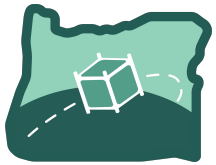


OreSat

Communication Protocols and Ground Stations

Open Source CubeSat Workshop 2021

Glenn LeBrasseur, KJ7SU

Portland State Aerospace Society at Portland State University
1900 SW 4th Avenue ste 160, Portland, OR 97201
503-459-7218 / glennl@pdx.edu

OreSat0 is a Flight Heritage Mission

- OreSat (aka OreSat1) - An all-up mission for a first time satellite group, and we're building everything, and it's our "first satellite!" We're totally gonna die!
  … So ...

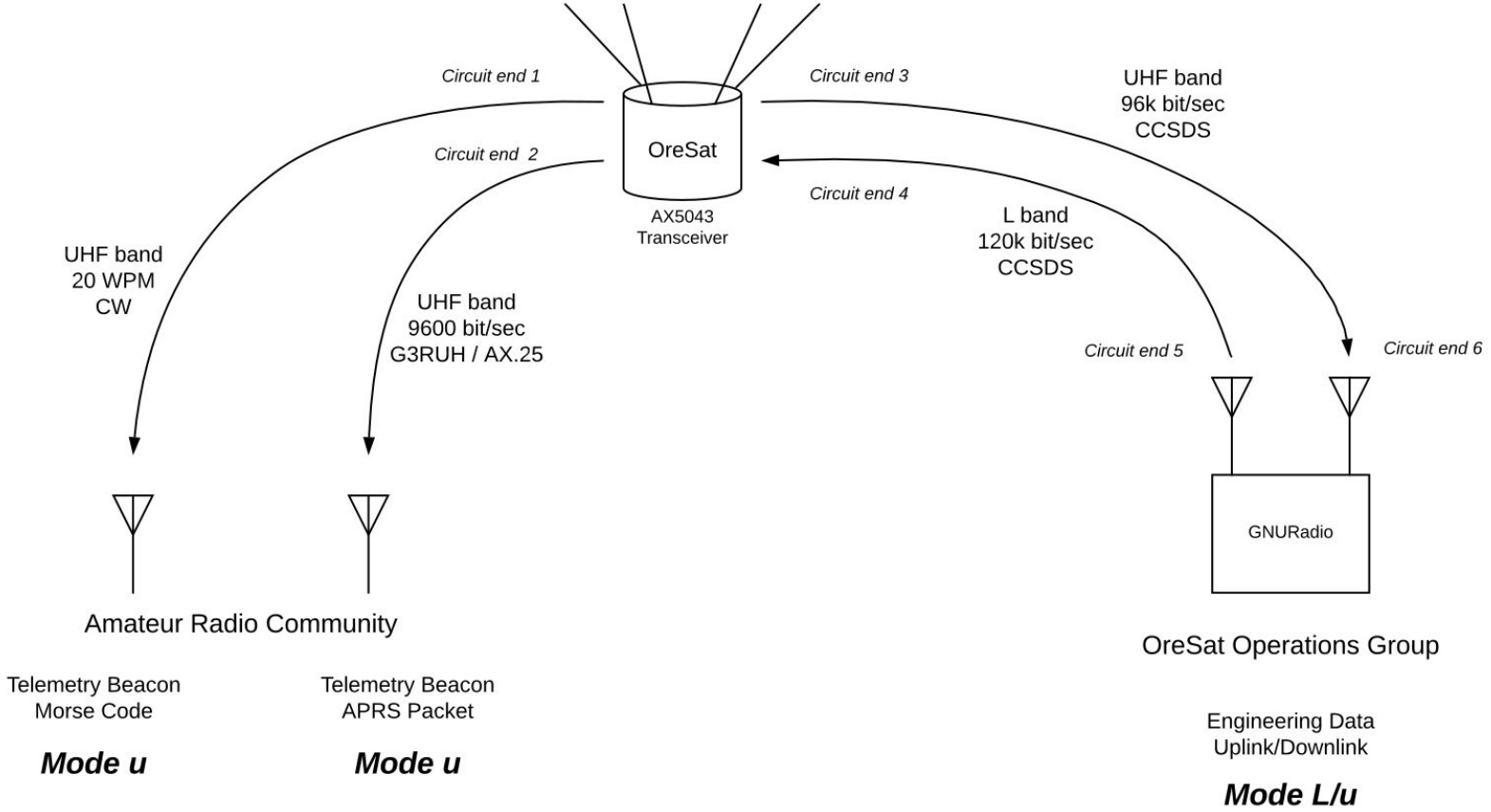
- OreSat 0 - Flight Heritage for **Critical Subsystems**
  - Battery
  - Solar power
  - Communications and antennas
  - Bus, structure, and deployables

- OreSat 0.5 - Verify **ADCS Subsystem**

- OreSat 1 - Now we get on with the mission

Communication Channels

Communication Channels

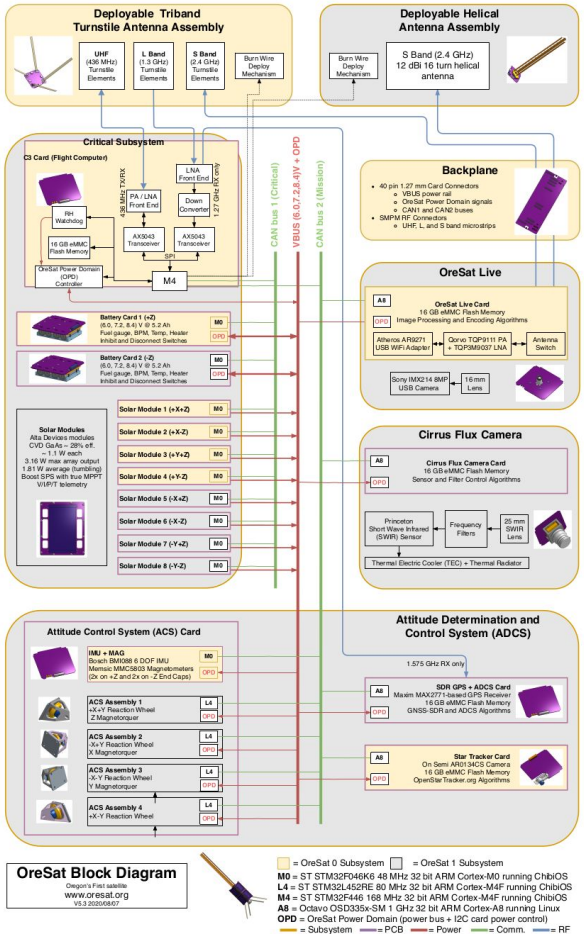


Communication Channel Design

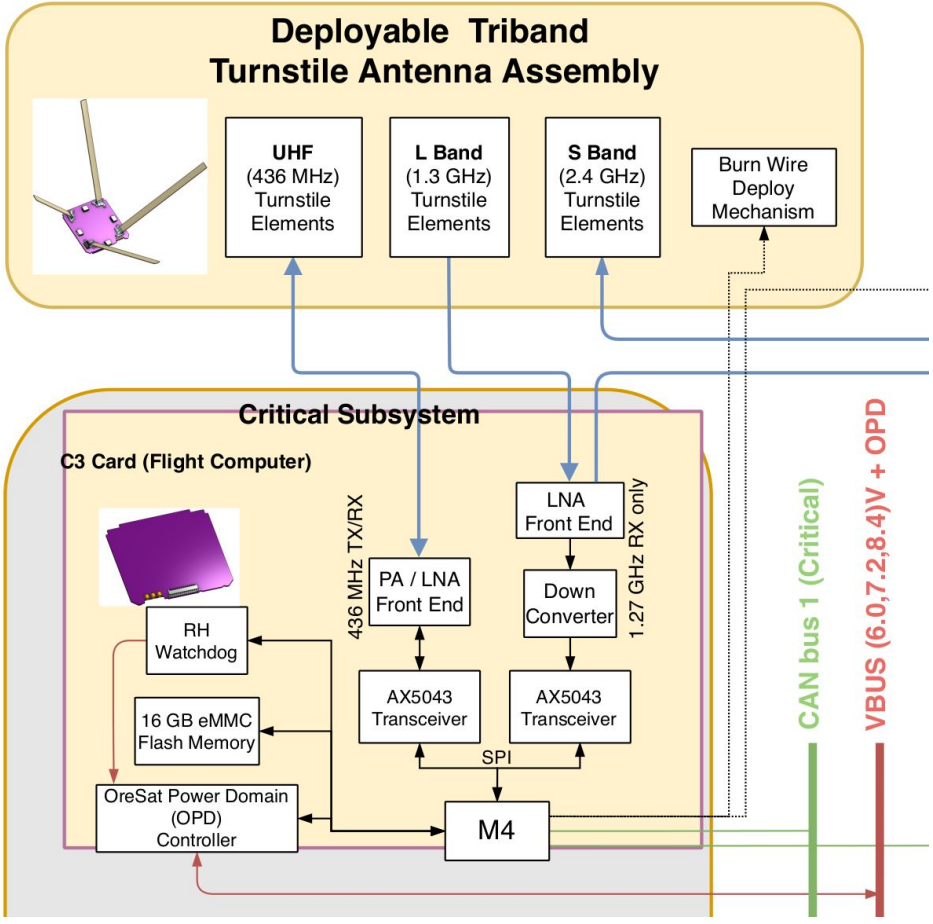
Channel	Emission Designator	Modulation Index	BW (kHz)	BW * Time (Product)	Bit Rate (Bit/Sec)	Eb/No (dB for BER)
UHF Beacon	20K0F1D	0.6666667	20	0.5	9,600	10.7 / 10^4
UHF EDL	96K0F1D	0.5	96	0.5	96,000	10.9 / 10^5
L EDL	120KF1D	0.5	120	0.5	120,000	10.9 / 10^5
CW	150HA1A					

