Building & Testing the SATNOGS Rotor

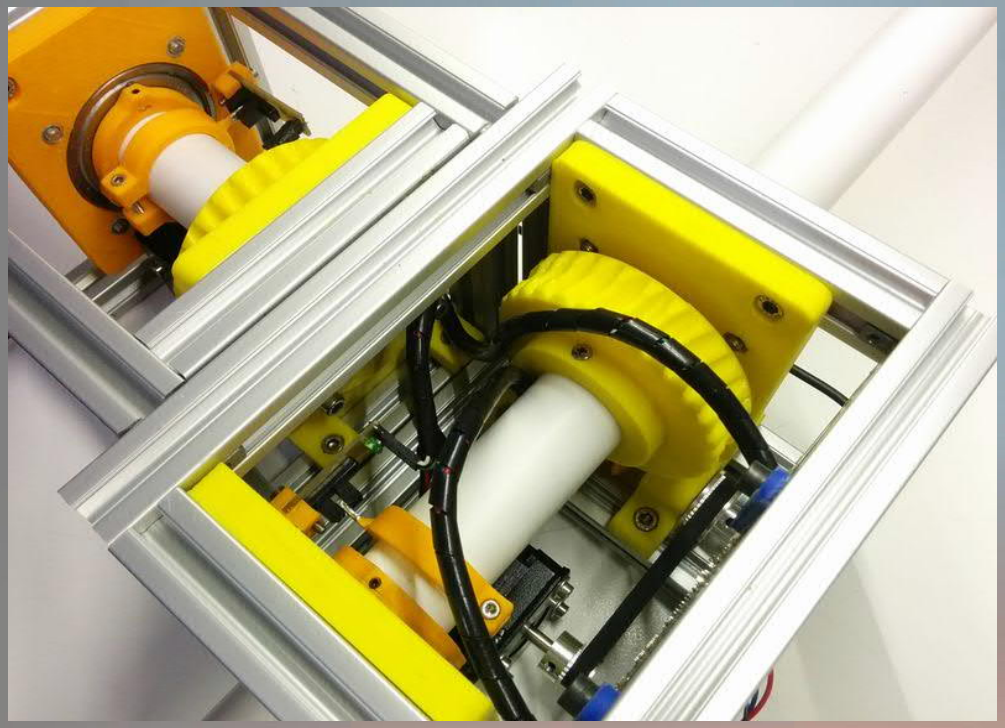
Mike Pecorini, KD2RPE & Ralph Iden, WB9ICF


action
plan
idea

What is SatNOGS?

- SatNOGS is an open source ground station and network project.
- The SatNOGS network of ground stations are focused on Low Earth Orbit (LEO) satellites, including amateur radio birds.
- Components are designed to be built from readily available and affordable as well.

SatNOGS Rotator Specs



- AZ/EL speed of 7 degrees per second.
- 11” x 5.5” x 5.5” and ~11 pounds.
- 2020 Aluminum T-Slot and 3D printed construction.
- NEMA 17 stepper or DC motors
- Can be built for $200 or less.
- https://wiki.satnogs.org/SatNOGS_Rotator_v3#Mechanical_Analysis_.5BWIP.5D


IZ5RZR WebTv

Project Goals & Objectives

- Successfully build and test rotor.
- Present project at the May 2020 MCWA meeting.
- Do actual field testing at Field Day.
- Bring to the Lake County Maker Faire as part of MCWA's exhibit.
- Practice our project management and maker skills.
- Learn new things.

Planning the project

- Complicated projects require planning.
- Started out as a face-to-face napkin meeting to outline our ideas.
- Identified goals, milestones, and the overall timeline.
- A comprehensive Bill of Materials was needed.
- Tasks and responsibilities were identified.
- A project communication mechanism was needed (Slack)

Materials to be used

- 20 mm x 20 mm aluminum extruded T-Slot for frame.
- Stainless steel hardware for rust prevention.
- Weatherproof enclosure for electronics.
- Filament material for most parts was PETG
  - Design called for ABS, but printing ABS would prove challenging in the Winter.
  - PETG was thought to be a good choice as it is more durable than ABS.
  - Using PETG did take away the option to use an Acetone cloud to smooth the parts.
  - Nylon 12 was used for two parts (the worm gears) due to its fatigue resistance.

December 2019

- Planning began in earnest.
- A face-to-face kickoff meeting was held to develop the general plan.
- A dedicated Slack channel for the project was established.
- The Bill of Materials was started and items were checked off as they were acquired.
- Took a couple of weeks off for Christmas and prototyping the updated MCWA website.

Part	Qty To Buy	Qty In project	Sold in Packs of	Unit of Measure	Distributor	Ref	Distributor Ref	Project Section	Price	Cost to Project	Status	atNOGS Li	Mike Link
Aluminum	2	2	1	PCE	Motedis	1-1 and C1	2287	Hardware	$ 0.90	$ 1.80	Received	https://www.motedis.c	
Shaft Side	4	4	1	PCE		C1010-3		Custom Par	$ 1.26	$ 5.06	Complete		
Shaft Side	4	4	1	PCE		C1011-3		Custom Par	$ 0.27	$ 1.08	Complete		
Worm Whe	2	2	1	PCE		C1020-1		Custom Par	$ 1.28	$ 2.56	Complete		
Shaft Colla	2	2	1	PCE		C1021-1		Custom Par	$ 0.54	$ 1.08	Complete		
Shaft Was	2	2	1	PCE		C1022-1		Custom Par	$ 0.09	$ 0.18	Complete		
Motor Mou	2	2	1	PCE		C1030-1		Custom Par	$ 0.60	$ 1.20	Complete		
Encoder G	2	2	1	PCE		C1040-1		Custom Par	$ 0.57	$ 1.14	Complete		
Homing Pi	2	2	1	PCE		C1041-1		Custom Par	$ 0.03	$ 0.06	Complete		
End-Stop M	2	2	1	PCE		C1042-1		Custom Par	$ 0.10	$ 0.20	Complete		
Encoder M	2	2	1	PCE		C1043-1		Custom Par	$ 0.37	$ 0.74	Complete		
Aluminum	18	18	1	PCE	Motedis	C1050-1	22206	Custom Par	$ 1.25	$ 22.50	Received	https://ww	https://www
Aluminum	8	8	1	PCE	Motedis	C1050-5	22206	Custom Par	$ 1.73	$ 13.84	Received	https://ww	https://www
Threaded r	1	1	1	m		C1060-1		Hardware	$ 2.50	$ 2.50			https://www
Worm Mou	4	4	1	PCE		C1061-5 and C1061-6		Custom Par	$ 0.44	$ 1.76	Complete		
Worm Gea	2	2	1	PCE		C1062-1		Custom Par	$ 17.81	$ 35.62	Complete	https://www.shapeway	
Deep groov	4	4	1	PCE		H1011-1		Hardware	$ 0.60	$ 2.40	Received		https://www
Deep groov	4	4	1	PCE		H1012-1		Hardware	$ 4.99	$ 19.96	Received		https://www
Inner brack	40	40	1	PCE	Motedis	H1020-1	099I9006	Hardware	$ 0.75	$ 30.00	Ordered	https://ww	https://www
T-nut B-typ	0	36	1	PCE	Motedis	H1021-1	096H06410	Hardware	$ 0.09	$ -	Received	https://ww	https://www
M5 Nut DIN	4	4	1	PCE		H1030-1		Hardware	$ 0.03	$ 0.12			
M5 Washe	6	6	1	PCE		H1031-1		Hardware	$ 0.03	$ 0.18			
Timing Pul	2	2	1	PCE		H1040-1		Hardware	$ 6.09	$ 12.18	Received		https://www
Timing Bel	2	2	1	PCE		H1200-1		Hardware	$ 12.88	$ 25.76	Received		https://www
M3 Nut DIN	0	26	1	PCE		H1070-1		Hardware	$ 0.03	$ -			
M4 Nut DIN	0	24	1	PCE		H1080-1		Hardware	$ 0.03	$ -			

