

SOFTWARE- DEFINED APRS TRACKER

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Edge of Space Sciences
GPSL - June 2019



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 over 75,000 students and 55 schools
- 289 launches AND 289 recoveries!



THE CHALLENGE OF SCALE

More Flights

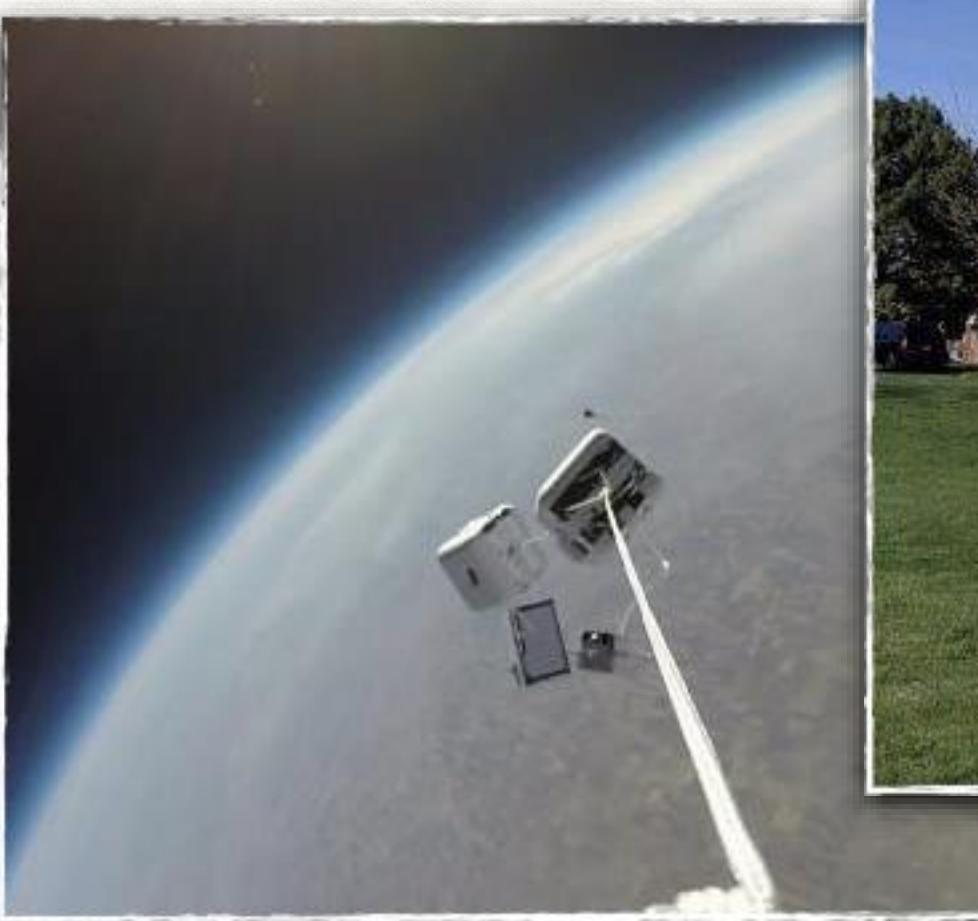
- The number of flights can be a launch day decision (eg. FAA regs can double # of flights)
- Additional qualification and test flights

Systems Requirements / New Technologies

- Flight systems redundancy (eg. more APRS beacons)
- New systems testing (ex. ADS-B)
- New methods for predictions (ex. radiosonde data)

Customers!

- More consumers of EOSS services
- Increased payload size/number
- New/alternative services



SYSTEM OVERVIEW



WHAT IS A TRACKER?



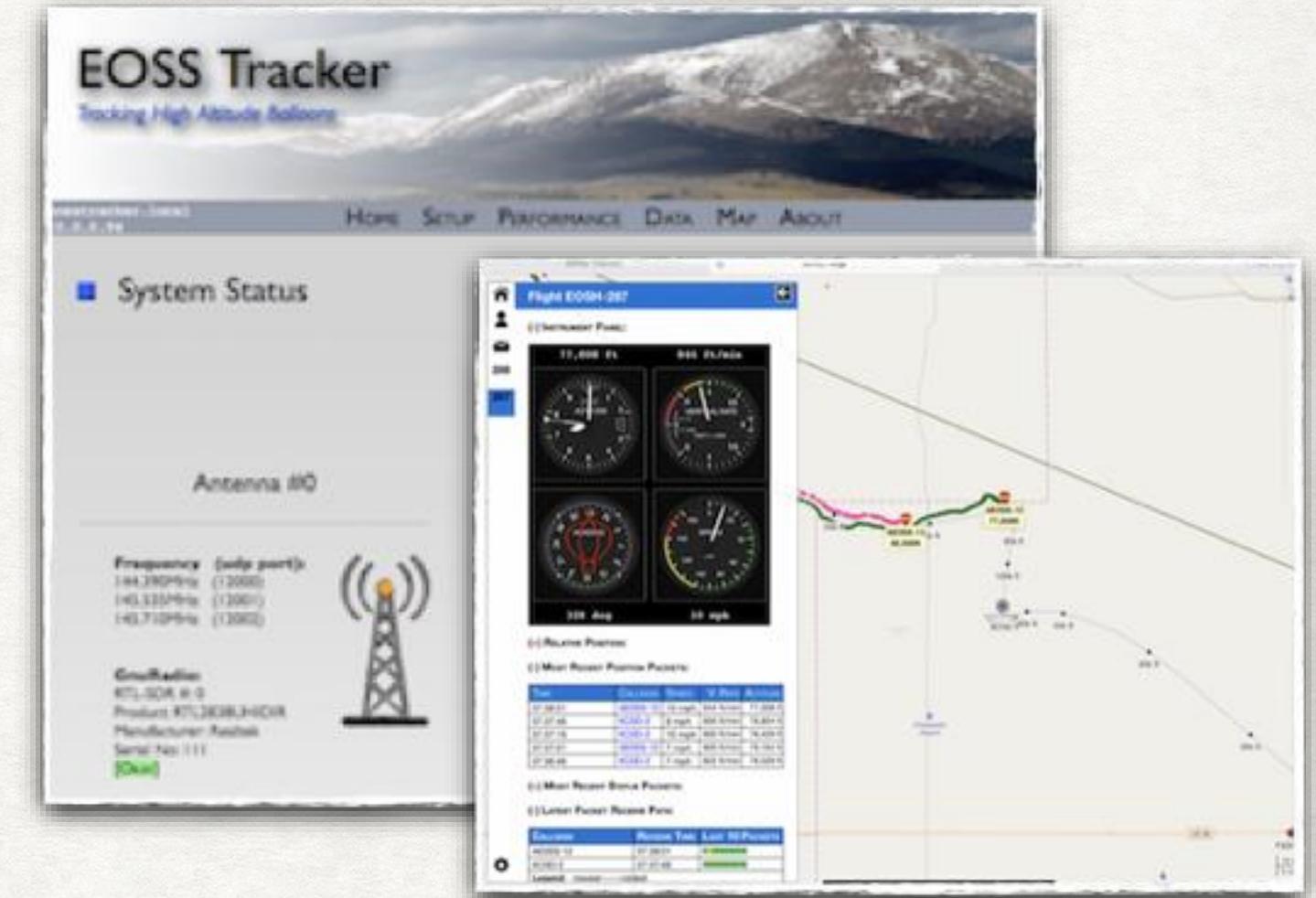
SDR-BASED APRS TRACKER

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

BASIC IDEA



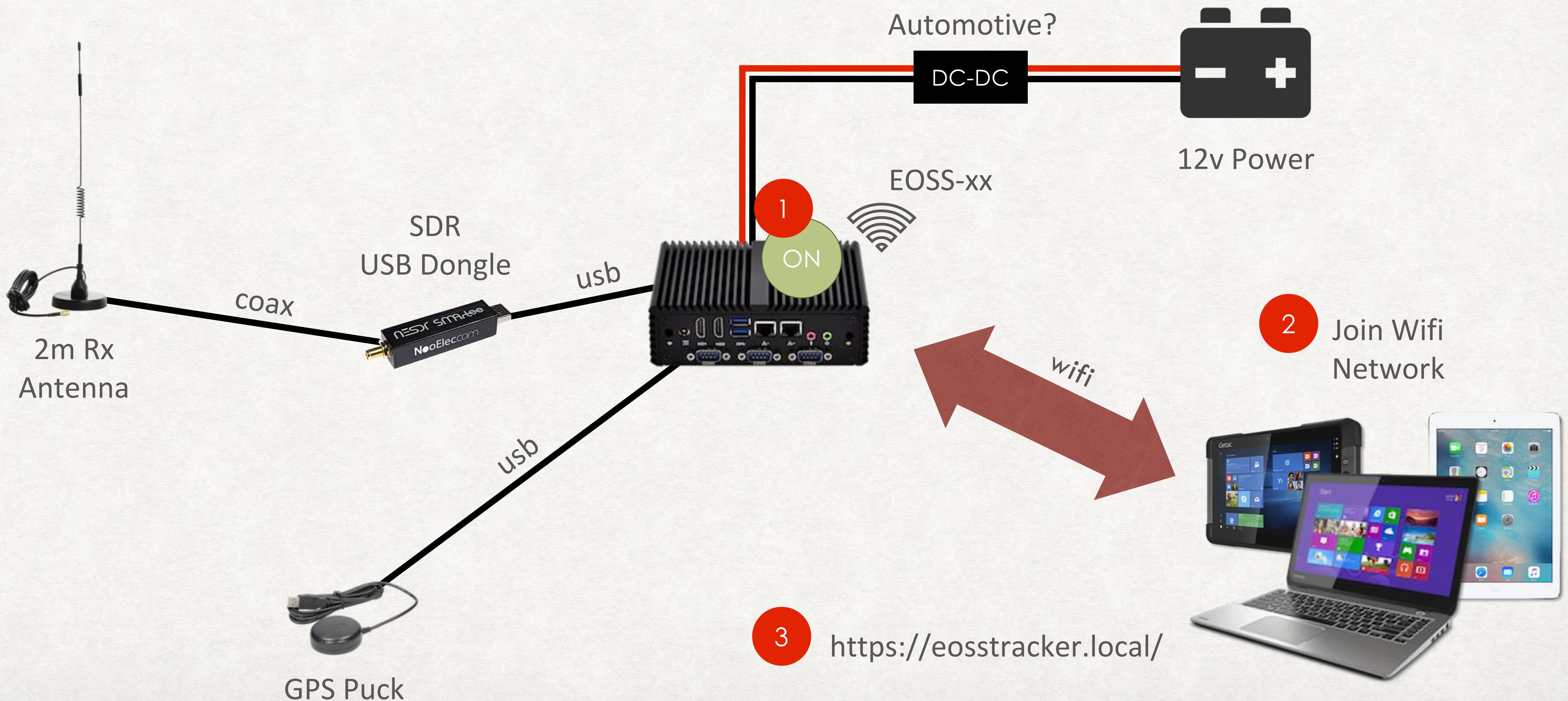
- Small computer
- SDR USB dongle
- 2m antenna
- Ubuntu Linux
- Open-source software

Wifi Network



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

CONNECTIONS



HOME SCREEN

System Status

Antenna #0

Frequency (udp port):
144.390MHz (12000)
145.535MHz (12001)
145.710MHz (12002)

GnuRadio:
RTL-SDR #: 0
Product: RTL2838UHIDIR
Manufacturer: Realtek
Serial No: 111
[OKAY]

Igating status: [NO]
Beaconing status: [NO]



Menu

EOSS Tracker

Tracking High Altitude Balloons

eosstracker.local
10.0.0.94

HOME SETUP PERFORMANCE DATA MAP ABOUT EOSS-04



Processes

System Processes

PROCESS	STATUS
direwolf	[OKAY]
aprsc	[OKAY]
gpsd	[OKAY]
backend daemon	[OKAY]

Start and Stop Processes:

Use these controls to start or stop the system daemons.

Start **Stop**

CONFIGURATION SETTINGS	
Callsign and SSID:	n/a
Timezone:	America/Denver
Igating:	no
Beaconing:	no

GPS State

GPS STATE				
UTC Time:	2019-04-26 19:56:12			
Latitude:	39.348841			
Longitude:	-104.797509			
Speed MPH:	0.0			
Altitude (ft):	6695.0			
GPS Fix:	[3D FIX]			
PRN:	Elev:	Azim:	SNR:	Used:
1	37	80	32	Y
7	24	142	21	Y
11	37	59	25	Y
13	36	272	33	Y
15	16		22	YY
17			0	Y
			23	YY
			16	Y
			216	30
	2	48	22	N
30	59	147	0	N
131	43	199	0	N
135	36	220	0	N
138	44	184	0	N
65	4	339	0	N
71	2	252	0	N
72	9	298	0	N
73	61	350	26	N
74	20	317	11	N
80	40	105	18	N
82	31	33	28	N
83	75	100	0	N
84	30	192	16	N
94	32	33	0	N

Note: GPS state is only updated while system processes are running

SETUP SCREEN

Configuration

- (+) Flights
- (+) Trackers
- (+) Prediction Data
- (+) Launch Sites
- (+) Frequencies
- (+) System Configuration

Flights: A balloon flight, its APRS beacons (callsigns), frequencies, and launch sites.

