EDGE OF SPACE SCIENCES

May 2022

EDGE OF SPACE SCIENCES (EOSS)

- Edge of Space Sciences is a Denver, Colorado based non-profit organization that promotes science and education.
- Formed in 1990 with the mission of promoting science and education through high altitude balloons and amateur radio.
- Payloads to above 99% of Earth’s atmosphere - “The poor man’s space program”.
- Directly or indirectly involved with 75,000+ students and 55 schools.
- 15-20 balloon flights per year supporting Colorado Space Grant Consortium and STEM school programs of all ages
- 324 launches <u>AND</u> 324 recoveries!

OPERATIONS

TYPICAL FLIGHT
Coordination with FAA and Denver Air Traffic Control (Part-101 Waiver)
POP!
80-100k Feet
Parachute
~90 Minute Ascent
~45 Minute Descent
Tracking Teams
• Locate Payloads
• Identify Landowner
• Obtain Landowner Permission to Access
Hike in And Recover
One of Six FAA Approved Locations
LAUNCH SITE
LANDING

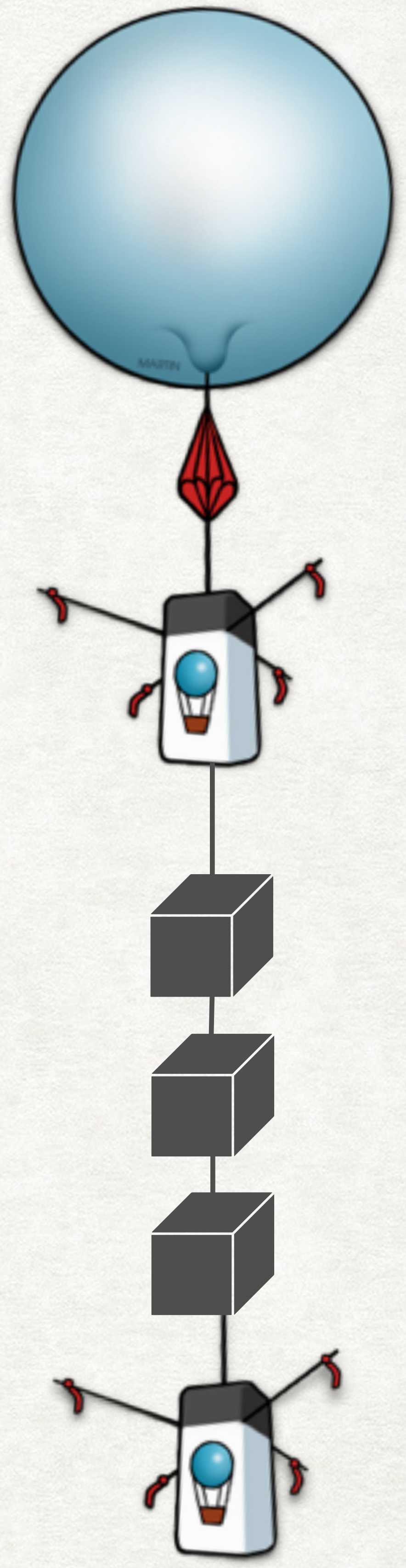
HAM RADIO IS INTEGRAL

Amateur Radio Usage:

- UHF (70cm) for voice
- VHF (2m) APRS for telemetry

Flight String

- Redundant APRS beacons
- ADS-B Beacon (if available)

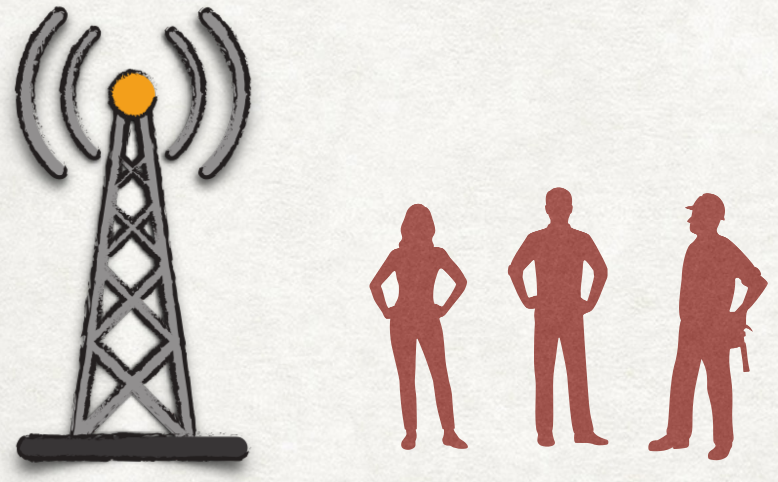


Ground Station:

- Analog and DMR radio comms
- SDR-based APRS system
- APRS igate
- FAA coordination (APRS data push)

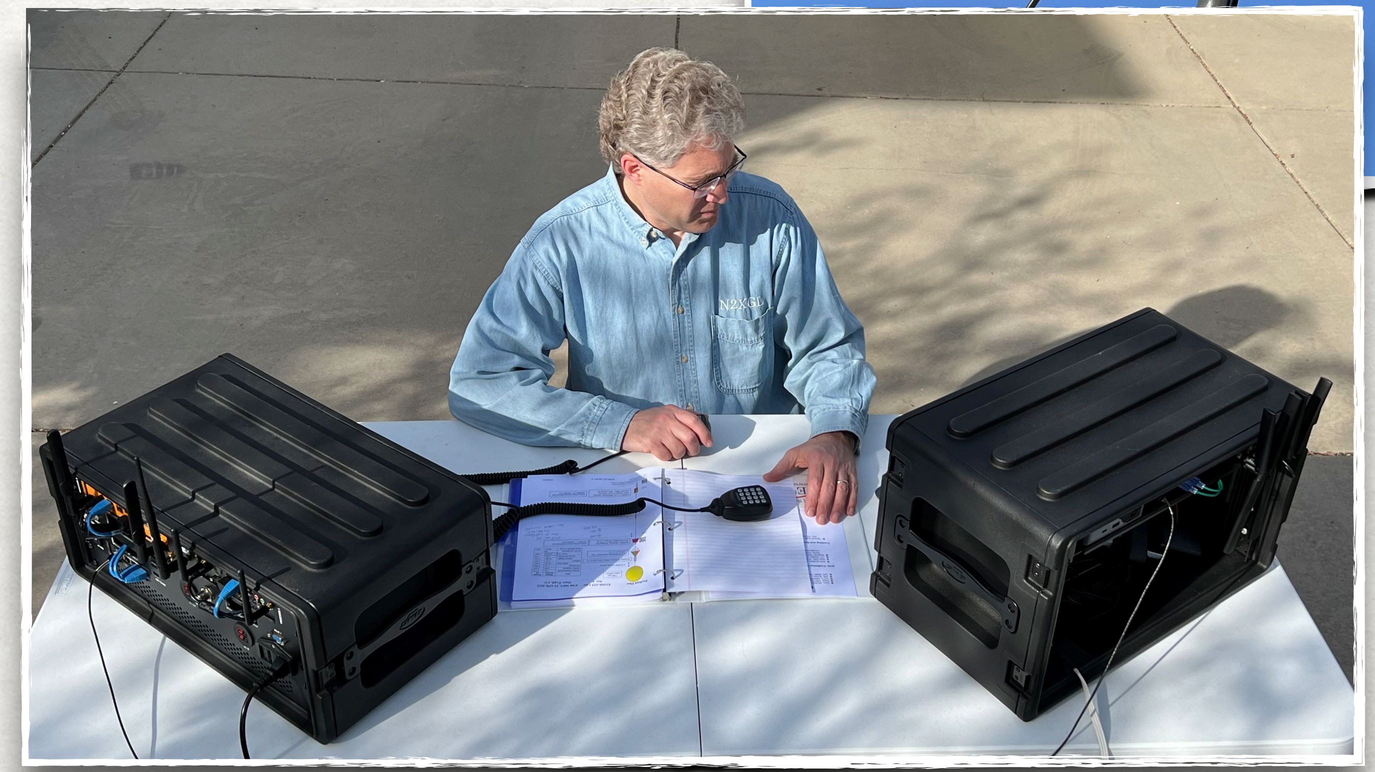
Tracking Teams

- Analog and DMR radio comms
- SDR-based APRS system
- Some have APRS igate



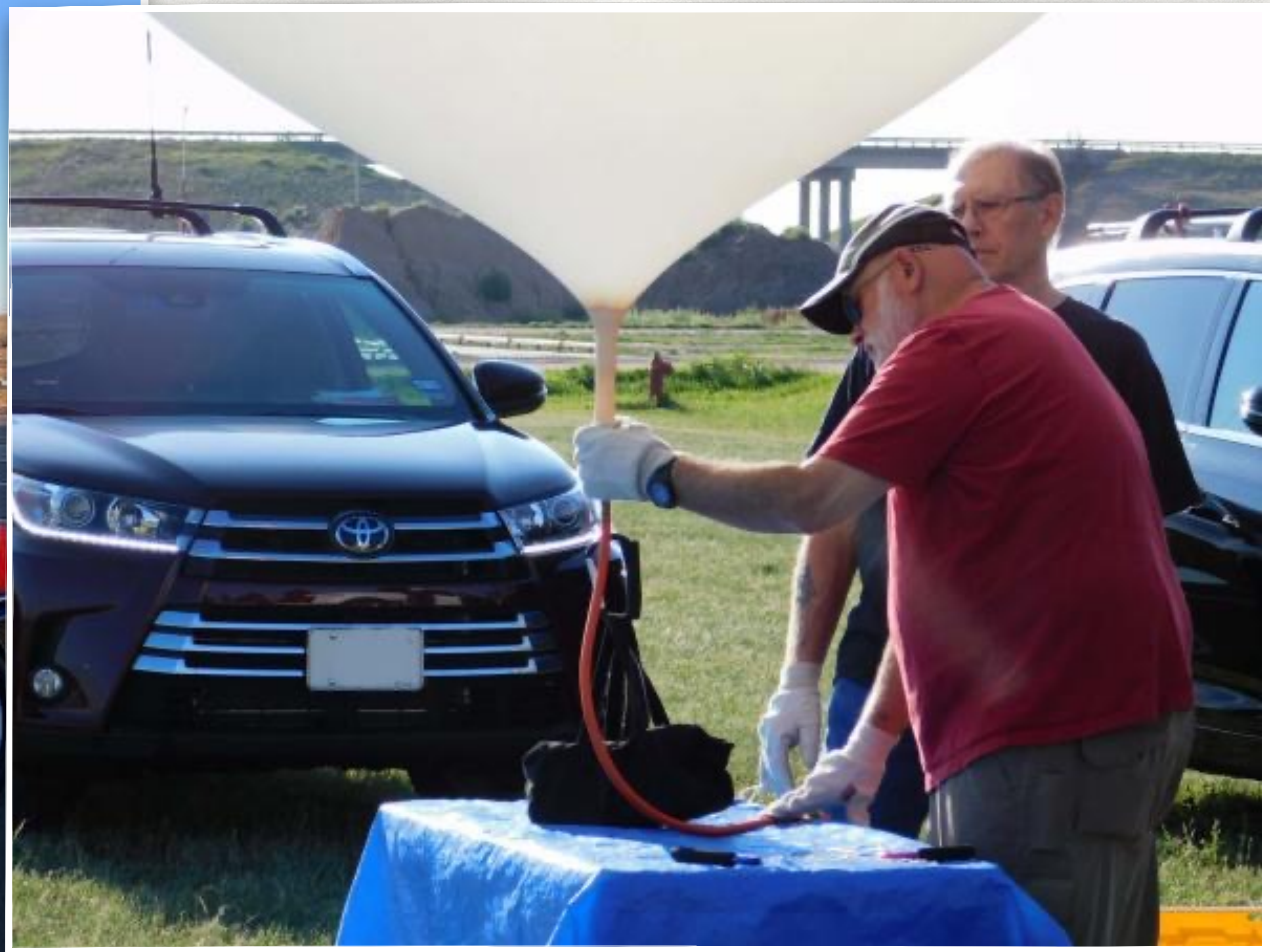
LAUNCH SITE

AEØSS GROUND STATION



- 70cm FM and DMR repeaters comms / net
- 2m SDR-based APRS system
- APRS igate, cellular data modems, WiFi
- ADS-B reception and upload (FlightRadar24)
- FAA coordination (voice and APRS data push)

BALLOON FILL



STRING UP THE FLIGHT LINE

LAUNCH

Balloon

RELEASE - cutdown system

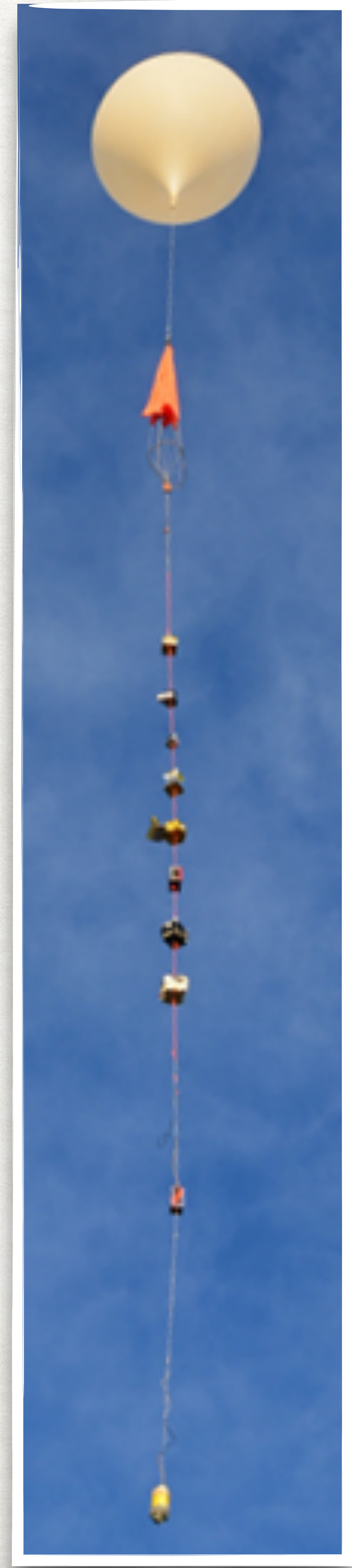
Parachute

TOP APRS beacon

Customer payloads

ADS-B beacon

BOTTOM APRS beacon



TRACKING TEAMS

- Typically 5-7 vehicles - a team in each vehicle
- Pre-positioned down range to track and recover payloads
- Leverage amateur radio to coordinate and communicate
- Most teams use SDR tracking system
- Will transmit cut-down to balloon if necessary

RECOVERY

INTERMISSION

EOSS PAYLOADS

EOSS PAYLOADS

RELEASE

- Custom designed release mechanism, bluetooth linked to TOP
- Placed between parachute and latex balloon
- Will release balloon from flight string upon command

TOP

- Custom designed APRS beacon and balloon release controller
- Uses accelerometer to sense balloon burst
- Commands RELEASE to release balloon from flight string upon burst
- Bluetooth linked to the RELEASE
- ~1-Watt 2m radio (different frequency from the BOTTOM)

