AIRBORNE WEATHER AND TRAFFIC INFO USING RASPBERRY PI

CHICAGO UNIFORUM – 28 JUNE, 2016

GRANT PRELLWITZ

GRANT PRELLWITZ

- Prellwitz Computing Services started 1984
- Harper College programmer 2001
- FAA Certifications
  - Private Pilot 2004
  - Instrument rating 2006
  - FAA Ground Instructor (Advanced, Instrument) 2007

WHAT WE'LL COVER

- RADAR – Air Traffic Control Surveillance
- The Automatic Dependent Surveillance – Broadcast
- Security Concerns
- What is Stratux
- Stratux vs. Commercial
- Building Stratux
- In the Cockpit: weather & traffic
- At Home: FlightAware & PiAware

ATC SURVEILLANCE

PRIMARY RADAR

- High-frequency waves sent out
- Measures time to return

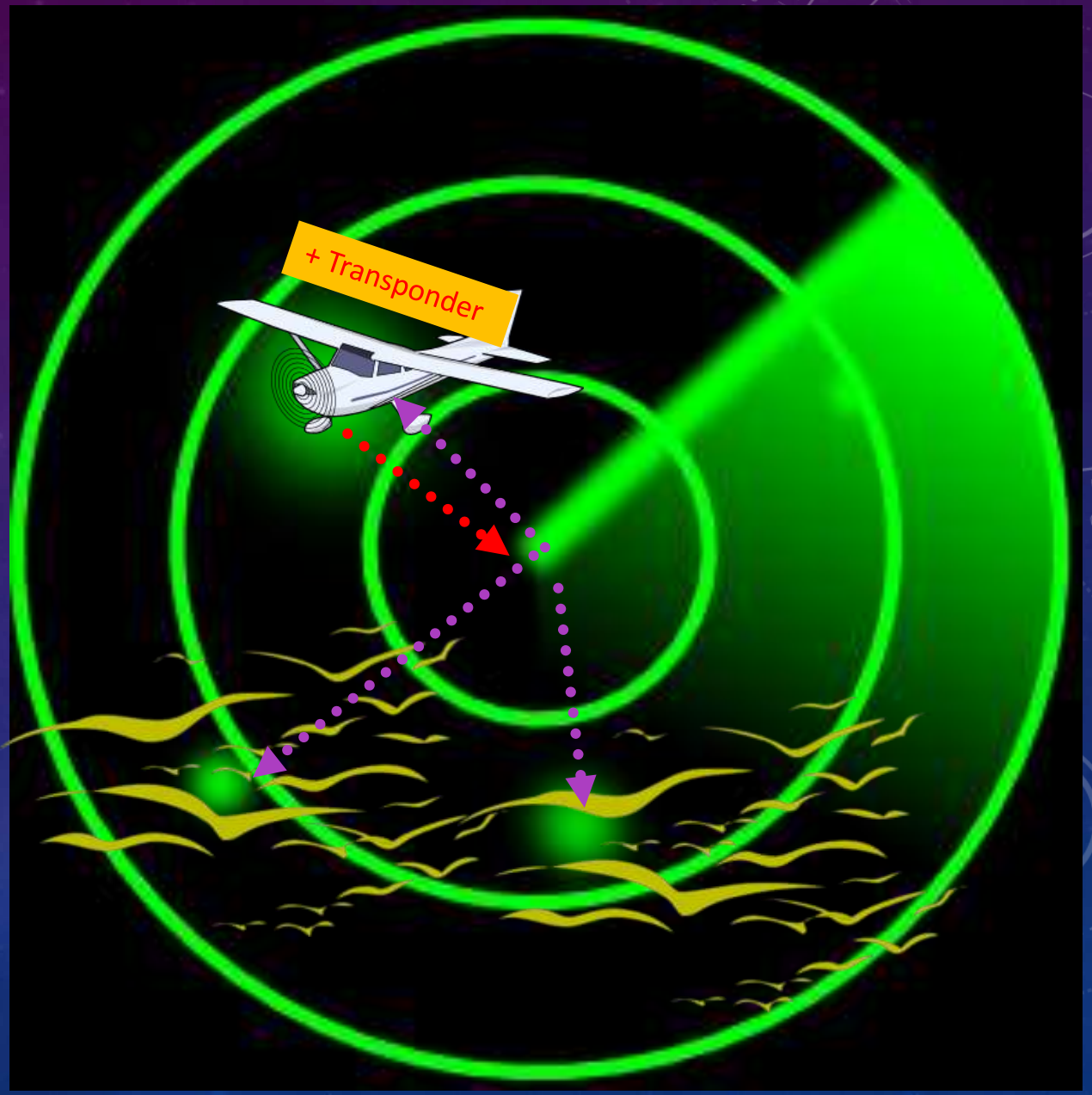
By Unknown - FAA ASR-9/Mode S Service Life Extension Program Photogaller, transfered from English Wikipedia where it was uploaded originally by w:en:User:Dmcdevit, Public Domain, https://commons.wikimedia.org/w/index.php?curid=2762854

SECONDARY RADAR

Transponder Types:

Mode A : 4 digit code
Mode C : + altitude

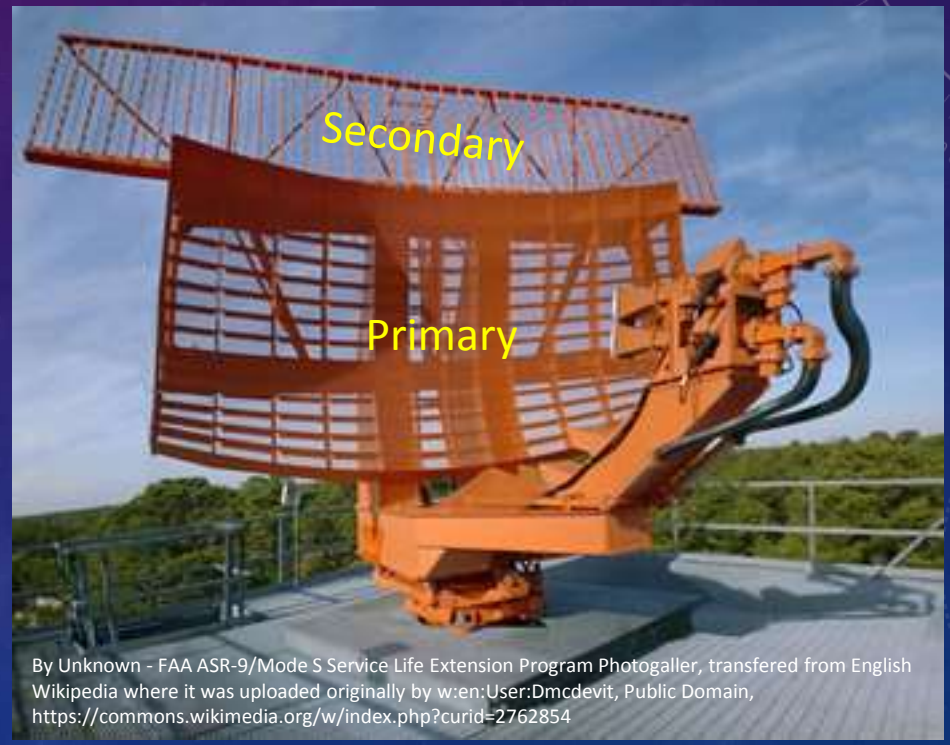
Mode S : + aircraft call sign, fixed 24-bit address



HOW THE ATC SURVEILLANCE SYSTEM WORKS

RADAR Limitations

- Line of sight
- Accuracy decreases with distance
- Requires ground station
- 4 – 20 sweeps per minute
- Location only sent to ATC
- Expensive to maintain



By Unknown - FAA ASR-9/Mode S Service Life Extension Program Photogaller, transfered from English Wikipedia where it was uploaded originally by w:en:User:Dmcdevit, Public Domain, https://commons.wikimedia.org/w/index.php?curid=2762854