Trackers: Team member callsigns that will be beaconing their position.

Prediction Data: Ability to load EOSS proprietary pre-launch, flight path predictions to be plotted on the map. Working towards more generic capabilities (ex. CSV from habhub).

Launch Sites: Names, locations, and elevations.

Frequencies: Edit the list of selectable frequencies for flight beacons.

System Configuration: Timezones, callsigns, igating, external radio connections.

SETUP SCREEN: FLIGHTS

Flights

Add a New Flight:

ENTER FLIGHT AND ASSOCIATED BEACONS				
ACTION	Flight			
	EOSS-XXX	Description	Launch Site: <input type="text" value="Crow Valley"/>	Tracking: <input checked="" type="checkbox"/>
Beacons				
1	CALL-XX	144.340MHz	Description	
2	CALL-XX	144.340MHz	Description	
3	CALL-XX	144.340MHz	Description	
4	CALL-XX	144.340MHz	Description	
5	CALL-XX	144.340MHz	Description	

Flight name/identifier

Flights are tied to a specific launch site

Track this flight on the map?

144.340MHz

144.340MHz

144.340MHz

144.340MHz

A beacon's frequency is chosen from the dropdown (*)

* Frequencies are pre-determined within the EOSS specific version of the unit.

SETUP SCREEN: TRACKERS

(-) Trackers

Use this section to add new trackers or update existing ones. Trackers can be assigned to teams.

TEAM AND FLIGHT ASSIGNMENT	CALLSIGN	NOTES	MOVE TO THIS TEAM
Alpha At Large	KC0D-7	Mark	Alpha
Bravo At Large	N0JPS	John	Bravo
	W9CN	Mike	Bravo
Charlie At Large	KC0RPS	Jim, Sunday Only	Charlie
	W0NFW	George	Charlie
Delta At Large	K0SCC	Stephen	Delta
Echo At Large	K0SCC	John and Nancy	Echo
Golf At Large			
Ground Sta At Large			
Hotel At Large	KE7KCK	Tom (President)	Hotel
India At Large	WB0DKT	Glenn, Darren	India
Juliet At Large	KD0SEM	Dave	Juliet
Kilo At Large	N0NDM	Larry, Nick, Elijah	Kilo

Add a New Tracker:

ACTION	CALLSIGN	NOTES	TEAM ASSIGNMENT
+ (Green)	N6BA-6	Jeff	Golf

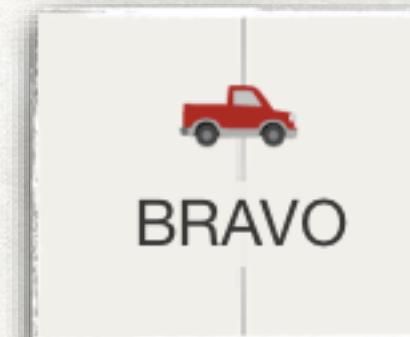
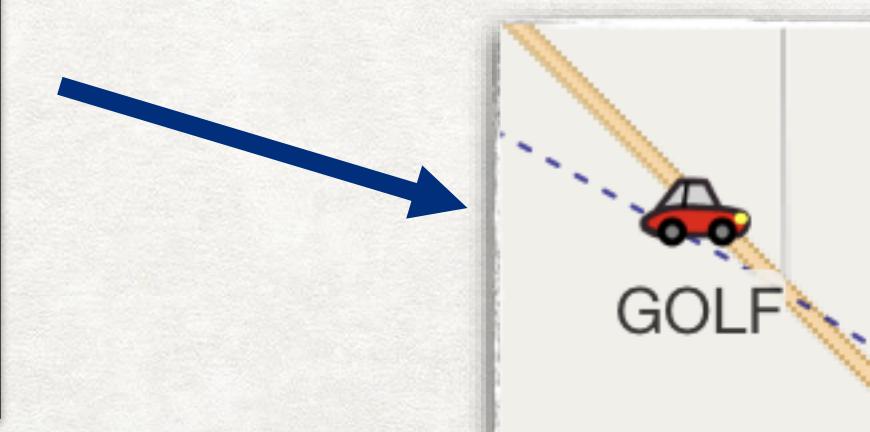
TEAM AND FLIGHT ASSIGNMENT	CALLSIGN	NOTES	MOVE TO THIS TEAM
BRAVO At Large			
GOLF At Large			
INDIA At Large			
JOULIET At Large			
KILO At Large			

Teams can be assigned to specific flights

Golf At Large	N6BA-6	Jeff	Golf
	WA0GEH	Marty	Golf

Individual trackers can be moved to different teams as needed

Trackers are then displayed on the map using the “team” name.



SETUP SCREEN: FREQUENCIES

Frequencies

Existing Frequencies:	
Action	Frequency
	144.340 MHz
	144.360 MHz
Standard	144.390 MHz
	144.905 MHz
	145.045 MHz
	145.535 MHz
	145.645 MHz
	145.710 MHz
	145.765 MHz

Add additional frequencies here

Add a New Frequency:

Action	Frequency
	14x.xxx

Note: Range of frequencies must fit within a ~2MHz contiguous spectrum.

SETUP SCREEN: LAUNCH SITES

Launch Sites

Add a Launch Site

ACTION	LAUNCH SITE	LATITUDE (DECIMAL DEGREES)	LONGITUDE (DECIMAL DEGREES)	ELEVATION (FEET)
	launch site	latitude <input type="button" value="^"/>	longitude <input type="button" value="^"/>	altitude <input type="button" value="^"/>

Existing Launch Sites

ACTION	LAUNCH SITE	COORDINATES	ELEVATION
	Crow Valley	40.642, -104.334	5,100 ft
	Deer Trail	39.610, -104.042	5,200 ft
	Eaton	40.527, -104.723	4,800 ft
	Genoa	39.280, -103.491	5,600 ft
	GPSL2019 - Pella, IA	41.3936, -92.8897	890 ft
	Limon	39.234, -103.697	5,400 ft
	Wiggins	40.228, -104.075	4,500 ft
	Windsor	40.474, -104.962	4,900 ft

SETUP SCREEN: SYSTEM CONFIGURATION

Timezone

CONFIGURATION ITEM	VALUE
Timezone used throughout the interface.	Timezone: America/Denver

Symbol/Comment

APRS COMMENT AND STATION SYMBOL

APRS comment. For each outgoing packet, this comment will be included (limited to 60 characters).	EOSS Tracker
APRS symbol. Choose the appropriate symbol to represent your station.	 Overlay: Truck

Callsign & Igating

CALLSIGN AND SSID

ITEM	VALUE
Callsign and SSID. Enter your ham radio callsign and select an appropriate SSID.	Callsign: N6BA SSID: 6

IGATING TO THE INTERNET

IGATING	Enable igating for received APRS packets. This assumes the system has Internet connectivity.	Enable igating: <input checked="" type="checkbox"/>
	APRS-IS passcode for connections to APRS-IS systems.	Passcode: 11111
	Beacon to APRS-IS at this rate (i.e. every mins:secs), directly over an internet connection. Instead of relying solely on RF beaconing for getting APRS beacons to APRS-IS servers, this system can beacon directly to APRS-IS if enabled. Note: If RF beaconing is enabled below, APRS-IS direct beaconing will use those beaconing rates instead of the time value listed here.	Enable: <input type="checkbox"/> Mins:secs 15:00

SETUP SCREEN: SYSTEM CONFIGURATION CONT.