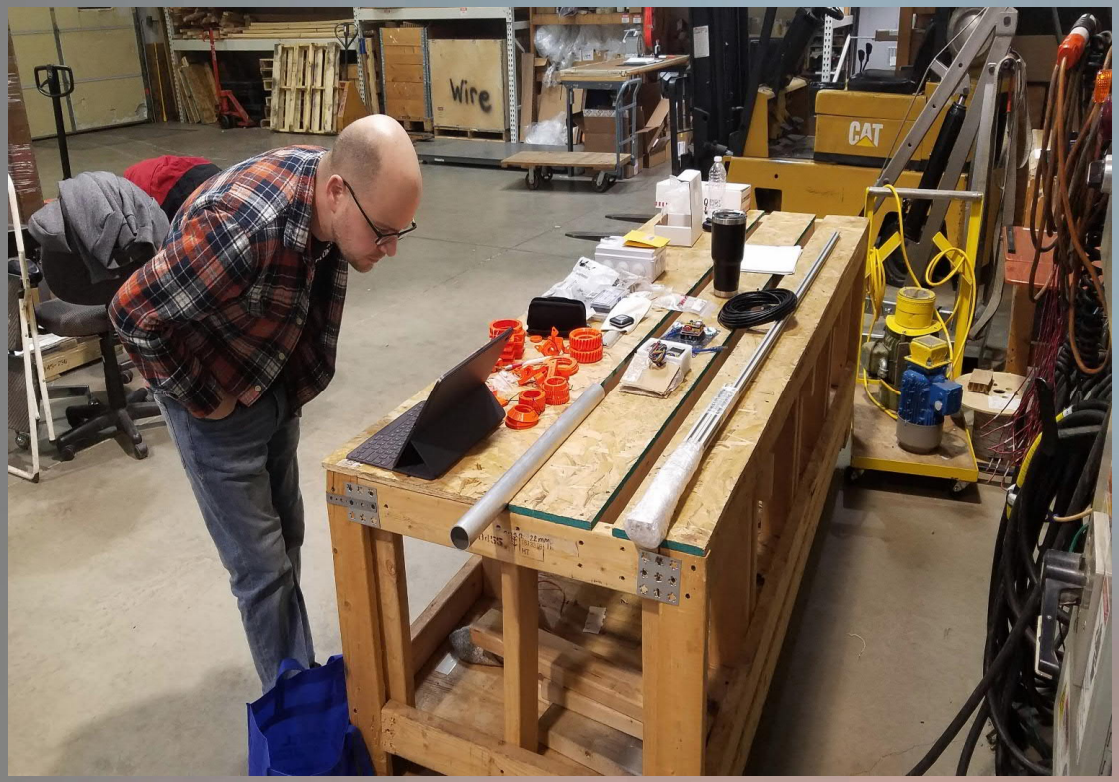
January 2020

- Mike began building the 3D parts using PETG on his Prusia printer.
- The model (STL) files are available on the Internet.
- The parts turned out remarkably well and didn't seem to need further smoothing to be functional.

January 2020

- The two worm gears were a concern due to the critical nature of these parts and the difficulty of printing them in PETG.
- It was decided to have these two parts printed by a 3D printing service (Shapeways). This allowed them to be printed using Nylon 12.
- They were among the most expensive parts in the build ($36). The two timing belts were the next most expensive parts ($26).

January 2020



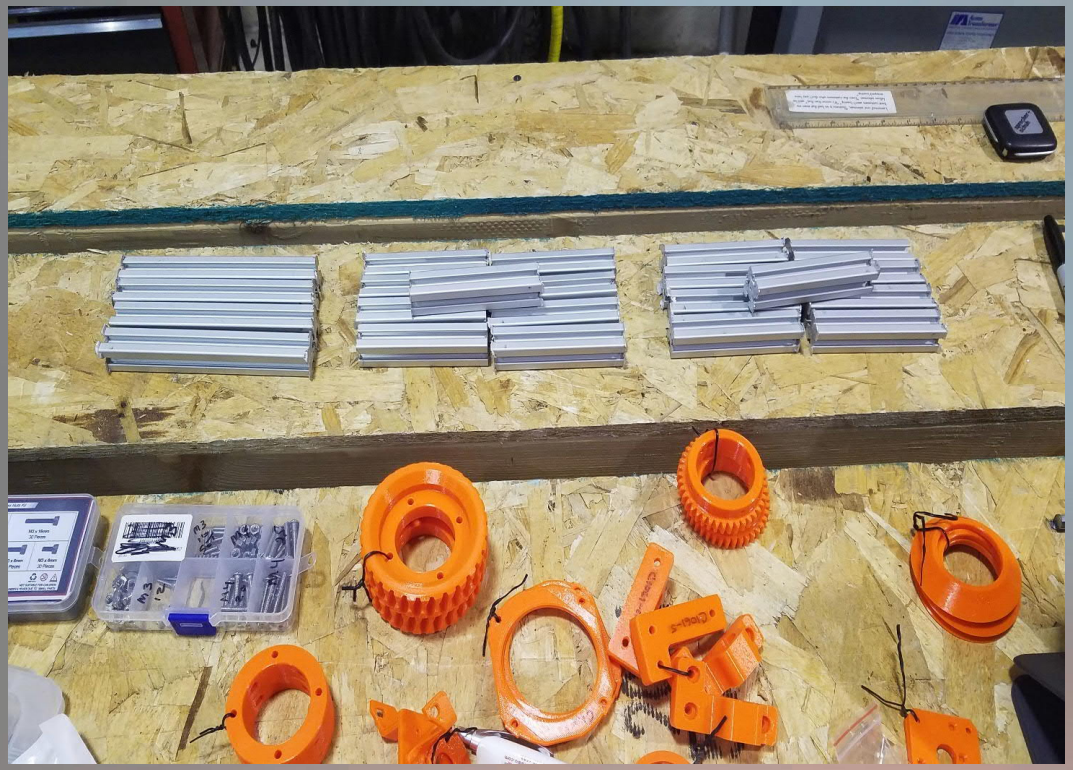
- Mike checks the Bill of Material against the parts that are assembled on the table.