ADS-B

ADS-B

Automatic – No interrogation

Dependent – Rely on others

Surveillance – Who and where

Broadcast – Party line

ADS-B

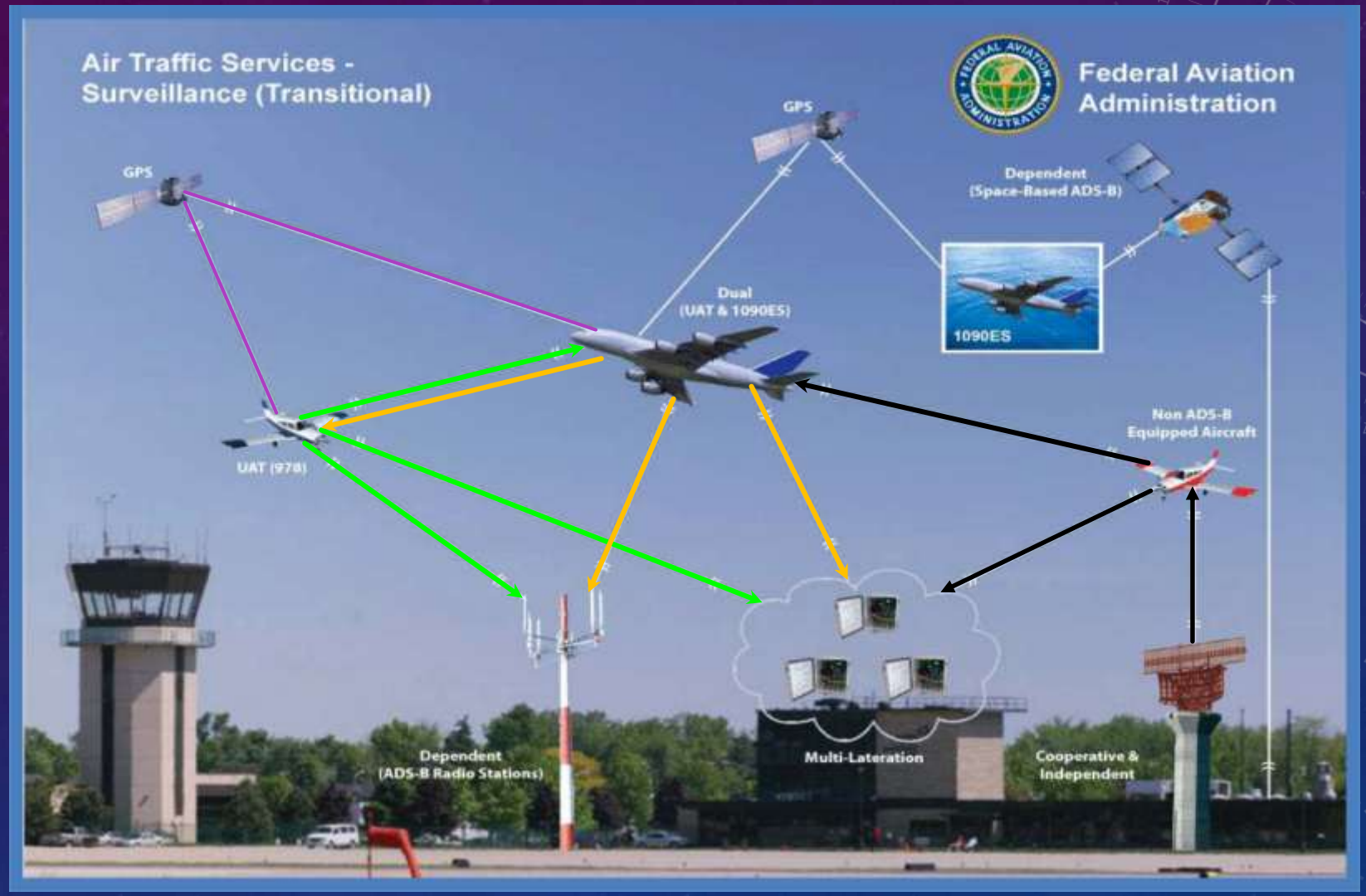
1090ES

- 1090MHz
- Airlines
- International
- Congested frequency
- No weather

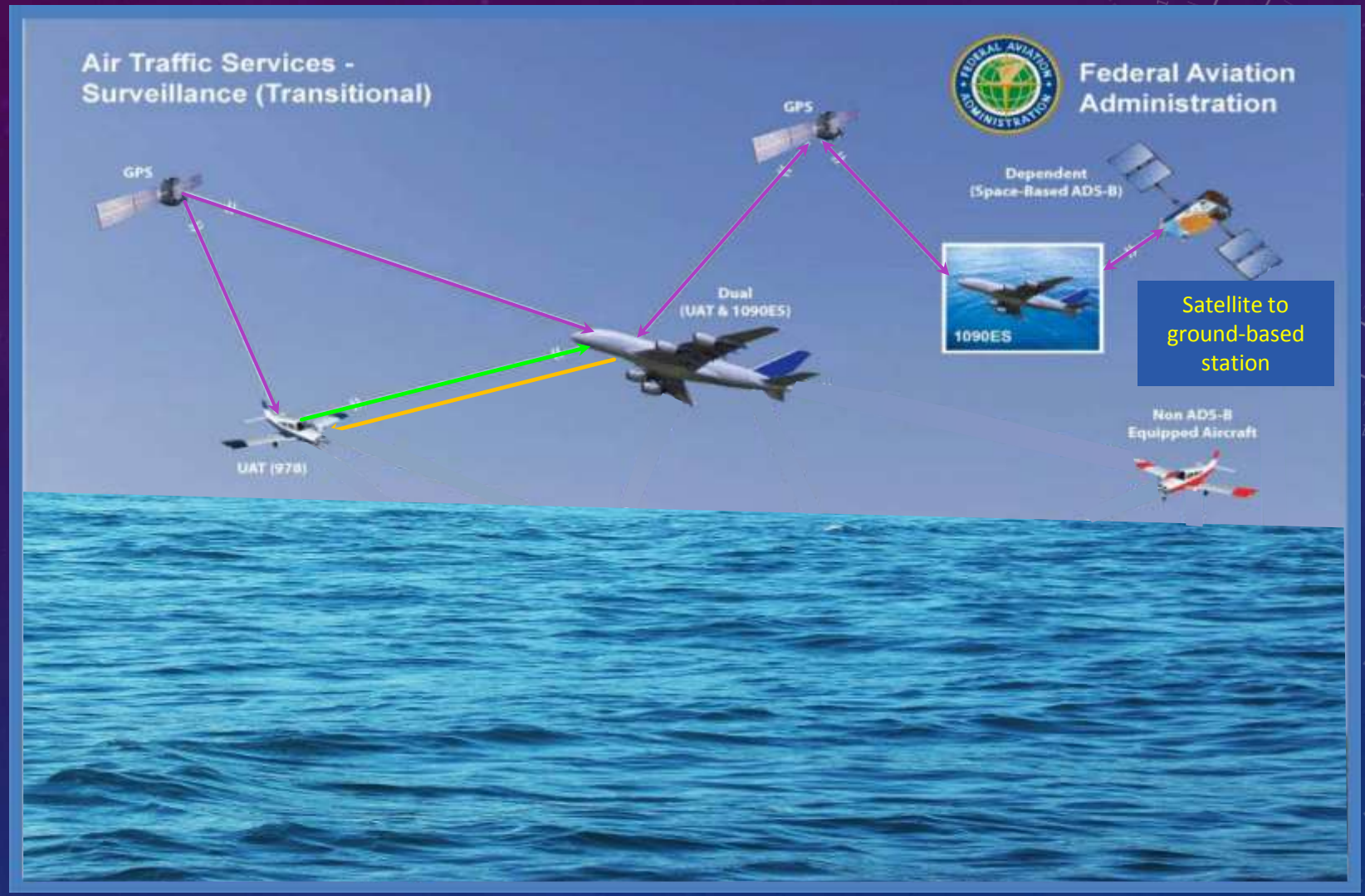
UAT

- 978MHz
- General Aviation (below 10,000’)
- US Only
- Uncongested frequency
- Weather

ADS-B OUT


Air Traffic Services -
Surveillance (Transitional)
Federal Aviation Administration
GPS
GPS
Dependent
(Space-Based ADS-B)
Dual
(UAT & 1090ES)
1090ES
UAT (978)
Non ADS-B
Equipped Aircraft
Dependent
(ADS-B Radio Stations)
Multi-Lateration
Cooperative &
Independent