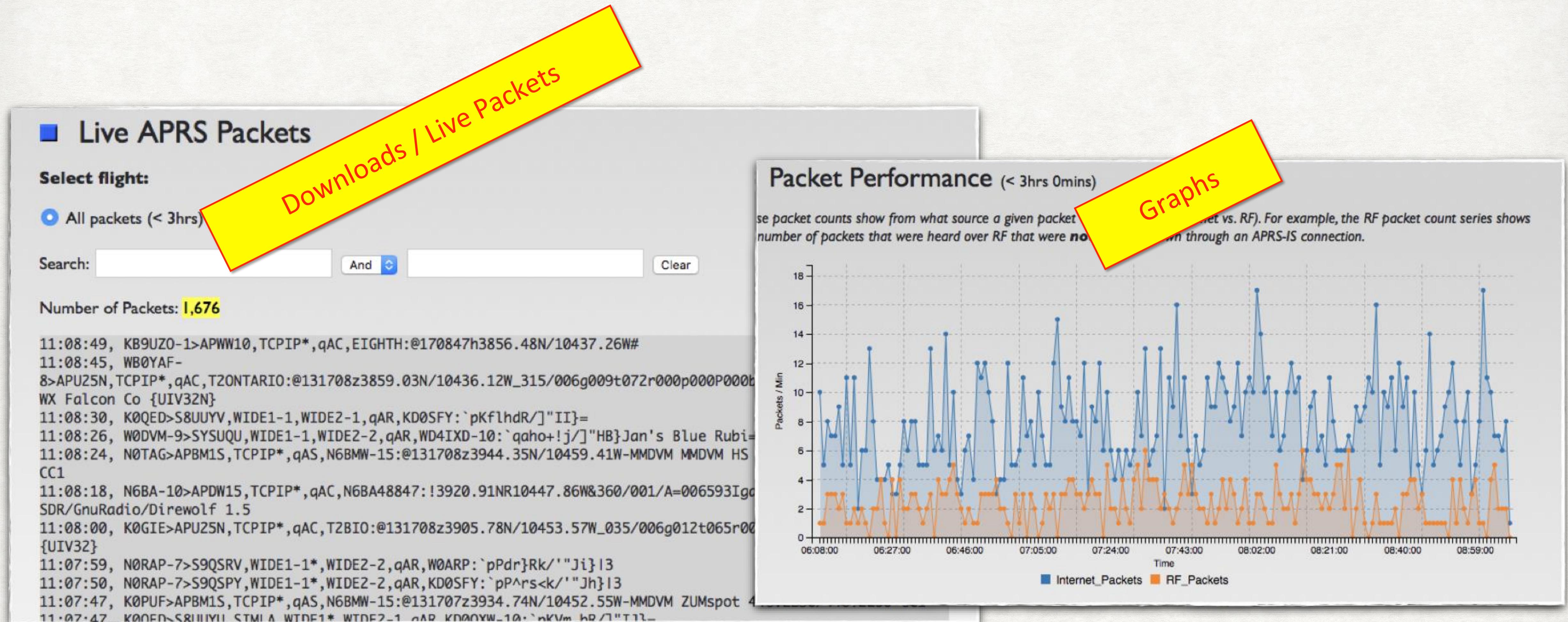
External Radio

RF Beaconing

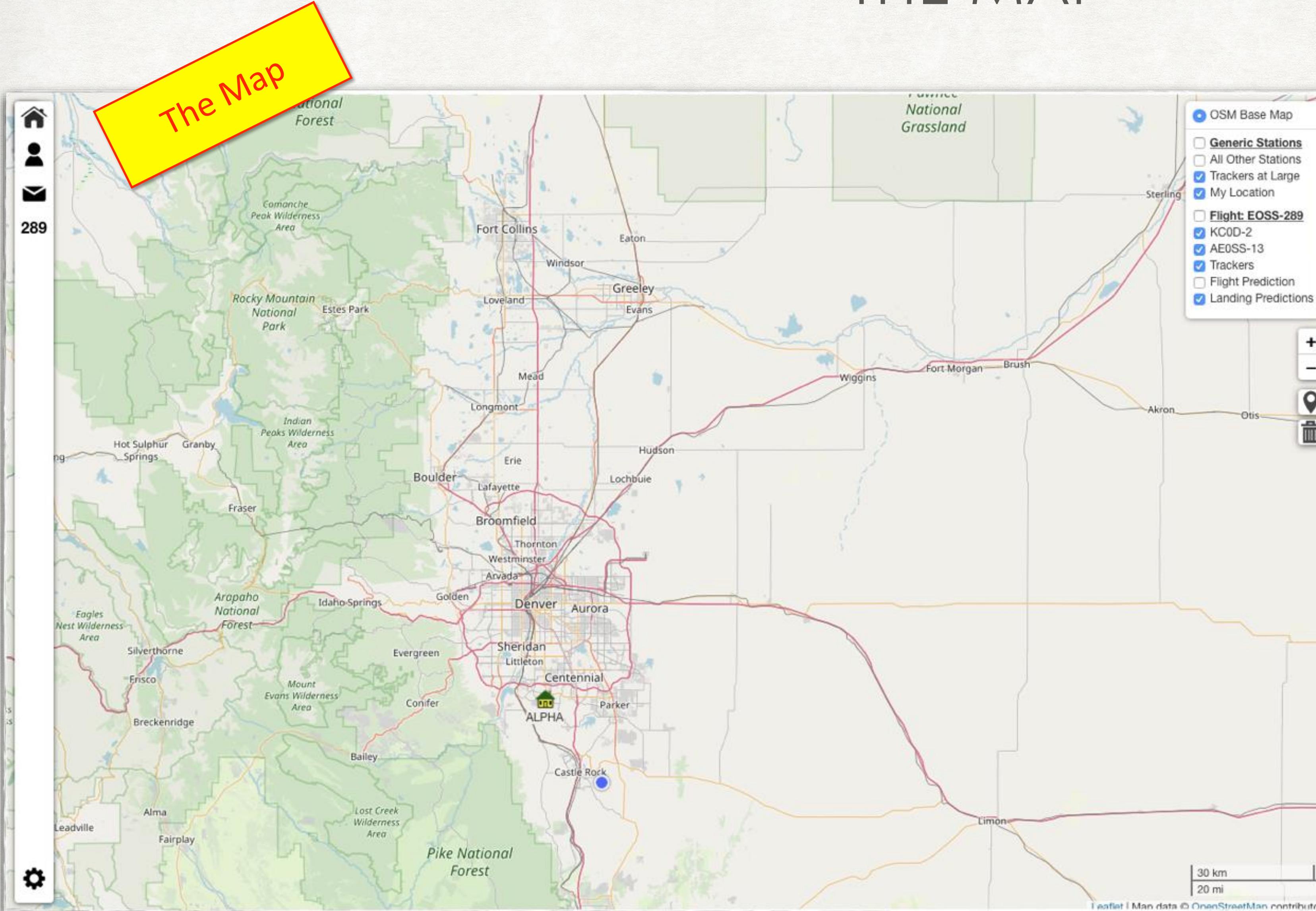
BEACONING

EXTERNAL RADIO CONNECTION	
System audio output device. Choose the audio device on this system that will be used to output audio to an external radio. Device 0 is usually the onboard headphone jack.	Device 2: USB-Audio - USB AUDIO CODEC <input type="button" value="..."/>
External radio PTT connection. Choose the serial device on this system that will be used to trigger the PTT on the external radio. Select "NONE" if using a third party device like SDR#.	Port: none <input type="button" value="..."/> Line Ctrl: RTS <input type="button" value="..."/>
<p>Your mileage may vary. Still in early stages of development.</p>	
Enable RF beaconing of position with APRS over RF. This requires an external radio set to an appropriate frequency.	Enable beaconing: <input checked="" type="checkbox"/>
Include EOSS within your APRS path when tracking flights with EOSS. This system will always use WIDE1-1,WIDE2-1, but one optionally can append "EOSS" to that path. For example, WIDE1-1,WIDE2-1,EOSS.	Include EOSS: <input checked="" type="checkbox"/>
Fast speed threshold. For speeds above this value, beacon this frequently.	Mph <input type="text" value="45"/> Mins:secs <input type="text" value="01:00"/>
Slow speed threshold. For speeds below this value, beacon this frequently.	Mph <input type="text" value="5"/> Mins:secs <input type="text" value="10:00"/>
Frequency threshold. Never beacon more frequently than this.	Mins:secs <input type="text" value="02:00"/>
Fast speed direction change threshold. For speeds above the fast threshold, beacon when the direction travel changes by at least this many degrees.	Degrees <input type="text" value="20"/>
Slow speed direction change threshold. For speeds below the slow threshold, beacon when the direction travel changes by at least this many degrees.	Degrees <input type="text" value="60"/>

DATA



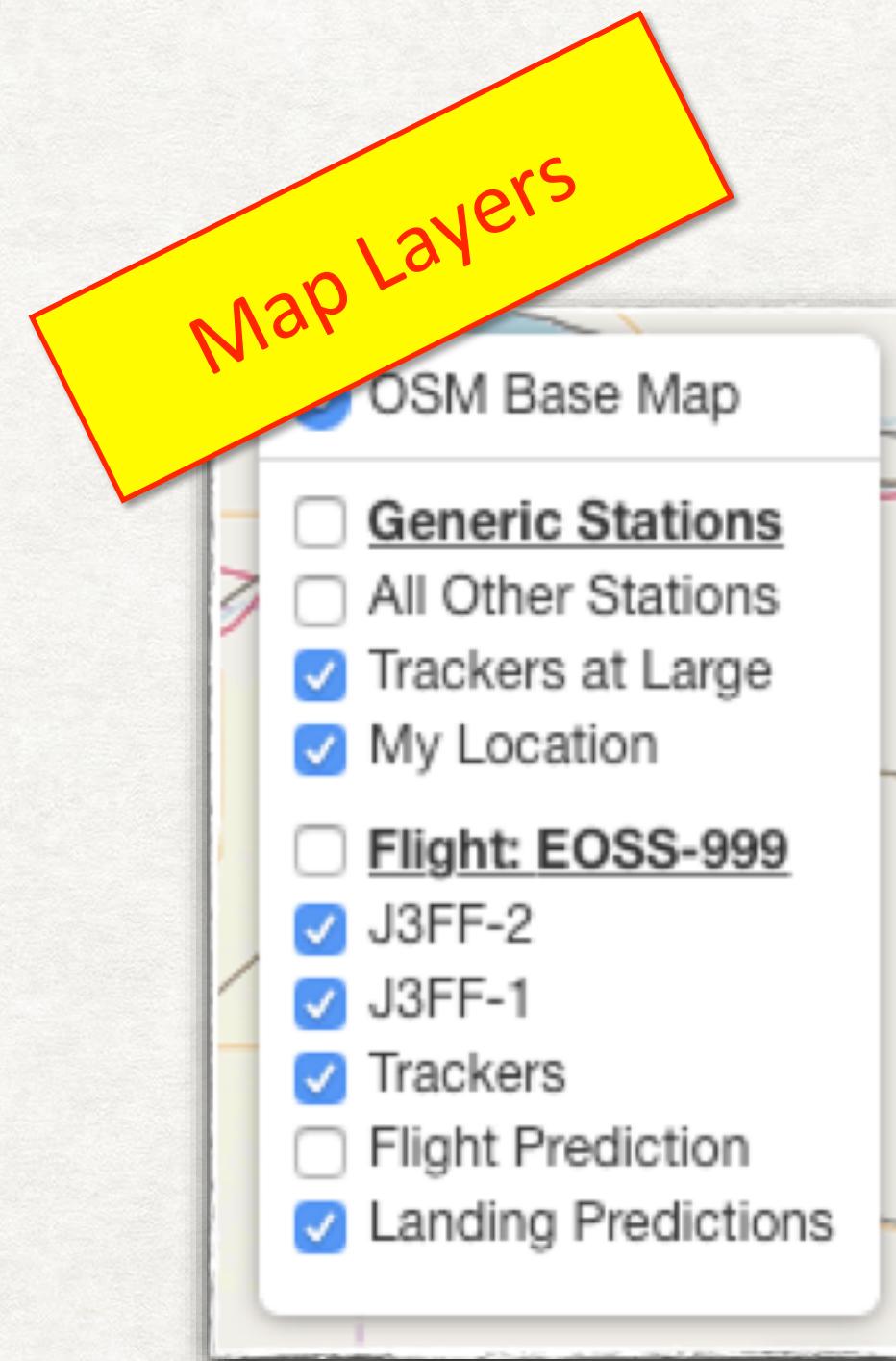
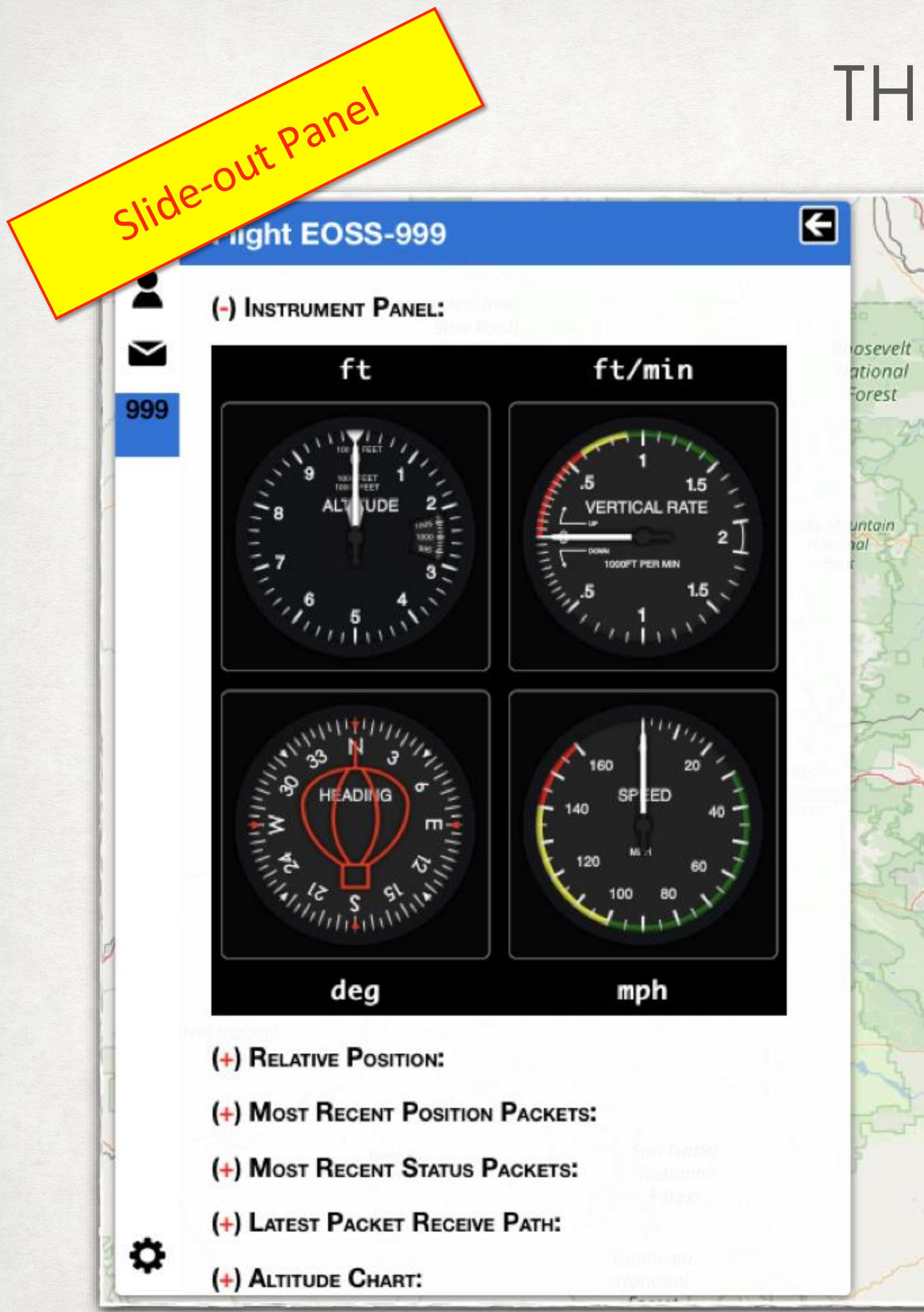
THE MAP



Map Features:

- Plots paths, APRS objects
- Pan/Zoom
- Tablet/phone friendly
- No Internet needed
- Pre-rendered tiles
- Will update every 5 seconds