January 2020

January 2020

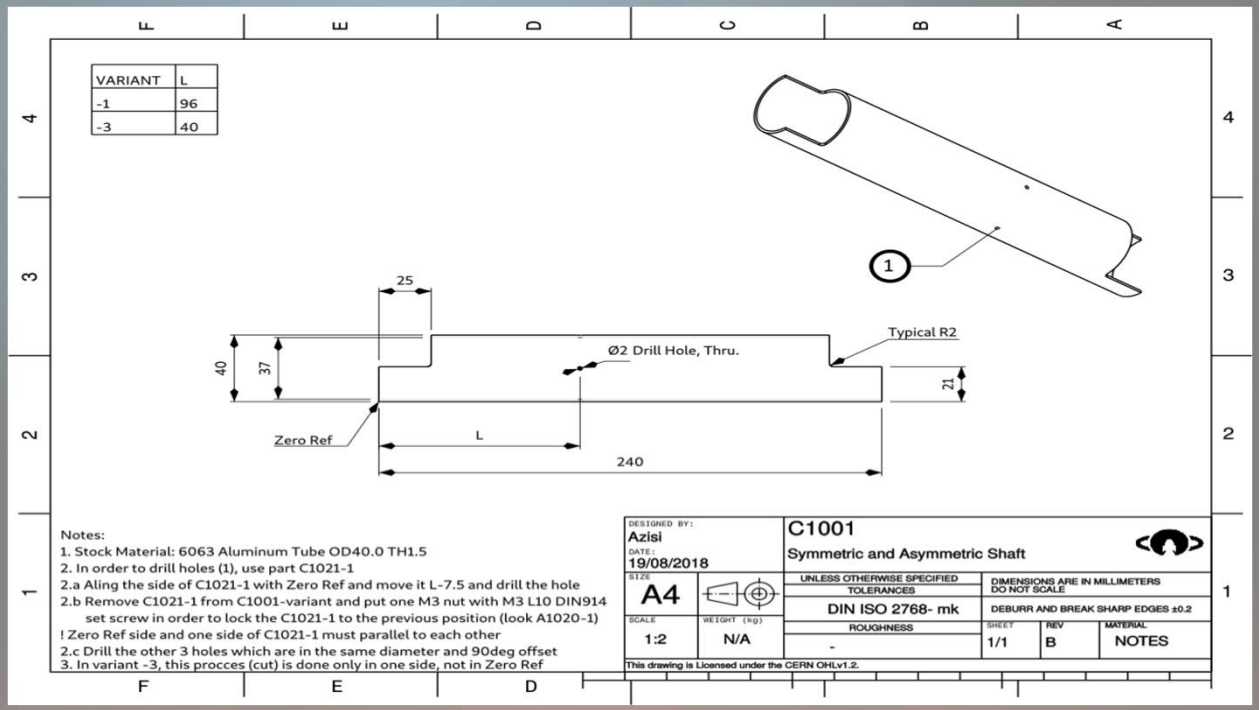
January 2020

January 2020

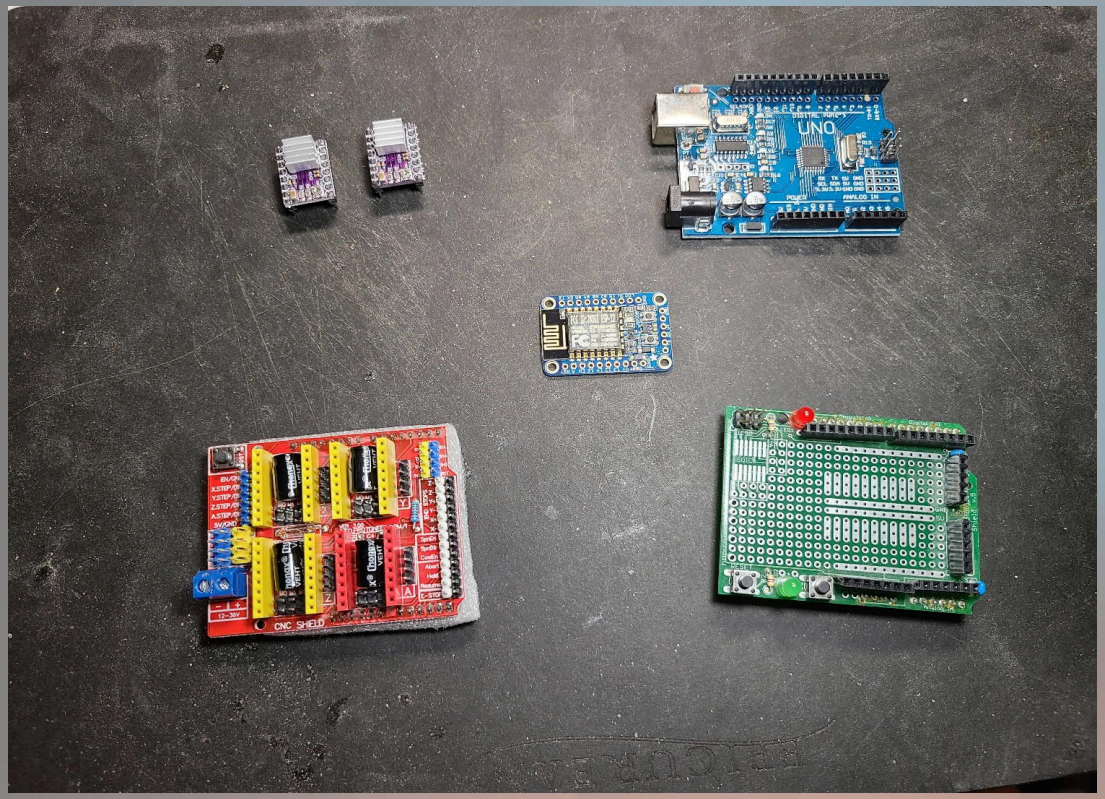


- After some time in the shop, the parts were roughed out and ready for post-processing.
- Due to a miscalculation, the 2020 stock ran out (we had ordered extra, but still ended up being four pieces shy of what was needed.
- There was also the fabricating of the mast, which was deferred until a later time.