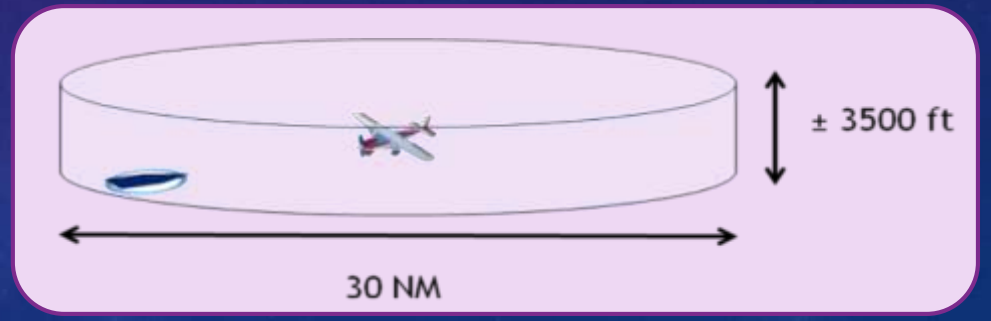
ADS-B OUT


Air Traffic Services -
Surveillance (Transitional)
Federal Aviation Administration
GPS
GPS
Dependent
(Space-Based ADS-B)
Dual
(UAT & 1090ES)
1090ES
Satellite to ground-based station
Non ADS-B Equipped Aircraft
UAT (978)

ADS-B IN

Traffic Information Service – Broadcast (TIS-B)

- Traffic direct from other aircraft
- Ground stations integrate information
  - 1090ES, UAT, Regular RADAR returns
  - Limited coverage area
- Display on cockpit display
  - Panel mount or Tablet



FLIGHT INFORMATION SYSTEMS –BROADCAST (FIS-B)

- Weather
- Subscription-free
- Comparable to XM Aviation Weather ($35-55/mo)
- Only on UAT

SECURITY & PRIVACY

SECURITY ISSUES

- Eavesdropping
- Jamming
  - Ground station flood denial
  - Aircraft flood denial
- Message Injection
  - Ground Station Target Ghost Injection/Flooding
  - Aircraft Target Ghost Injection/Flooding
- Message Deletion
  - Aircraft Disappearance
- Message Modification
  - Virtual aircraft hijacking
  - Virtual trajectory modification

Source: On the Security of the Automatic Dependent Surveillance-Broadcast Protocol

Martin Strohmeier∗, Vincent Lenders+, Ivan Martinovic∗ ∗University of Oxford, United Kingdom +armasuisse, Switzerland

arXiv:1307.3664v2 [cs.CR] 15 Apr 2014

STRATUX VS COMMERCIAL

WEATHER IN THE COCKPIT

1. No in-cockpit weather
   - Check before leaving
   - Get briefing on radio via Flight Watch
   - Must visualize weather
2. Garmin 496 Aviation GPS
   - $3000 unit (in 2007)
   - $55/month XM Weather ($660/yr)
   - $13/month XM Audio ($156/yr)
   - Works on the ground or in the air
3. Sporty's Stratus v1 ADS-B In
   - $800 unit (in 2014)
   - Single-band (978 UAT)
   - No weather subscription cost
   - No music, but iPad provides that
   - Power input broke, replaced with v2 dual band w/AHRS (Attitude Heading & Reference System)
4. Stratux ADS-B In
   - $130
   - Single-band (978 UAT)

STRATUX

- Build-it-yourself ADS-B In receiver conceived by Christopher Young
- Raspberry Pi 2 or later
- ADS-B antenna(s) using either single or dual RTL-SDR (Realtek RTL2832U Software Defined Radio)
- Optional GPS
- WiFi to use tablet display for many electronic flight bag (EFB) applications

- Raspbian OS (Debian-based)
- Numerous languages:
  - Google's Go
  - C
  - Python
  - JavaScript/HTML 5
  - bash

STRATUX VS COMMERCIAL

Stratux

- Based on Raspberry Pi
- Do-it-yourself, Upgradeable
- Crowd-sourced testing
- $75-$300
- Single or dual (optional $25) band
- GPS (optional $20-$35)
- No AHRS (in development)
- Case (optional $20-$50)

Commercial

- Proprietary architecture
- Prebuilt, Not upgradeable
- Professionally tested
- $500-$900
- Single or dual band
- GPS
- AHRS (optional)
- Case included

ADS-B WEATHER VS XM WEATHER

	ADS-B	XM
METARs	Yes. Low altitude stations provide data within 250-500nm. High altitude stations provide wider coverage	Yes, nationwide
TAFs	Yes, within 250-500nm	Yes, nationwide
Winds/Temps Aloft	Yes, within 500-1,000nm	Yes, nationwide
PIREPs	Yes, within 250-500nm	Yes, nationwide
Radar	Yes, for CONUS and some local U.S. regions elsewhere	Yes, for CONUS, Canada, and PR
Satellite Clouds	**No**	Yes
TFRs	Yes, within 100nm	Yes, nationwide
NOTAMs	Yes, within 100nm	**No**
AIRMET/SIGMET	Yes, within 250-500nm	Yes, nationwide
Special Use Airspace status	Yes, within 250-500nm	**No**

From https://www.foreflight.com/support/xmvfisb/

APPS WITH STRATUX RECOGNITION/SUPPORT

- Seattle Avionics FlyQ EFB 2.1.1+ (iOS)
- AvNav EFB 2.0.0+ (iOS)
- Naviator (Android)
- WingX Pro7 8.6.2+ (iOS)
- **FltPlan Go** (iOS, Android)
- AerovieReports (iOS)
- AvPlan EFB (iOS, Android?)
- iFly GPS 9.4+ (iOS, Android)
- DroidEFB 2.1.1+ (Android)