Spacecraft Transceiver

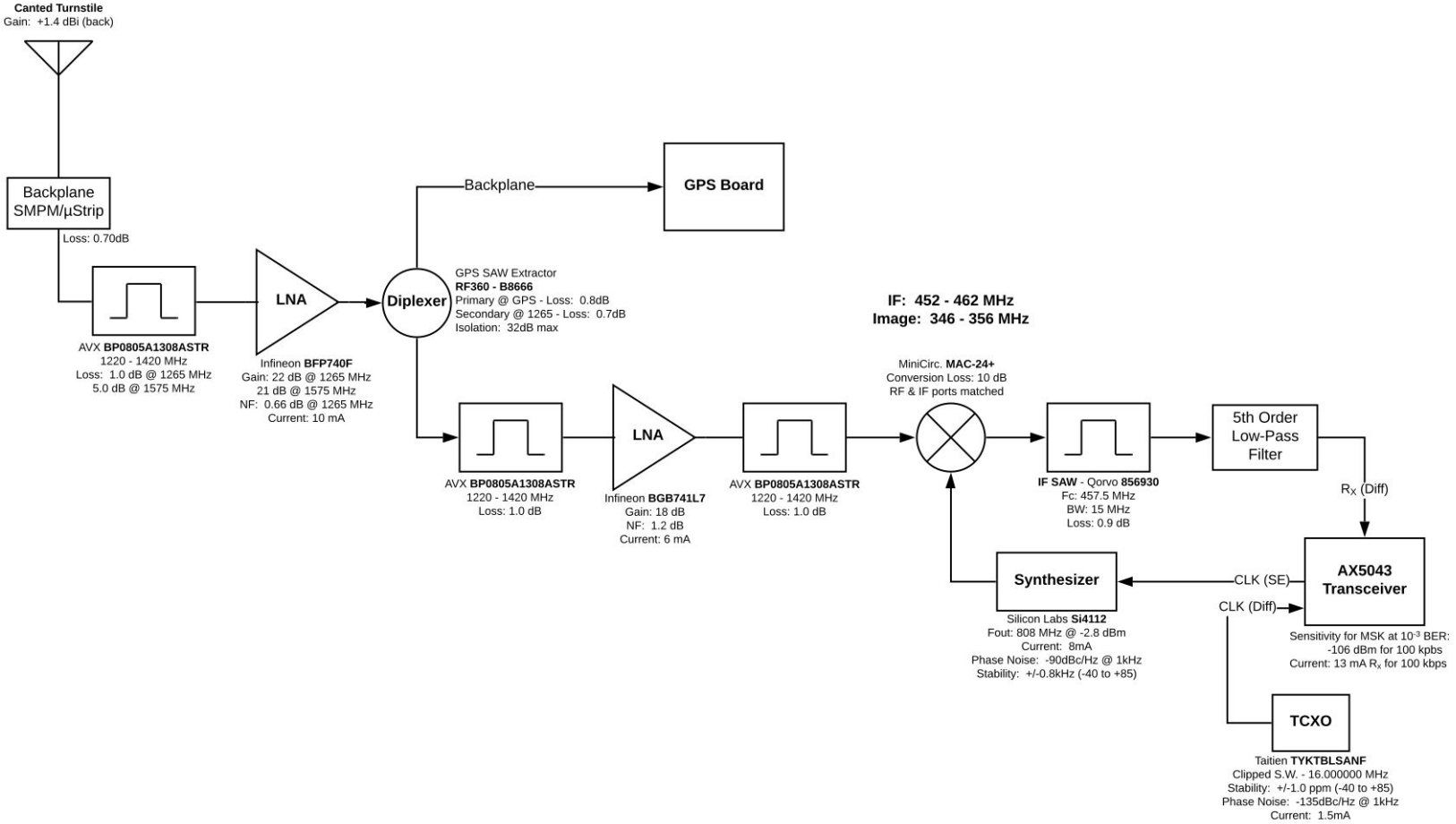
OreSat0 Spacecraft Block Diagram



C3 Card Has Two AX5043 Transceivers

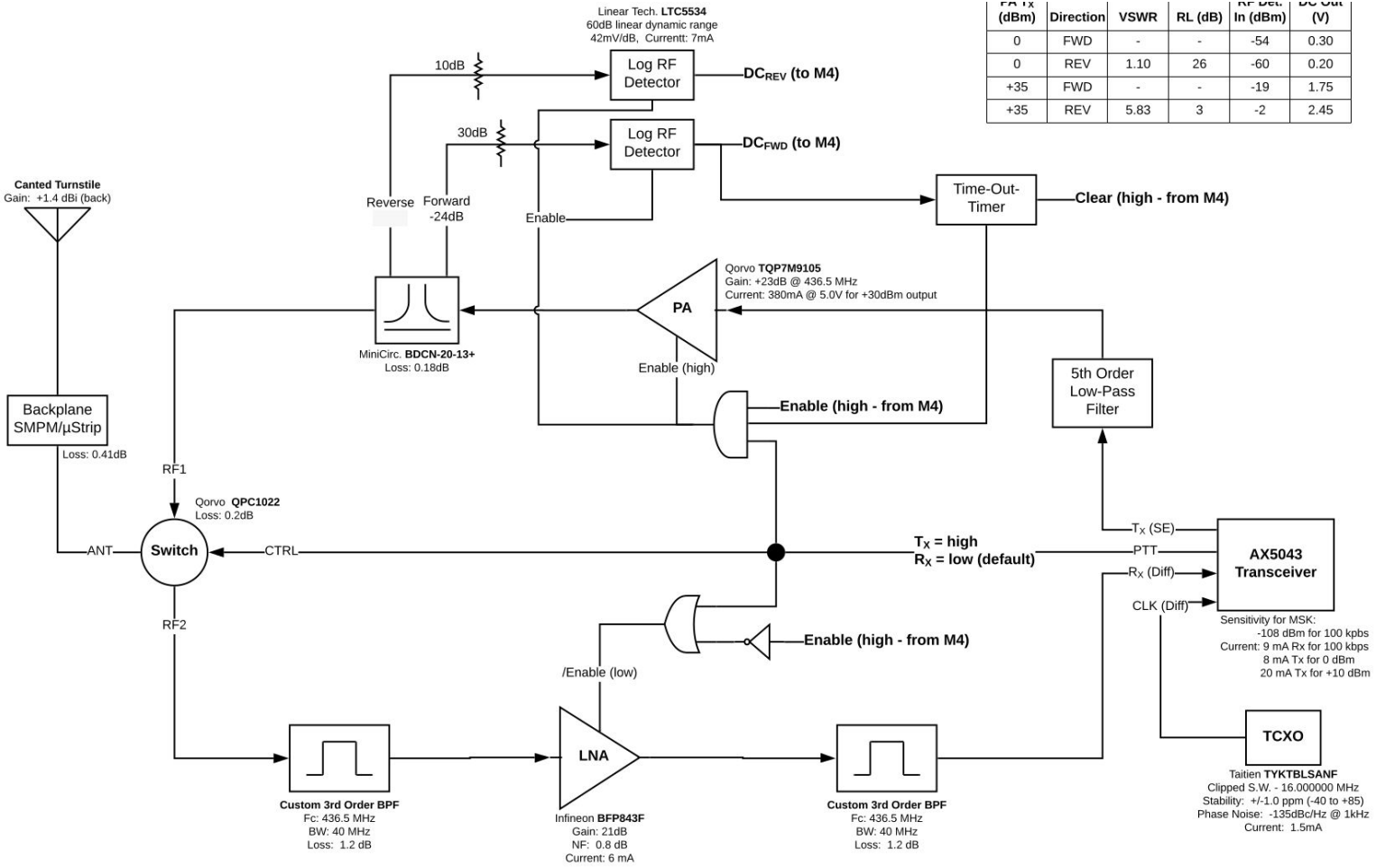


L Band Downconverter and Receiver



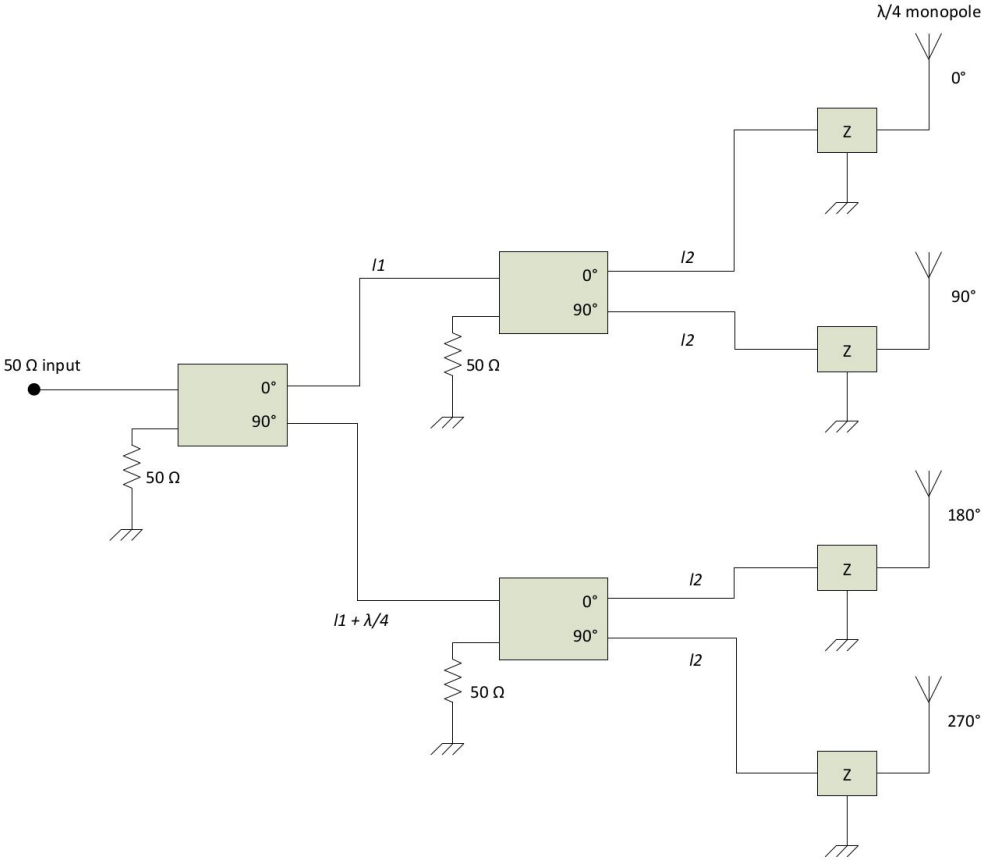
UHF Transceiver

PA Tx (dBm)	Direction	VSWR	RL (dB)	RF Det. In (dBm)	DC Out (V)
0	FWD	-	-	-54	0.30
0	REV	1.10	26	-60	0.20
+35	FWD	-	-	-19	1.75
+35	REV	5.83	3	-2	2.45



Canted Turnstile Antenna

Turnstile Antenna



Beacon

Beacon Format

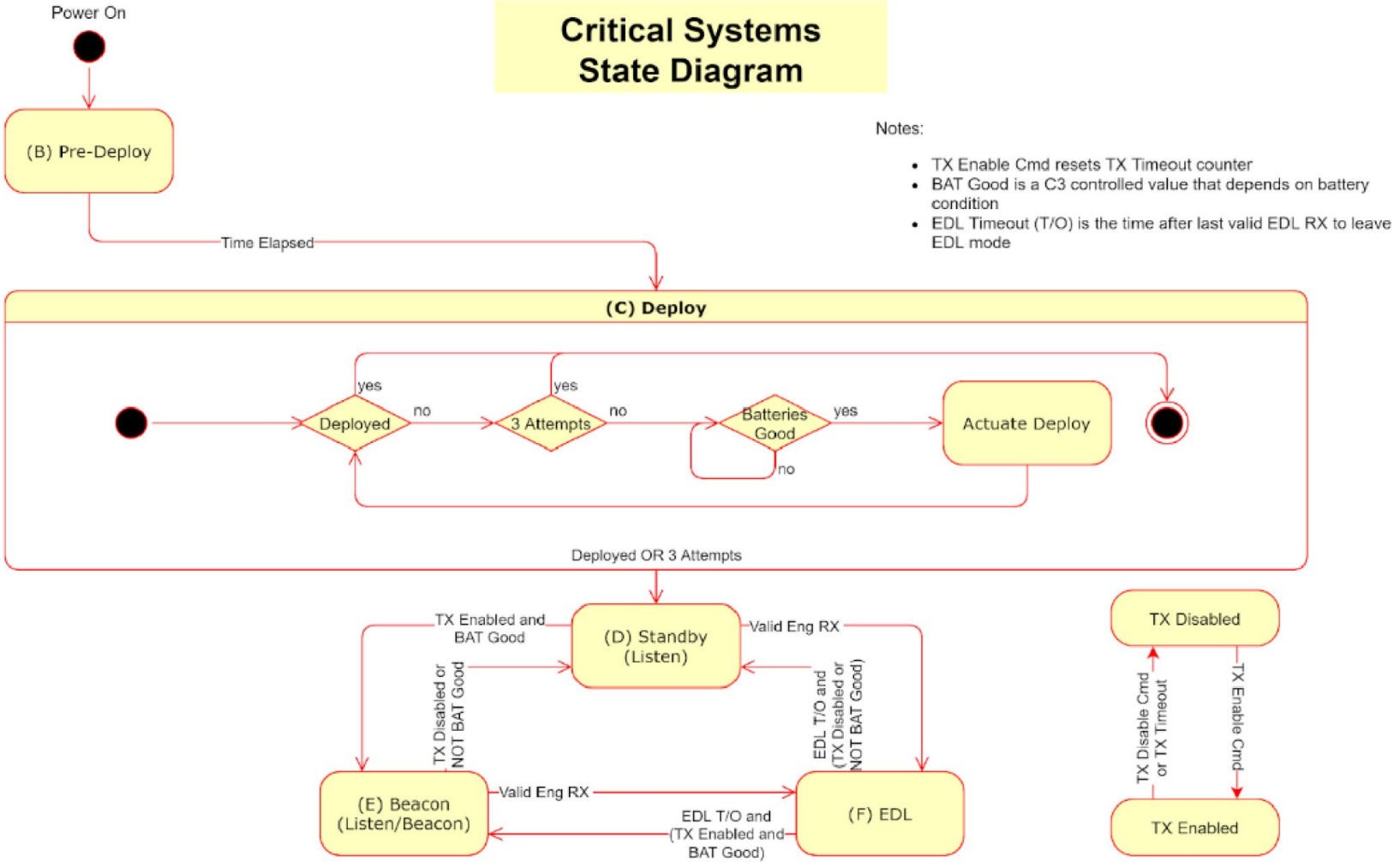
			Bytes Allocated:	243		MAX: 255 bytes
System	Subsystem	Data	Data Type	# Bytes	Units	Notes
APRS	Packet	Data type identifier	UINT8	3	ASCII String	"{{z" User-Defined APRS packet format
APRS	Packet	Revision	UINT8	1	Count	revision 2
C3	Packet	Craft ID	UINT8	1		Unique ID for Satellite (0 = OreSat0)
C3	M4	OreSat0 State	State	1	State	Character representing C3 critical state
C3	M4	Uptime	UINT32	4	Seconds	Stick at 0xFFFFFF if we reach 194 days of uptime :)
C3	RTC	Time	UINT32	4	Seconds	SCET coarse / UNIX timestamp
C3	M4	Temperature	INT8	1	deg C	Internal temp of the C3's STM32F439
C3	M4	Ref voltage	UINT8	1	0.02 V	Reference voltage on the C3's ADC (should be VCC = 3.3V)
C3	M4	Vbusp Voltage	UINT8	1	0.02 V	WAIT WHAT?! HOW DOES THE C3 KNOW THE BUS VOLTAGE?!!
C3	M4	Vbusp Current	UINT8	1	0.02 mA	"VBUS_ILIM" from U4 (TS59621 with 3.1k resistor)
C3	WDT	# timeouts	UINT16	2	Count	Stored in FRAM; Stick at 0xFFFF until reset from ground
C3	eMMC	% full	UINT8	1	% (0 - 100)	
C3	L RX	Bytes received	UINT32	4		
C3	L RX	Valid packets	UINT32	4		
C3	L RX	RSSI	UINT8	1	dBm	
C3	L RX	PLL Lock	State	1	Lock state	0 : AX5043 PLL Lock; 1 : Downconverter synth PLL lock; More space in bit field available
C3	UHF TX	Temperature	INT8	1	deg C	
C3	UHF TX FWD	Forward power	UINT16	2	dBm	"UHF_LOG_RF_FWD" from U32; Scaled to usable dBm range