January 2020

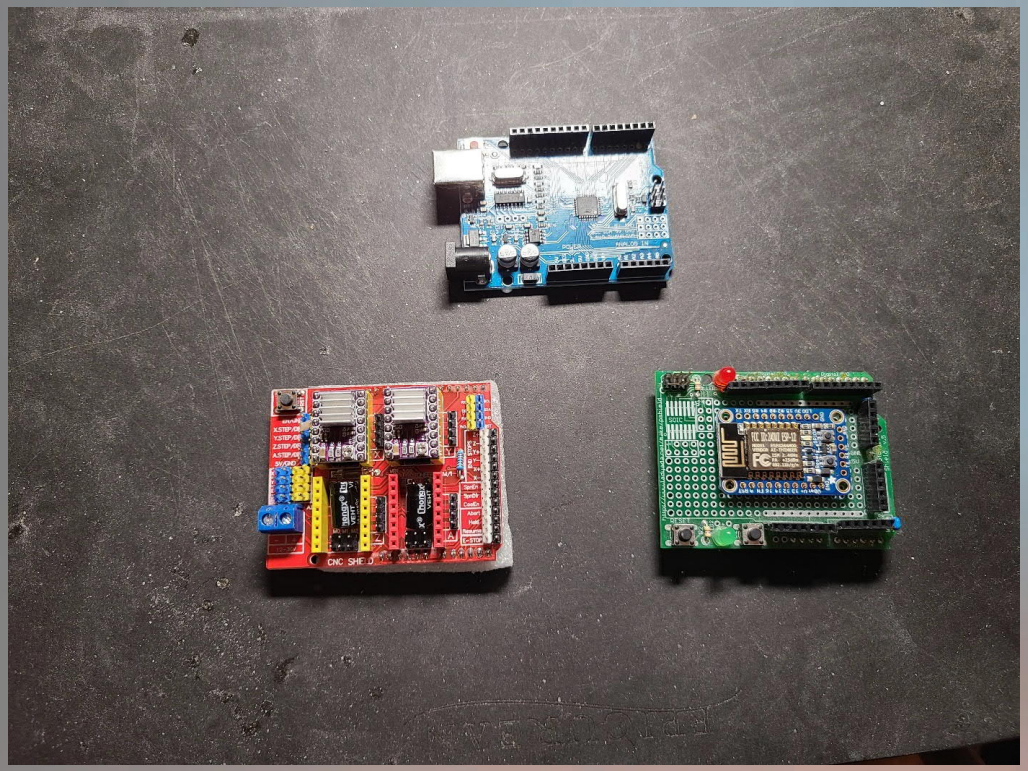


February 2020



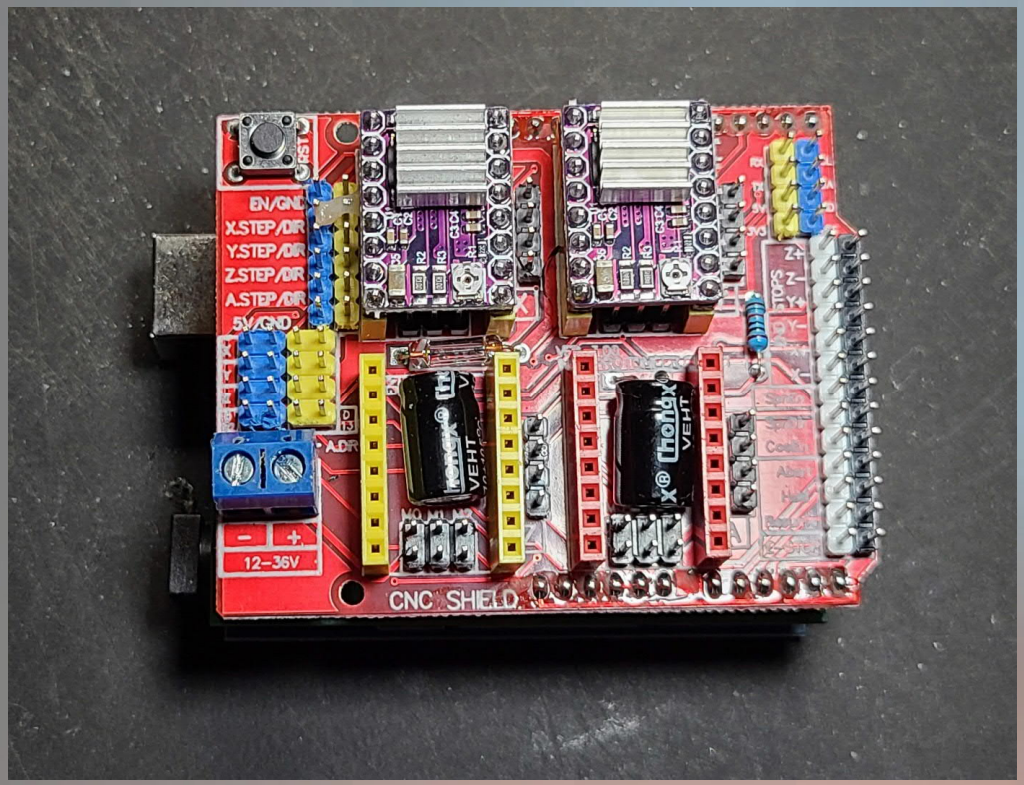
- February activities
  - More 2020 aluminum T-Slip material ordered.
  - Mike post-processing the parts already made (smoothing and deburring)
  - Ralph began assembly of electronics module.
  - Ralph and Mike put final touches on MCWA.org website refresh for a March 1, 2020 launch.

February 2020



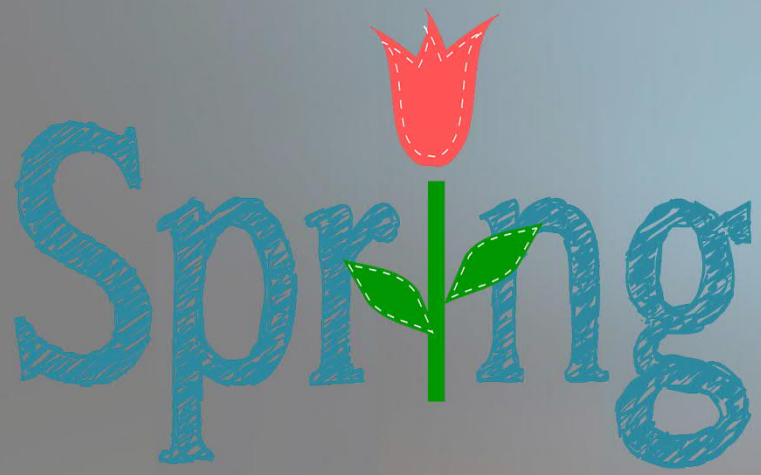
- Arduino Uno controller.
- CNC board with motor drivers installed.
- Arduino proto shield with ESP-8266 installed.

February 2020



- The controller “sandwich” after assembly.
- The controller is housed in a waterproof enclosure with connecting cables to the rotor passing through glands.
- The ESP-8266 communicates wirelessly to the laptop terminal to receive movement instructions.