ADS-B

- uAvionix ping200XR ADS-B Mode S Transponder
- Uses 1090MHz

BOTTOM

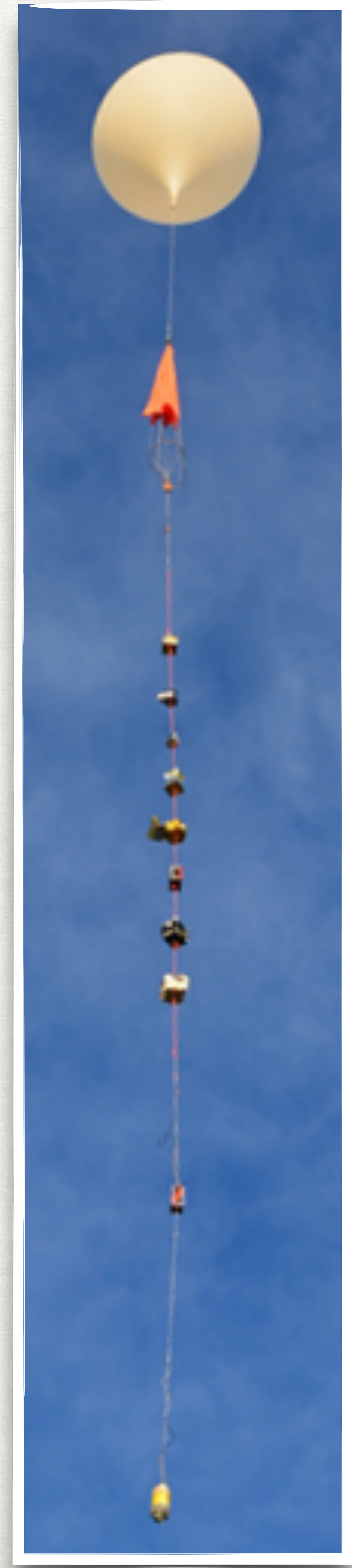
- Byonics-based APRS digipeater and beacon
- < 1-Watt 2m radio (different frequency from the TOP)

RELEASE - cutdown system

TOP APRS beacon

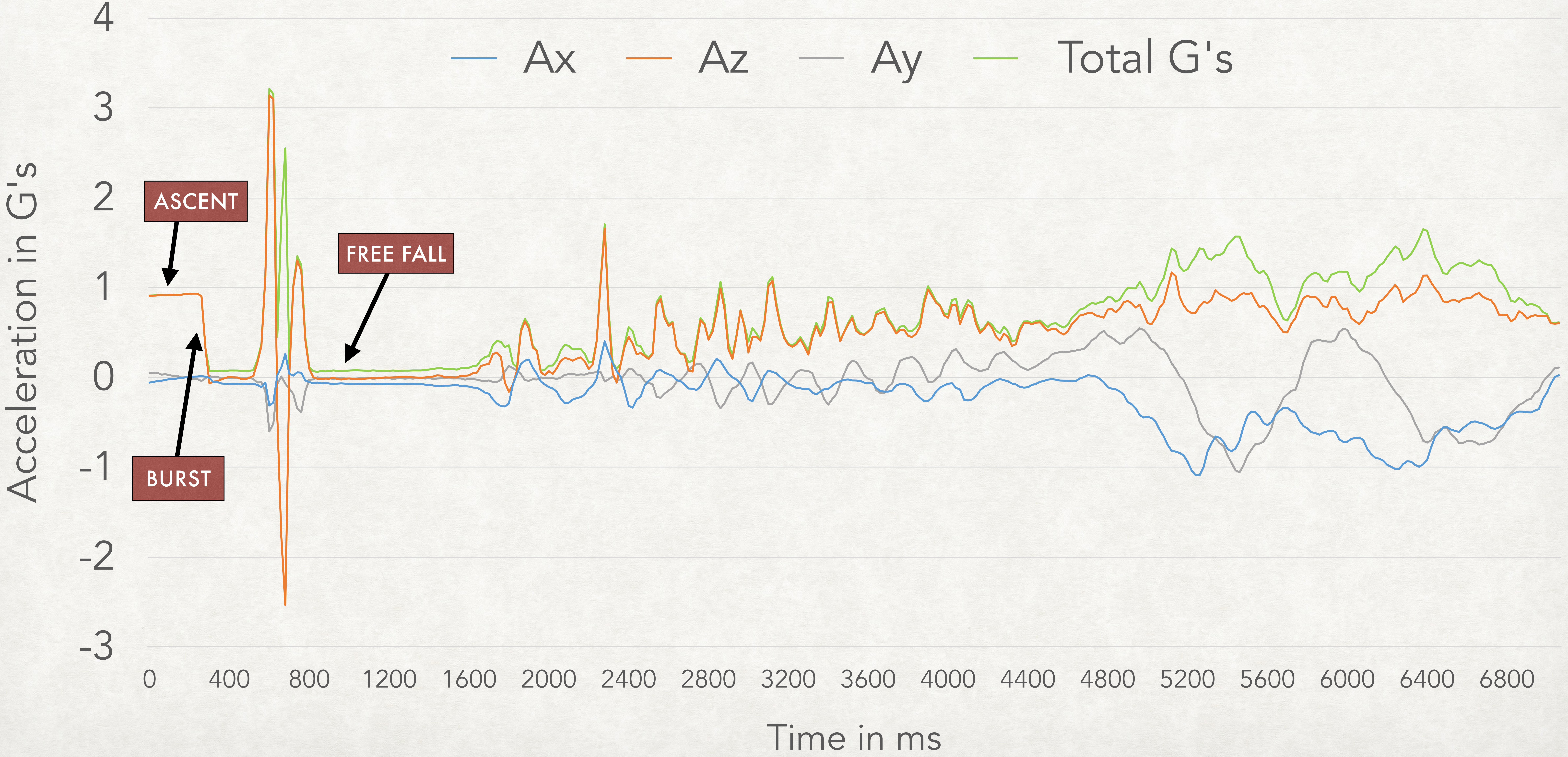
ADS-B beacon

BOTTOM APRS beacon



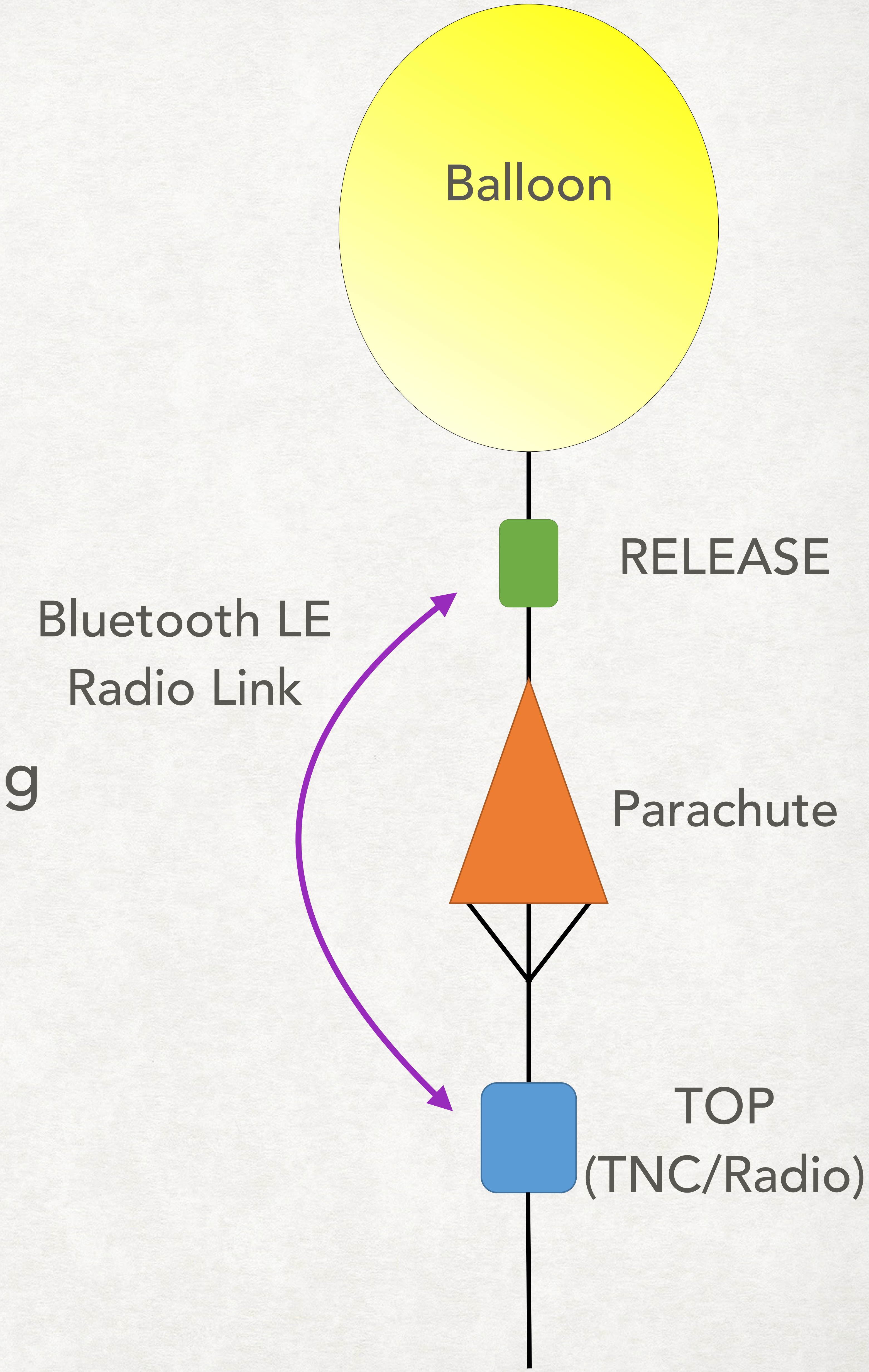
NEWTON'S 4TH LAW: RELEASE THE LATEX!!

ACCELEROMETER DATA

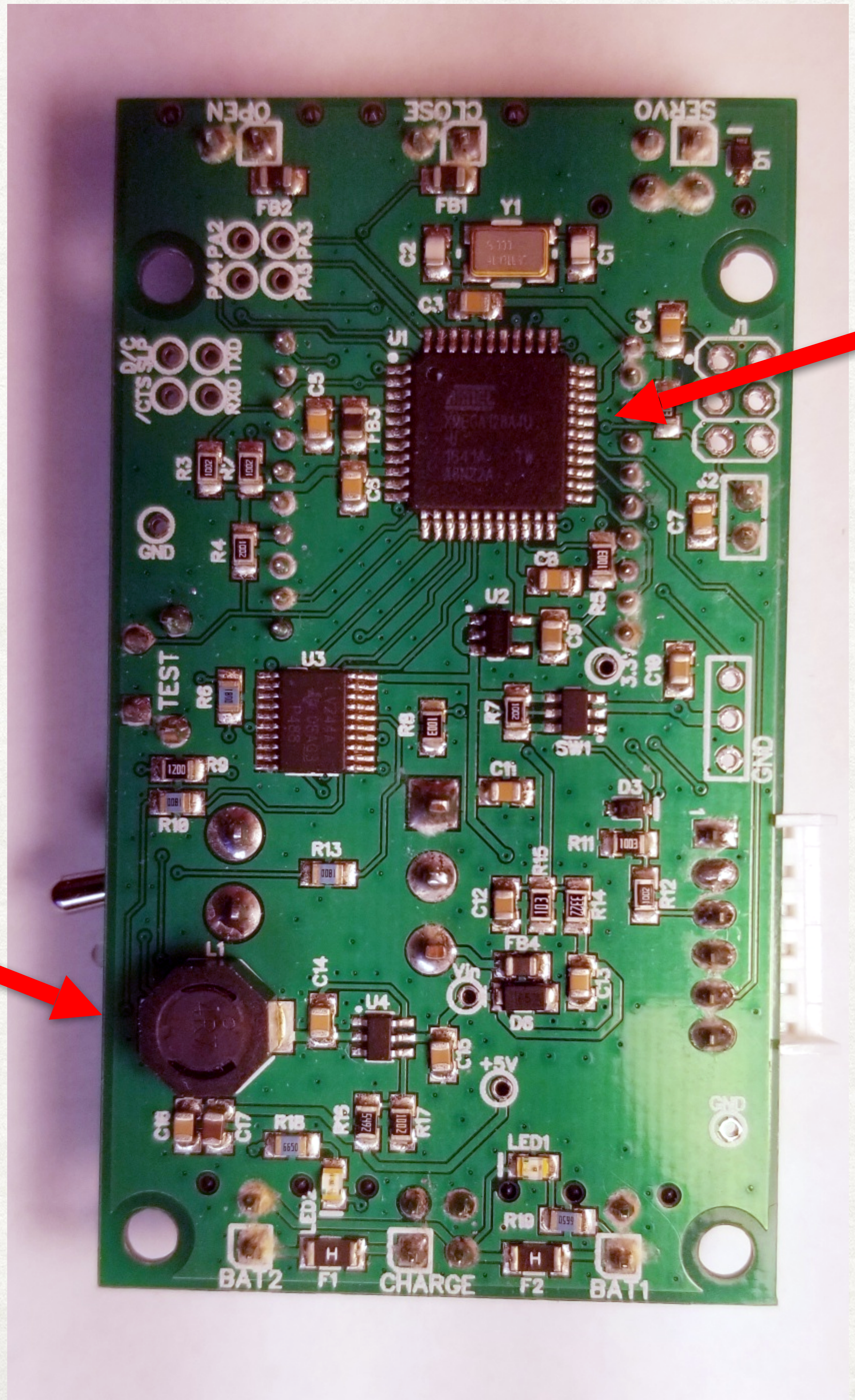


RELEASE PROCESS

1. Armed at 70k feet
2. Accelerometer in TOP beacon detects free fall after burst
3. "release" command sent to RELEASE via Bluetooth LE link
4. Warble tone transmitted over 2m radio to indicate burst
5. APRS message packet transmitted with max altitude
6. Servo on RELEASE opens, releasing balloon from flight string
7. Successful release and separation status transmitted using APRS and Morse code ("ok", "ok")
8. Typical release time of < 1 sec upon burst detection (servo movement takes the longest time)