C3	UHF TX REV	Reverse power	UINT16	2	dBm	"UHF_LOG_RF_REV" from U33; Scaled to usable dBm range
C3	UHF RX	Bytes received	UINT32	4		
C3	UHF RX	Valid packets	UINT32	4		
C3	UHF RX	RSSI	UINT8	1	dBm	Of last packet received; -126 to -45 dBm range; 1 dB step; after LNA, filters, and digital channel filter.
C3	UHF RX	PLL Lock	State	1	Lock state	0 : AX5043 PLL Lock; More space in bit field available
C3	FW Bank	Current and next bank	State	1		
C3	CAN1	State	State	1	State	Operational/High # errors/Other CAN status?
C3	CAN2	State	State	1	State	Operational/High # errors/Other CAN status?
C3	OPD	Current	UINT8	1	0.02 mA	"OPD_ILIM" from U? (MAX? with ?k resistor)
C3	OPD	State	UINT8	1	Bit field	Which OPDs are currently on
Battery	Pack 1	VBatt	UINT16	2	mV	Total battery pack voltage
Battery	Pack 1	VCell	UINT16	2	mV	Lowest cell in the pack: voltage
Battery	Pack 1	VCell Max	UINT16	2	mV	Lowest cell in the pack: maximum voltage (since ... last charge?)
Battery	Pack 1	VCell Min	UINT16	2	mV	Lowest cell in the pack: minimum voltage (since ... last charge?)
Battery	Pack 1	VCell 1	UINT16	2	mV	Cell 1 voltage
Battery	Pack 1	VCell 2	UINT16	2	mV	Cell 2 voltage
Battery	Pack 1	VCell Avg	UINT16	2	mV	Lowest cell in the pack: average voltage (since ... last charge?)
Battery	Pack 1	Temperature	INT16	2	deg C	Why is this a INT16 instead of an INT8?
Battery	Pack 1	Temperature Avg	INT16	2	deg C	Why is this a INT16 instead of an INT8?
Battery	Pack 1	Temperature Max	INT16	2	deg C	Why is this a INT16 instead of an INT8?
Battery	Pack 1	Temperature Min	INT16	2	deg C	Why is this a INT16 instead of an INT8?
Battery	Pack 1	Current	INT16	2	mA	Instantaneous current
Battery	Pack 1	Current Avg	INT16	2	mA	Average current
Battery	Pack 1	Current Max	INT16	2	mA	Max current
Battery	Pack 1	Current Min	INT16	2	mA	Min current
Battery	Pack 1	State	UINT8	1	Bit field	Bit 0: heater on/off , B1: discharge disabled, B2: charge disabled, B3: discharge status, B4: charge statu