March 2020

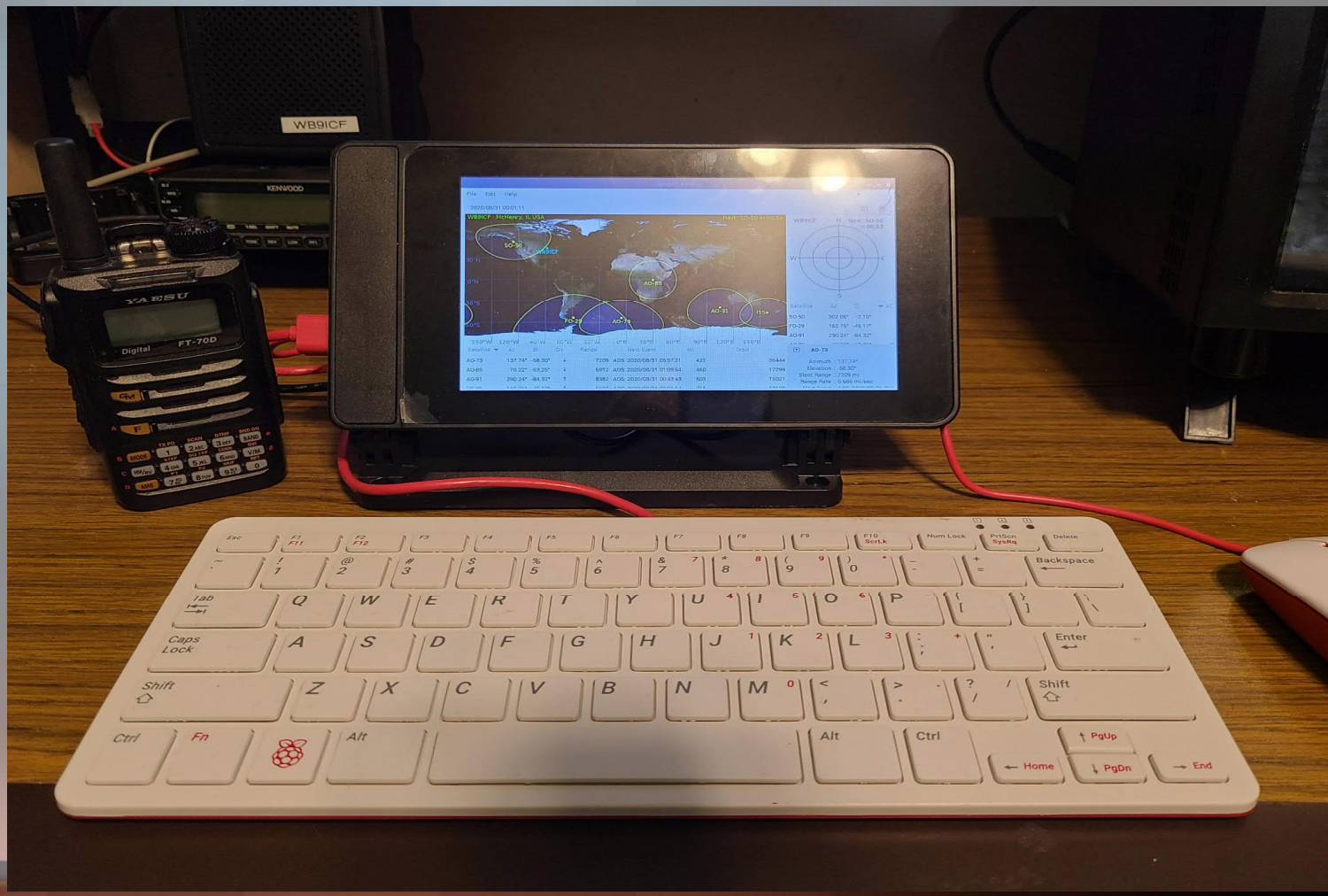


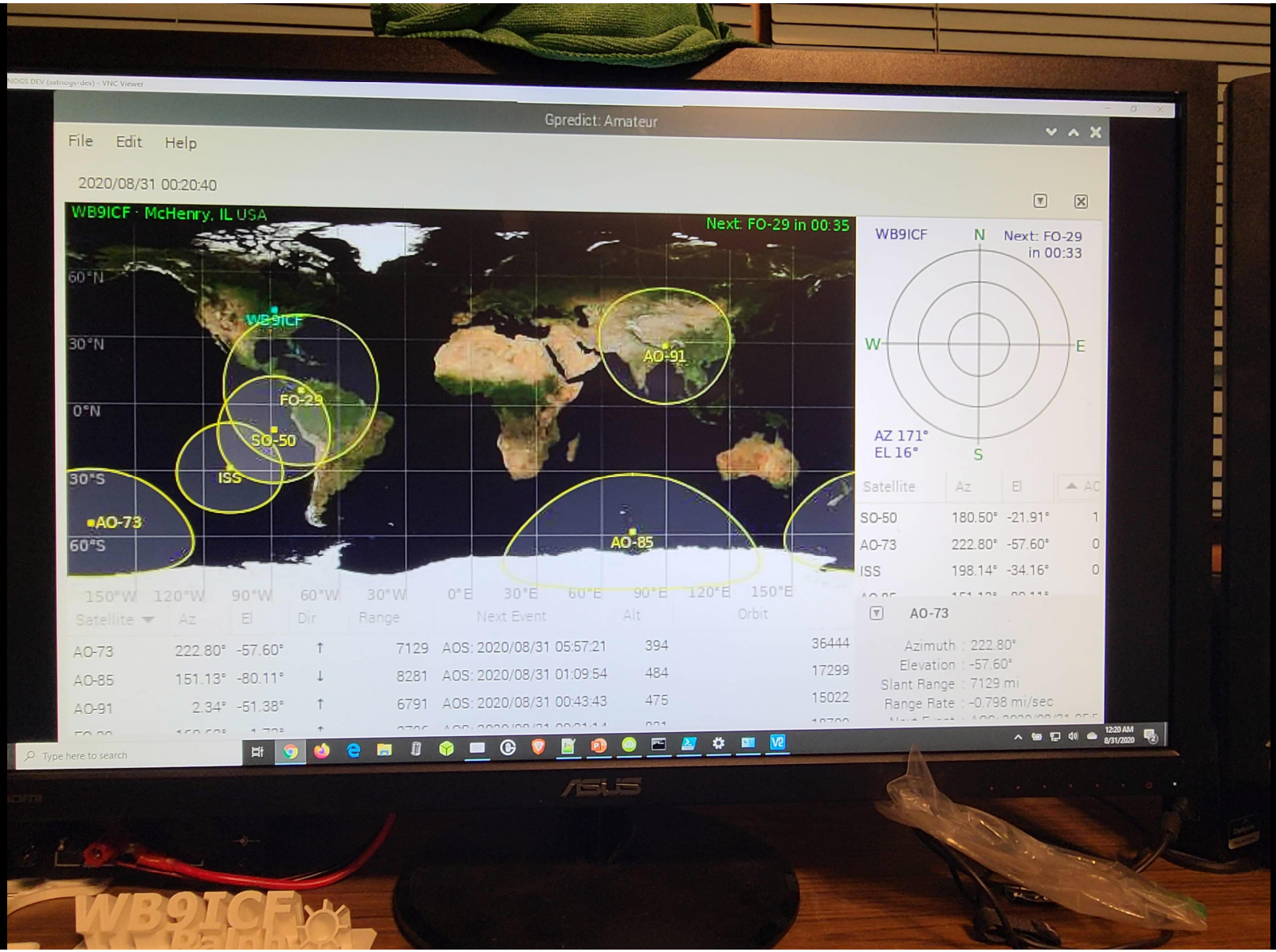
- Lots of work travel early in the month for Mike cut into project time.
- When Illinois went into COVID-19 lockdown, no in-person meetings were possible.
- Used the downtime to consider replacing the laptop with a Raspberry Pi (especially cool for the Maker Faire)