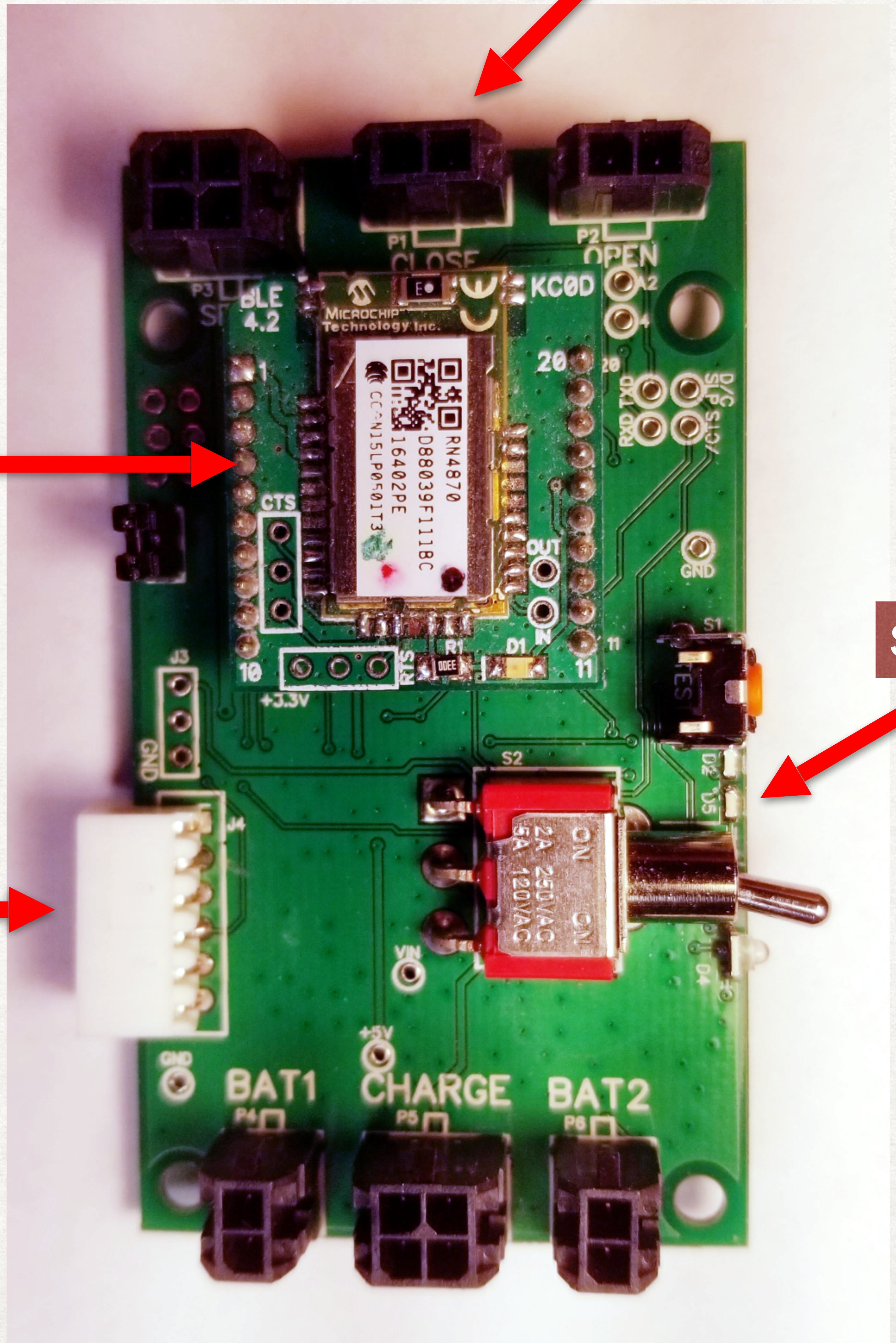
RELEASE HARDWARE



ATMEL AVR PROCESSOR

SWITCHING REGULATOR

CONNECTORS TO SERVO, STATUS SWITCH, SEPARATION CABLE

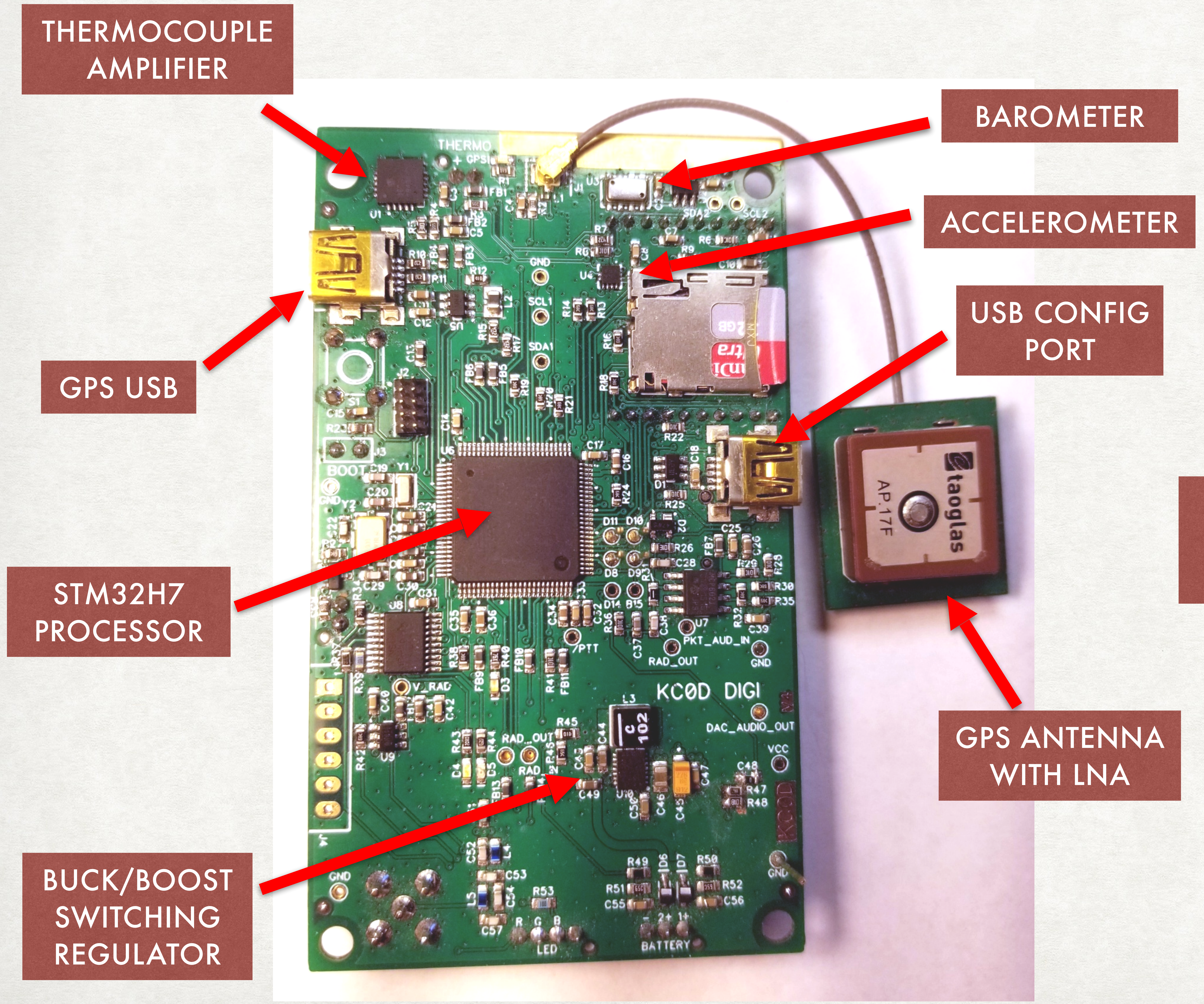


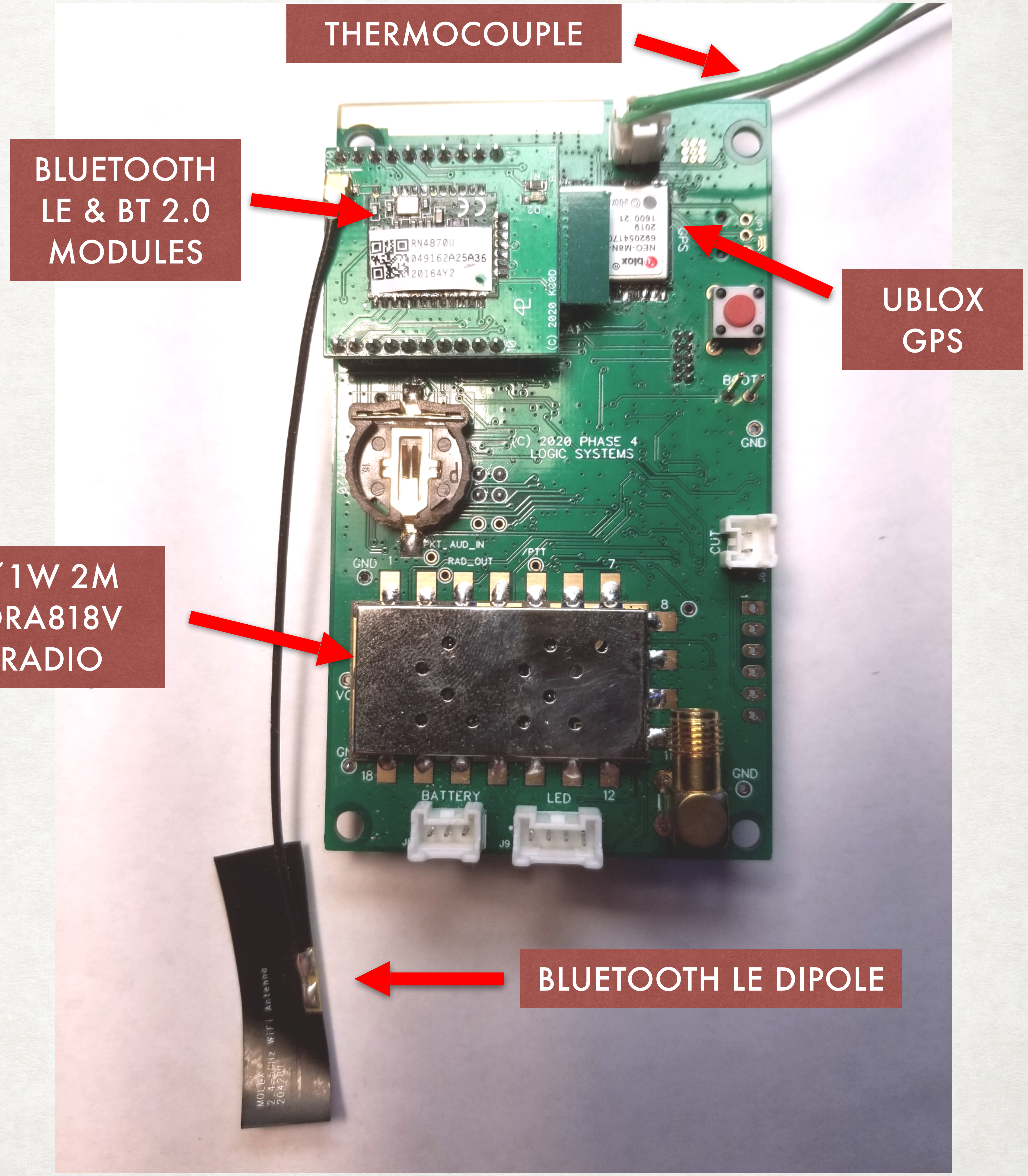
BLUETOOTH LE MODULE

SERIAL CONFIG PORT

STATUS LEDS

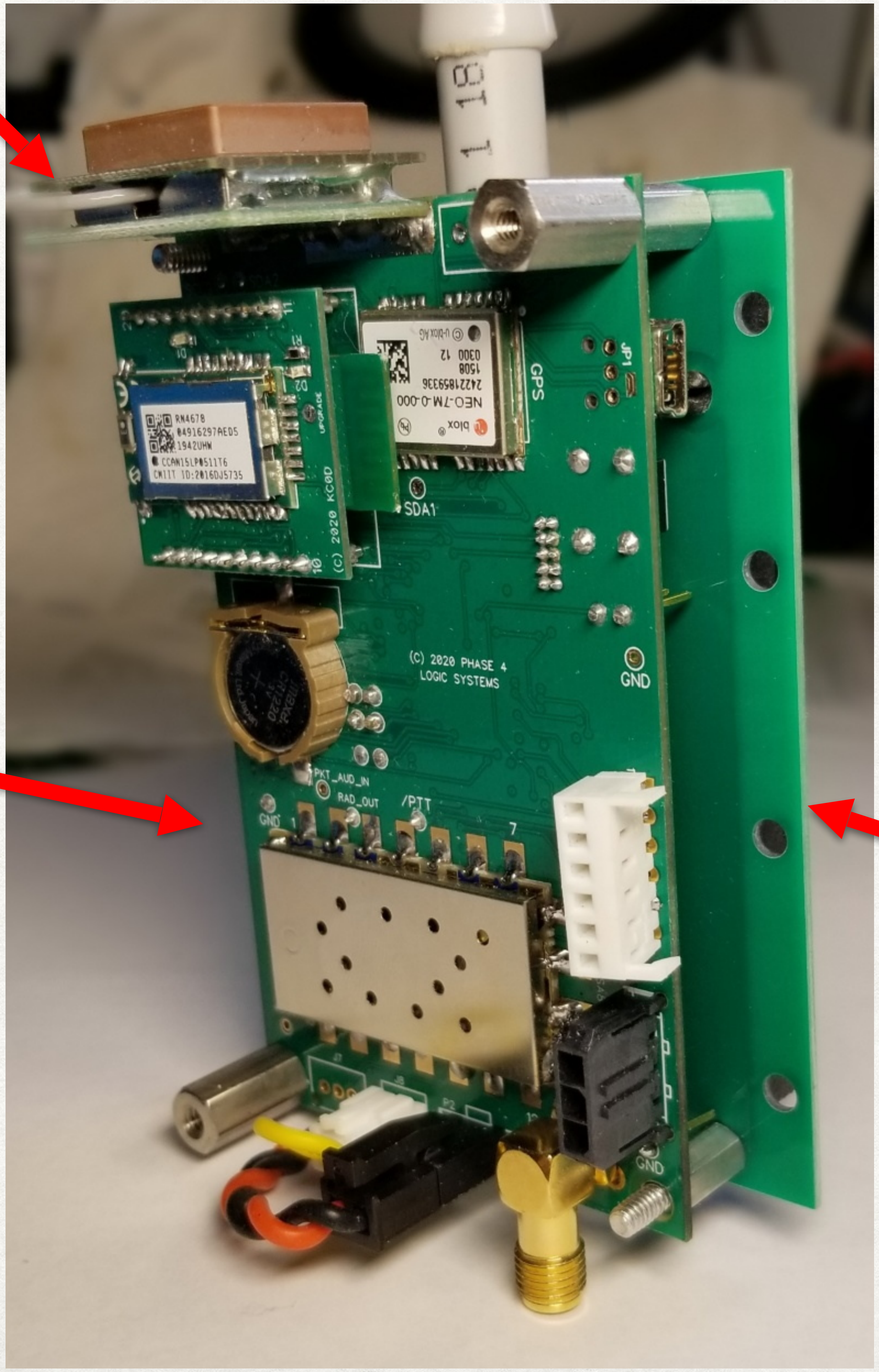
TNC/RADIO BOARD HARDWARE (THE TOP)





TNC/RADIO BOARD HARDWARE (THE TOP)

