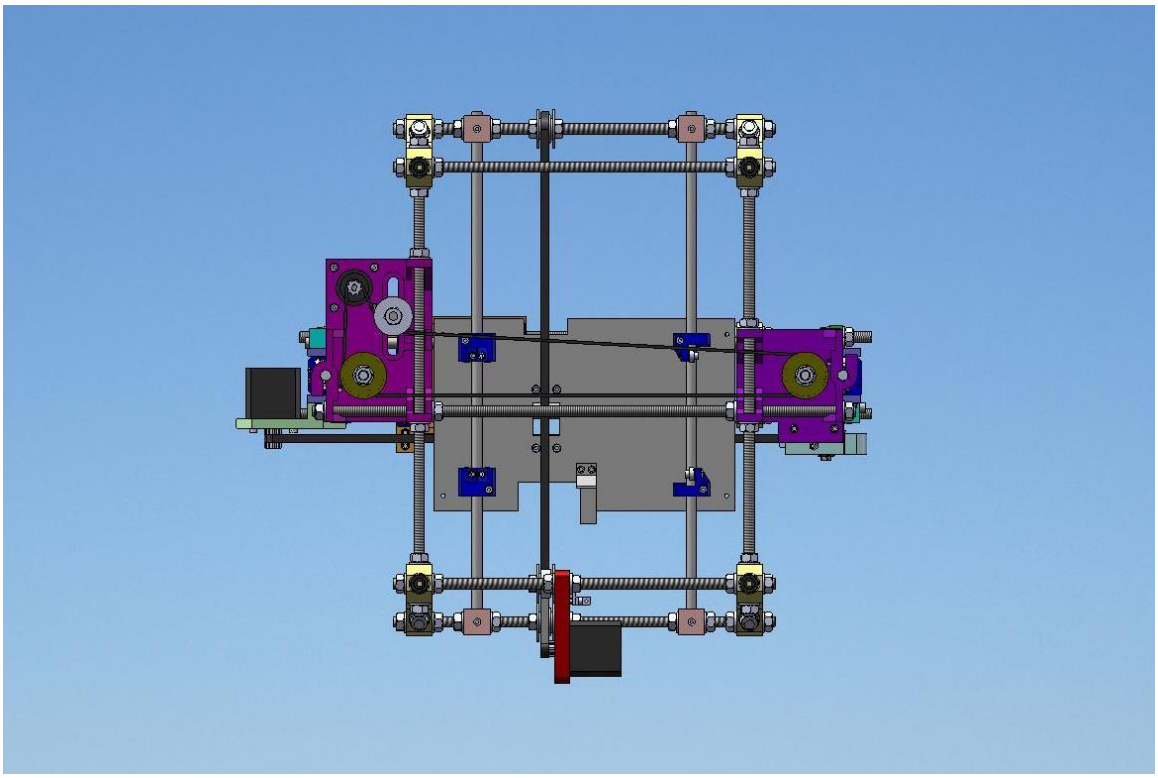


Back view, showing x belt, motor and idler

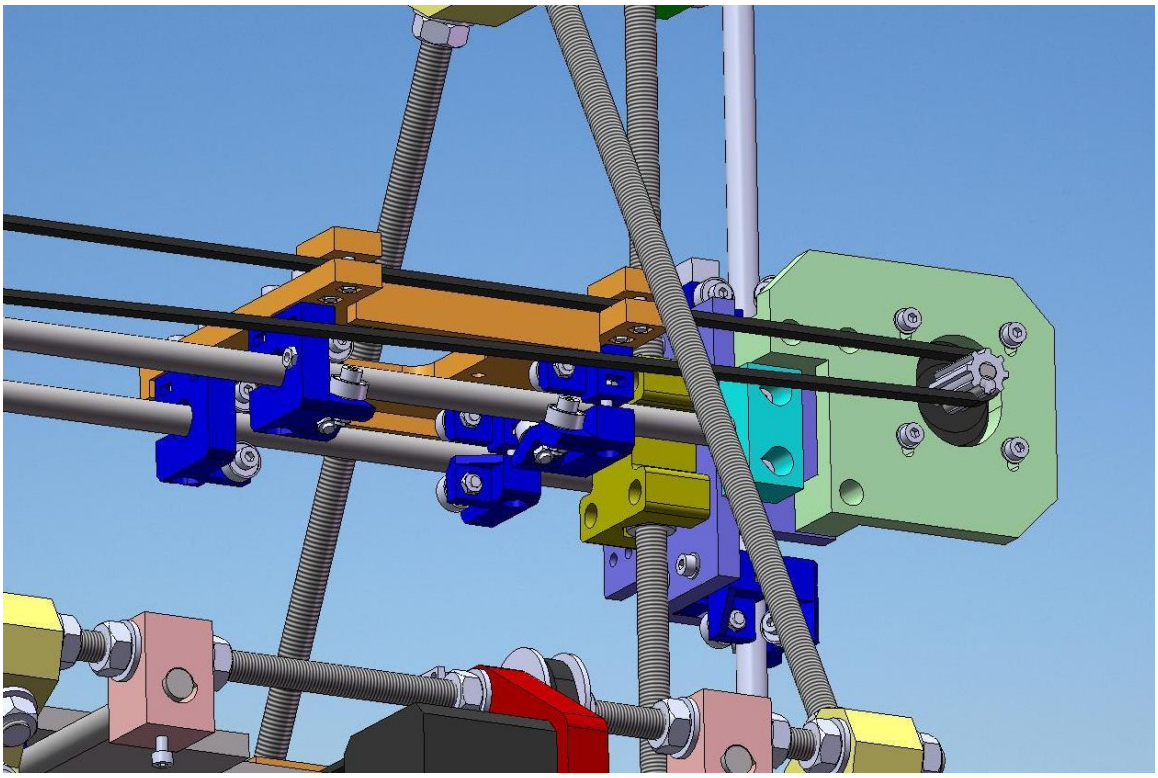