Beacon Format

C3	eMMC	% full	UINT8	1	% (0 - 100)	
C3	L RX	Bytes received	UINT32	4		
C3	L RX	Valid packets	UINT32	4		
C3	L RX	RSSI	UINT8	1	dBm	
C3	L RX	PLL Lock	State	1	Lock state	0 : AX5043 PLL Lock; 1 : Do
C3	UHF TX	Temperature	INT8	1	deg C	
C3	UHF TX FWD	Forward power	UINT16	2	dBm	"UHF_LOG_RF_FWD" from
C3	UHF TX REV	Reverse power	UINT16	2	dBm	"UHF_LOG_RF_REV" from
C3	UHF RX	Bytes received	UINT32	4		
C3	UHF RX	Valid packets	UINT32	4		
C3	UHF RX	RSSI	UINT8	1	dBm	Of last packet received; -126
C3	UHF RX	PLL Lock	State	1	Lock state	0 : AX5043 PLL Lock; More s

Transition Between Beacon and EDL

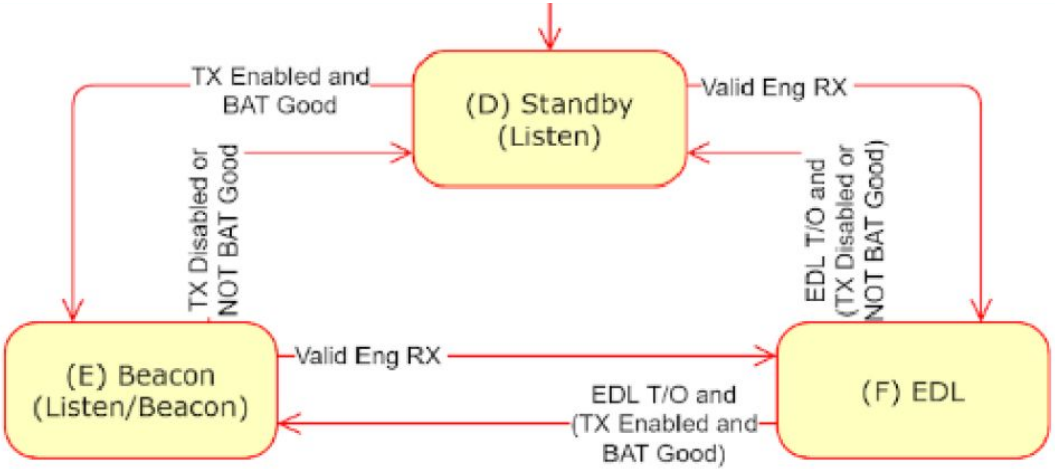
Critical Systems State Diagram

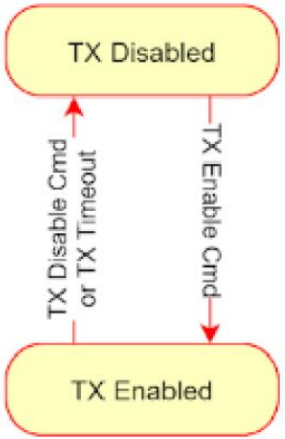


Notes:

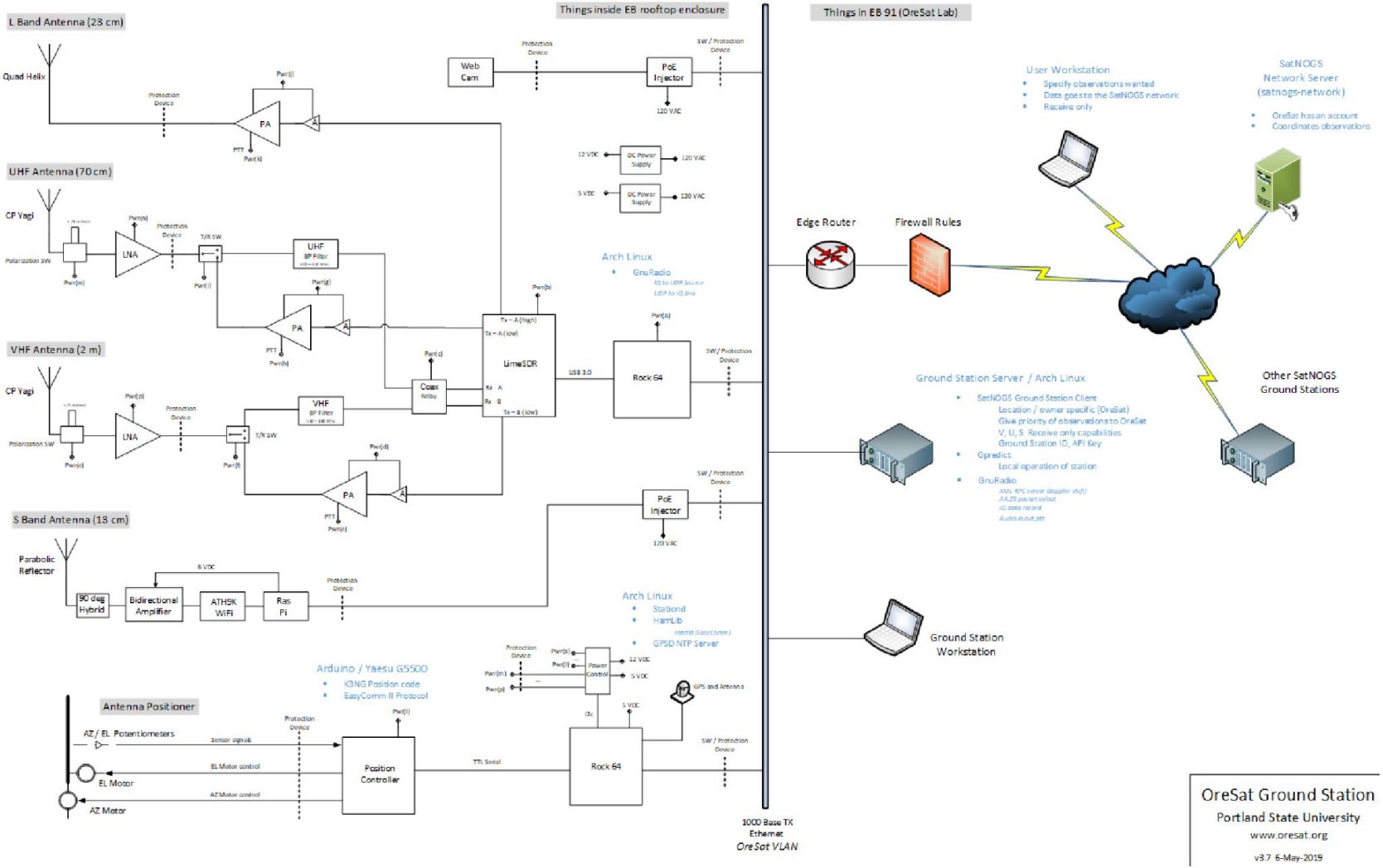
- TX Enable Cmd resets TX Timeout counter
- BAT Good is a C3 controlled value that depends on battery condition
- EDL Timeout (T/O) is the time after last valid EDL RX to leave EDL mode