GPS ANTENNA FACING SKY

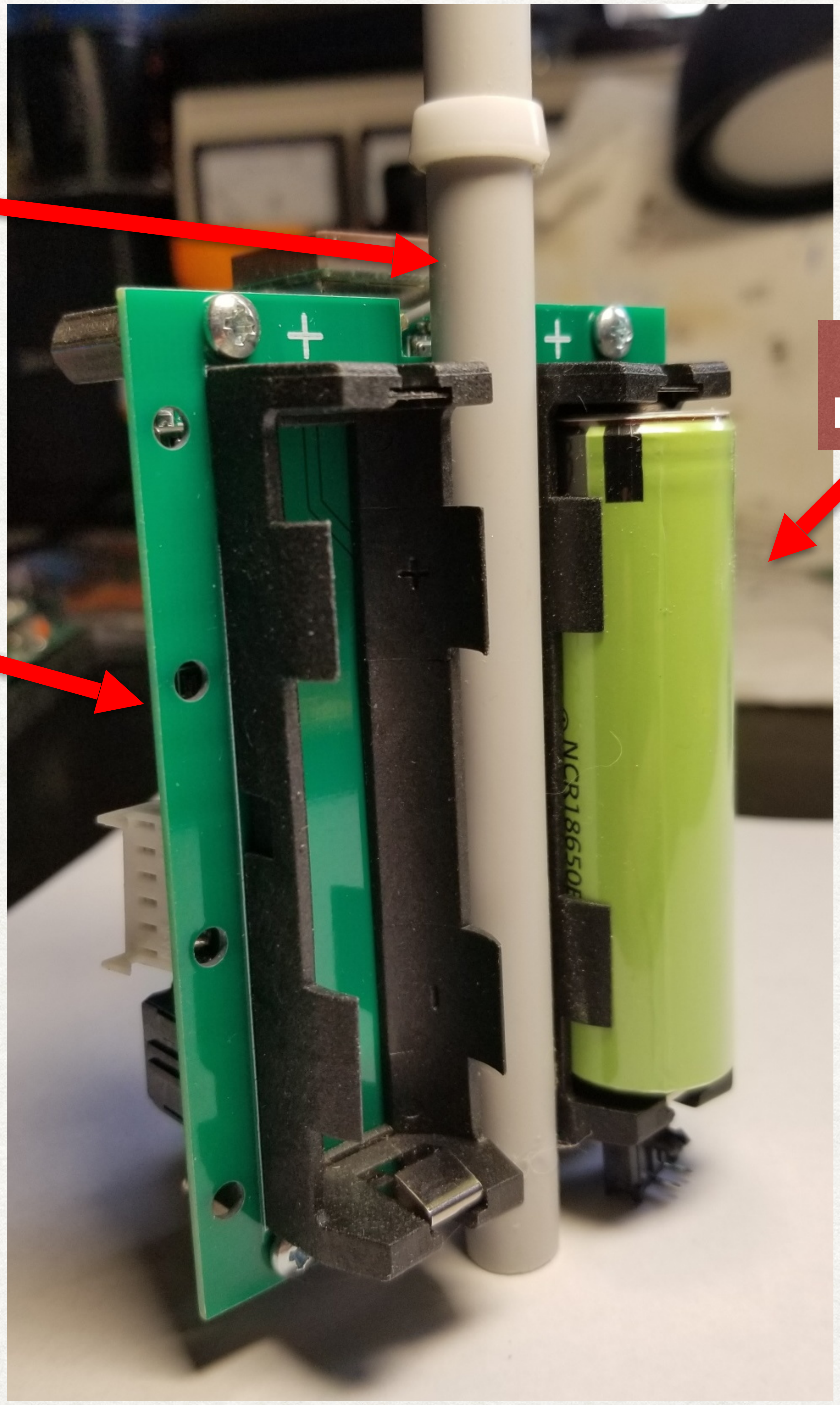


COMPONENT SIDE FACES INWARD

TUBE FOR FLIGHT STRING

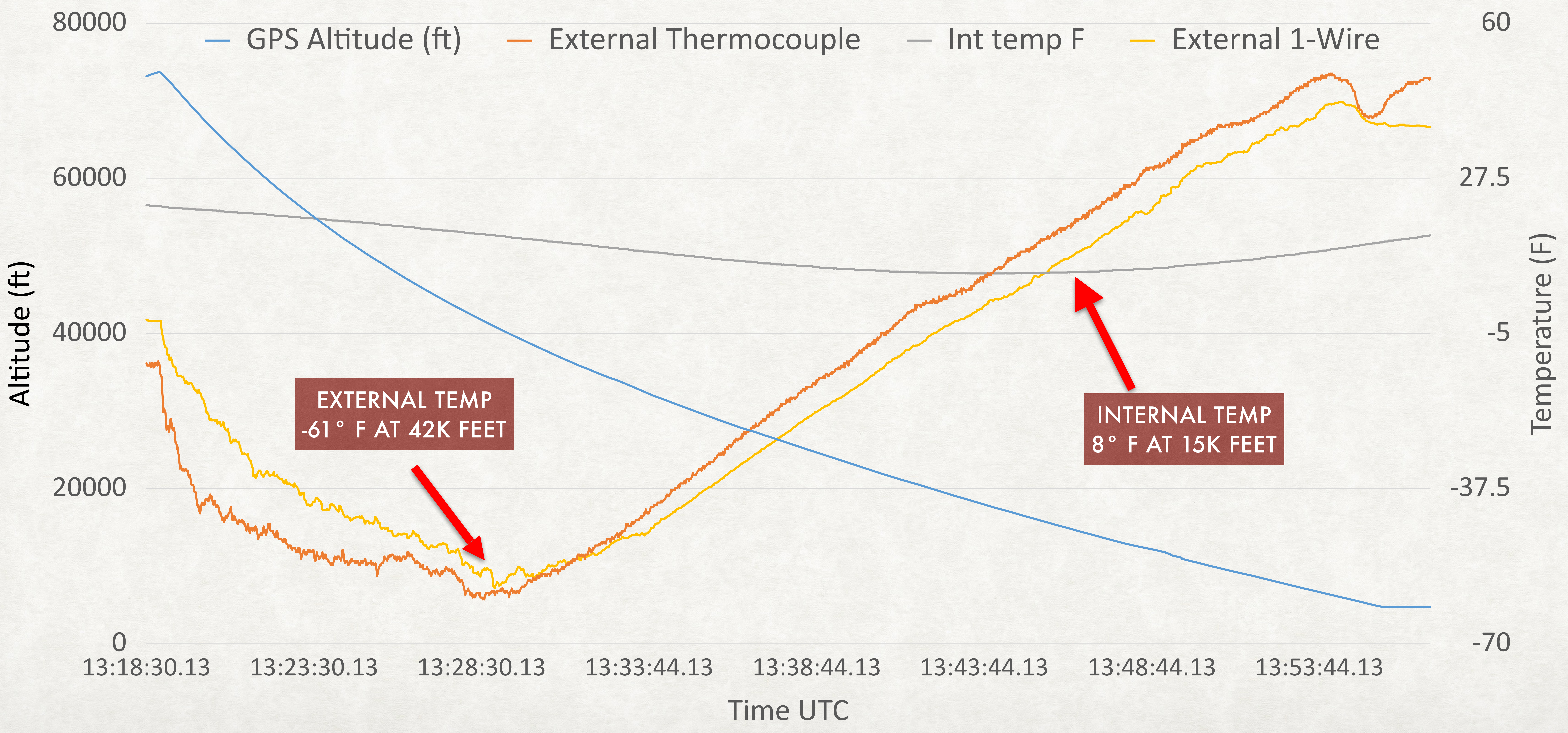
BATTERY BOARD 1 OR 2 CELLS

BATTERY BOARD



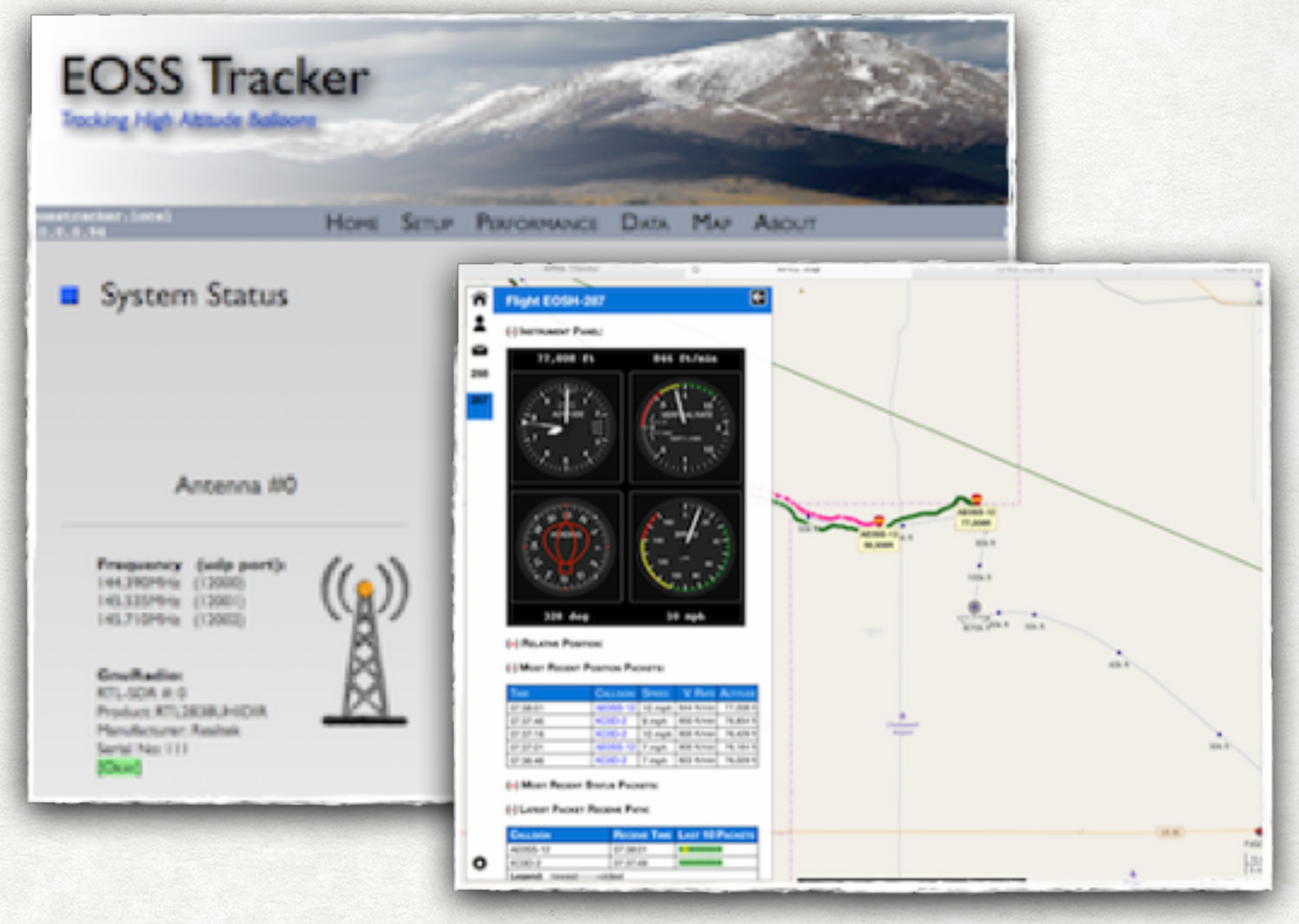
18650 BATTERIES

ALTITUDE VS TEMPERATURE ON DECENT



TRACKING TECH

SDR-BASED APRS TRACKER



What

- APRS application to aid operators in payload recovery

Primary Features

- Software based (no traditional radios)
- Simultaneous reception of APRS packets on multiple frequencies
- Offline maps (OpenStreetMap)
- Landing predictions
- Light weight user interface leverages a web browser
- Receive only, nothing transmitted or uploaded to the Internet (**)

** With a valid ham radio callsign, igating and RF beaconing are configurable

SOFTWARE DEFINED RECEIVER - BASIC IDEA

GPS Puck

Wifi Network

- Small computer *
- SDR USB dongle
- 2m antenna
- USB GPS puck
- Ubuntu Linux
- Open-source software

- Web-based interface
- Device of choice
- No wires
- Multiple device/user connections

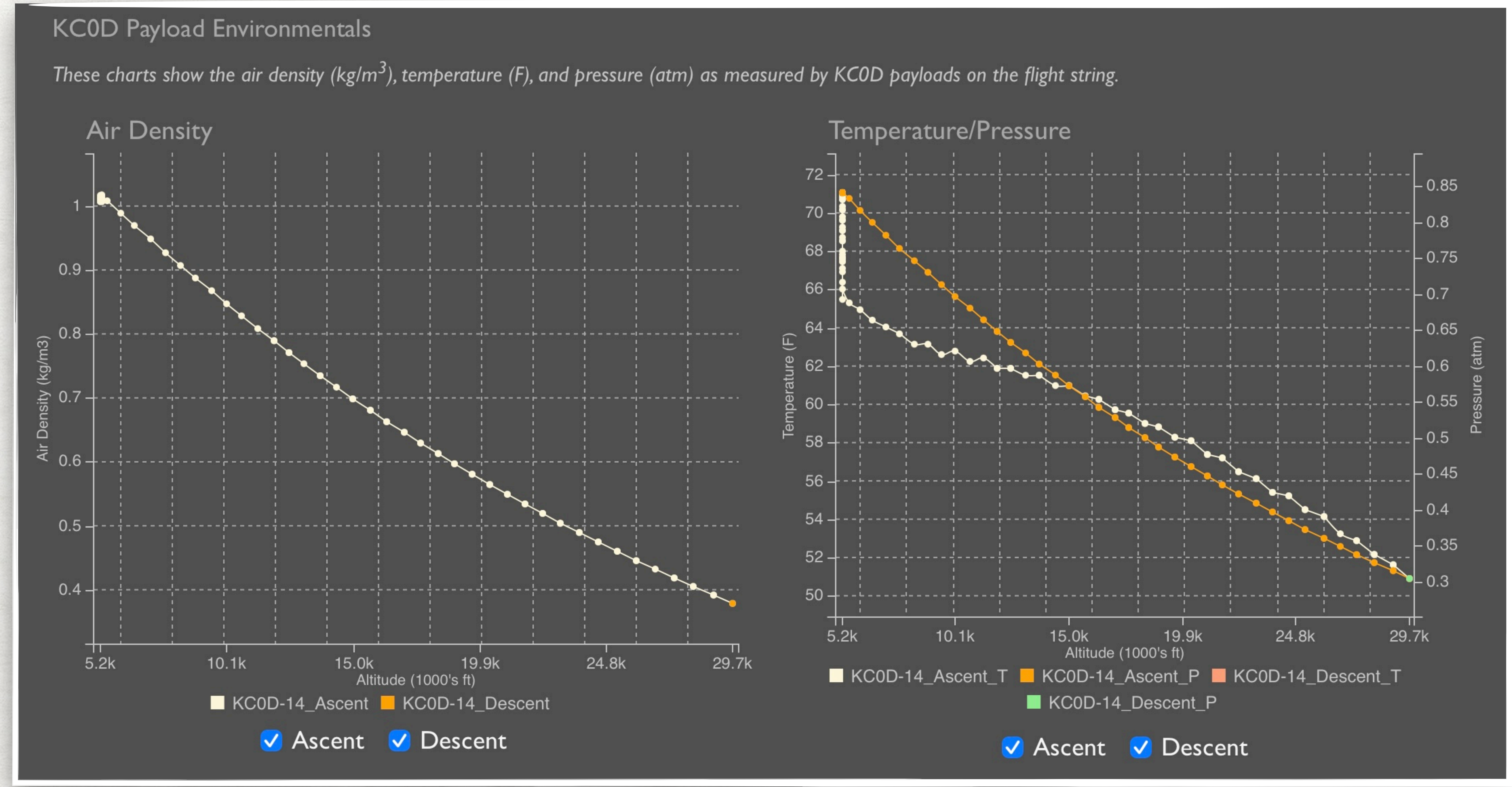
* Specs: Intel I5-4200U (4 core), 8GB Mem, 512GB storage