Tested weather/traffic displays

- **ForeFlight 7**+** (iOS) - weather, traffic. AHRS not functional
- Avare (Android)

**ForeFlight has an exclusive relationship with Appareo and Sporty's to market Stratus and does not support Stratux.

BUILDING STRATUX

PREBUILT

- Open Flight Solutions https://www.openflightsolutions.com/
- Quick-build kit
- $295,
  - Dual band (1090ES, 978 UAT)
  - Fan
  - High gain ½ wave antennas
  - GPS
  - Case
  - Support
  - No battery

HARDWARE


Kingston
8GB
Preloaded
With STRATUX

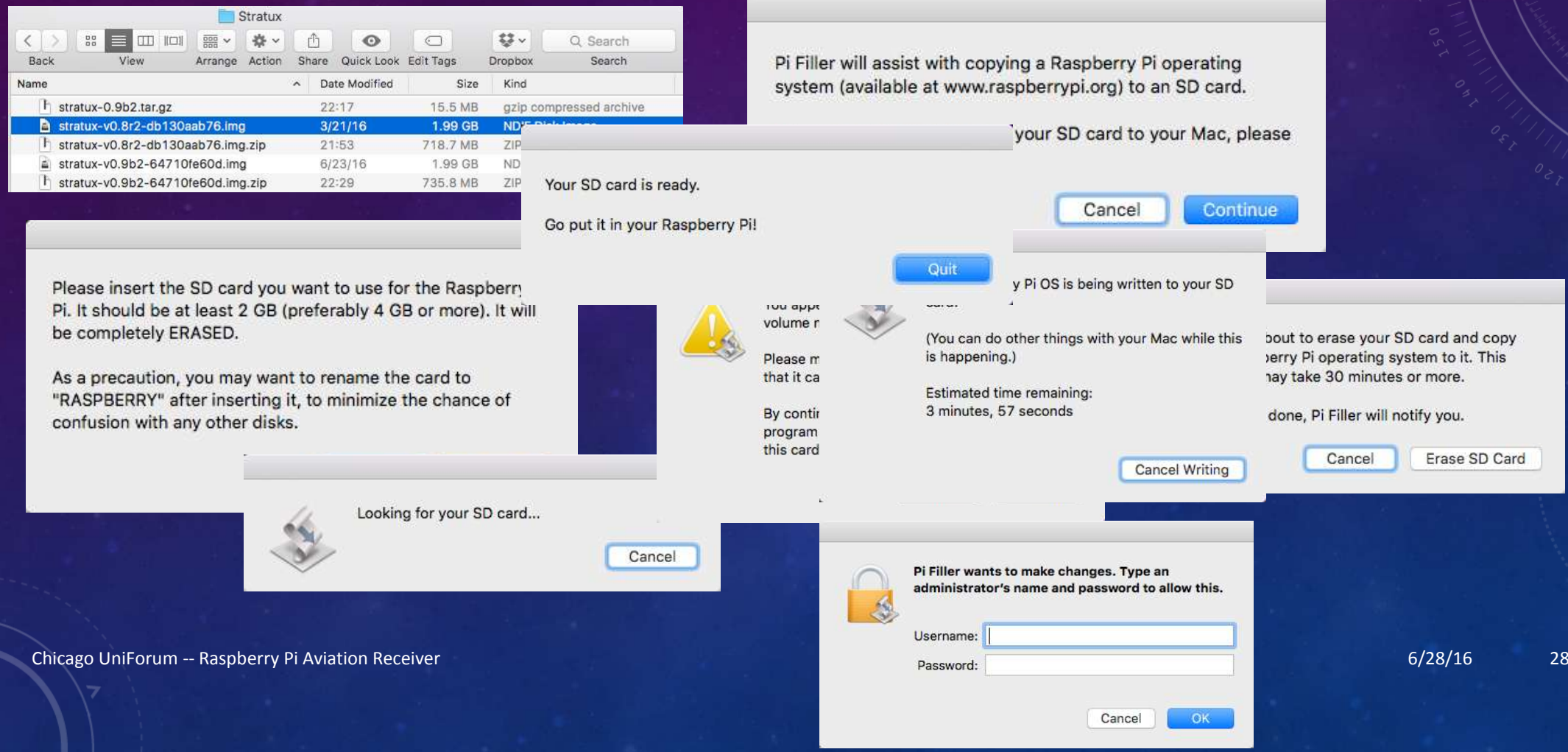

NooElec
NESDR
Nano 2
NooElec


Thingiverse
DASHBOARD
EXPLORE
LEARN
CREATE
Stratux Dual Band ADS-B TuffCase

BUILDING STRATUX – AVIATION RTL-SDR

- RTL-SDR – Realtek Software Defined Radio
- Download Stratux-*.img.zip
  - stratux-v0.8r2-db130aab76.img.zip 719MB stable from http://stratux.me -- cyoung's site
  - stratux-v0.9b2-64710fe60d.img.zip 735MB pre-release from https://www.reddit.com/r/stratux
- Unzip to .img file (about 2GB)
- Use Pi Filler (Mac) or Win32DiskImage (Windows) to write image to Micro SD card
- Source available at https://github.com/cyoung/stratux so you can tinker & contribute