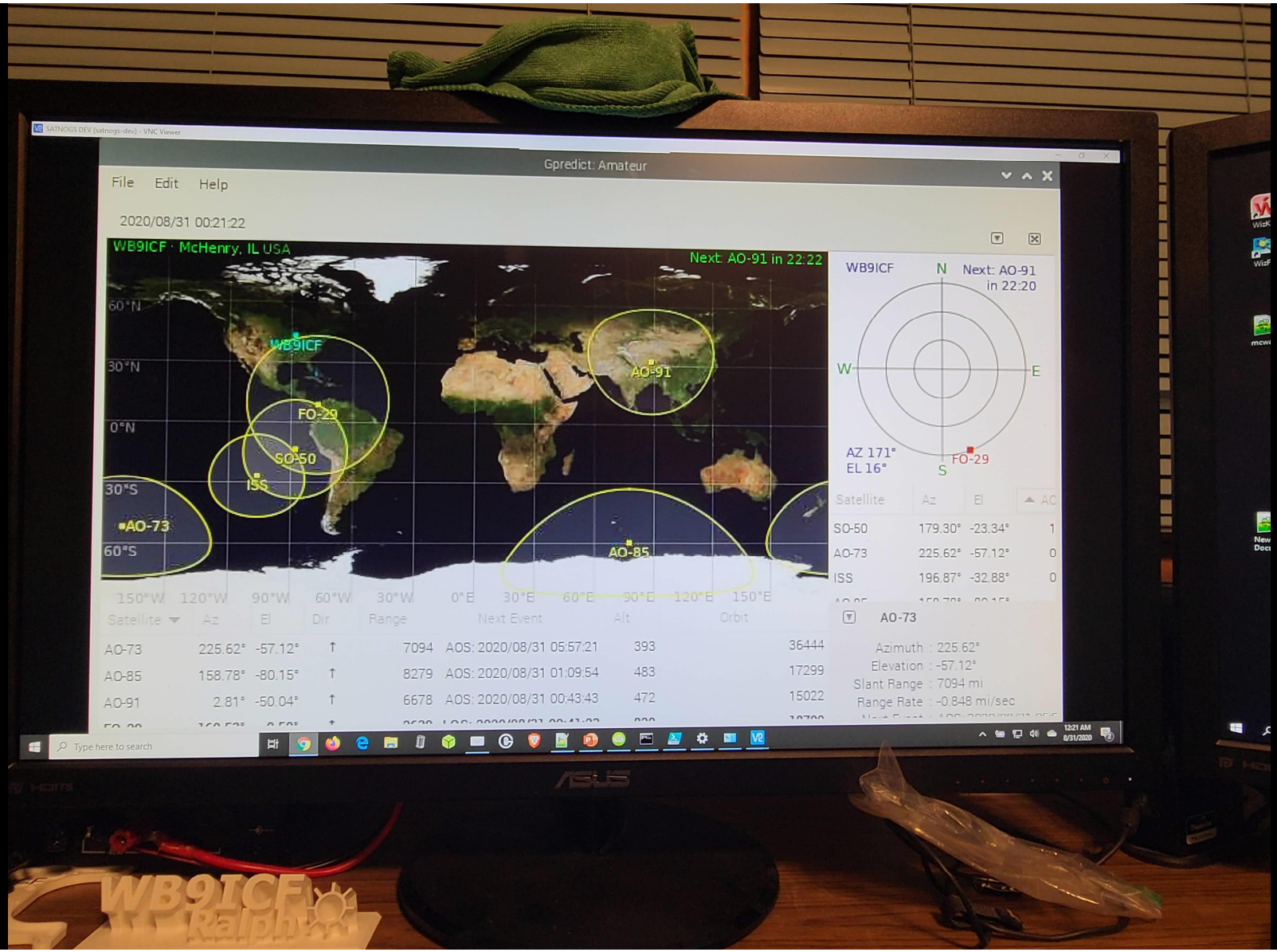
March 2020

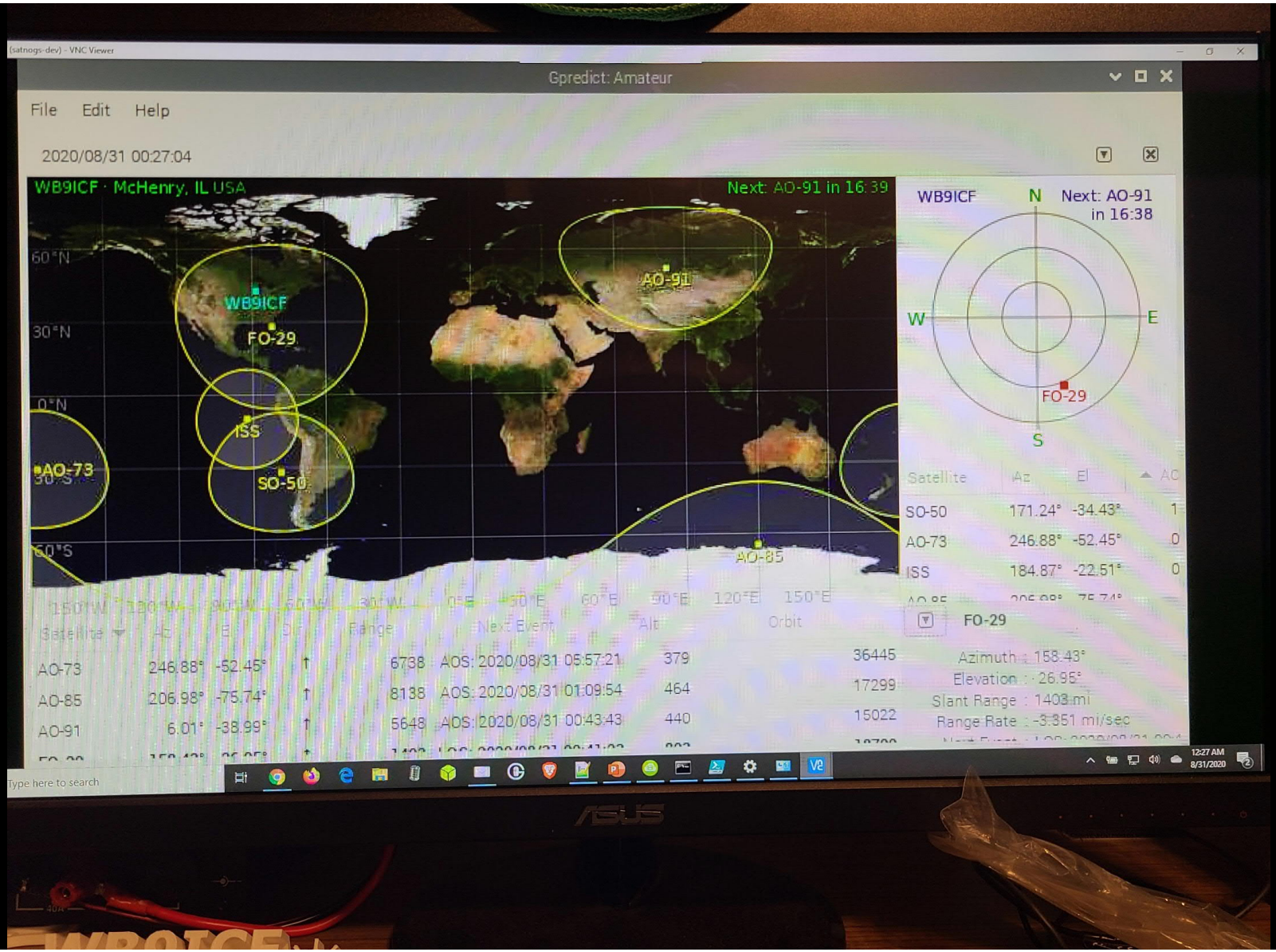
March 2020

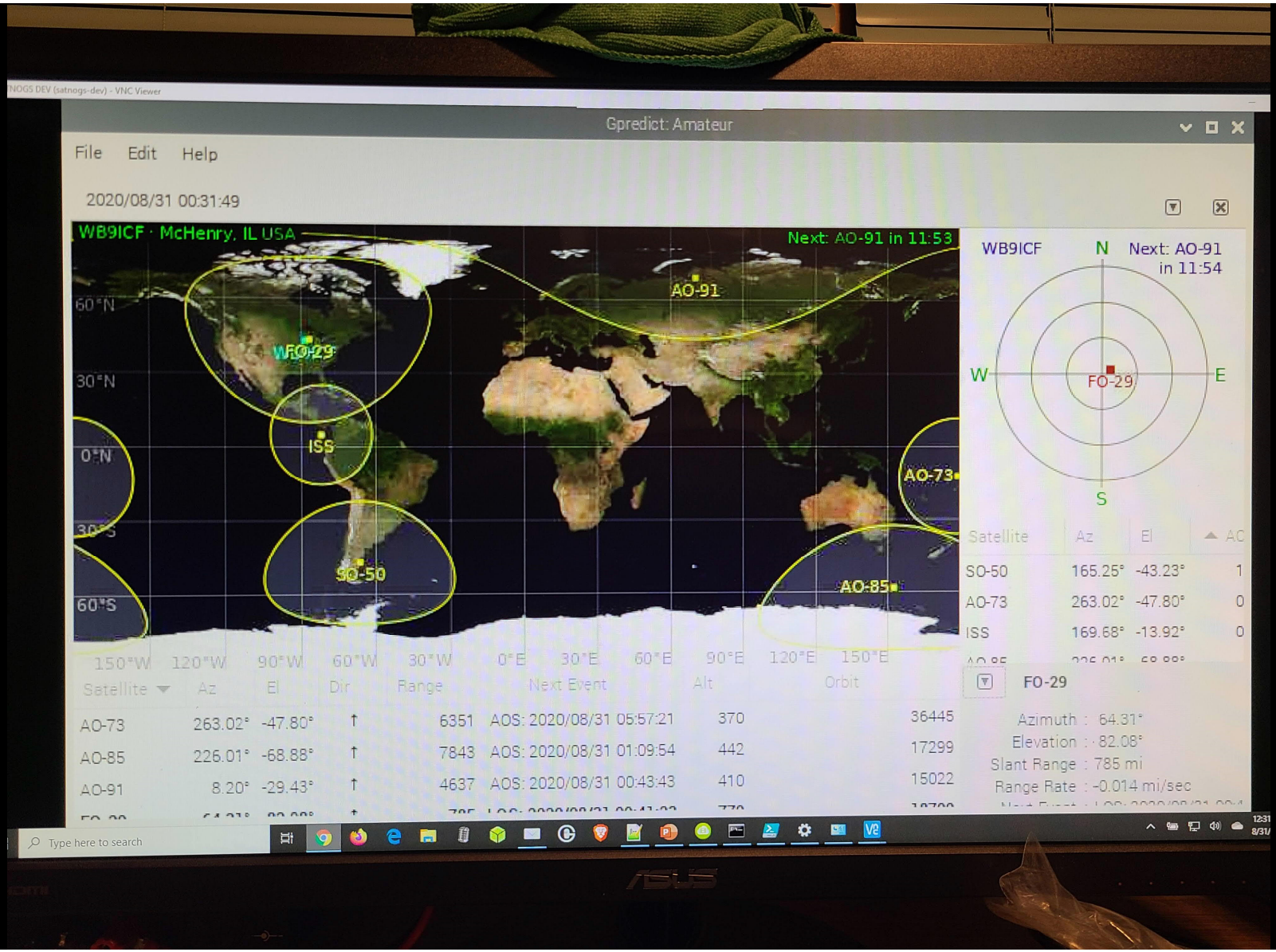
March 2020




Gpredict: Amateur
File Edit Help
2020/08/31 00:20:40
WB9ICF · McHenry, IL USA
Next: FO-29 in 00:35
WB9ICF
AO-91
FO-29
SO-50
ISS
AO-73
AO-85
WB9ICF N Next: FO-29 in 00:33
W E
S
AZ 171°
EL 16°
Satellite Az El AC
SO-50 180.50° -21.91° 1
AO-73 222.80° -57.60° 0
ISS 198.14° -34.16° 0
Satellite Az El Dir Range Next Event Alt Orbit
AO-73 222.80° -57.60° ↑ 7129 AOS: 2020/08/31 05:57:21 394 36444
AO-85 151.13° -80.11° ↓ 8281 AOS: 2020/08/31 01:09:54 484 17299
AO-91 2.34° -51.38° ↑ 6791 AOS: 2020/08/31 00:43:43 475 15022
AO-73
Azimuth : 222.80°
Elevation : -57.60°
Slant Range : 7129 mi
Range Rate : -0.798 mi/sec
Type here to search
ASUS
WB9ICF


SATNOGS DEV (satnogs-dev) - VNC Viewer
Gpredict: Amateur
File Edit Help
2020/08/31 00:21:22
WB9ICF · McHenry, IL USA
Next: AO-91 in 22:22
60°N
30°N
0°N
30°S
60°S
WB9ICF
FO-29
SO-50
ISS
AO-73
AO-91
AO-85
150°W 120°W 90°W 60°W 30°W 0°E 30°E 60°E 90°E 120°E 150°E
WB9ICF
N
Next: AO-91
in 22:20
W
E
S
AZ 171°
EL 16°
FO-29
Satellite Az El AC
SO-50 179.30° -23.34° 1
AO-73 225.62° -57.12° 0