BUILD PARTY

WEB-BASED INTERFACE

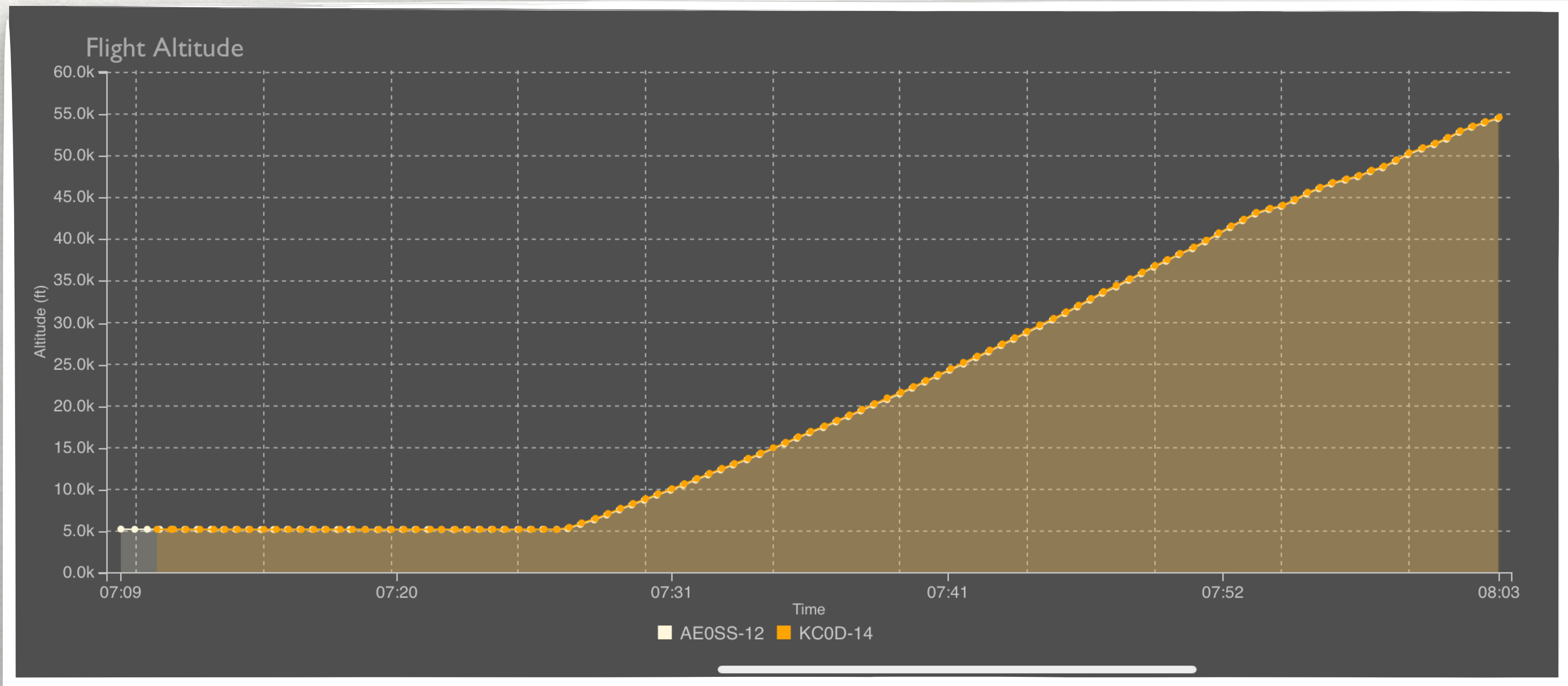
System Status

Antenna #0	Details
Frequencies	144.390MHz (12000) 144.340MHz (12001) 144.905MHz (12002) 145.645MHz (12003) 145.765MHz (12004)
GnuRadio Status	[Okay]
SDR Information	RTL-SDR #: 0 Product: RTL2838UHIDIR Manufacturer: Realtek Serial No: goo
Igating Status	[IGATING]
Beaconing Status	[NO]

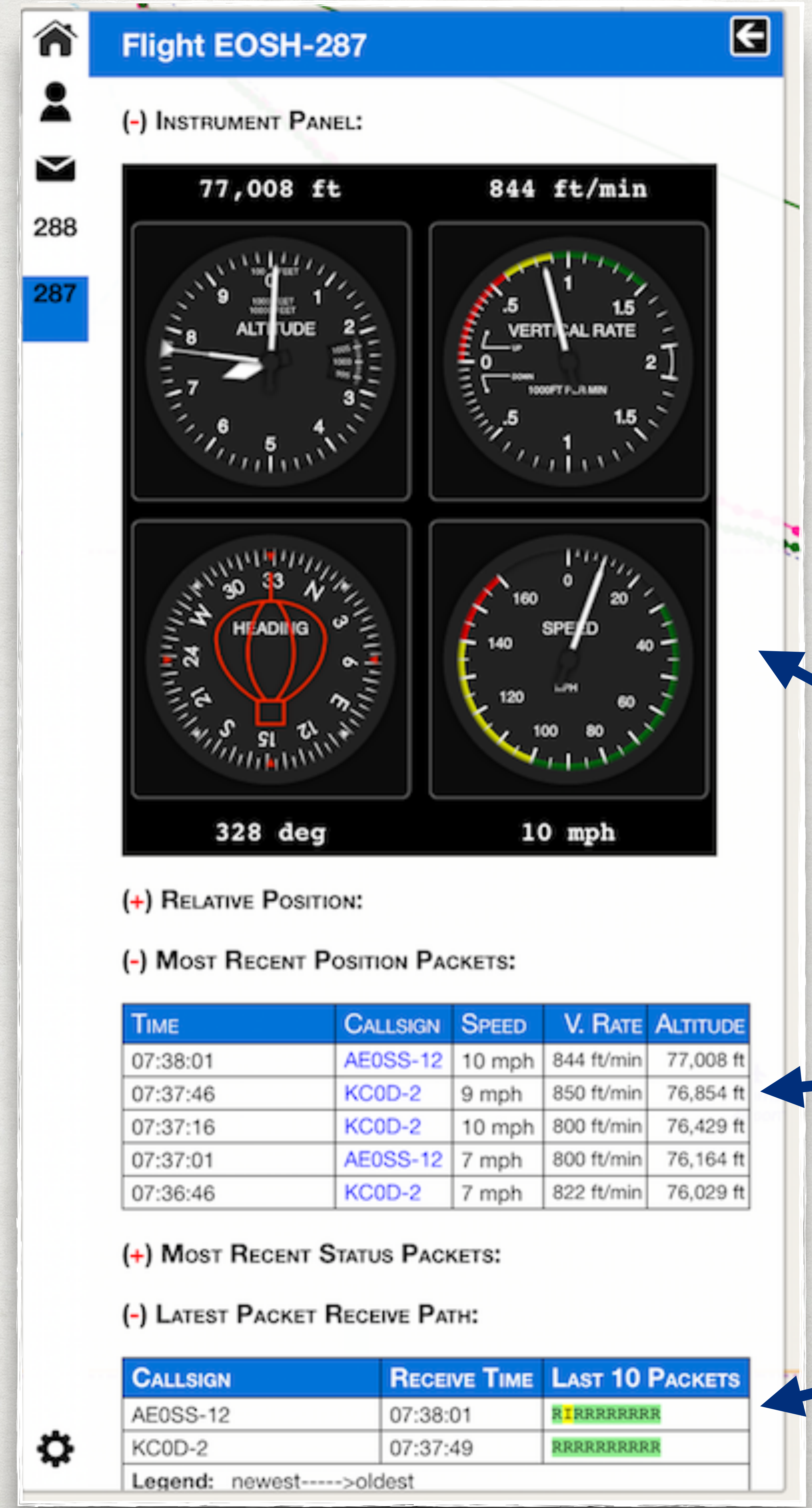


Existing Flights

EOSS-320 (TRACKING)				
	EOSS-320	Wstmnstr Acad Heavy	Launch Site: Deer Trail	Tracking: ☑
	AE0SS-13	144.340 MHz	Bottom - Digi EOSS	
	KC0D-1	145.645 MHz	Top - Release Adam	
	KC0D-3	145.765 MHz	Qual	
EOSS-319 (TRACKING)				
	EOSS-319	Wstmnstr-EvrGrn HS Heavy	Launch Site: Deer Trail	Tracking: ☑
	AE0SS-12	144.340 MHz	Bottom - Digi EOSSA	
	KC0D-14	144.905 MHz	Top - Release Baker	



EXAMPLE - ASCENDING

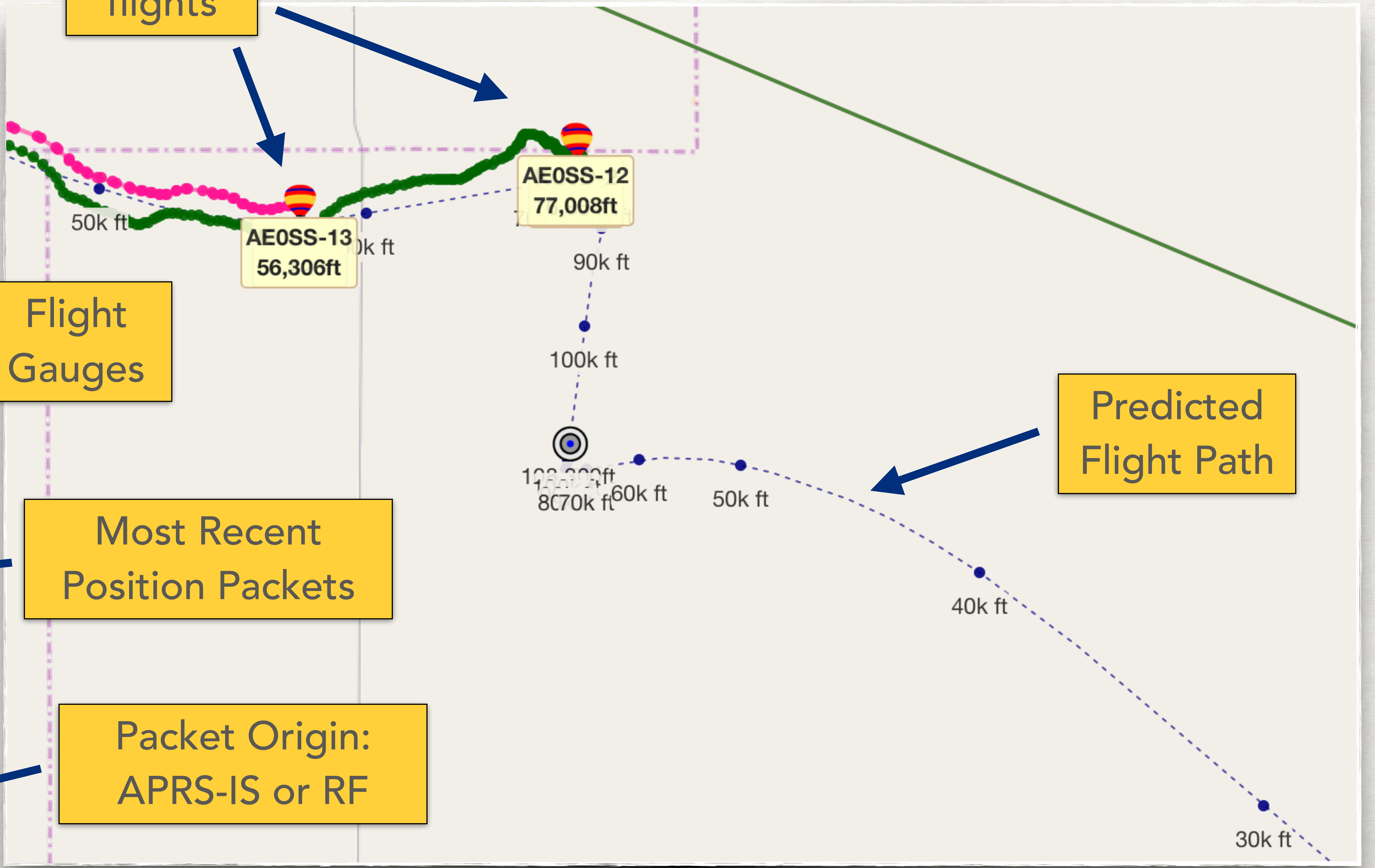


Flight Gauges

Most Recent Position Packets

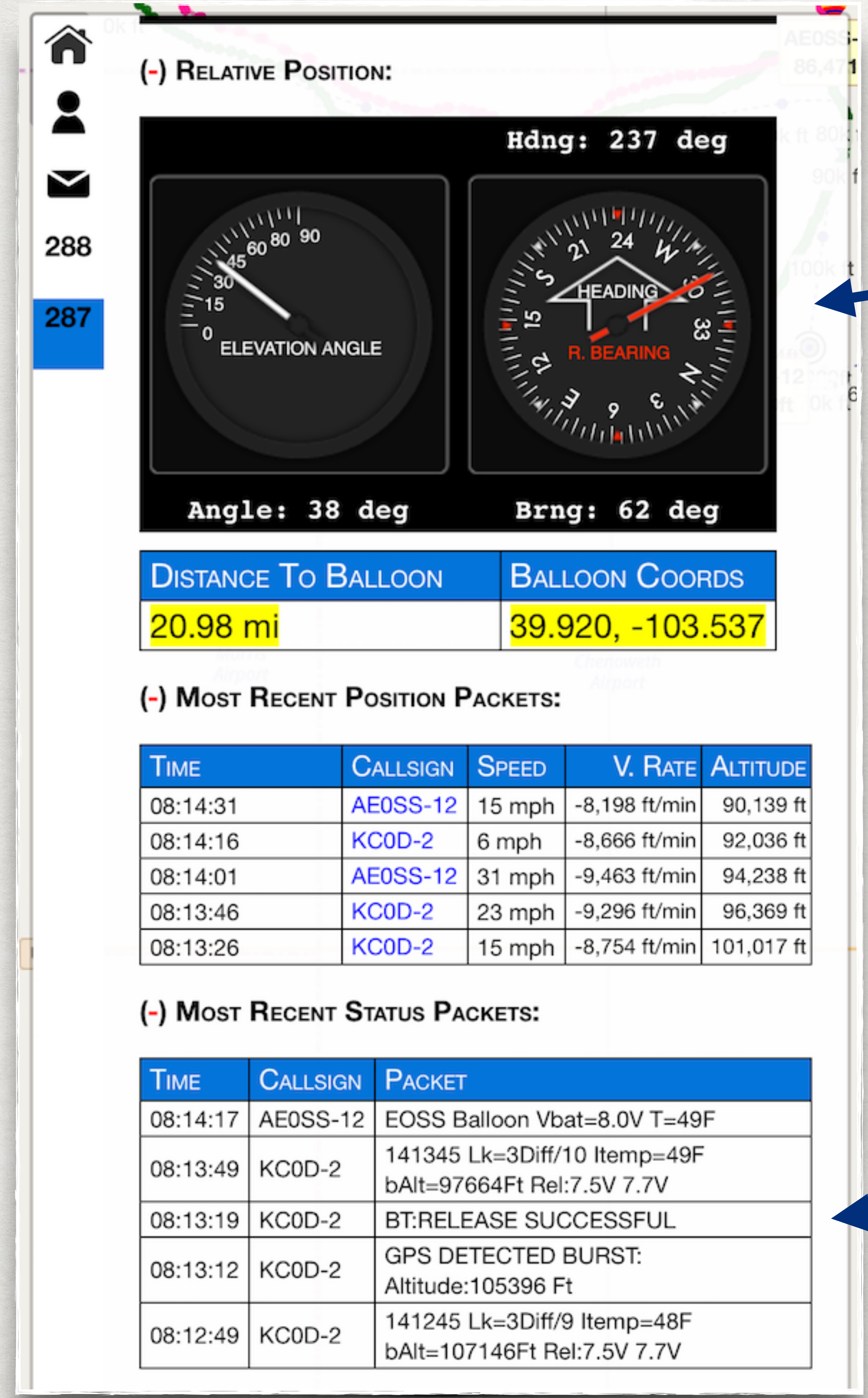
Packet Origin: APRS-IS or RF

Active flights



Predicted Flight Path

EXAMPLE - DESCENDING



288

287

(-) Relative Position:

Hdng: 237 deg

Angle: 38 deg

Brng: 62 deg

Distance To Balloon	Balloon Coords
20.98 mi	39.920, -103.537

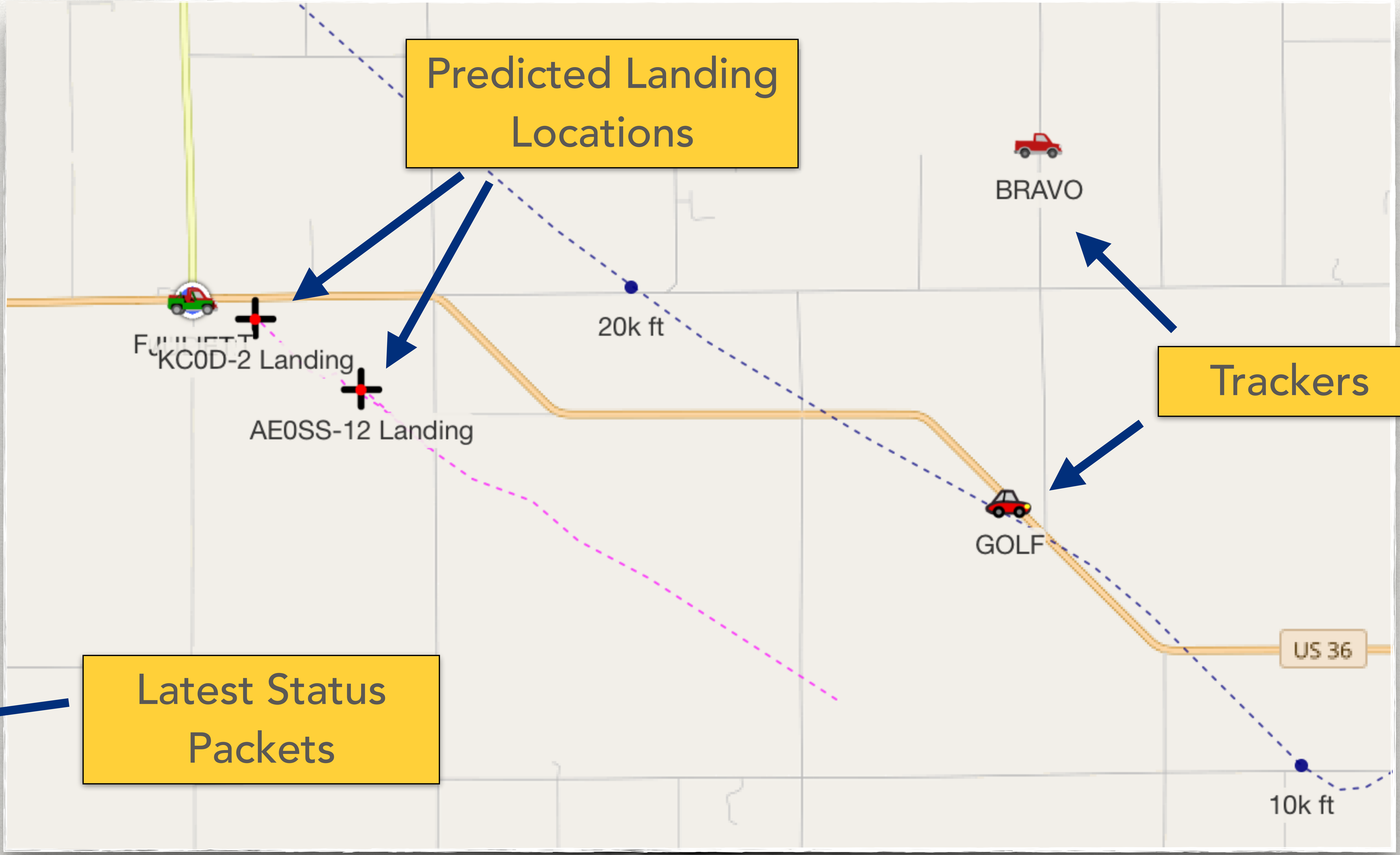
(-) Most Recent Position Packets:

Time	Callsign	Speed	V. Rate	Altitude
08:14:31	AE0SS-12	15 mph	-8,198 ft/min	90,139 ft
08:14:16	KC0D-2	6 mph	-8,666 ft/min	92,036 ft
08:14:01	AE0SS-12	31 mph	-9,463 ft/min	94,238 ft
08:13:46	KC0D-2	23 mph	-9,296 ft/min	96,369 ft
08:13:26	KC0D-2	15 mph	-8,754 ft/min	101,017 ft

(-) Most Recent Status Packets:

Time	Callsign	Packet
08:14:17	AE0SS-12	EOSS Balloon Vbat=8.0V T=49F
08:13:49	KC0D-2	141345 Lk=3Diff/10 Itemp=49F bAlt=97664Ft Rel:7.5V 7.7V
08:13:19	KC0D-2	BT:RELEASE SUCCESSFUL
08:13:12	KC0D-2	GPS DETECTED BURST: Altitude:105396 Ft
08:12:49	KC0D-2	141245 Lk=3Diff/9 Itemp=48F bAlt=107146Ft Rel:7.5V 7.7V