STEPS WITH MAC

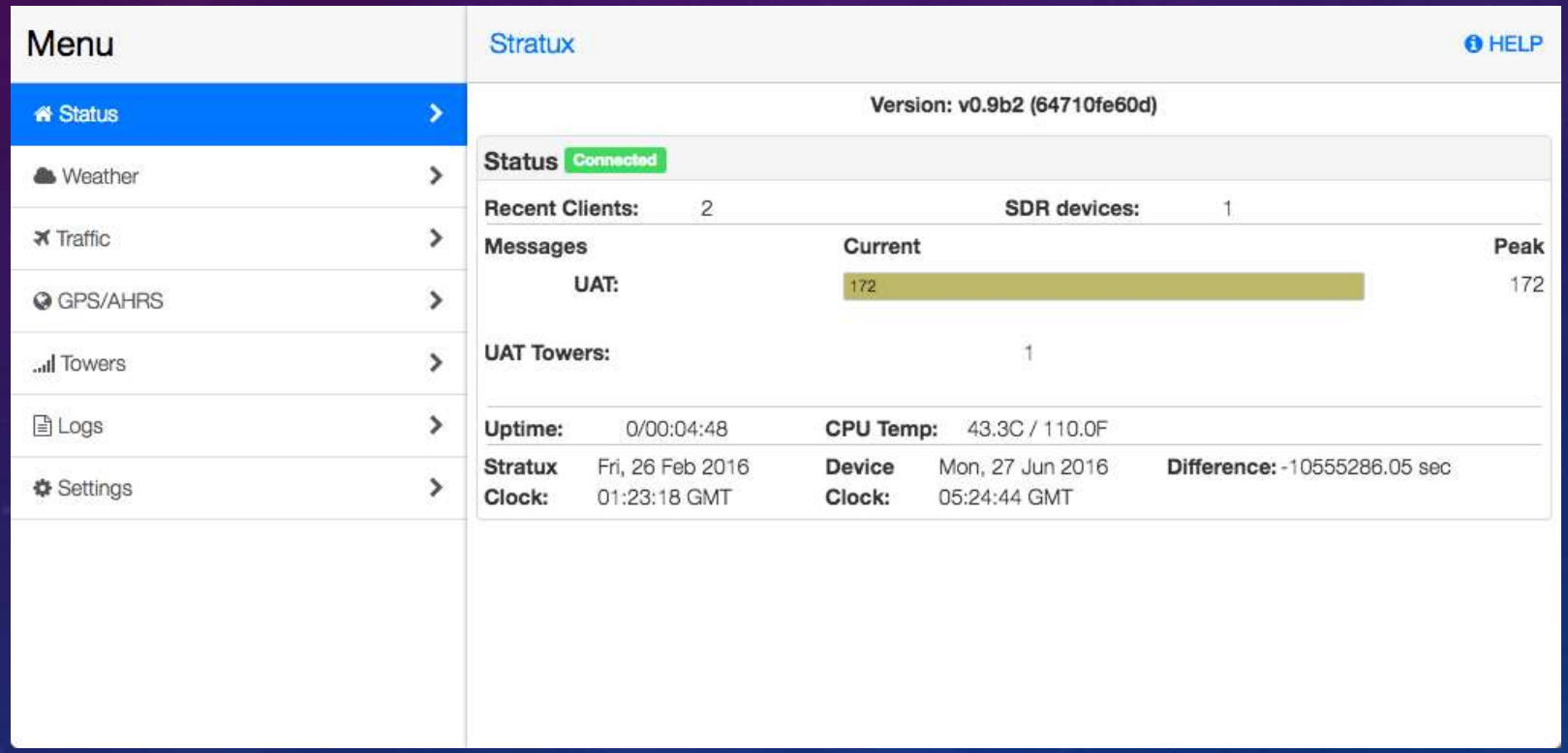


START UP

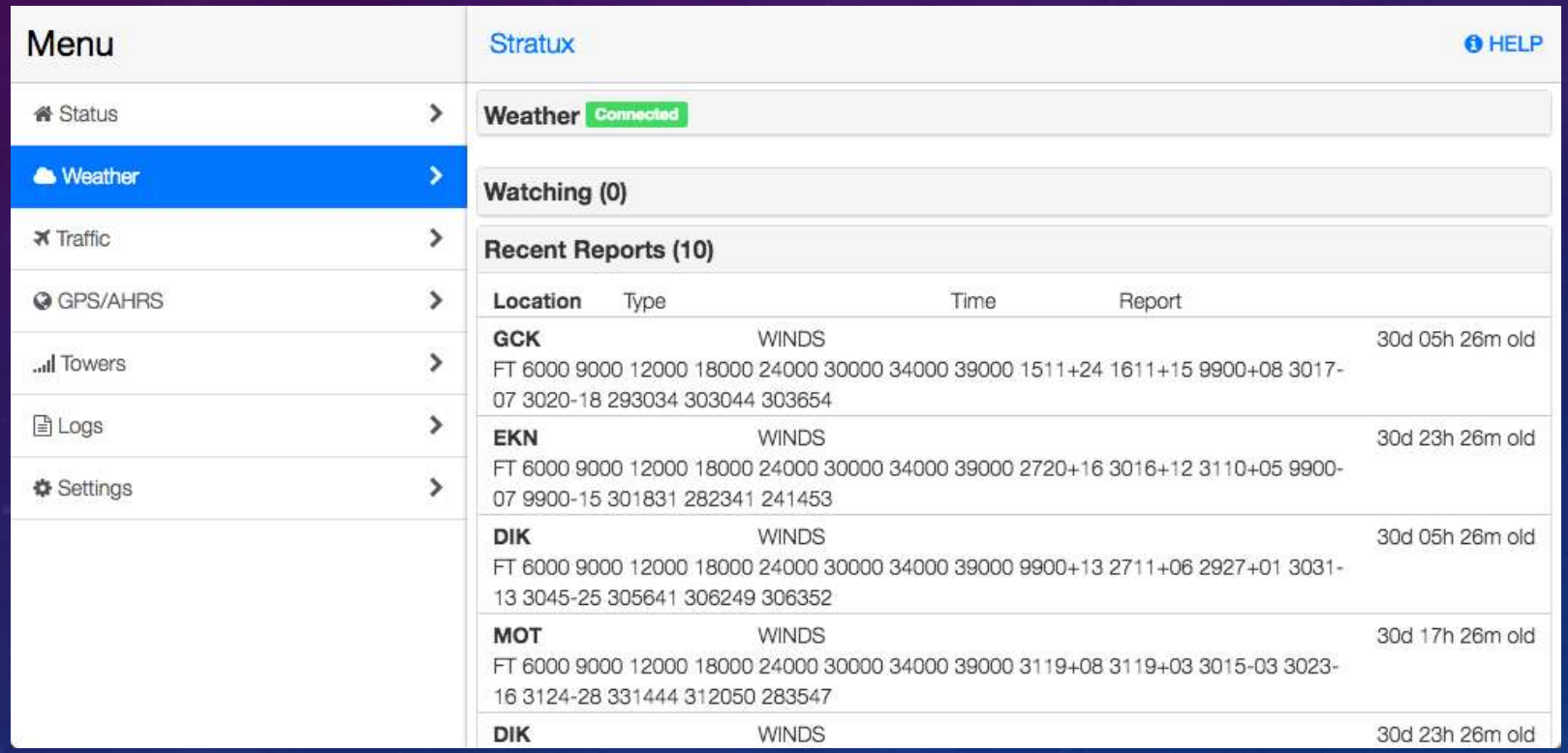
- Attach the heat sinks
- Snap the Raspberry Pi board into the case and snap the case top on
- Insert micro-SD card *after* putting the case top on
- Plug antenna(s) into USB ports – 1 or 2 ADS-B, GPS
- If using Raspberry Pi 2, plug in WiFi dongle. Not needed for RPi 3 or later.
- Plug into RELIABLE 2+ amp power supply (red light must be solid on)
- Green light should flash as the OS loads and the lights for the antennas should light
  - If the green light stays constant, the OS isn't loading properly
- Connect a device to the STRATUX WiFi and point a browser to http://192.168.10.1