ISS 196.87° -32.88° 0
Satellite Az El Dir Range Next Event Alt Orbit
AO-73 225.62° -57.12° ↑ 7094 AOS: 2020/08/31 05:57:21 393 36444
AO-85 158.78° -80.15° ↑ 8279 AOS: 2020/08/31 01:09:54 483 17299
AO-91 2.81° -50.04° ↑ 6678 AOS: 2020/08/31 00:43:43 472 15022
AO-73
Azimuth : 225.62°
Elevation : -57.12°
Slant Range : 7094 mi
Range Rate : -0.848 mi/sec
Type here to search
12:21 AM
8/31/2020
ASUS
WB9ICF
Ralph

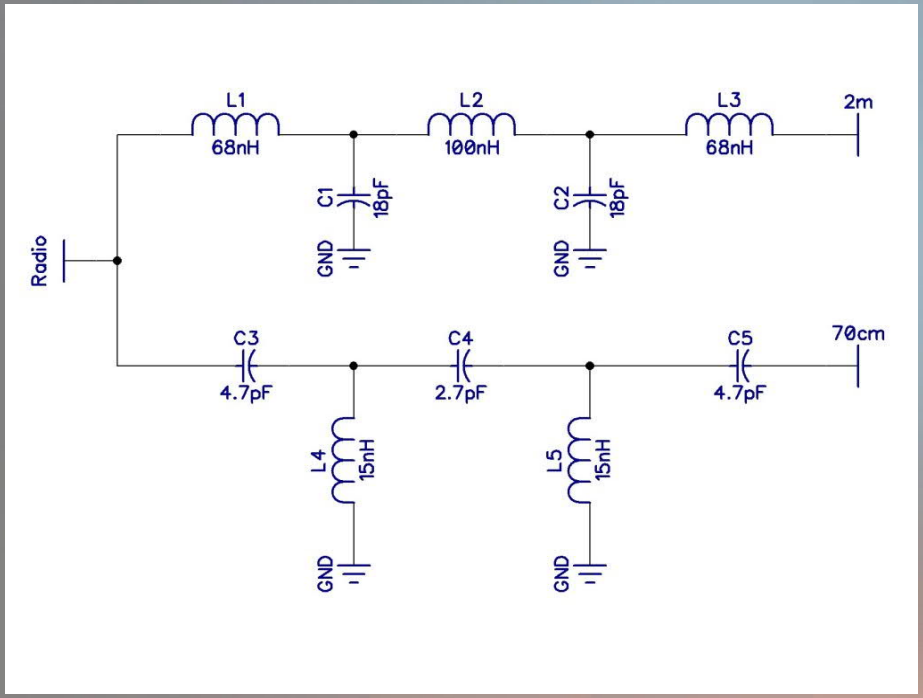

(satnogs-dev) - VNC Viewer
Gpredict: Amateur
File Edit Help
2020/08/31 00:27:04
WB9ICF · McHenry, IL USA
Next: AO-91 in 16:39
60°N
30°N
0°N
30°S
60°S
WB9ICF
FO-29
ISS
AO-73
SO-50
AO-91
AO-85
150°W 120°W 90°W 60°W 30°W 0°E 30°E 60°E 90°E 120°E 150°E
WB9ICF
N
Next: AO-91
in 16:38
W
E
S
FO-29
Satellite Az El AO
SO-50 171.24° -34.43° 1
AO-73 246.88° -52.45° 0
ISS 184.87° -22.51° 0
FO-29
Azimuth : 158.43°
Elevation : 26.95°
Slant Range : 1403 mi
Range Rate : -3.351 mi/sec
Satellite Az El Range Next Event Alt Orbit
AO-73 246.88° -52.45° 6738 AOS: 2020/08/31 05:57:21 379 36445
AO-85 206.98° -75.74° 8138 AOS: 2020/08/31 01:09:54 464 17299
AO-91 6.01° -38.99° 5648 AOS: 2020/08/31 00:43:43 440 15022
Type here to search
12:27 AM
8/31/2020