Relative Location of Flight

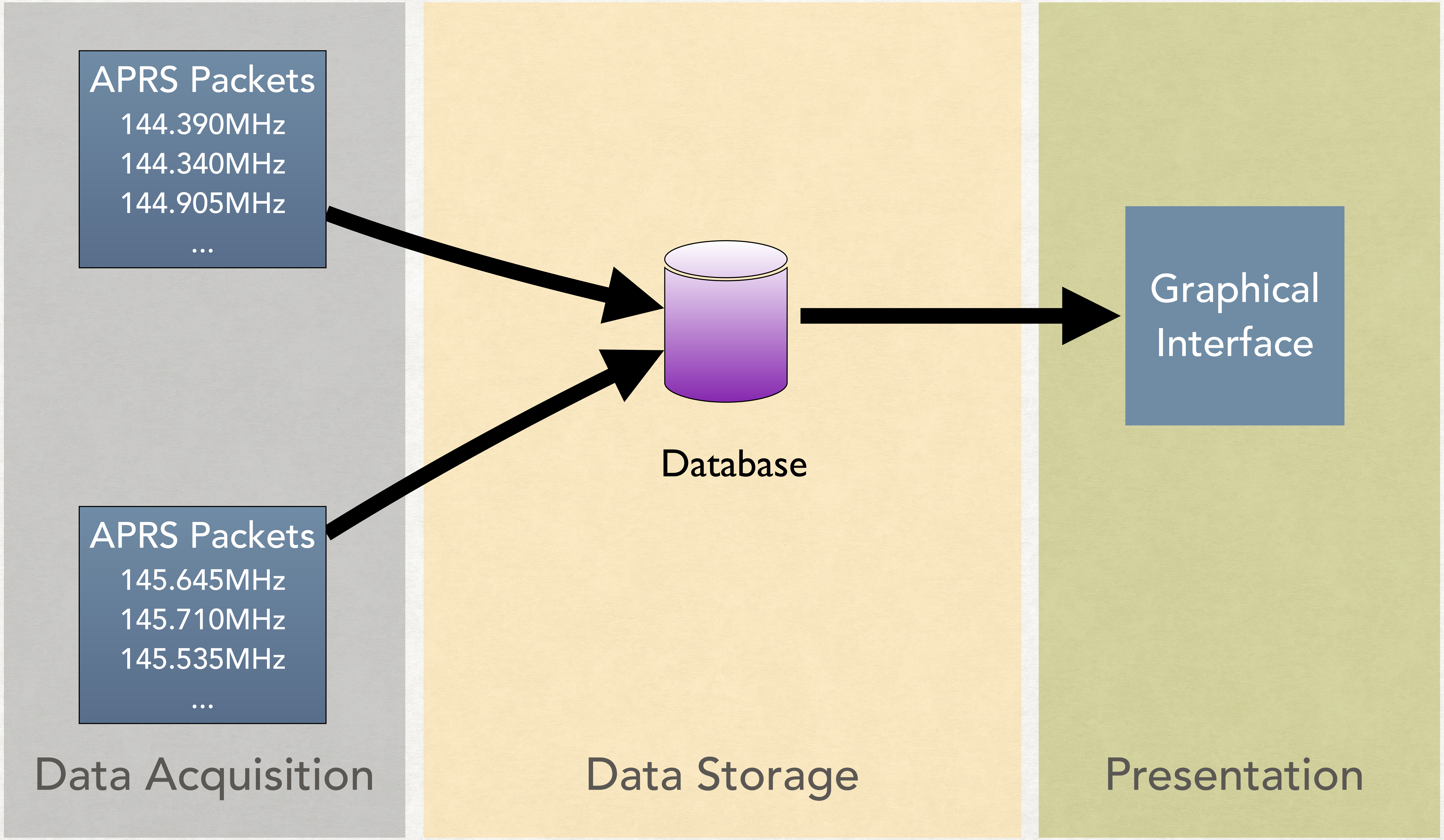


Predicted Landing Locations

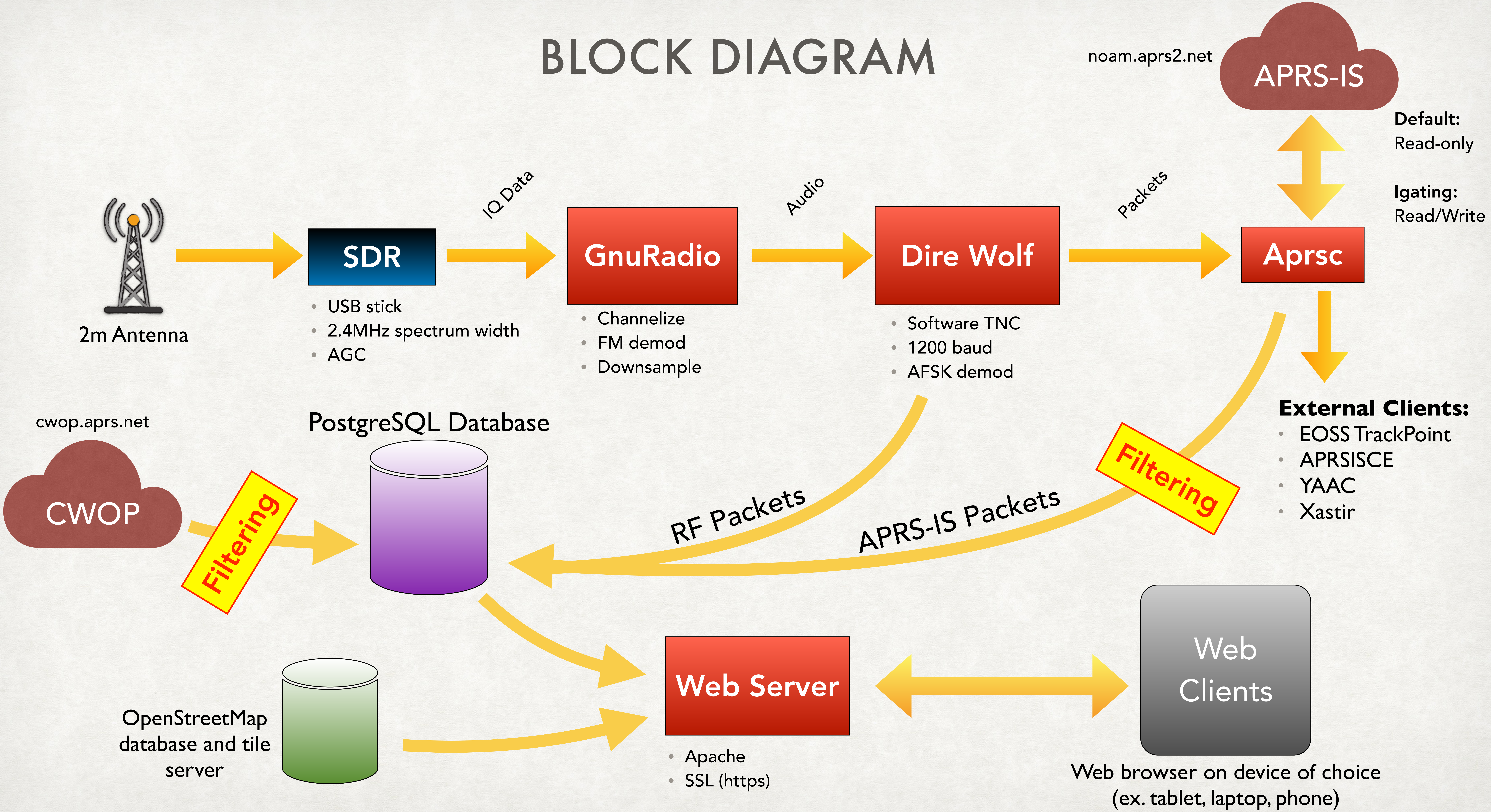
Trackers

Latest Status Packets

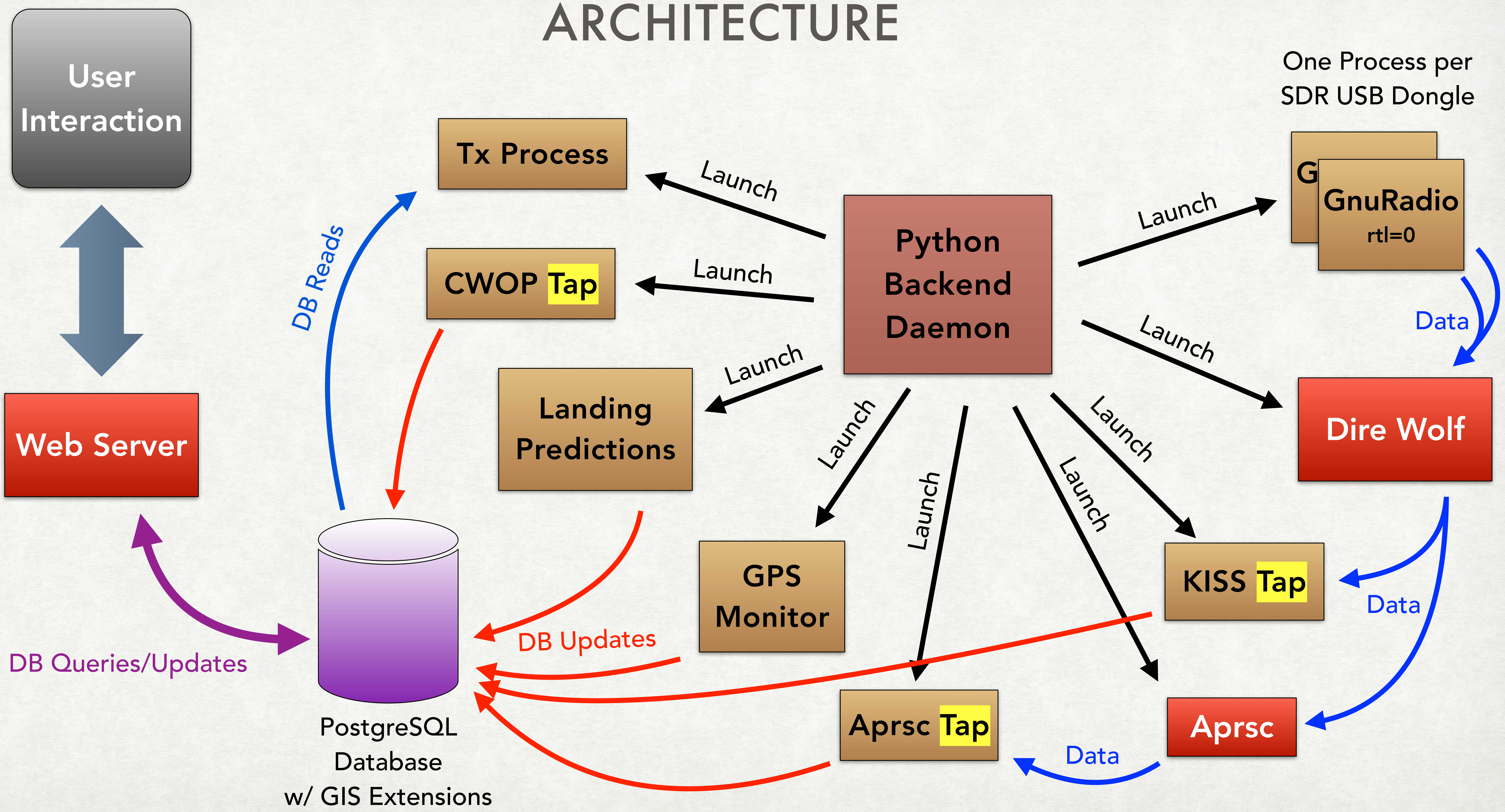
CORE CONCEPT



BLOCK DIAGRAM

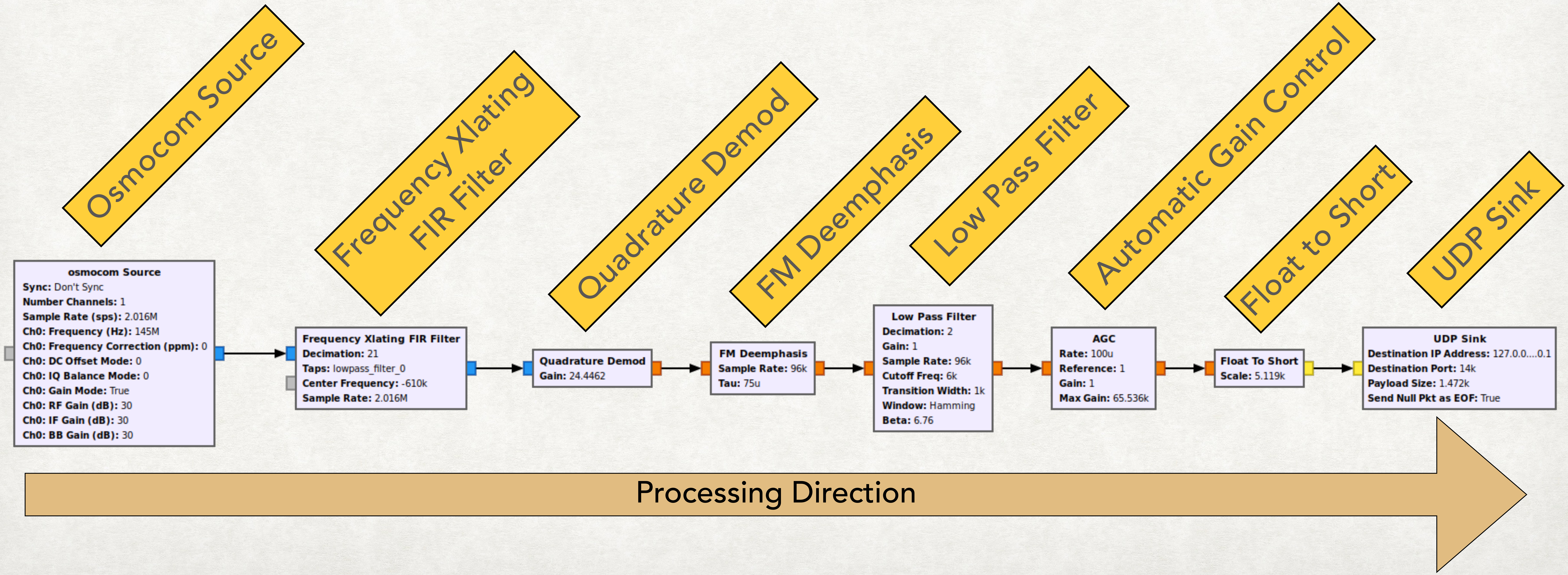


ARCHITECTURE



GNURADIO - FM SIGNAL PROCESSING CHAIN

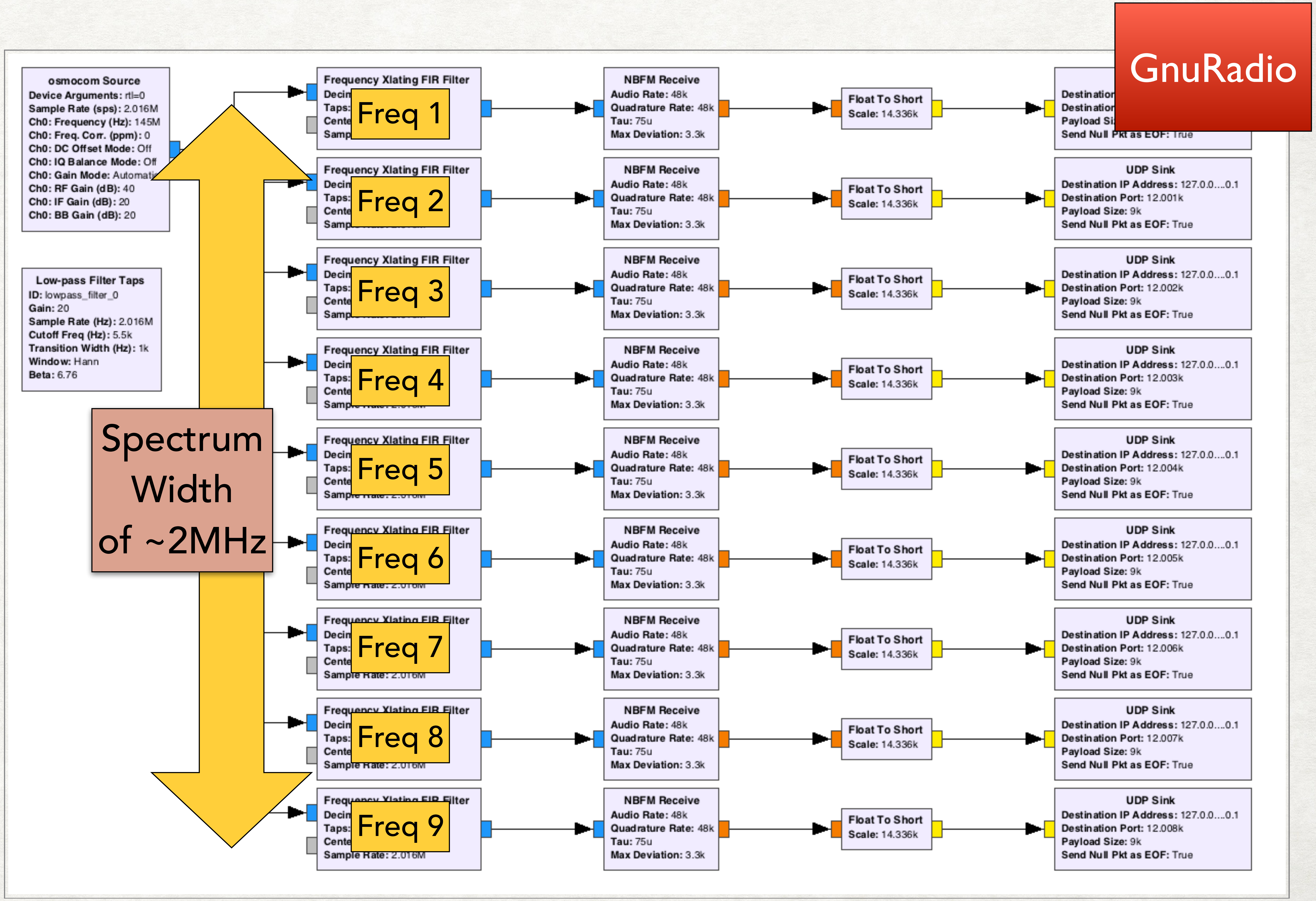
- Separate processing chain used for each frequency
- Parameters are dynamically determined at startup (python based)
- Resulting audio sent to Dire Wolf for APRS decode



GNURADIO: LOTS-O-PROCESSING CHAINS

Benefits

- Frequency agile (within spectrum width)
- Parallel processing
- Processing chains built dynamically at startup
- Platform tested with up to 9 processing chains
- Always listens on 144.39MHz



DIRE WOLF

Dire Wolf

Dire Wolf Configuration File

Channel #1

AUDIO FROM GNURADIO

```
# RTL: 0   Frequency: 144.39MHz
ADEVICE0 udp:12000 null
ARATE 50000
ACHANNELS 1
CHANNEL 0
MYCALL N6BA-10
MODEM 1200
FIX_BITS 1
```

Channel #2

AUDIO FROM GNURADIO

```
# RTL: 0   Frequency: 144.34MHz
ADEVICE1 udp:12001 null
ARATE 50000
ACHANNELS 1
CHANNEL 2
MYCALL N6BA-10
MODEM 1200
FIX_BITS 1
```

Channel #3

AUDIO FROM GNURADIO

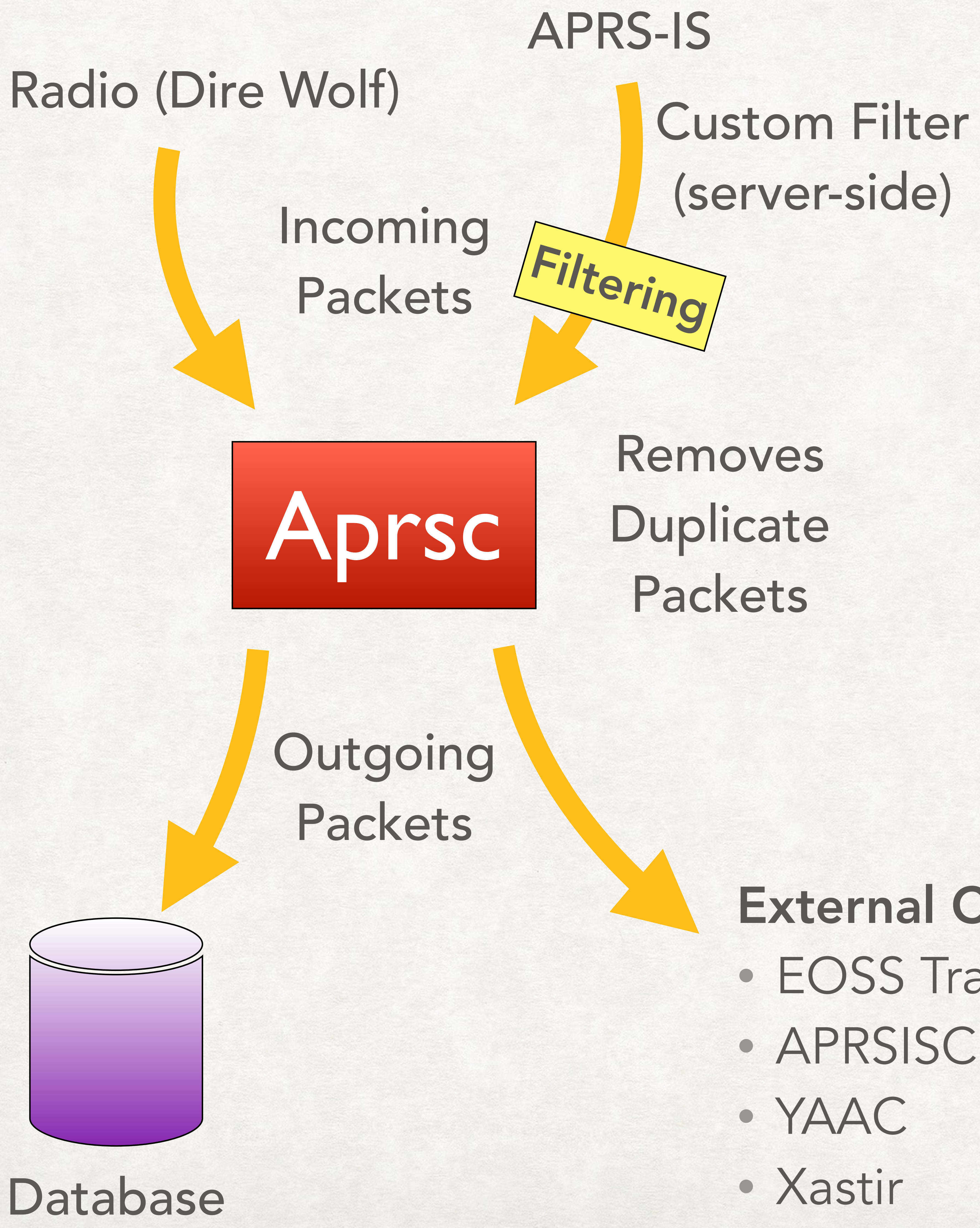
```
# RTL: 0   Frequency: 145.535MHz
ADEVICE2 udp:12002 null
ARATE 50000
ACHANNELS 1
CHANNEL 4
MYCALL N6BA-10
MODEM 1200
FIX_BITS 1
```

```
..other config info..
```

APRS PACKETS (TEXT)

APRSC

APRSC



External Clients:

- EOSS TrackPoint
- APRSISCE
- YAAC
- Xastir

aprsc Configuration File

```
ServerId E0SS01949
PassCode xxxxx
MyAdmin "HAB Tracker"
MyEmail me@emailnotset.local
RunDir data
LogRotate 10 5
UpstreamTimeout 15s
ClientTimeout 48h
Listen "Full feed"                                      fullfeed tcp ::  10152 hidden
Listen ""                                               fullfeed udp ::  10152 hidden
Listen "Client-Defined Filters"                         igate tcp ::  14580
Listen ""                                               igate udp ::  14580
Uplink "Core rotate" ro  tcp  noam.aprs2.net 14580 filter r/39.75/-103.6/400
HTTPStatus 0.0.0.0 14501
FileLimit        10000
```

Note: Custom code added to APRSC for custom server-side filtering of the full feed.