Transitions Between Beacon and EDL



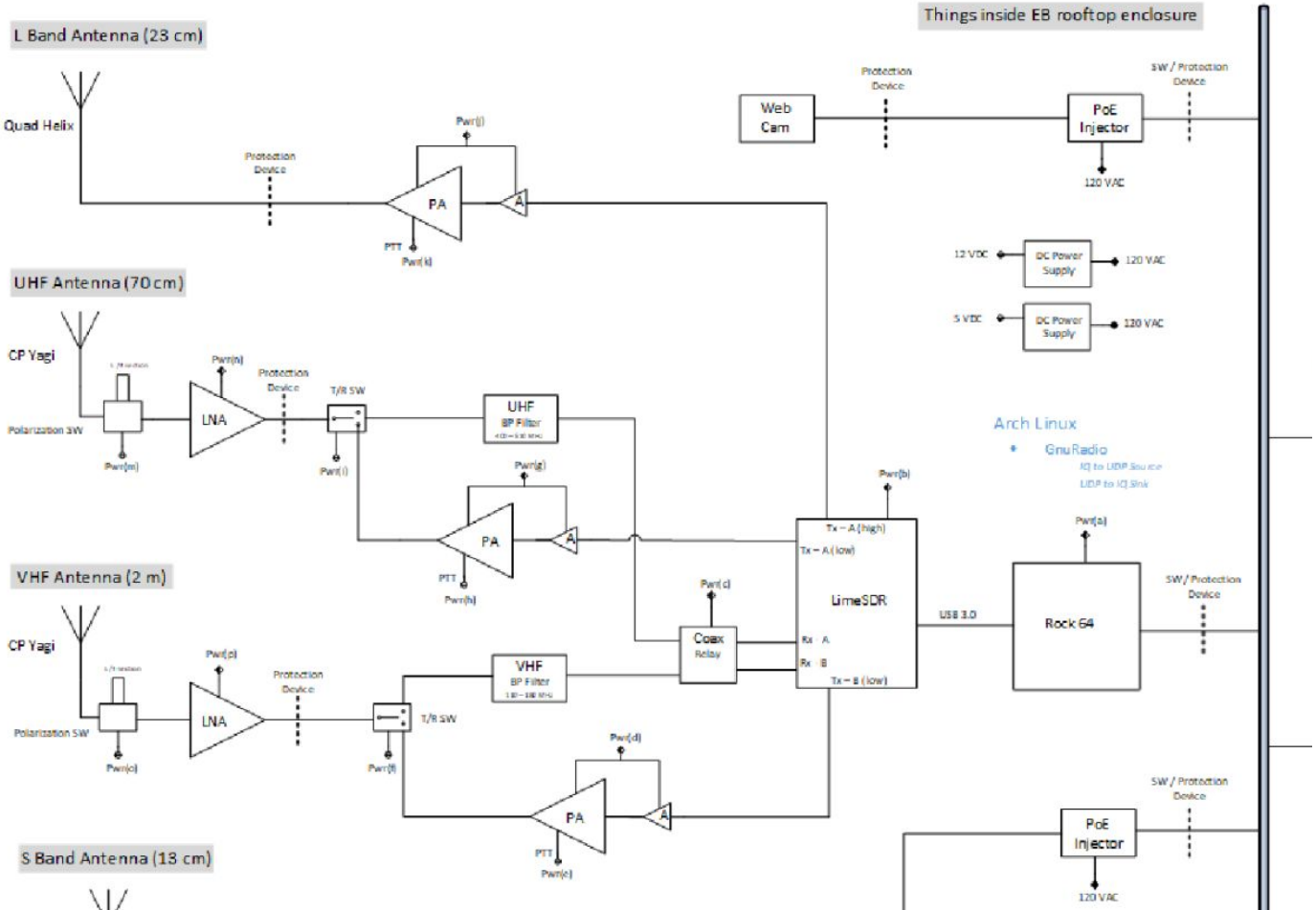


UniCIOGS Ground Station

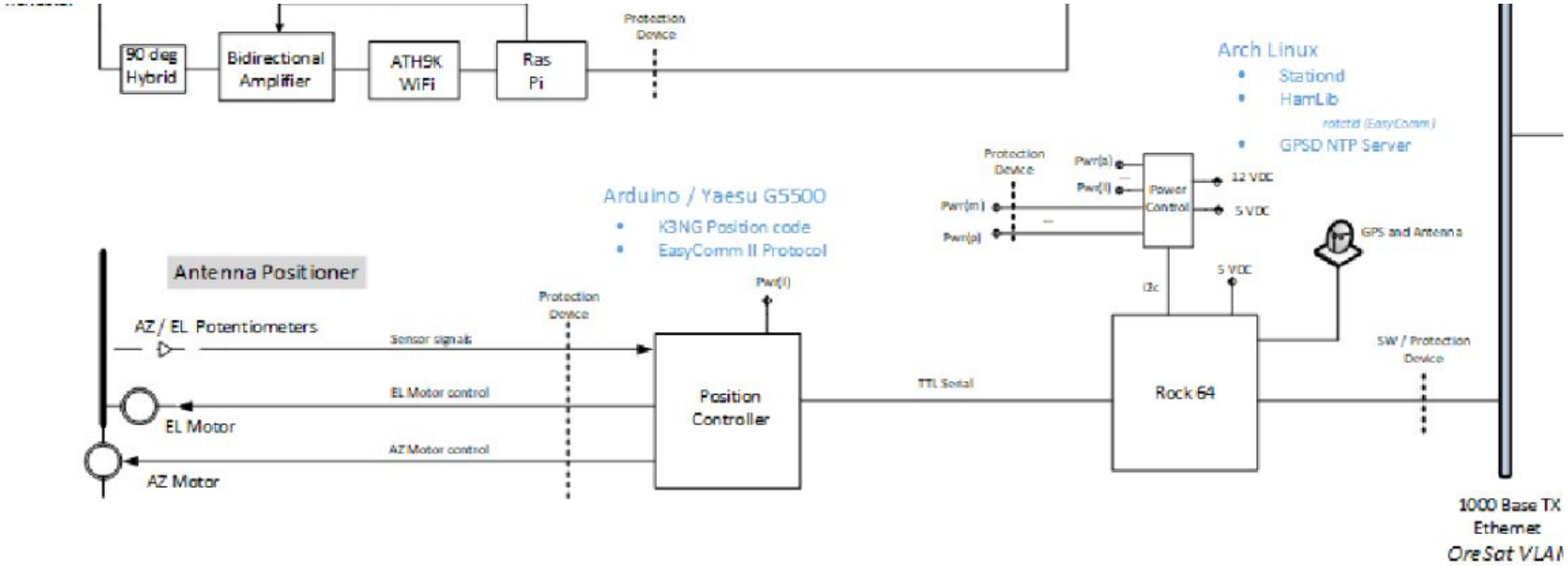


OreSat Ground Station
Portland State University
www.oresat.org
v3.7 6-May-2019

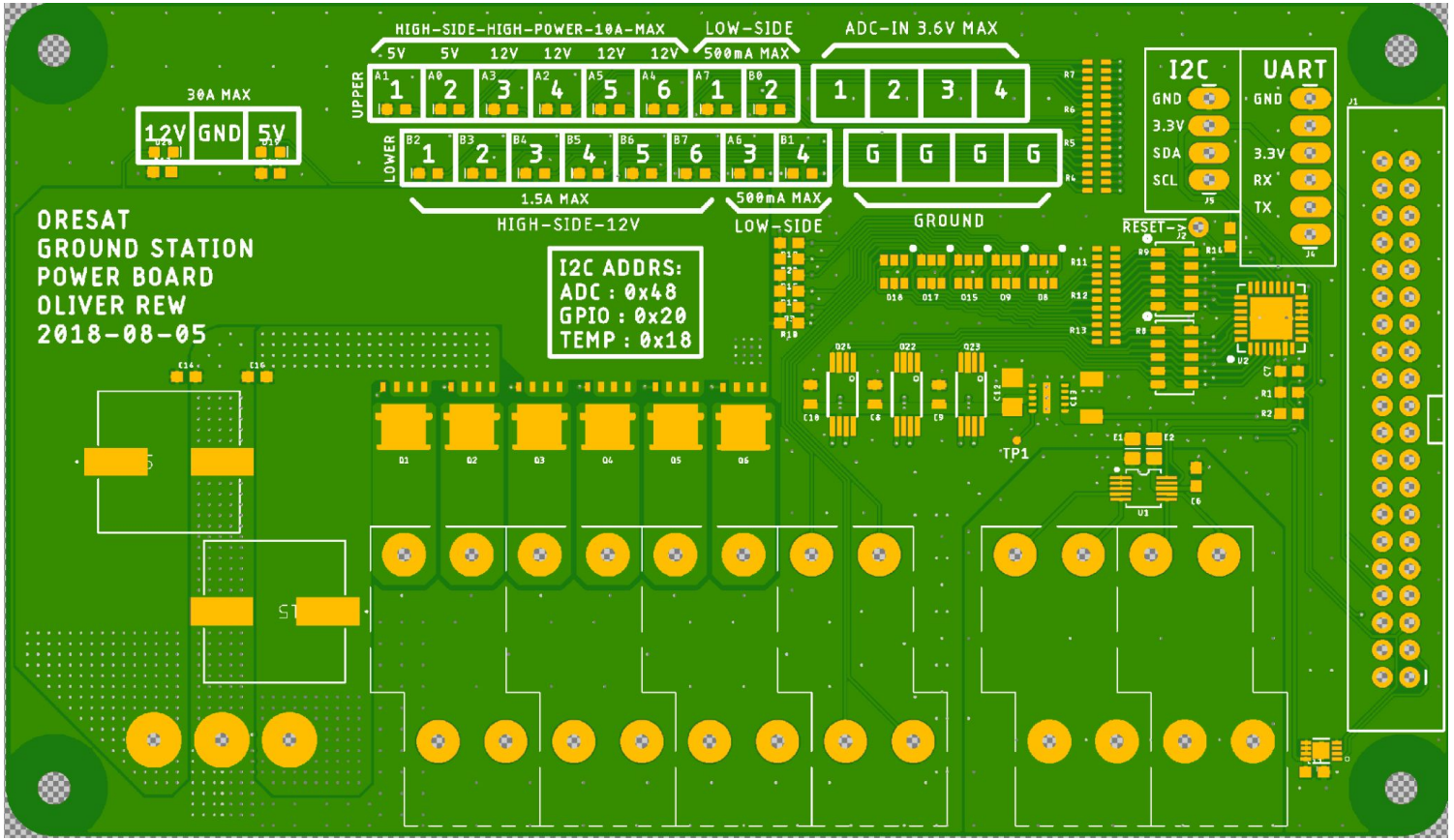
RF Paths


Things inside EB rooftop enclosure
L Band Antenna (23 cm)
Quad Helix
Protection Device
Pwr(j)
PA
PTT
Pwr(k)
Web Cam
Protection Device
PoE Injector
SW / Protection Device
120 VAC
12 VDC
DC Power Supply
120 VAC
5 VDC
DC Power Supply
120 VAC
UHF Antenna (70 cm)
CP Yagi
Polarization SW
Pwr(m)
LNA
Pwr(n)
Protection Device
T/R SW
Pwr(l)
UHF BP Filter
Pwr(g)
PA
PTT
Pwr(h)
Arch Linux
GnuRadio
IQ to UDP Source
UDP to IQ Sink
Pwr(b)
Tx – A (high)
Tx – A (low)