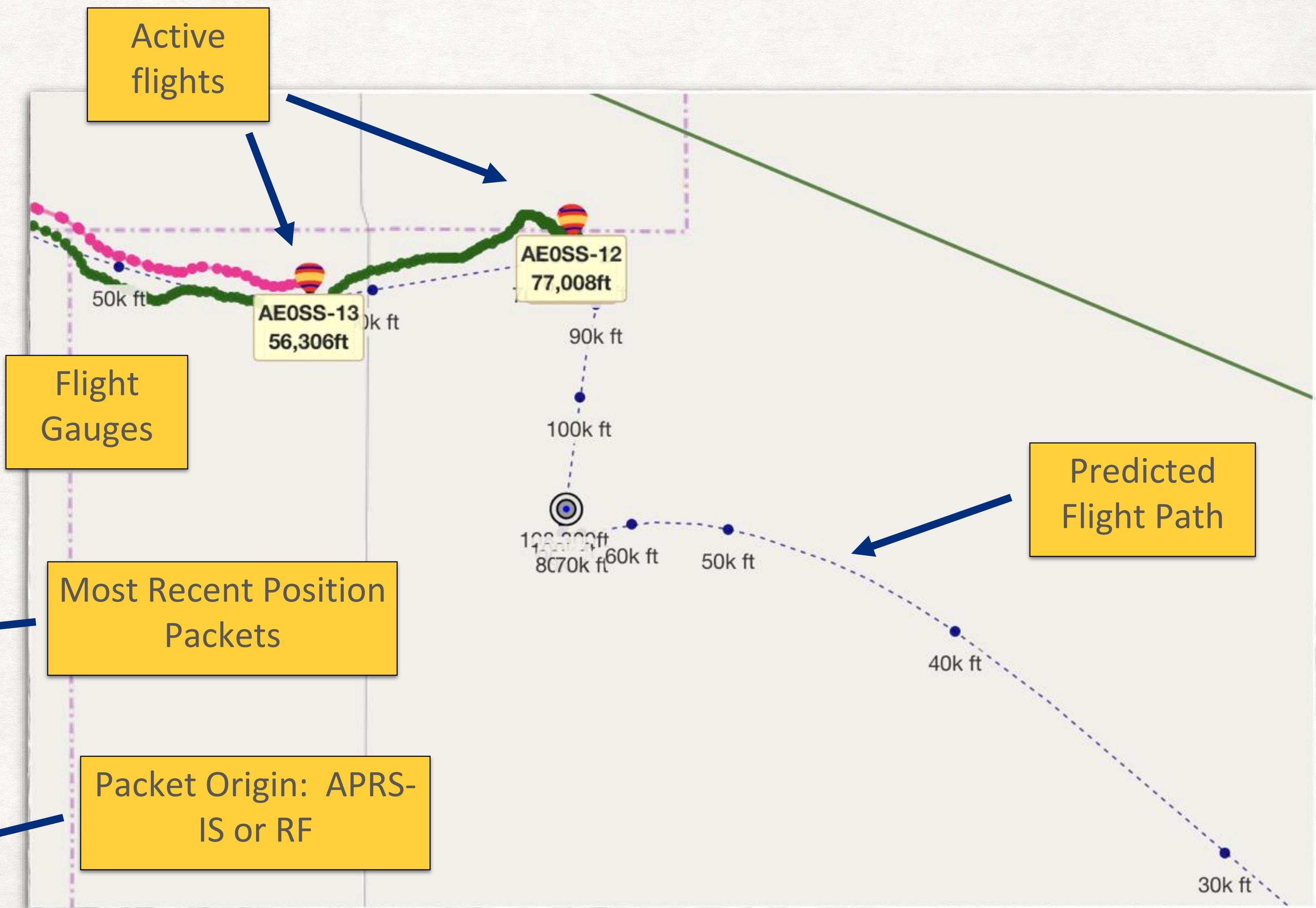
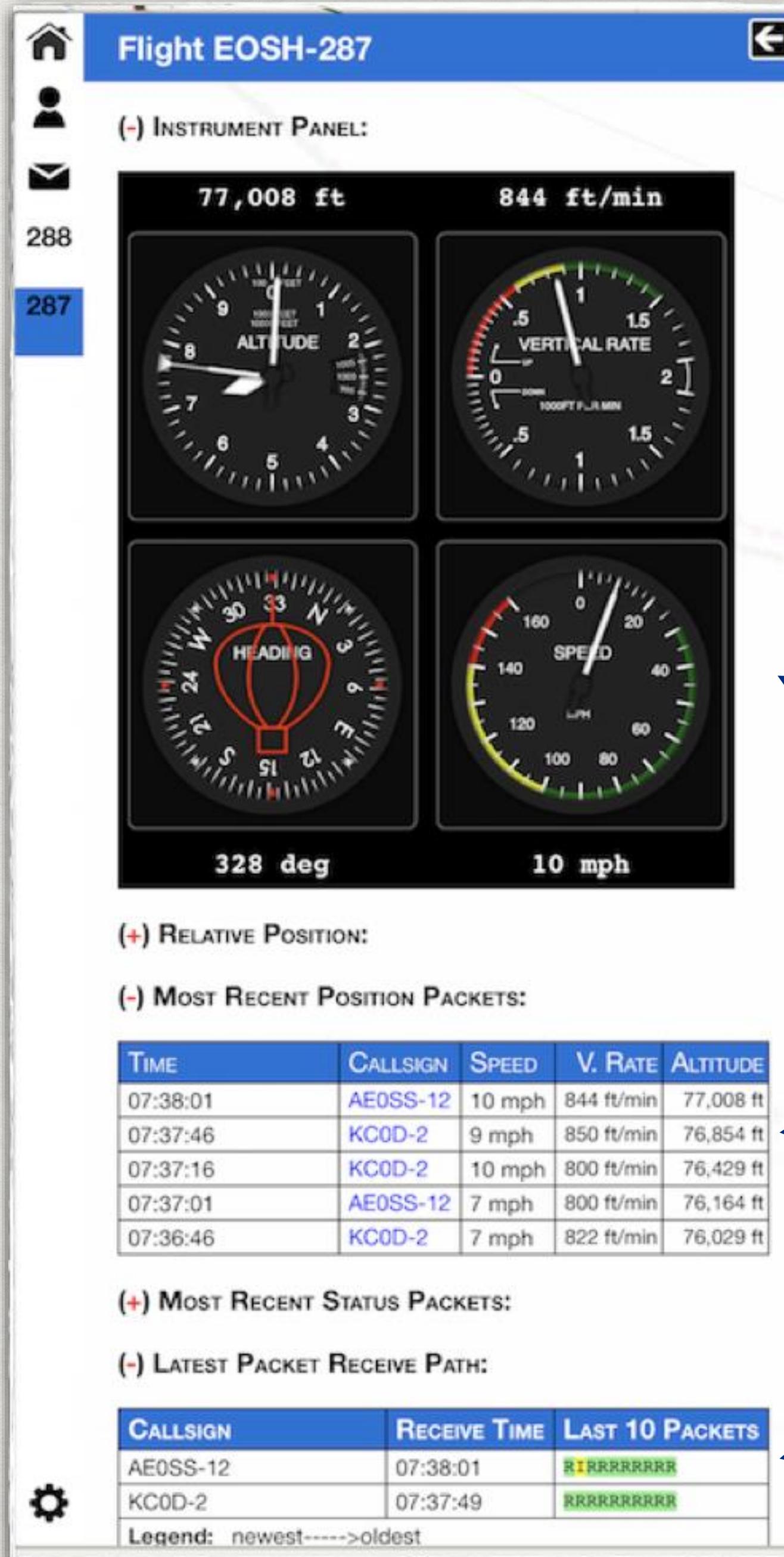
THE MAP: OPERATIONS



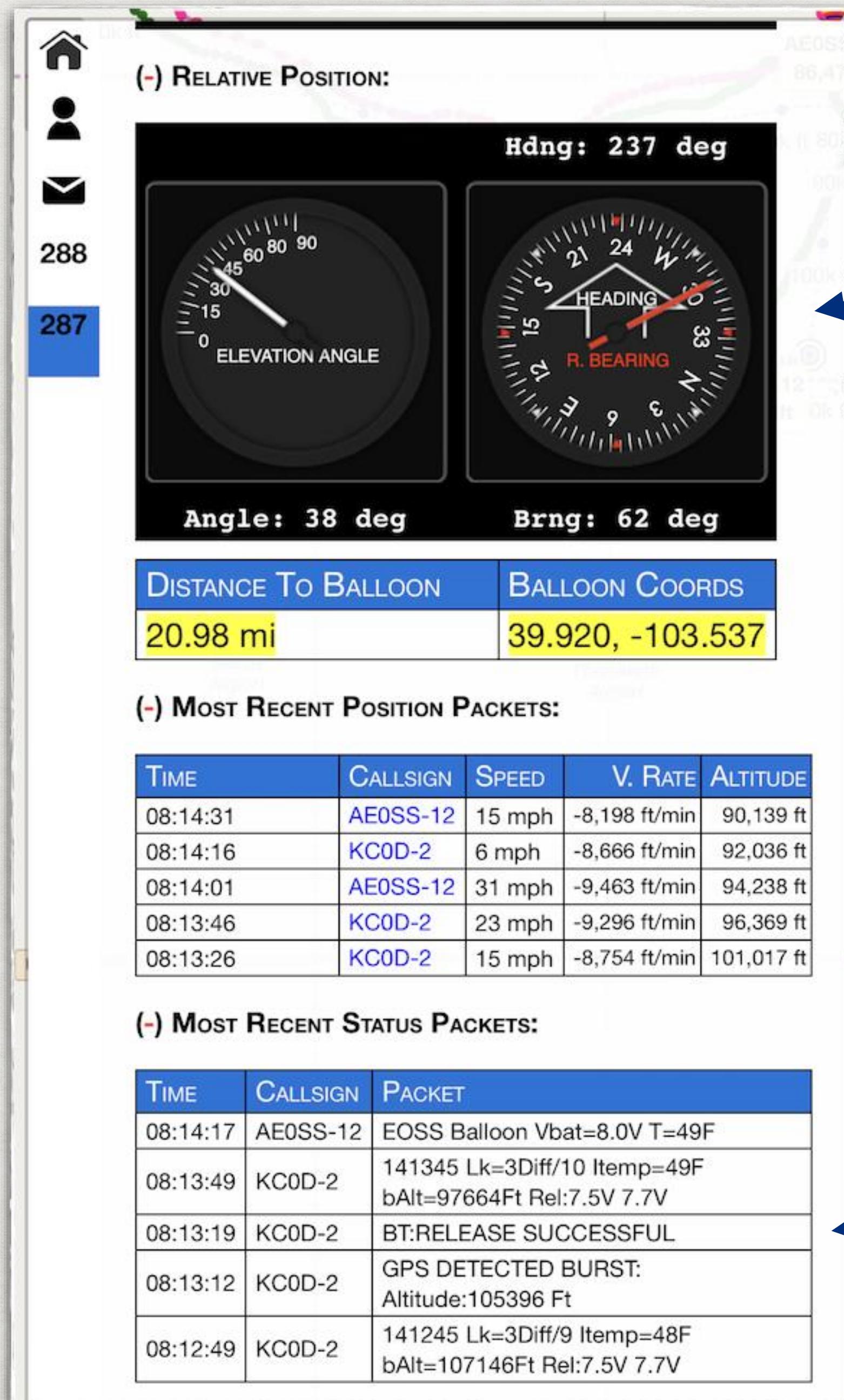
Operations:

- Track flight beacons/callsigns
- Pre-mission flight predictions
- Realtime landing predictions
- Tracker visibility / awareness
- Toggle layers on/off

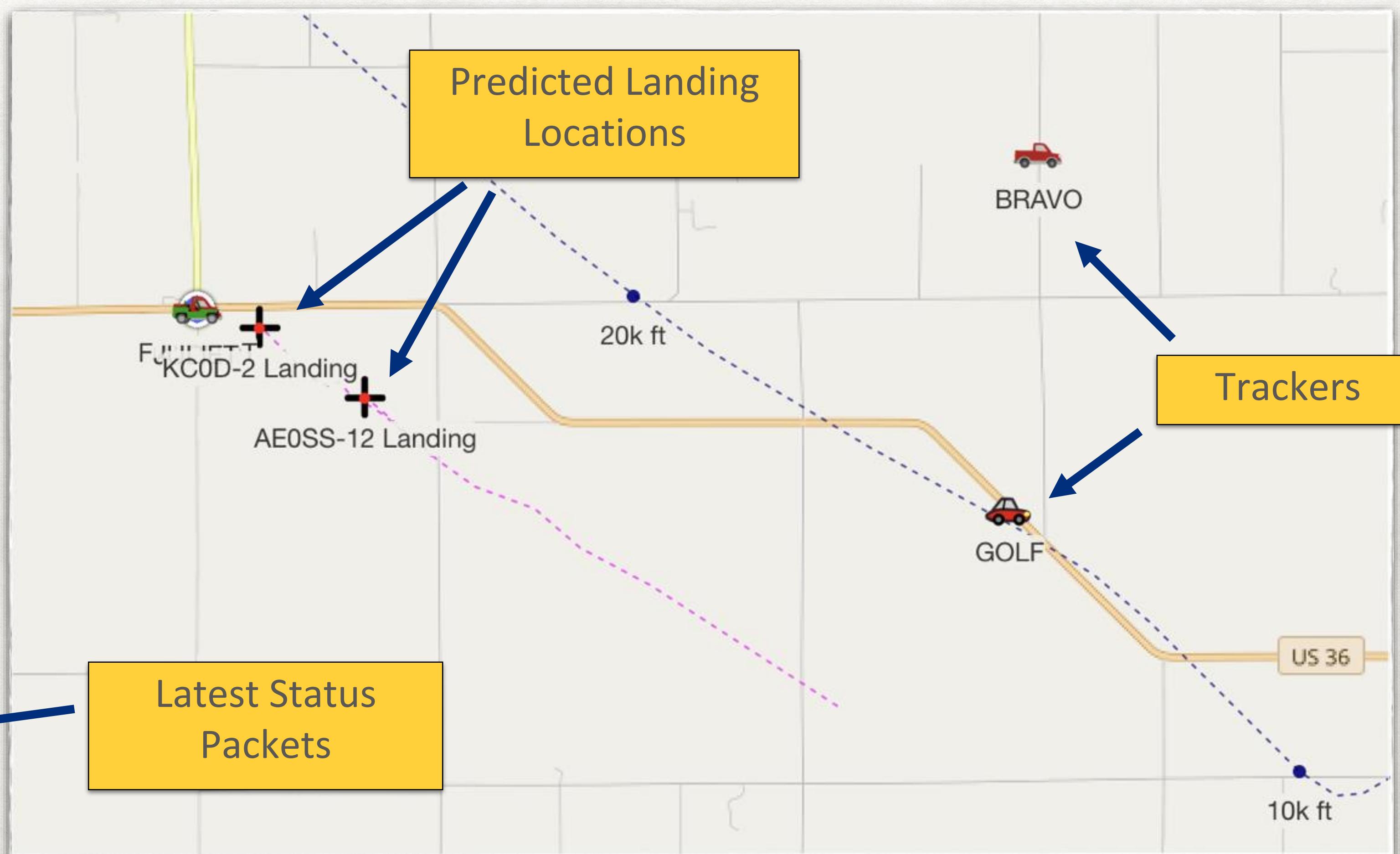
EXAMPLE - ASCENDING



EXAMPLE - DESCENDING



Relative Location of Flight



STANDARDS

STANDARDIZED PLATFORM

Components:

- RTL-SDR (USB interface)
- Small industrial computer (Intel i5 CPU)
- GPS puck (USB interface)



RTL-SDR

Benefits:

- Relatively inexpensive
- USB interfaces
- Future: plenty of expansion/interfaces



Small Computer



GPS Puck

STANDARDIZED OS / SOFTWARE

Distribution Model:

- GNU General Public License v3.0



Operating System / Software:

- Ubuntu Server 18.04LTS



EOSS STANDARDIZED SET OF FREQUENCIES

APRS Frequencies

- EOSS uses a set of 7 frequencies for APRS traffic
- Specifically selected to reduce interference for multi-flight missions
- Dropdown selection prevents human errors when entering frequencies for beacons
- The system will always listen on 144.39MHz

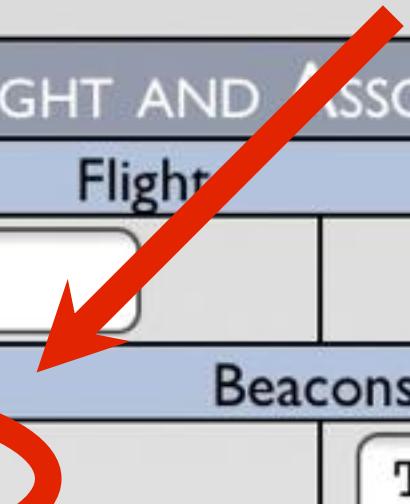
(-) Flights

Use this section to add new flights or update existing ones. To enable landing prediction calculations for the flight.

Add a New Flight:

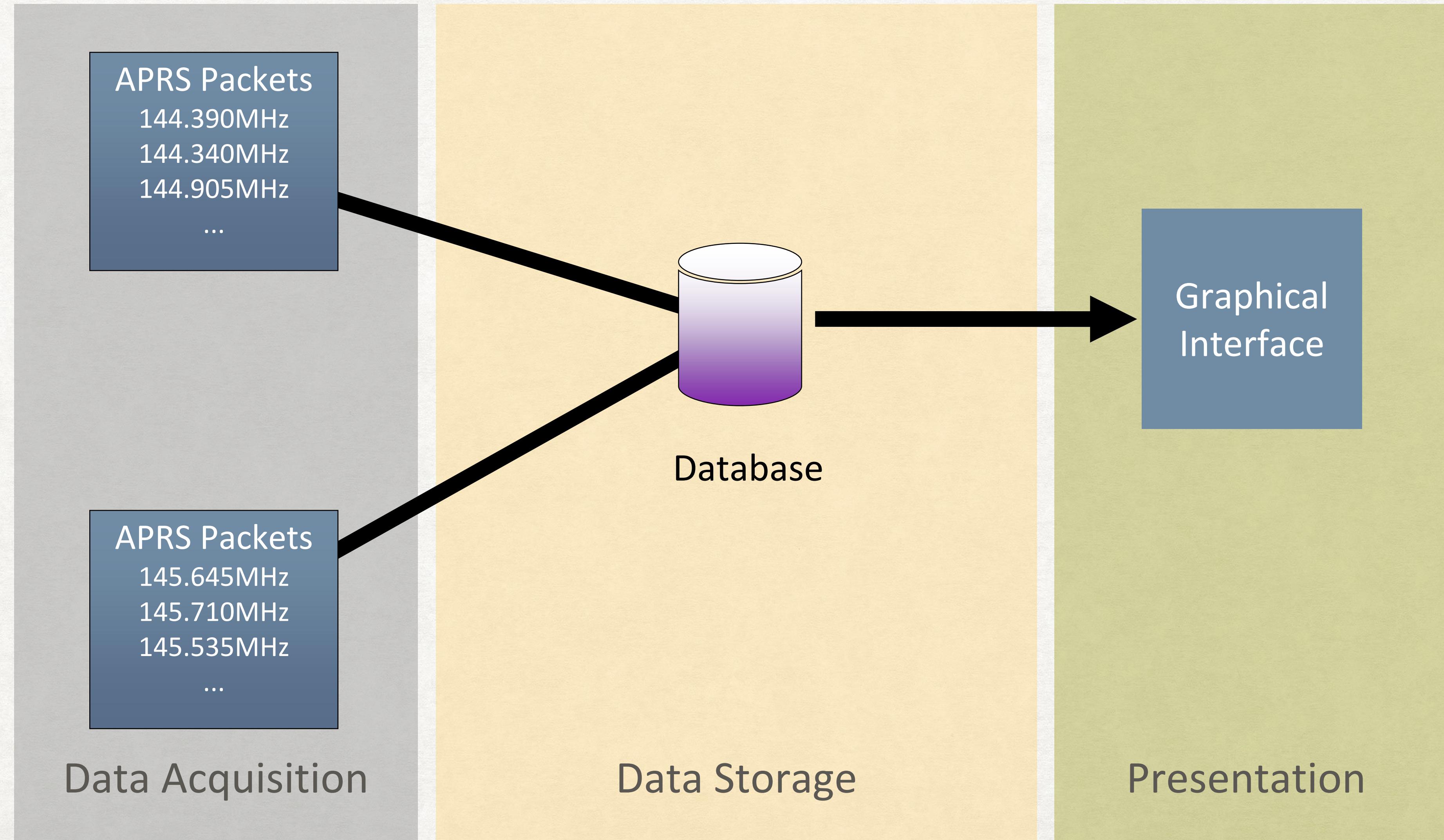
ACTION	ENTER FLIGHT AND ASSOCIATED BEACONS			
	Flight			Beacons
	TEST-999	Test Flight	Launch Site: Wiggins	Tracking: <input checked="" type="checkbox"/>
1	C4LL-11	144.340MHz	Test Beacon	
2	CALL-XX	144.340MHz	Description	
3	CALL-XX	144.340MHz	Description	
4	CALL-XX	144.340MHz	Description	
5	CALL-XX	144.340MHz	Description	