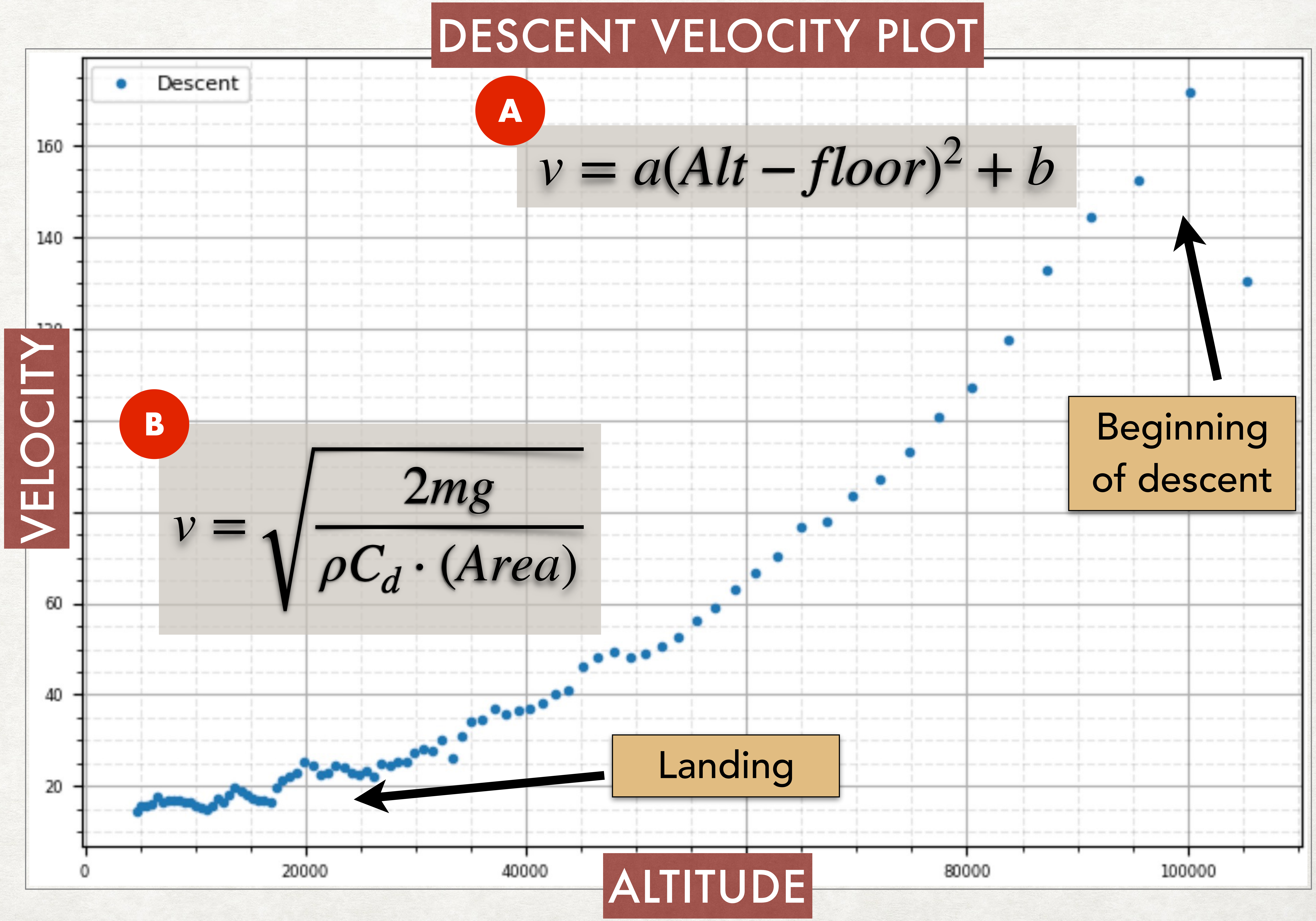
LANDING PREDICTIONS: ALGORITHM

During the Ascent

- Wind vectors (N, S, E, W) are saved from the ascent to be reapplied during the descent
- Updraft/downdraft wind vectors are estimated by comparison to mean values for ascent velocities

During the Descent

- Upper portion of descent uses curve fitting (A)
- Lower portion of descent uses drag equation for parachutes (B)
- Uses a piecewise, weighted function for predictions

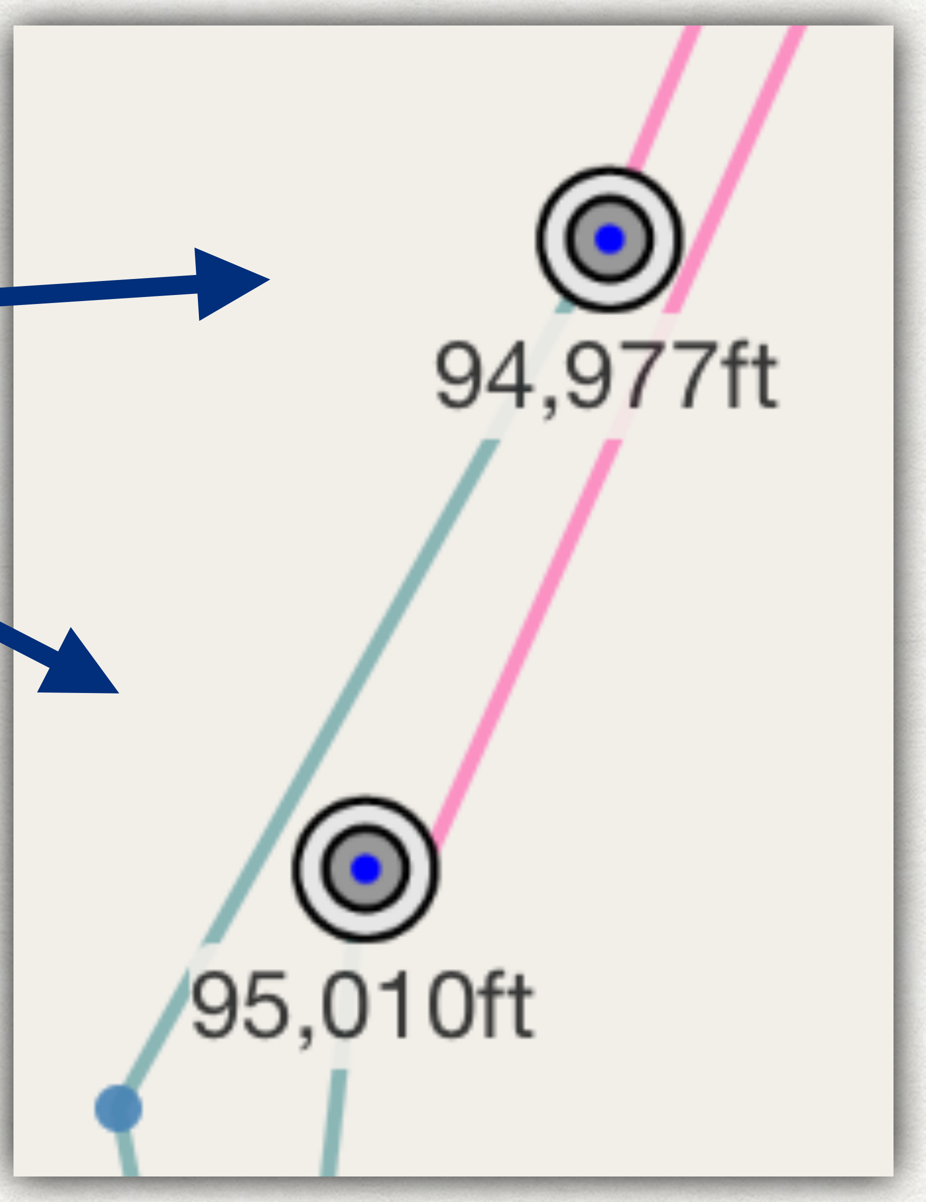


LANDING PREDICTIONS: PLOTTING

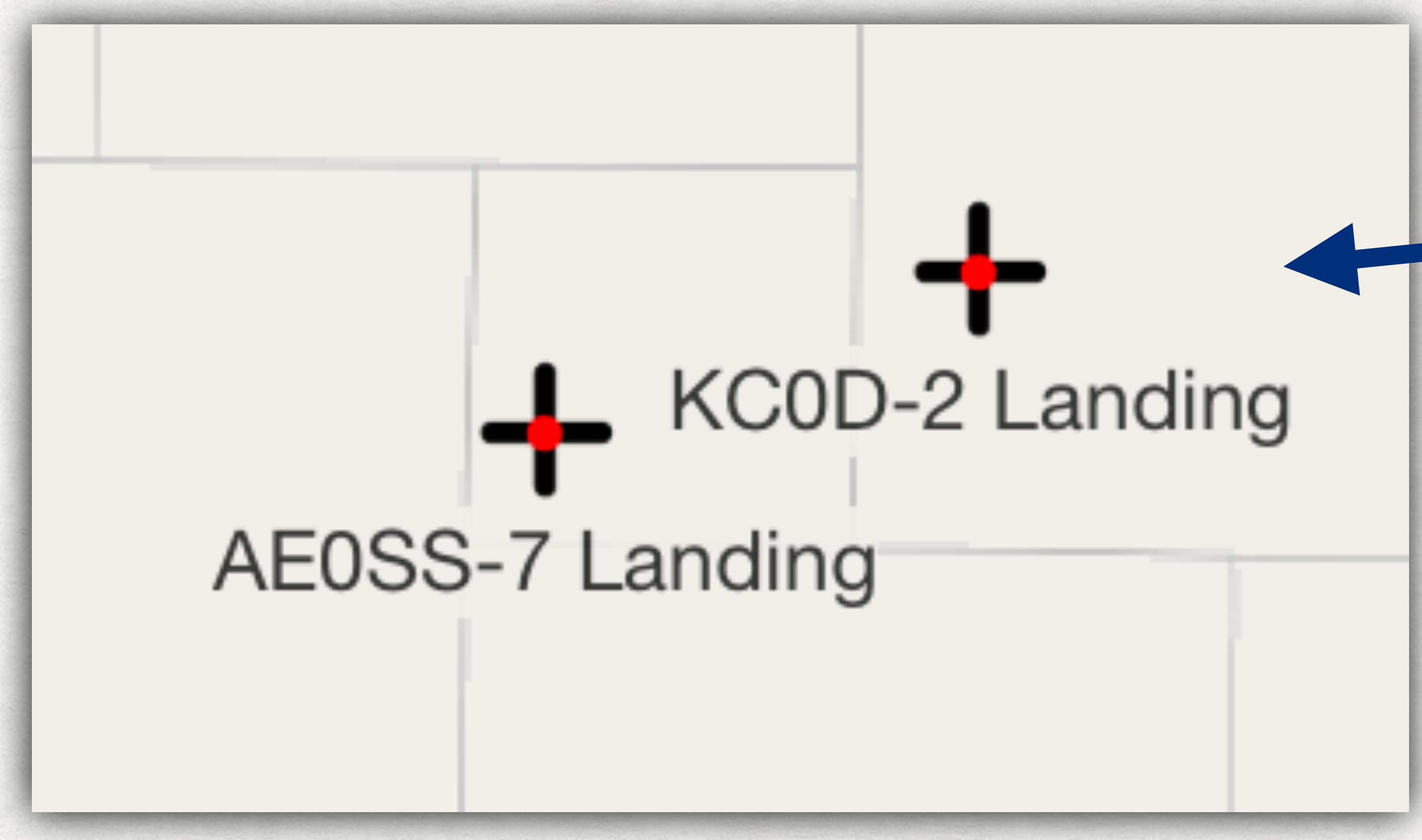
About

- Plotted separately for each beacon on a flight
- Icon on the map (+ marks the spot)
- Runs automatically, no user intervention required

1 Approximate burst location plotted on map for each beacon



2 Predicted landing location plotted on map for each beacon



FUTURE IDEAS

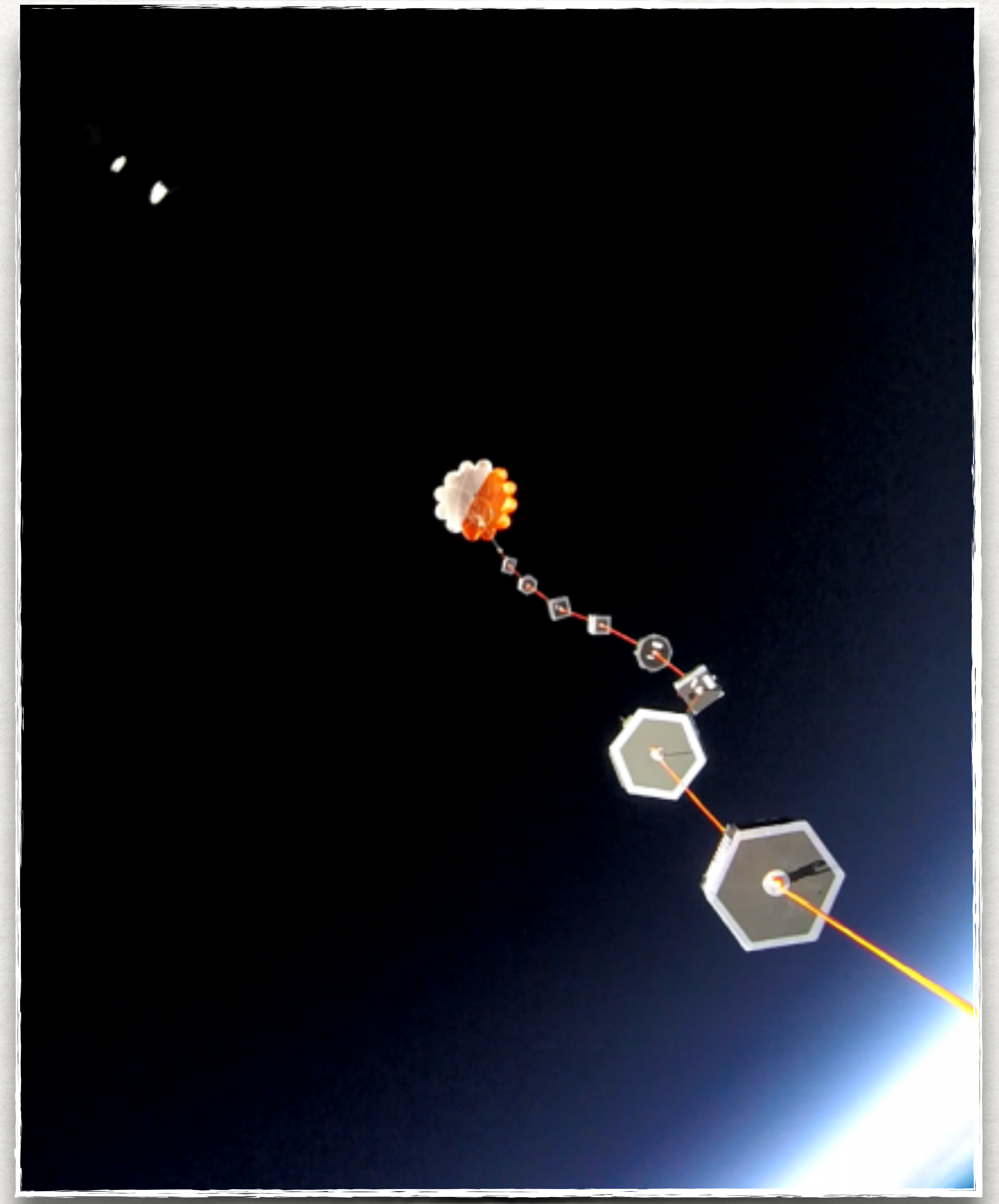
- Self aware beacons. Working to have the APRS beacons predict their own landing location and transmit that.
- Advanced mapping. Google Earth Pro and other online sources can provide satellite imagery, topographical, and other maps.
- APRS messaging and status. Transmissions of arbitrary APRS status and message packets to enhance situational awareness and communications.
- Analysis using GPU acceleration. Analysis of past EOSS and radiosonde flights could yield interesting results to be leveraged with landing predictions.
- Higher performance SDR
- 5GHz Wifi
- NVidia Jetson for in-vehicle GPU acceleration of workloads
- Endless pursuit of decimal dust!!!

GETTING INVOLVED

WHERE CAN YOU HELP?

…wherever you want!

- Customer relationships
- Ground station
- Launch team
- Fill team
- Tracking teams
- FAA interfacing
- Technology (beacons, tracking software, etc.)
- Club leadership
- Club website management
- …and everywhere in between



PLEASE REACH OUT TO...

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THANK YOU




BREAK FOR LIVE STUFF