LimeSDR
Rx A
Rx B
Tx – B (low)
USB 3.0
Pwr(a)
Rock 64
SW / Protection Device
Pwr(c)
Coax Relay
VHF Antenna (2 m)
CP Yagi
Polarization SW
Pwr(o)
LNA
Pwr(p)
Protection Device
T/R SW
Pwr(f)
VHF BP Filter
Pwr(d)
PA
PTT
Pwr(e)
S Band Antenna (13 cm)
PoE Injector
SW / Protection Device
120 VAC

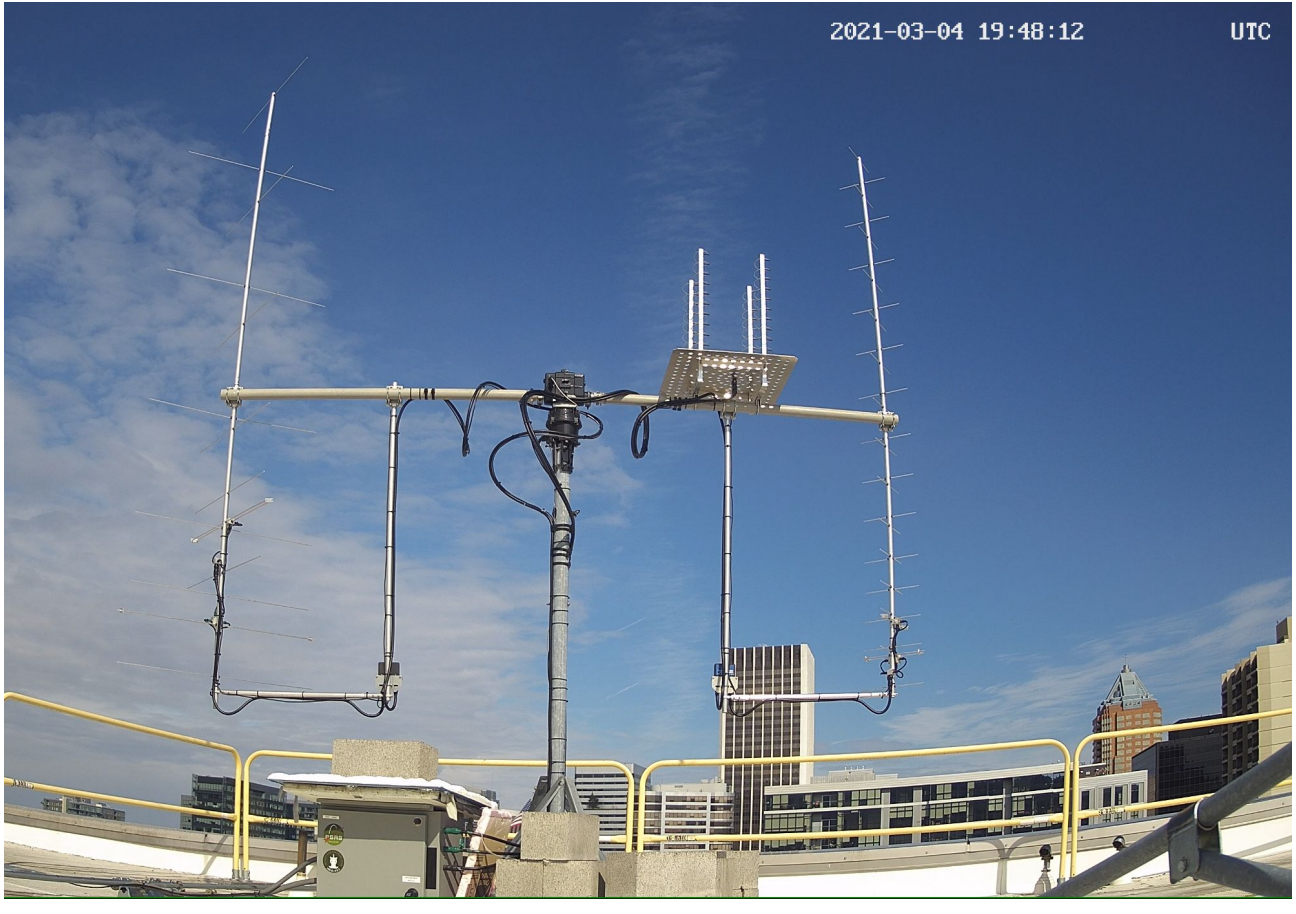
Rotator and Power Control



Power Control Board



Station on Engineering Building Roof



Enclosure Containing Everything

Station Control State Machine

Main State Switcher

Input Tokens

V-Tx
U-Tx
L-Tx
Power-On
Operate
S-On
S-Off
Kill

Outputs

all-bits: GPIO [15..0]

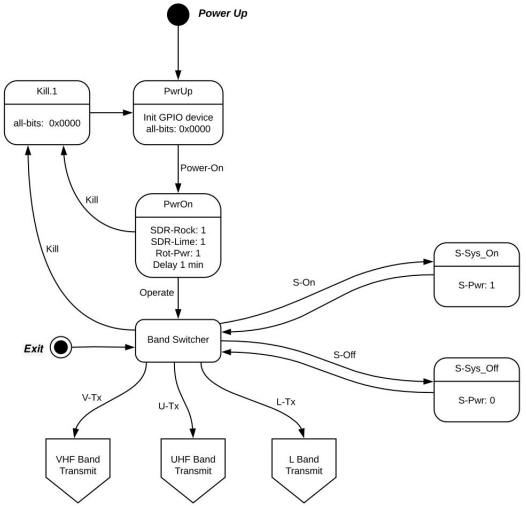
V-Key:
V-PTT:
V-PA:
V-LNA:
V-Pol:

U-Key:
U-PTT:
U-PA:
U-LNA:
U-Pol:

L-PTT:
L-PA:

S-Pwr:

SDR-Rock:
SDR-Lime:
Rot-Pwr:



stationd
Station Houskeeping Control Program

OreSat
G.N. LeBrasseur
31-Jul-2018

Pg 1 of 4

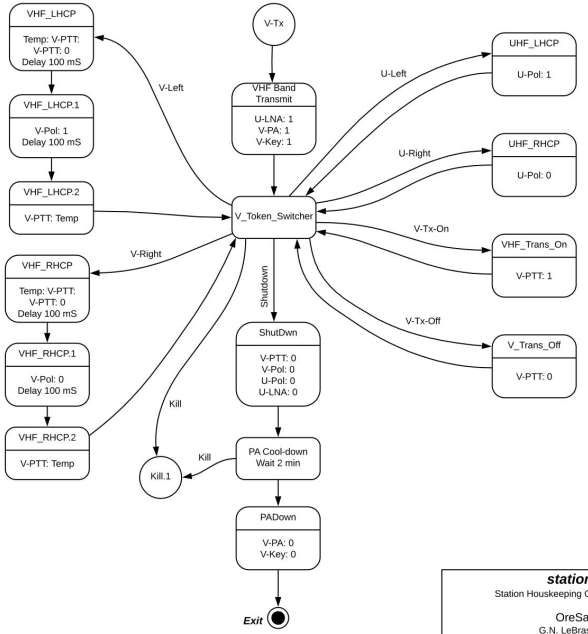
VHF Control

Input Tokens

V-Left
V-Right
U-Left
U-Right
V-Tx-On
V-Tx-Off
Shutdown
Kill

Outputs

U-LNA:
U-Pol:
V-Pol:
V-PTT:
V-PA:
V-Key:

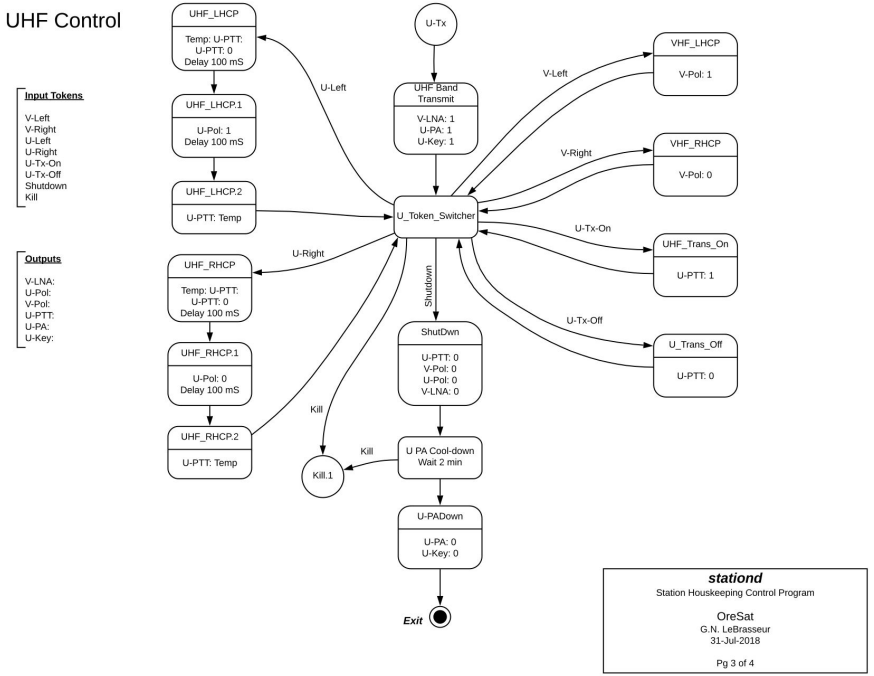


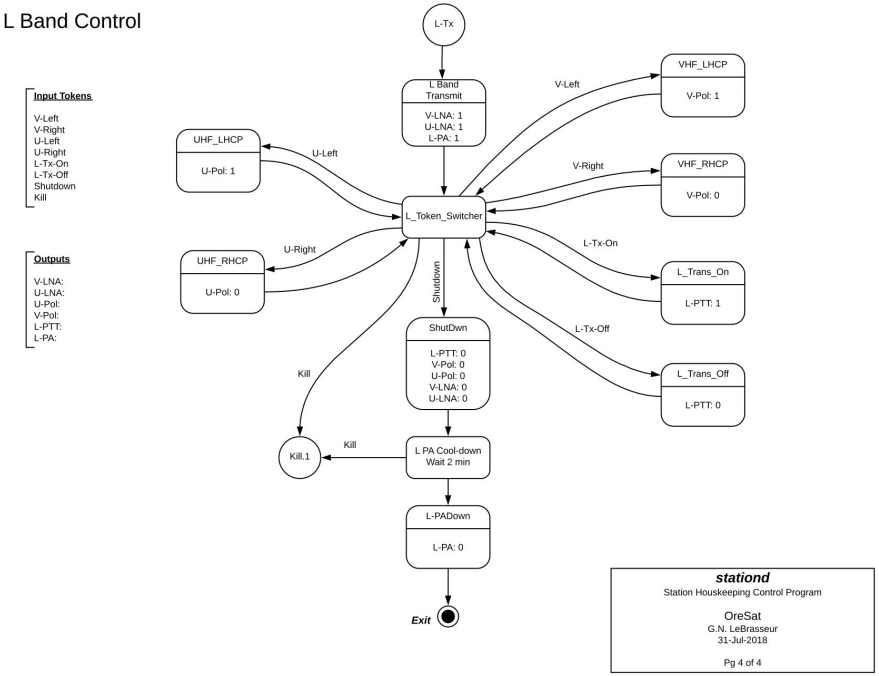
stationd
Station Houskeeping Control Program