NOGS DEV (satnogs-dev) - VNC Viewer
Gpredict: Amateur
File Edit Help
2020/08/31 00:31:49
WB9ICF · McHenry, IL USA
Next: AO-91 in 11:53
AO-91
FO-29
ISS
AO-73
SO-50
AO-85
60°N
30°N
0°N
30°S
60°S
150°W 120°W 90°W 60°W 30°W 0°E 30°E 60°E 90°E 120°E 150°E
WB9ICF
N
Next: AO-91 in 11:54
W
E
S
FO-29
Satellite Az El AC
SO-50 165.25° -43.23° 1
AO-73 263.02° -47.80° 0
ISS 169.68° -13.92° 0
Satellite Az El Dir Range Next Event Alt Orbit
AO-73 263.02° -47.80° ↑ 6351 AOS: 2020/08/31 05:57:21 370 36445
AO-85 226.01° -68.88° ↑ 7843 AOS: 2020/08/31 01:09:54 442 17299
AO-91 8.20° -29.43° ↑ 4637 AOS: 2020/08/31 00:43:43 410 15022
FO-29
Azimuth : 64.31°
Elevation : 82.08°
Slant Range : 785 mi
Range Rate : -0.014 mi/sec
Type here to search

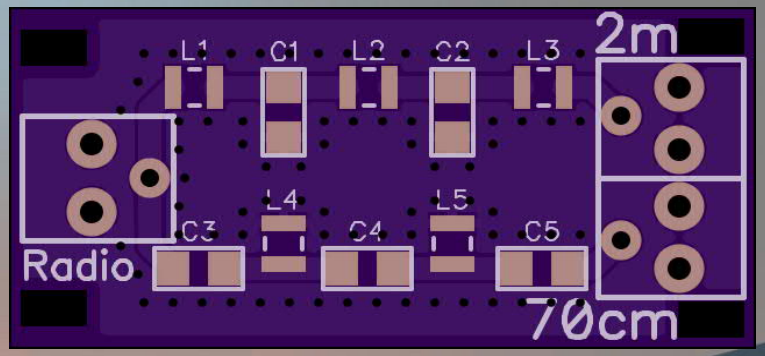
April 2020

- MCWA April meeting canceled, May program at jeopardy.
- More time for experimenting with other items (e.g., diplexer and yagis)
- Mike took a job offer back in New Jersey and relocated there in late April.

April 2020



- Inexpensive 2m/70cm diplexer by KW4FB than can handle 10-15 watts.
- Total cost <$10 plus coax and connectors.
- Have PCB and parts for four more units.



Project Future

- “It’s not dead, Jim.” – just on hiatus
- Mike has the mechanical parts in NJ.
- Ralph has the electronics in IL.
- We are looking forward to a time when we can put the two modules together and finally finish the project.

Did we meet our objectives?

- Despite the best planning, the best execution, and contingency plans...

- Life happens -

- We had fun and learned lots of new things.

Acknowledgements

- Libre Space Foundation and their contributors for their SatNOGS project, reference designs, and engineering data. (https://satnogs.org)
- Gary Dembski (W9GD) for his guidance and advice, help with parts procurement, and other special assistance without which this project wouldn't have had the progress that it had.

The End. Or is it?

Project Retrospection

What did we set out to do?

- Successfully build and test the SatNOGS version 3 rotor.
- Present the project at the May 2020 MCWA meeting.
- Perform field testing during Field Day 2020.
- Demonstrate system at the Lake County Maker Faire as part of MCWA's amateur radio exhibition for Faire goers.

What actually happened?

- Successfully build and test the SatNOGS version 3 rotor.
- COVID-19 distancing and relocation of one of the team members prevented the timely completion of the project.

- Present the project at the May 2020 MCWA meeting.
- Project wasn't wrapped up in time for May meeting.

- Perform field testing during Field Day 2020.
- Couldn't field test a rotor that wasn't completely finished.

- Demonstrate system at the Lake County Maker Faire as part of MCWA's amateur radio exhibition for Faire goers.
- Faire was canceled for this year so MCWA wasn't able to demo anything.

What went well?

- Project started early (November 2019) knowing projects always have speedbumps.
- Identified “high risk” areas (like parts procurement) and tackled them first.
- Created a comprehensive Bill of Materials.
- Had the two worm gears printed in Nylon 12 by external 3D printing house.
- Established a Slack channel to keep the lines of communication open, monitor the schedule, and to flag issues that could delay project completion.

What went well?

- Ordered a small surplus of parts (2020 aluminum extrusion, controller boards, NEMA 17 stepper) for testing and for replacing parts that were ruined or damaged.
- Identified areas of expertise and divided the work accordingly.
- Found ways to save money on the build (electronic bundling, using PETG vs ABS, etc.)
- Asked for help and advice to ensure the project was headed in the right direction and weren’t being overly optimistic.

What went well?

- Created a Raspberry Pi 4, 7” touchscreen terminal with tracking software for shows.
- Put together a 10w-15w 2m & 70cm diplexer SMD project kit (4 extras available if anyone Is interested, about $9 plus coax and connectors).
- Constructed 2m and 70cm yagis, 3D printing the element and mast mounts, using aluminum elements and bronze driven elements.

What could have gone better?

- The COVID-19 pandemic completely derailed the project and its successful completion. No amount of planning could have changed that. Life happens.
- Mike (KD2RPE) moving out of the area for a job opportunity in April meant that project completion would need to be put on hold. Got to make a living.
- The technique for cutting the 2020 aluminum extrusion required significant post-processing to remove burrs and deformities.
- 3D printed 2m & 70cm yagis weren't scaled up to fit the mast size being used.

Summary

- Planning is essential.
- Start early as things always take longer than anticipated.
- Ask for help when needed.
- Recognize that other priorities will always be there (family time, work commitments, other projects, etc.)
- Divide up the work because many hands make light work.
- Order more materials than anticipated to avoid delays if supplies run short.

And most importantly…

- Despite the best planning, the best execution, and contingency plans…

- Life happens -

- We had fun and learned lots of new things.

Acknowledgements

- Libre Space Foundation and their contributors for their SatNOGS project, reference designs, and engineering data. (https://satnogs.org)
- Gary Dembski (W9GD) for his guidance and advice, help with parts procurement, and other special assistance without which this project wouldn't have had the progress that it had.

The End. Or is it?