Select specific frequency for each beacon on a flight

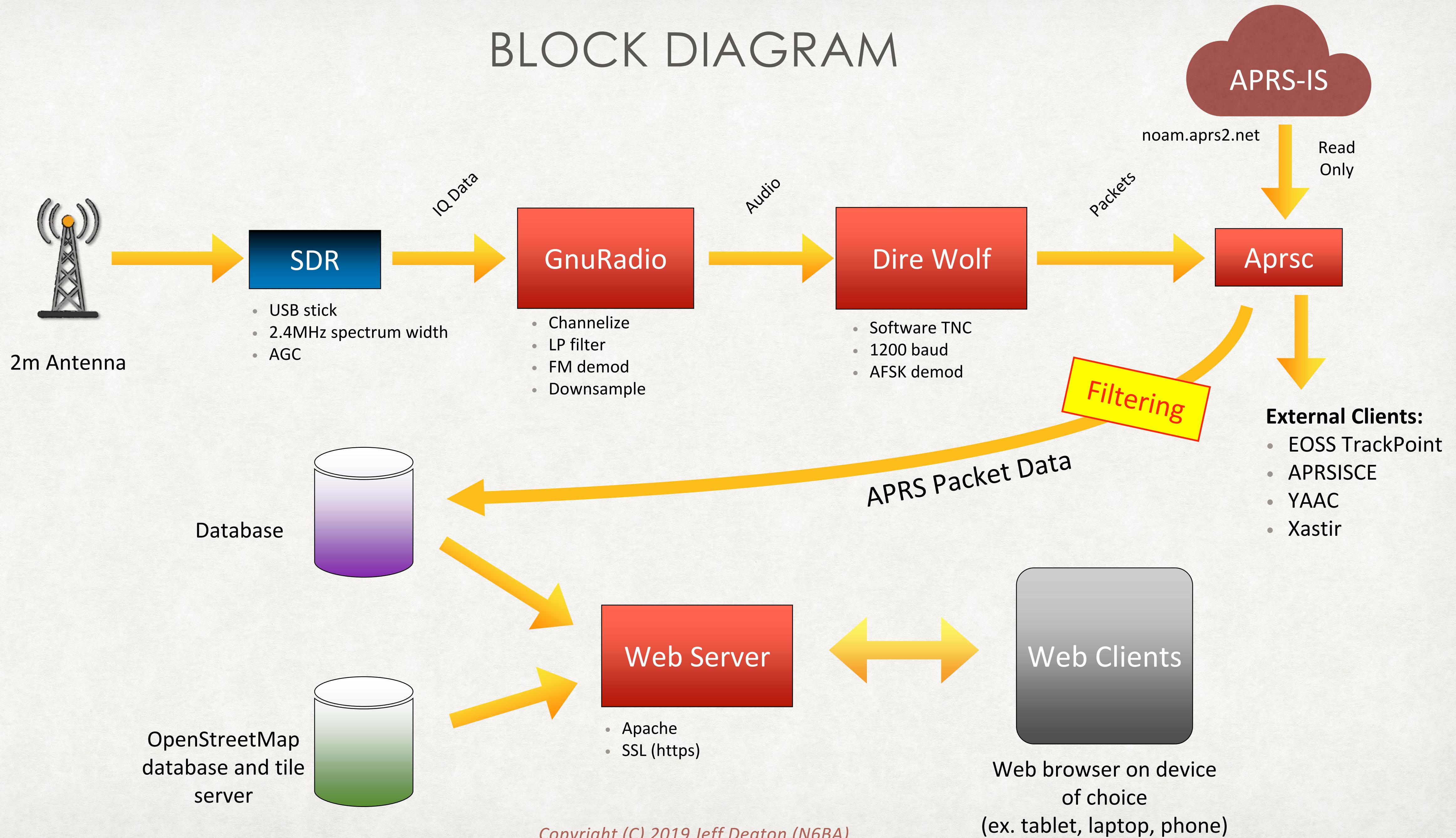


HOW IT WORKS

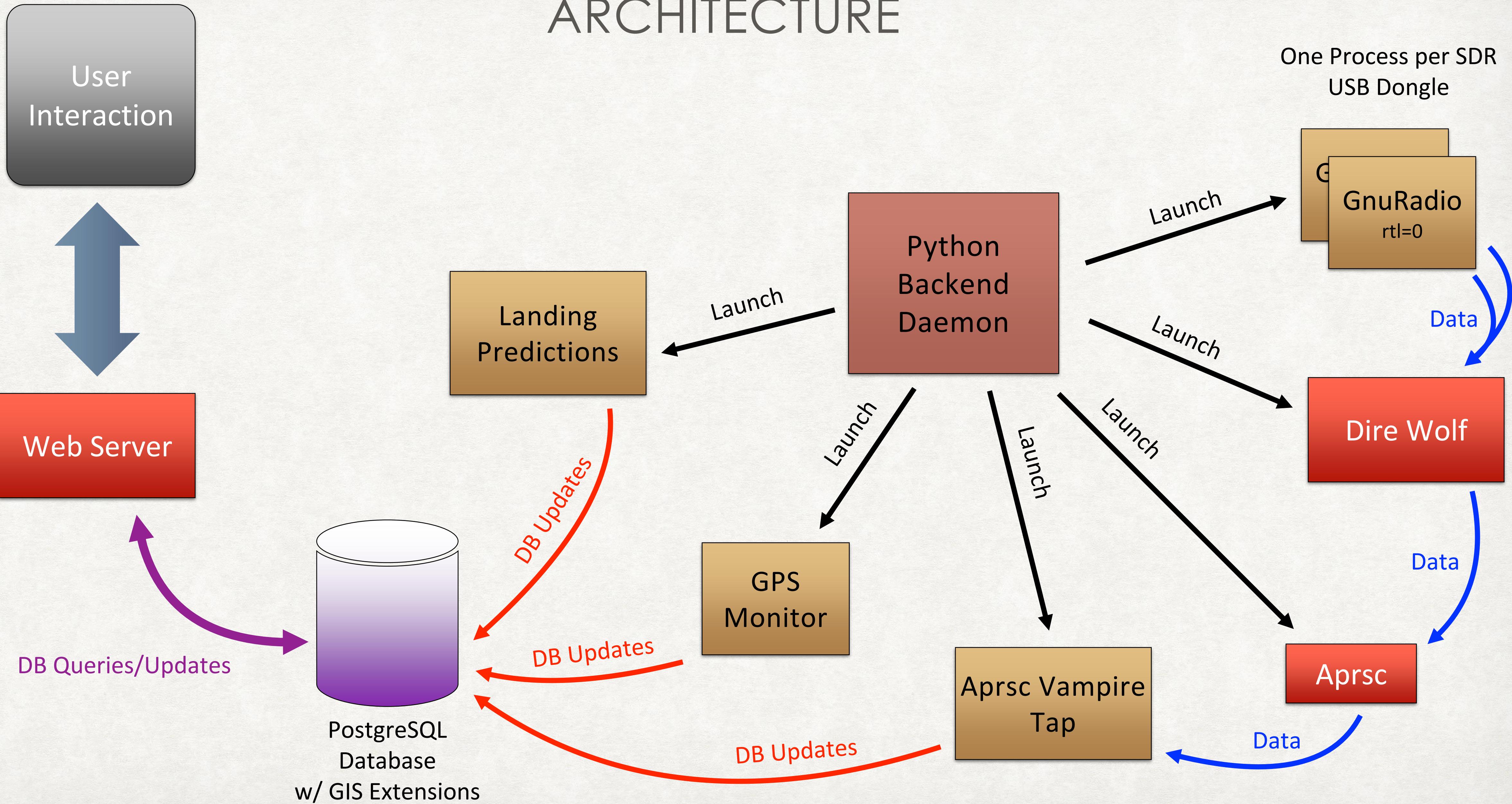
CORE CONCEPT



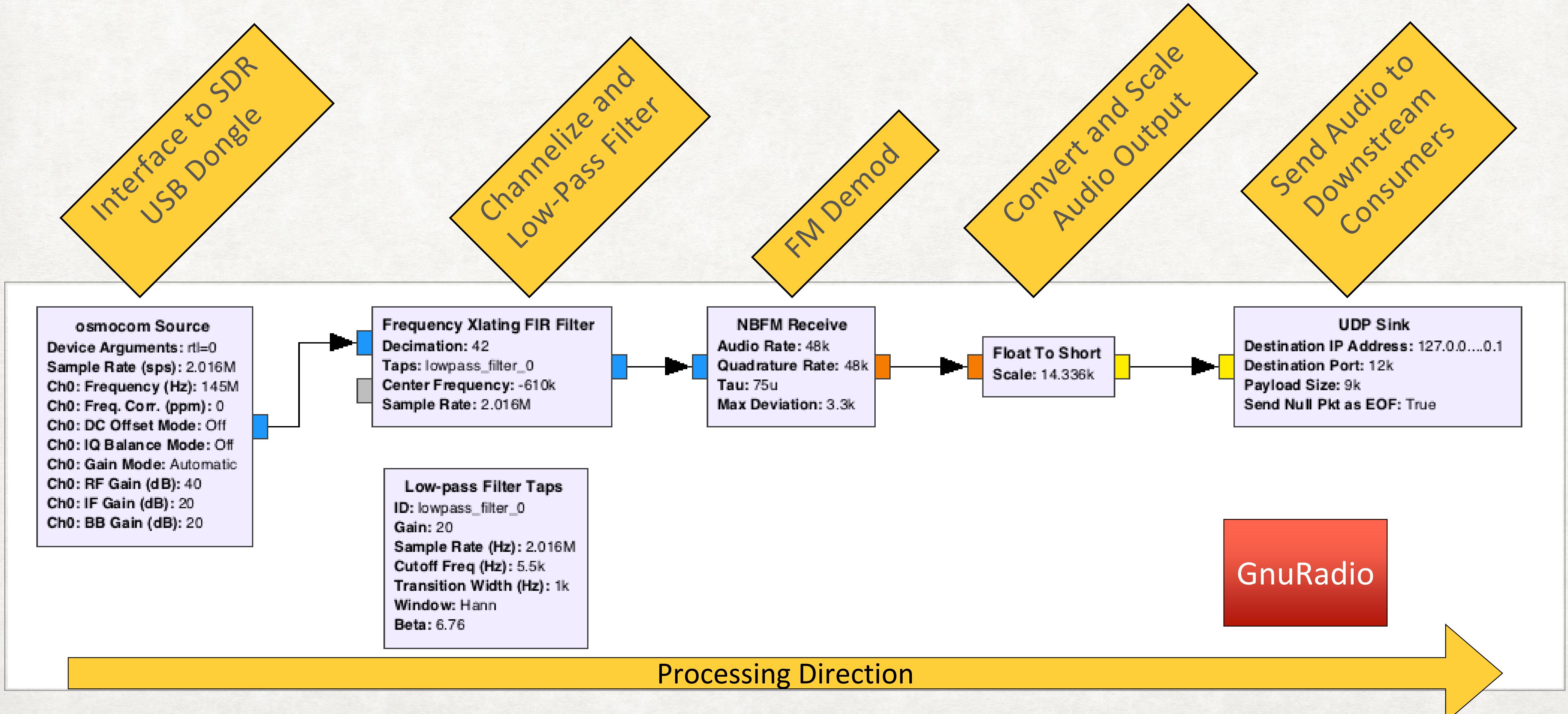
BLOCK DIAGRAM



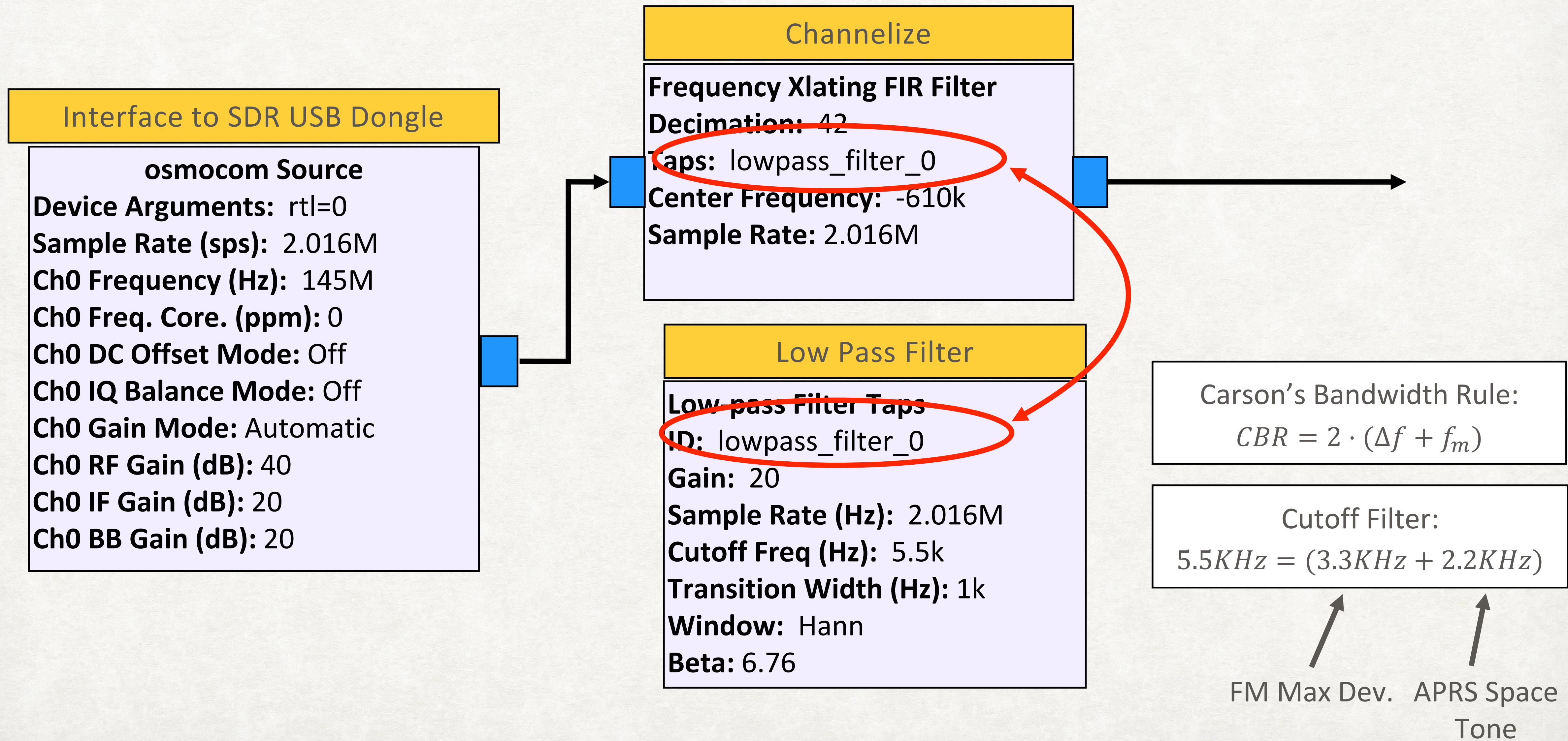
ARCHITECTURE



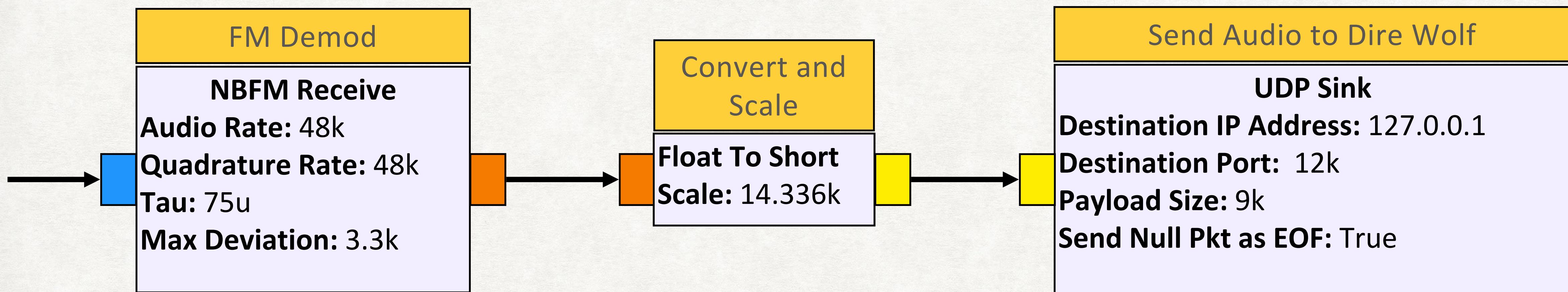
GNURADIO: SINGLE PROCESSING CHAIN



GNURADIO: DETAILS



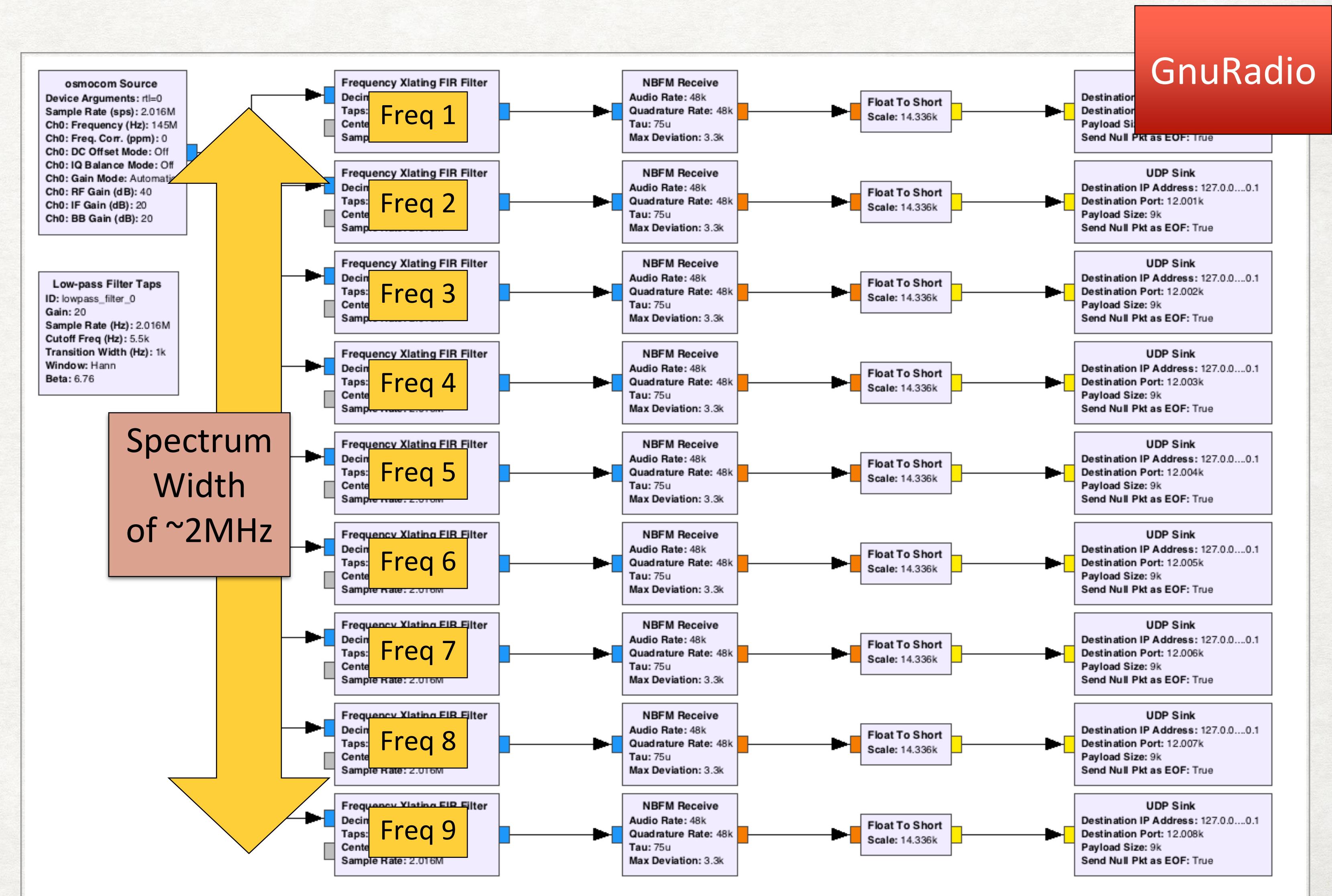
GNURADIO: DETAILS CONT.