OreSat
G.N. LeBrasseur
31-Jul-2018

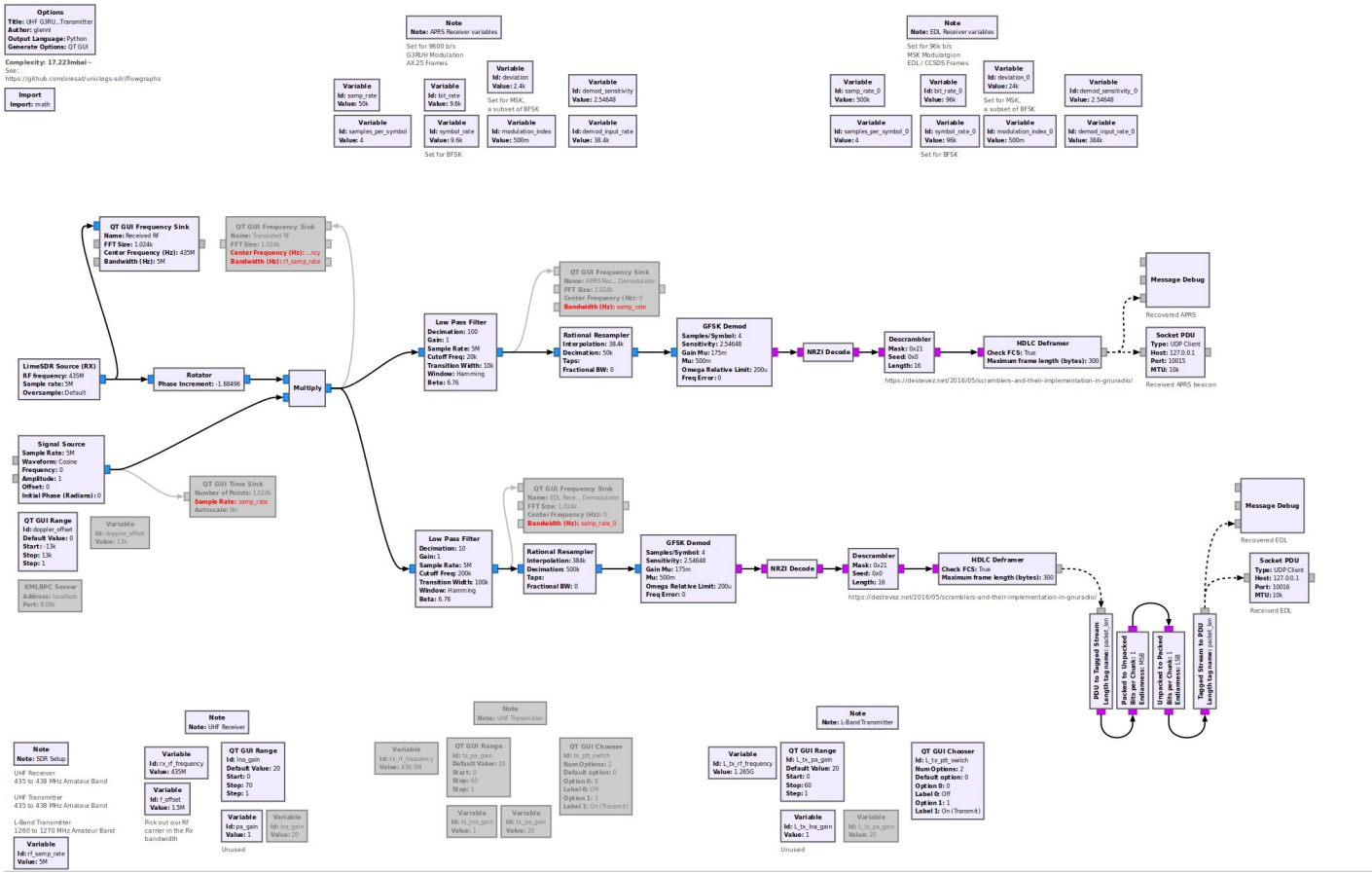
Pg 2 of 4

Station Control State Machine … continued

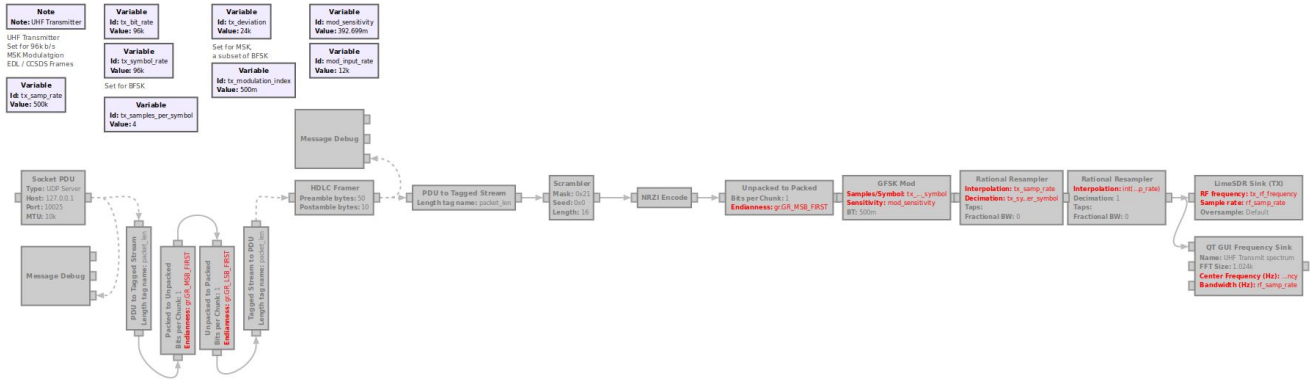


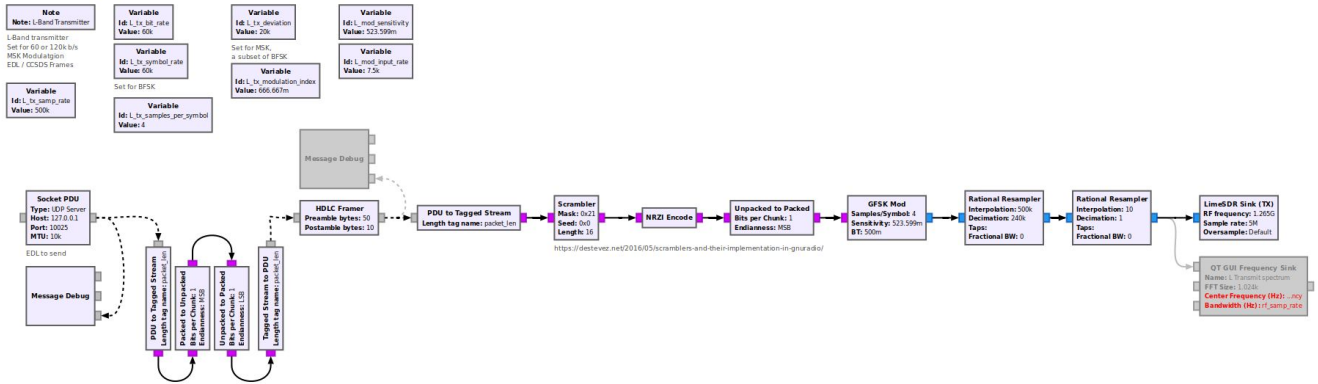


GNU Radio Flowgraph -- Receive

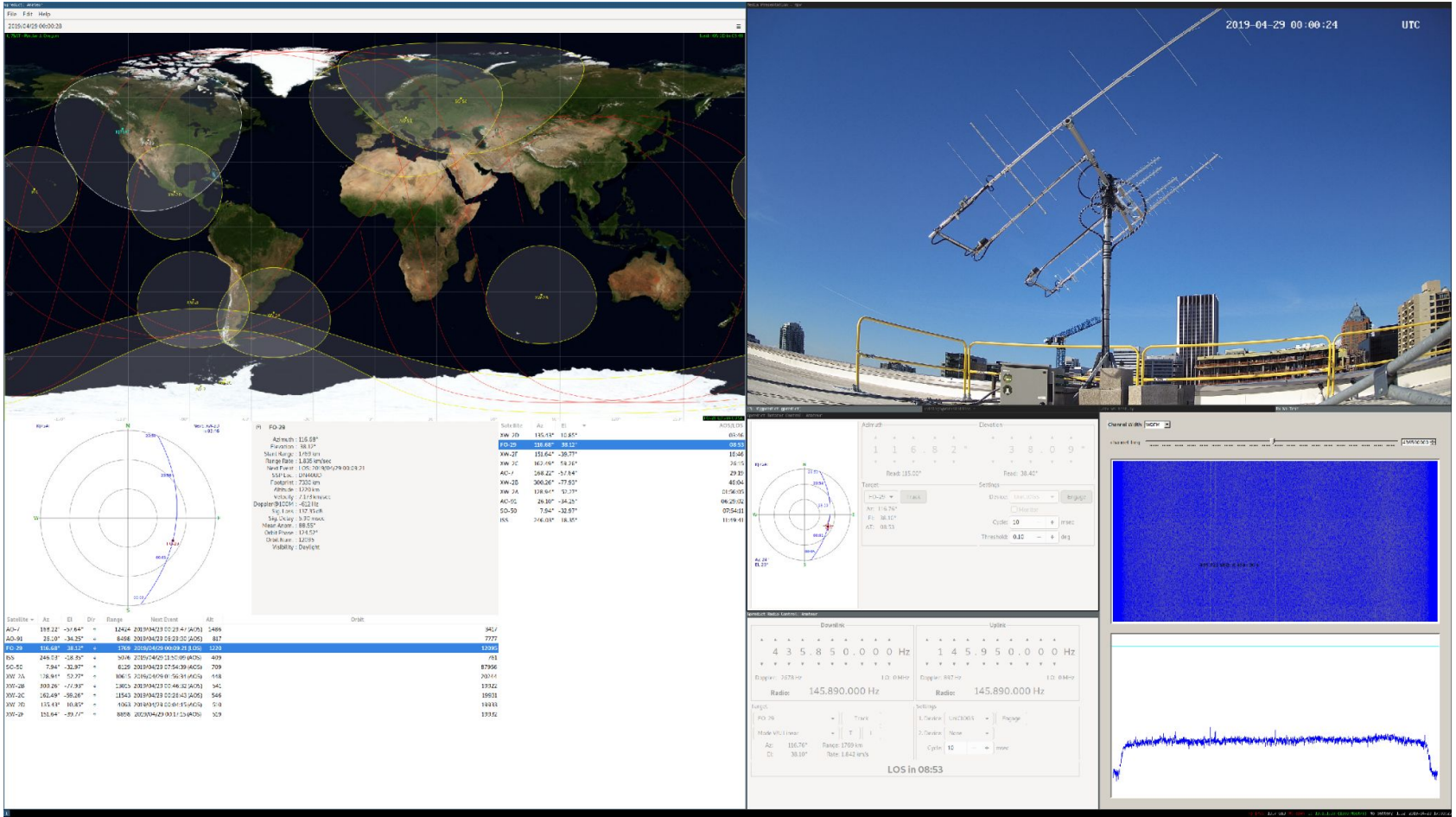


GNU Radio Flowgraph -- Transmit





Typical Remote Workstation



Future Considerations and Plans

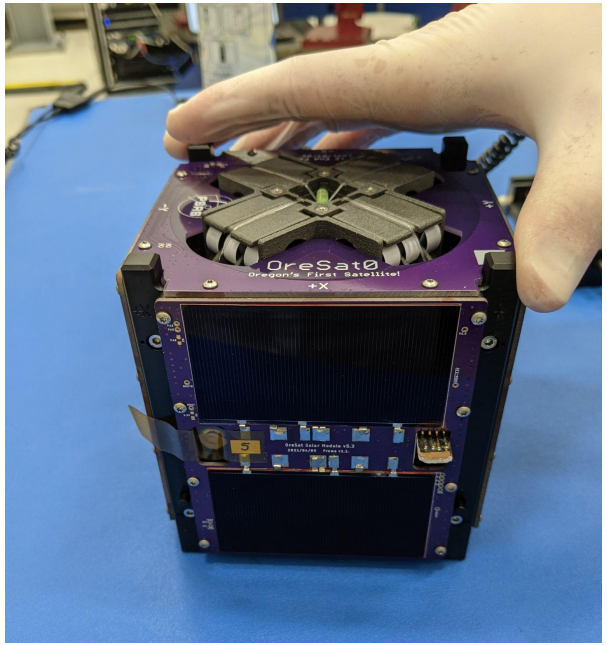
- CW Beacon
- DVB-S2
- S and X Bands
- Integration with SatNOGS
- How to receive a QSL card from us upon receiving our beacon

OreSat0 First Flight of OreSat

LAUNCH DETAILS

Handoff: December 12th, 2021
Launch: SpaceX Transporter-3
Launch Date: January 10th, 2022

SPACEFLIGHT



More Information

- A good place to start: https://www.oresat.org/
- Full source at: https://github.com/oresat
- More open source aerospace: https://www.pdxaerospace.org/
- Contact us at aerospace@pdx.edu
- QSL to **KJ7SAT** (Our club callsign)

Thank you!