Front view.

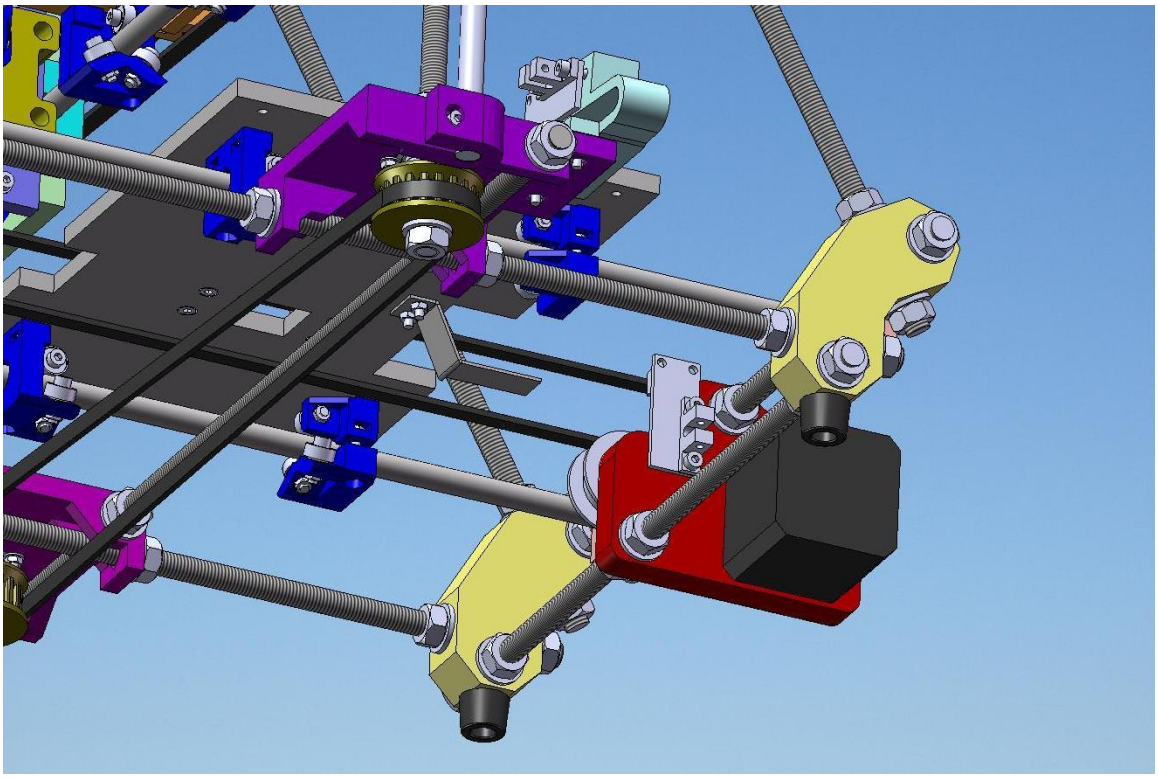
X idler, z drive nuts and 180 Z bearings.