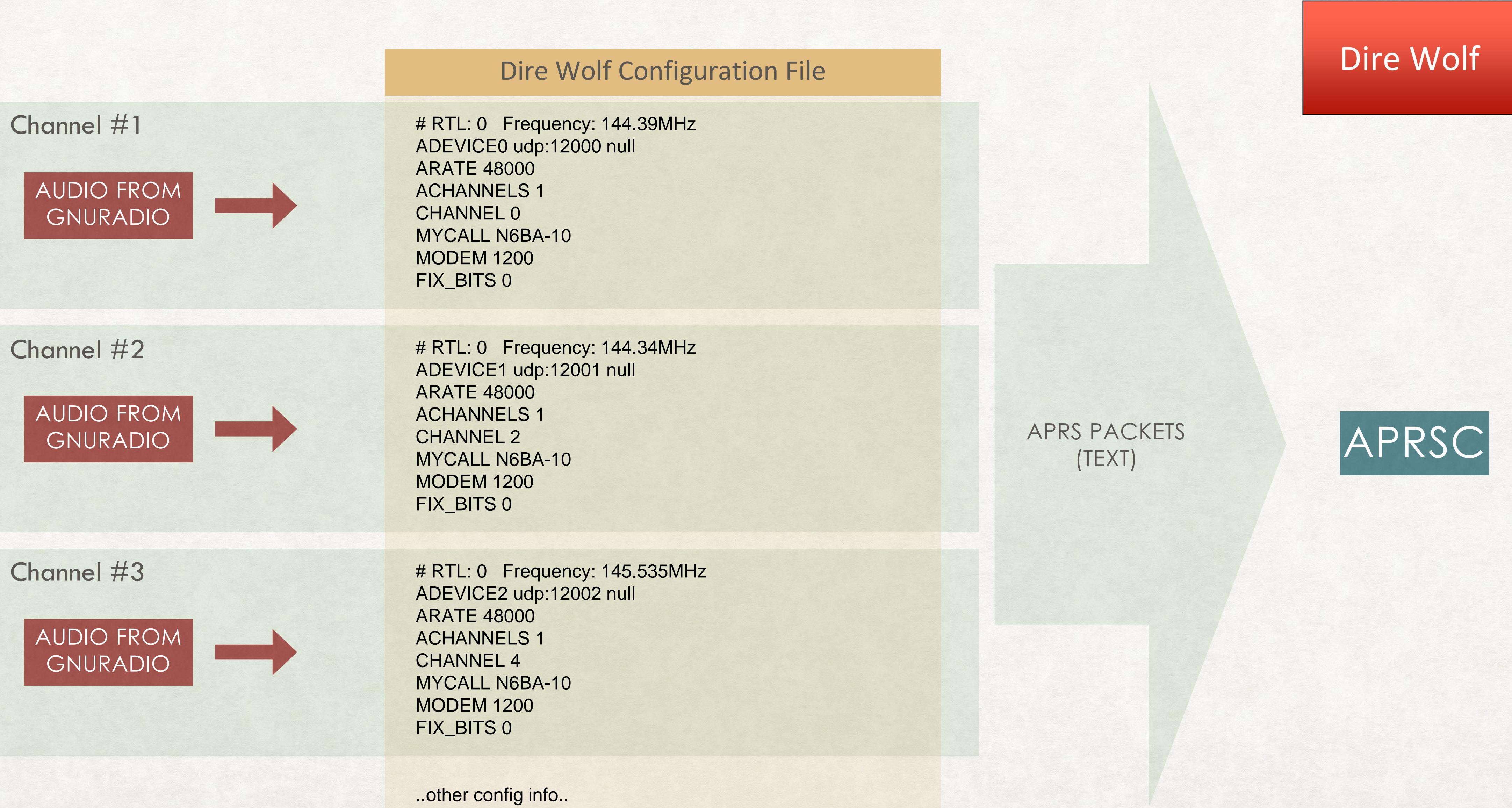
GNURADIO: LOTS-O-PROCESSING CHAINS

Benefits

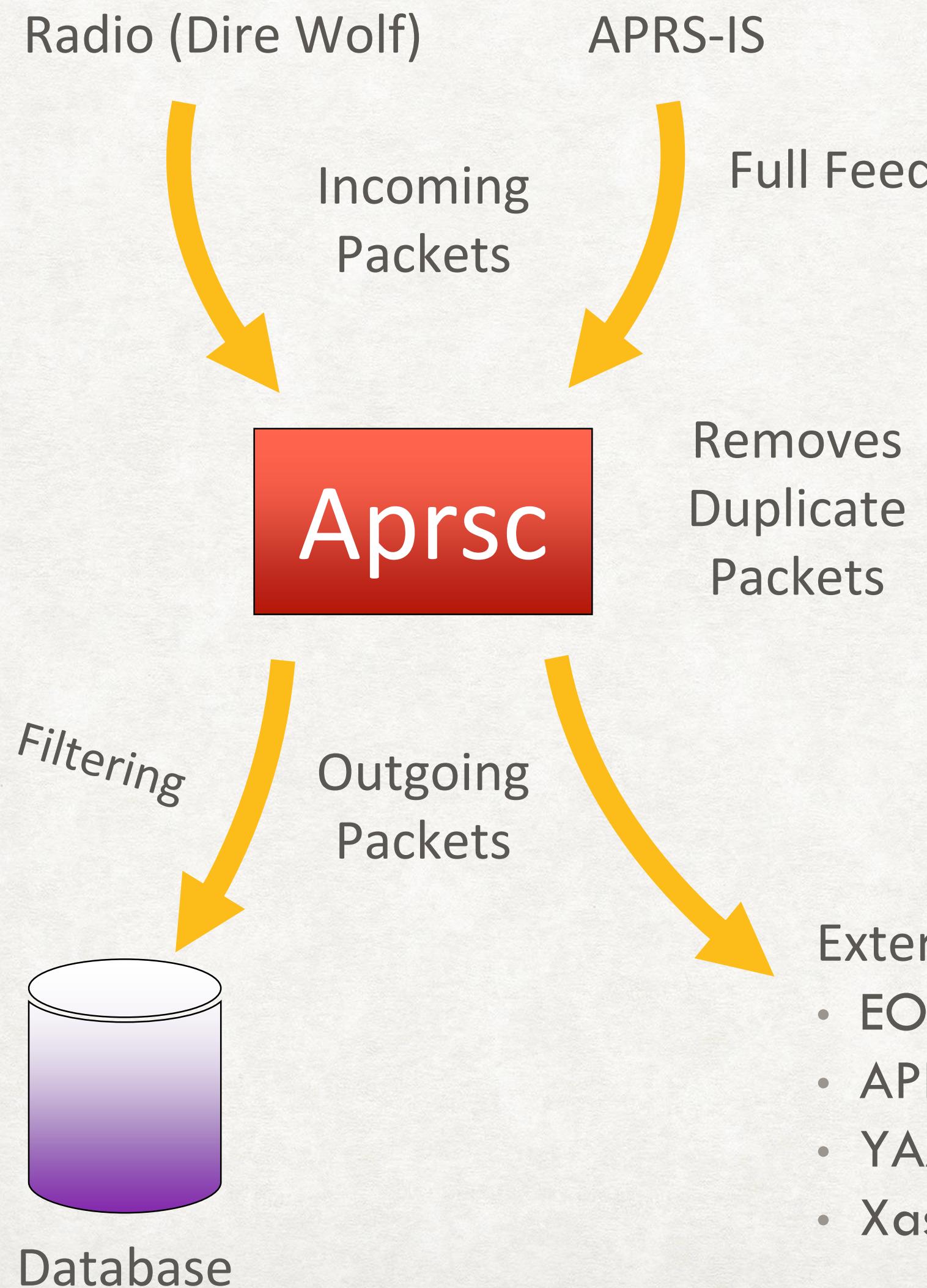
- Frequency agile (within spectrum width)
- Parallel processing
- Processing chains built dynamically at startup
- Platform tested with up to 9 processing chains
- Always listens on 144.39MHz



DIRE WOLF



APRSC



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"
Listen ""
Listen "Client-Defined Filters"
Listen ""
Uplink "Core rotate" ro tcp noam.aprs2.net 10152
HTTPStatus 0.0.0.0 14501
FileLimit 10000