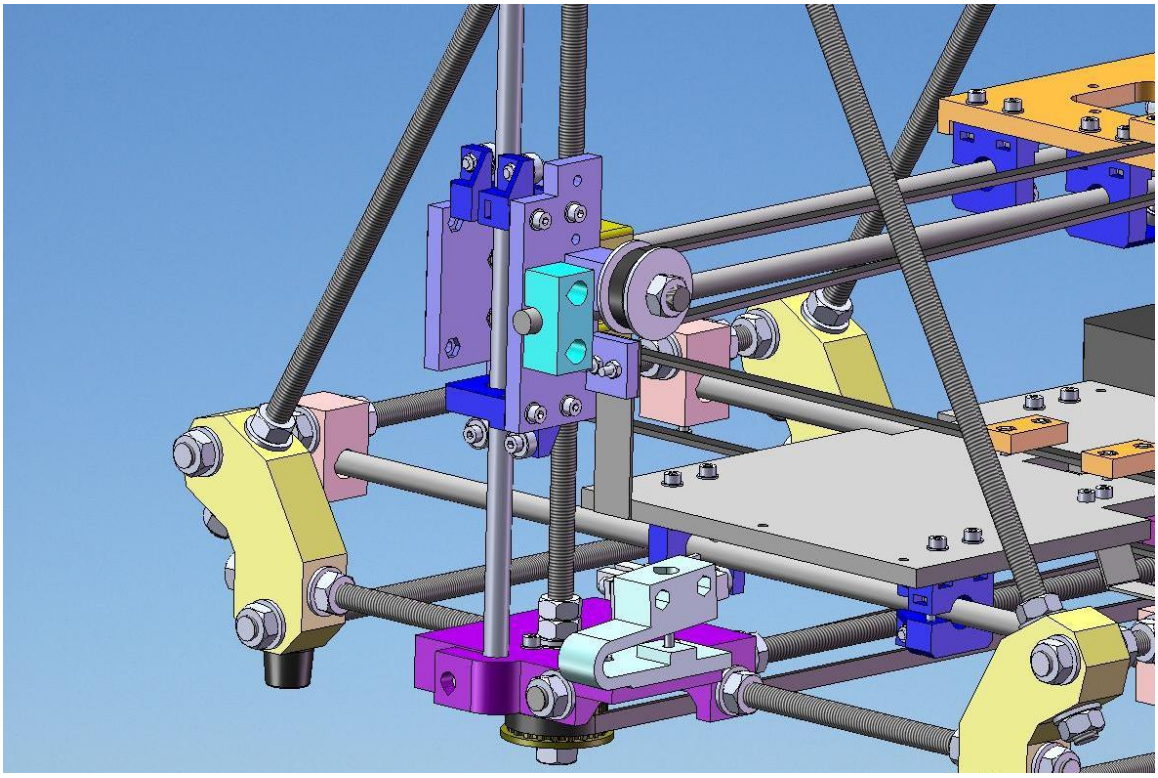
Bottom view, simplified Z belt and frog.



Close-up of X axis motor and carriage.



Y optoswitch and flag.



Z optoswitch mounted on printed spring with adjustment screw, and optoflag.

The following sections document the build process for this Mendel design. Enjoy!!!