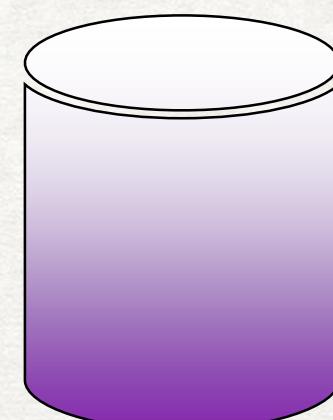
fullfeed tcp :: 10152 hidden
fullfeed udp :: 10152 hidden
igate tcp :: 14580
igate udp :: 14580
```

- External Clients:
- EOSS TrackPoint
 - APRSISCE
 - YAAC
 - Xastir

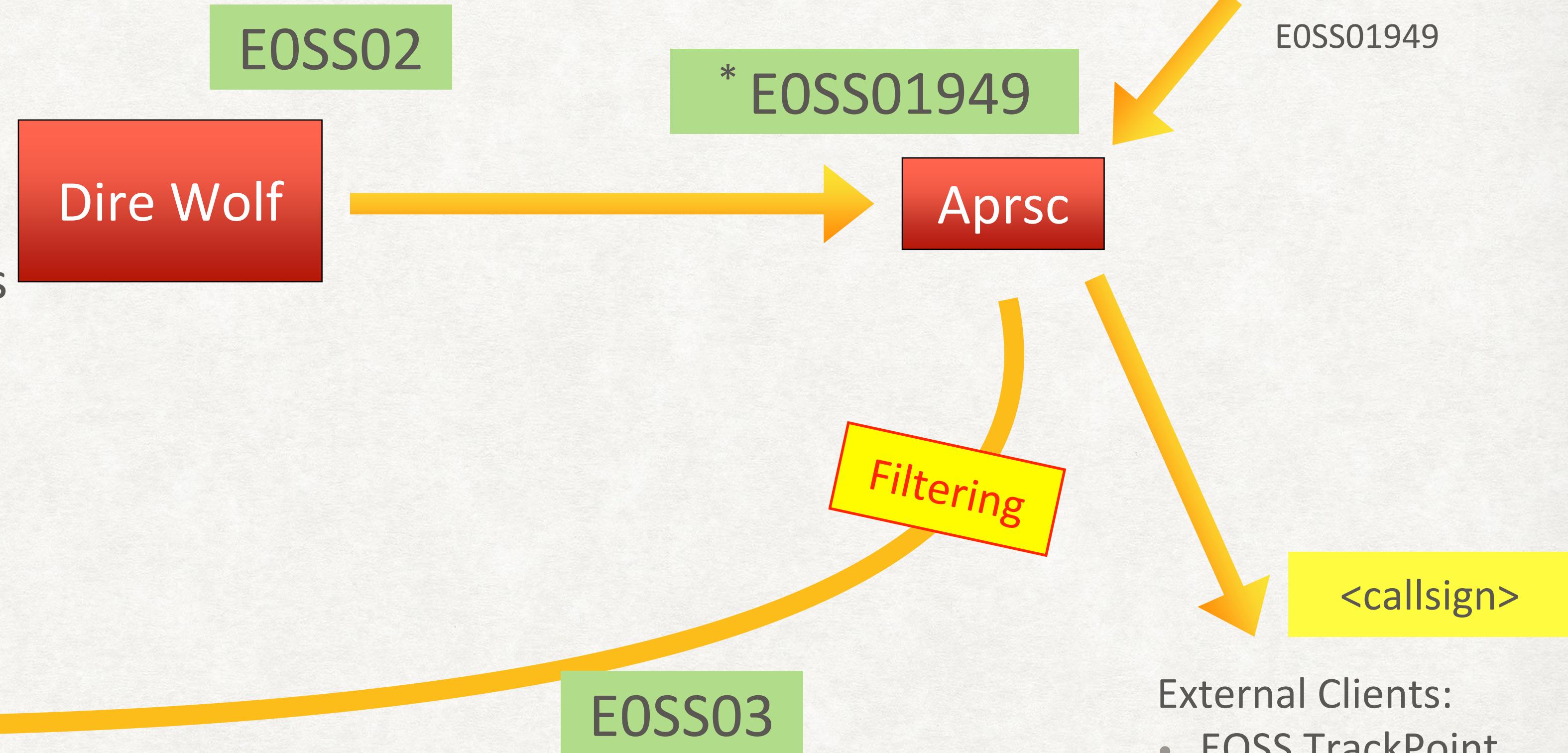
CALLSIGNS: DEFAULT BEHAVIOR

Callsigns

- **EOSS0x** callsign used internally
- For external client connections to APRSC, use individual callsign+passcode



Database



* The system will use randomized numbers to prevent duplicates



APRS-IS

EOSS01949

<callsign>

External Clients:

- EOSS TrackPoint
- APRSISCE
- YAAC
- Xastir

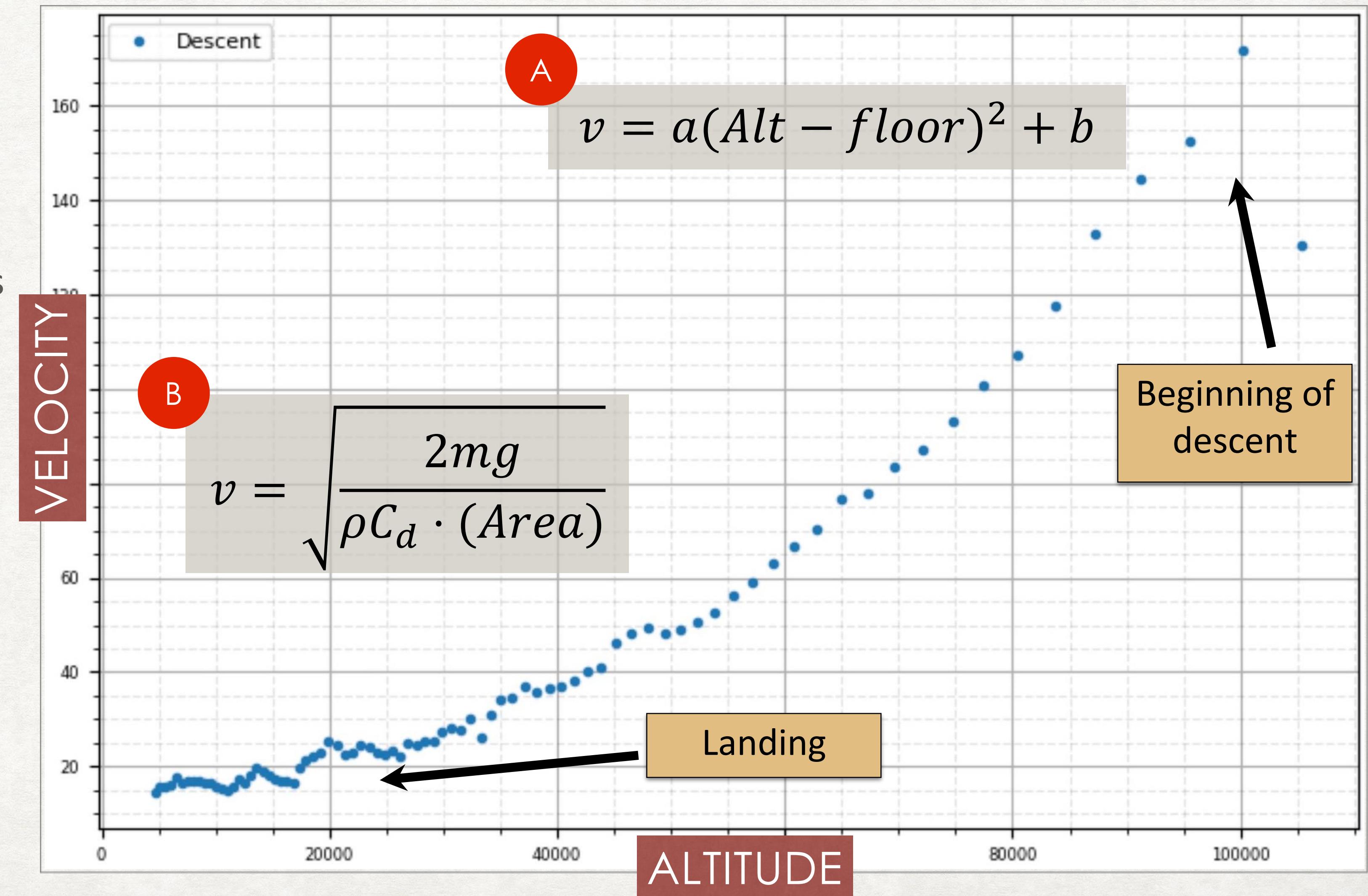
LANDING PREDICTIONS: ALGORITHM

During the Ascent

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

During the Descent

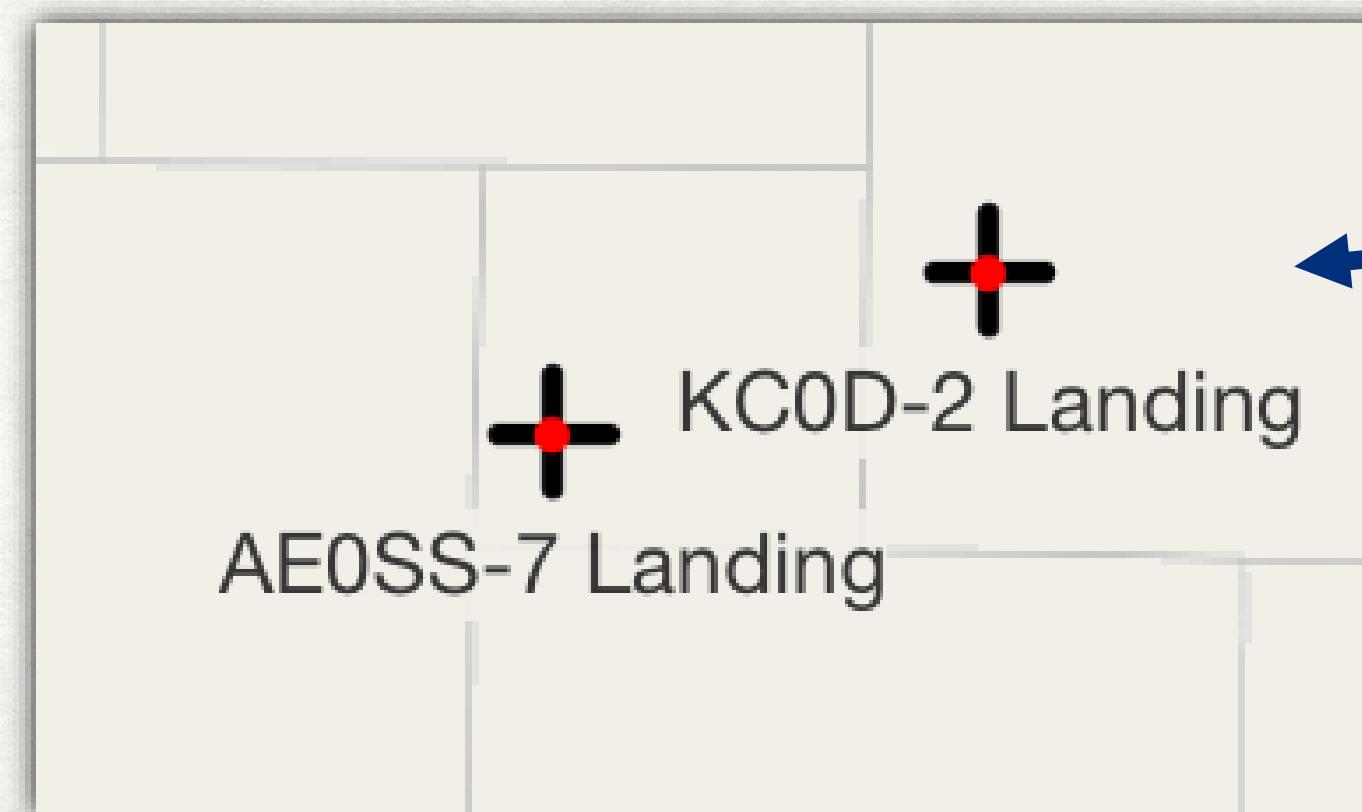
- Upper portion of descent uses curve fitting (A)
- Lower portion of descent uses drag equation for parachutes (B)
- Uses a piecewise, weighted function for predictions



LANDING PREDICTIONS: PLOTTING

About

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

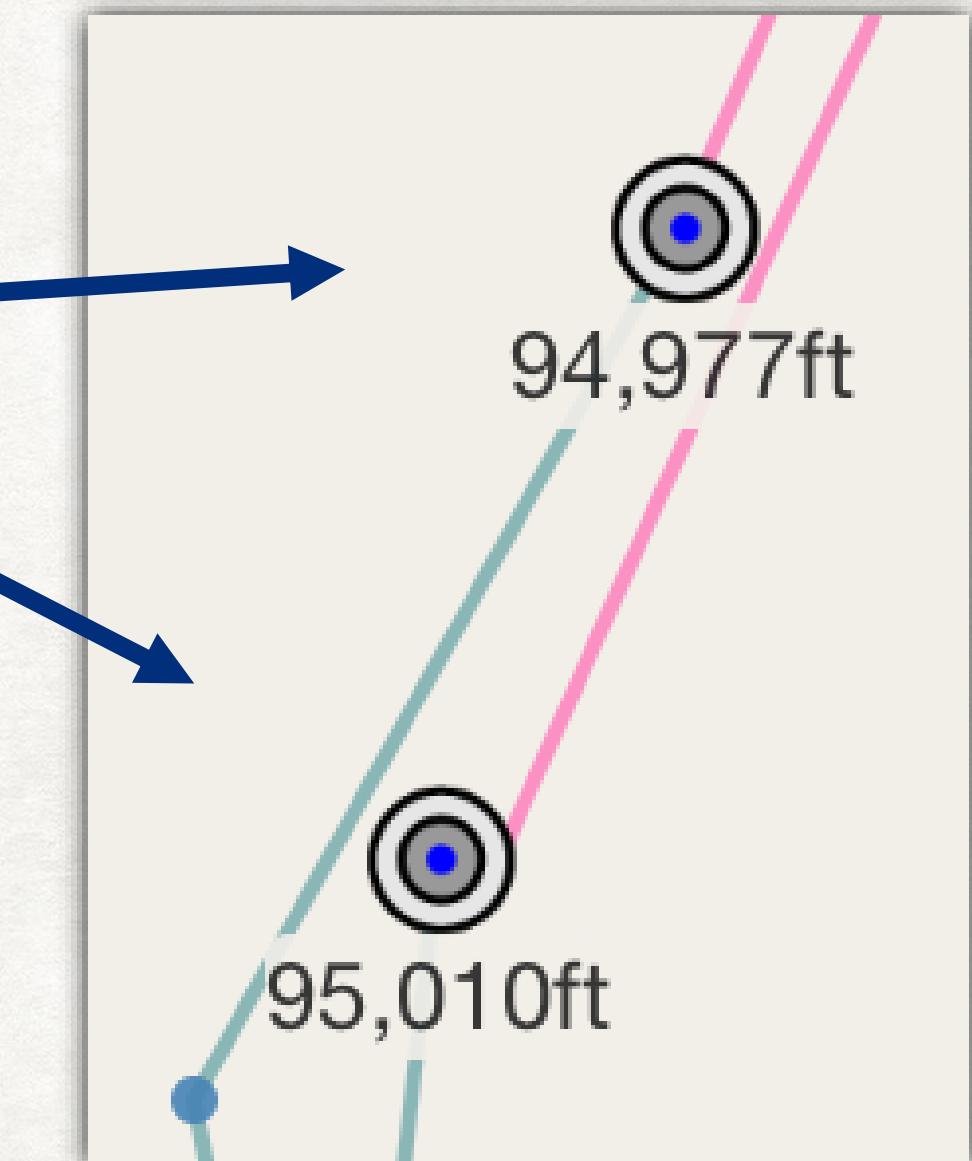


1

Approximate burst
location plotted on map
for each beacon

2

Once descending,
landing predictions
should be plotted on
the map



WHAT'S NEXT?

RELEASES

Version	Milestone	When	Notes
1.0	Initial release	Jan 2019	Initial release as part of the EOSS Kit
1.1	Current release	Spring 2019	Major usability improvements, prediction accuracy, filtering, beaconing, time zones
1.1 (generic?)	Community release	Fall 2019	Community version without EOSS specifics
1.2	Feature release	?	Kiosk/public-facing, grid coordinates (UTM), dashboards, audio notifications, frequency list management
2.0	Major platform change	Early 2020	Move platform to NodeJS backend, map sources, vector maps, inclusion of other GIS data (ex. Fed, BLM, state, counties, etc.)

FORKING THE CODE



EOSS-Specific Version

- Built for specific hardware platform
- Designed to work with current flight systems/beacons/frequencies
- Already have 30 systems in the field to support



Community Version

- Minus EOSS-specifics
- Minus offline maps (homework for the end user)
- GitHub repository for development
- Ubuntu personal package archive (PPA) for simple updates/upgrades

SHAMELESS SELF PROMOTION

BTW, we can also track your
flights tomorrow!

THANK YOU