STRATUX CONFIGURATION

STATUS – HTTP://192.168.10.1

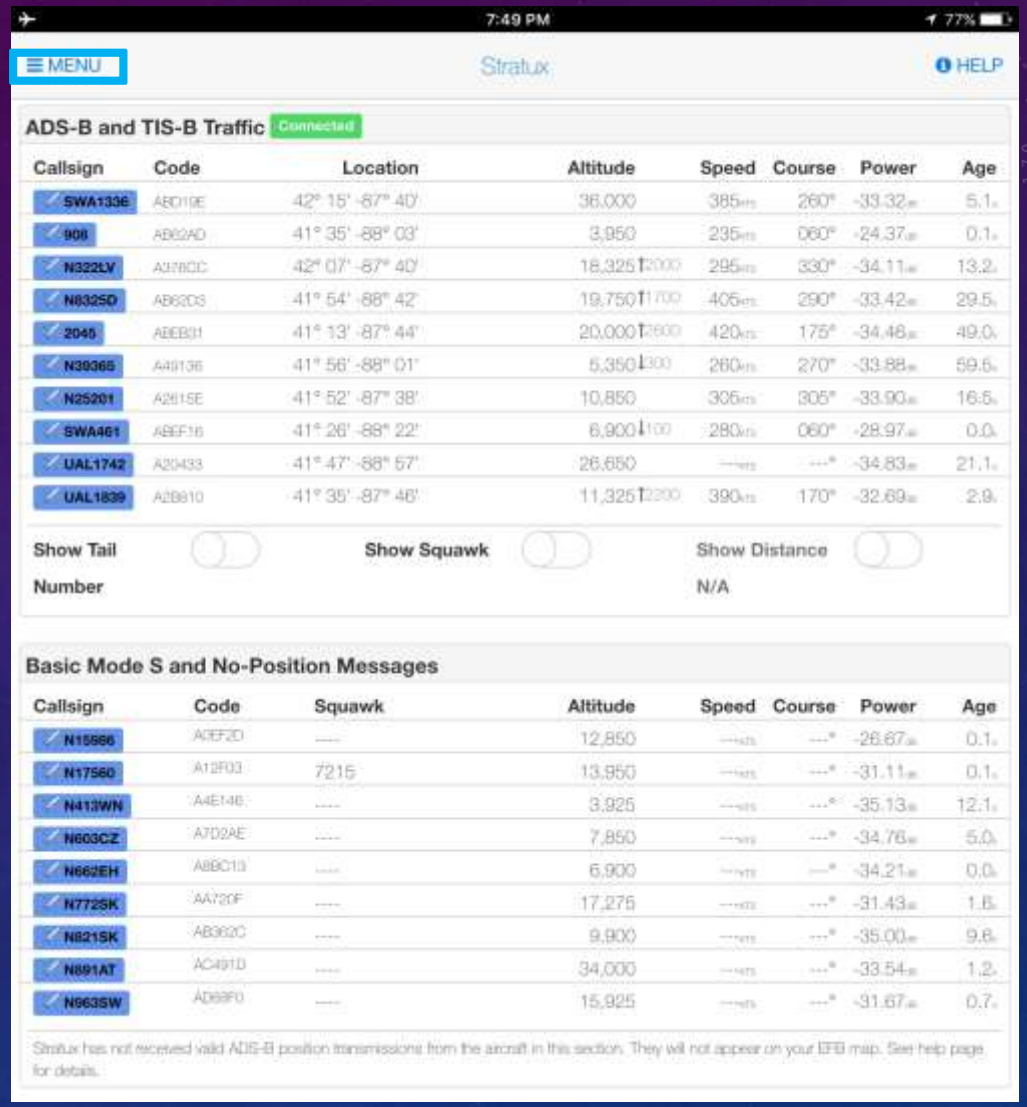


WEATHER

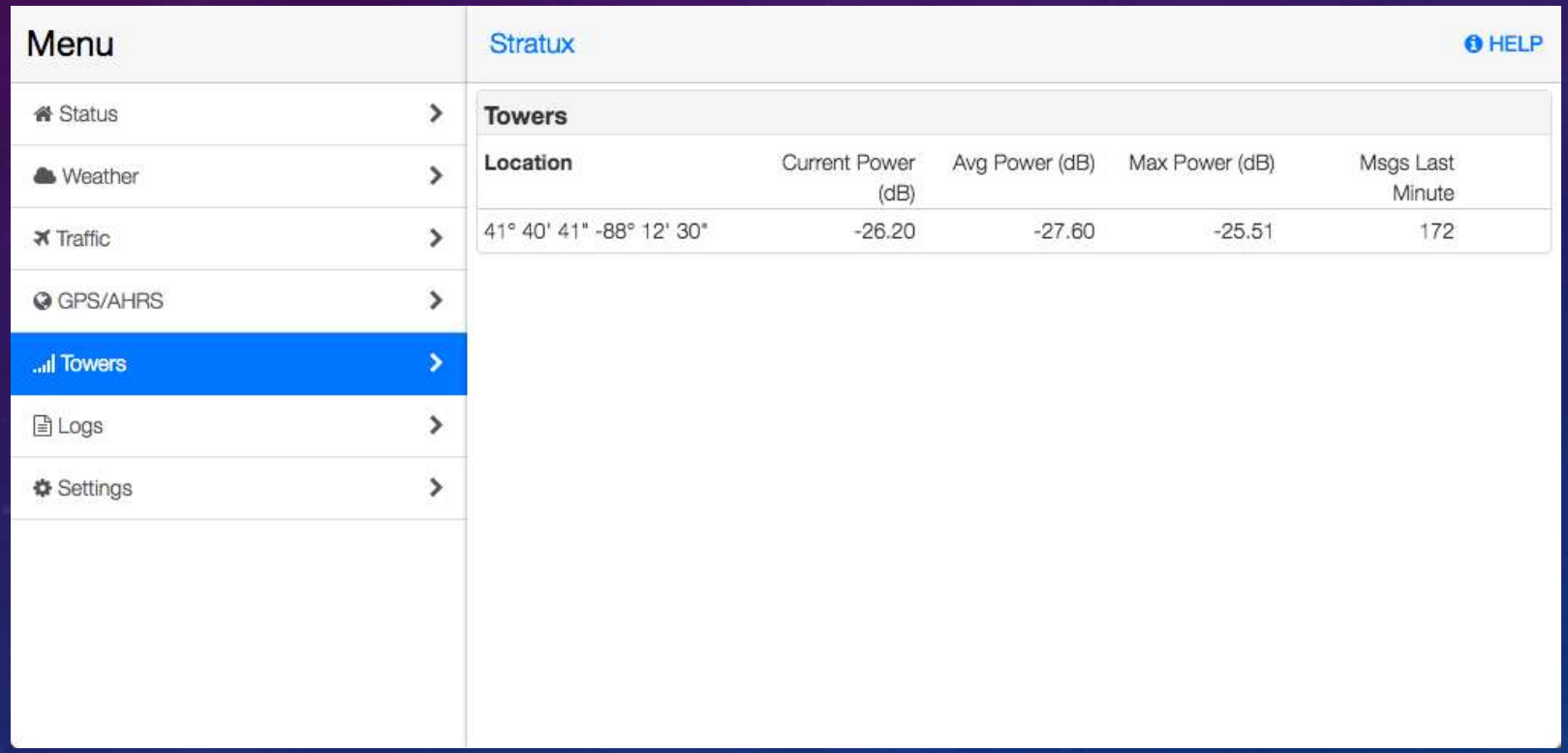

Menu
Status
Weather
Traffic
GPS/AHRS
Towers
Logs
Settings
Stratux
HELP
Weather Connected
Watching (0)
Recent Reports (10)
Location Type Time Report
GCK WINDS 30d 05h 26m old
FT 6000 9000 12000 18000 24000 30000 34000 39000 1511+24 1611+15 9900+08 3017-07 3020-18 293034 303044 303654
EKN WINDS 30d 23h 26m old
FT 6000 9000 12000 18000 24000 30000 34000 39000 2720+16 3016+12 3110+05 9900-07 9900-15 301831 282341 241453
DIK WINDS 30d 05h 26m old
FT 6000 9000 12000 18000 24000 30000 34000 39000 9900+13 2711+06 2927+01 3031-13 3045-25 305641 306249 306352
MOT WINDS 30d 17h 26m old
FT 6000 9000 12000 18000 24000 30000 34000 39000 3119+08 3119+03 3015-03 3023-16 3124-28 331444 312050 283547
DIK WINDS 30d 23h 26m old

TRAFFIC

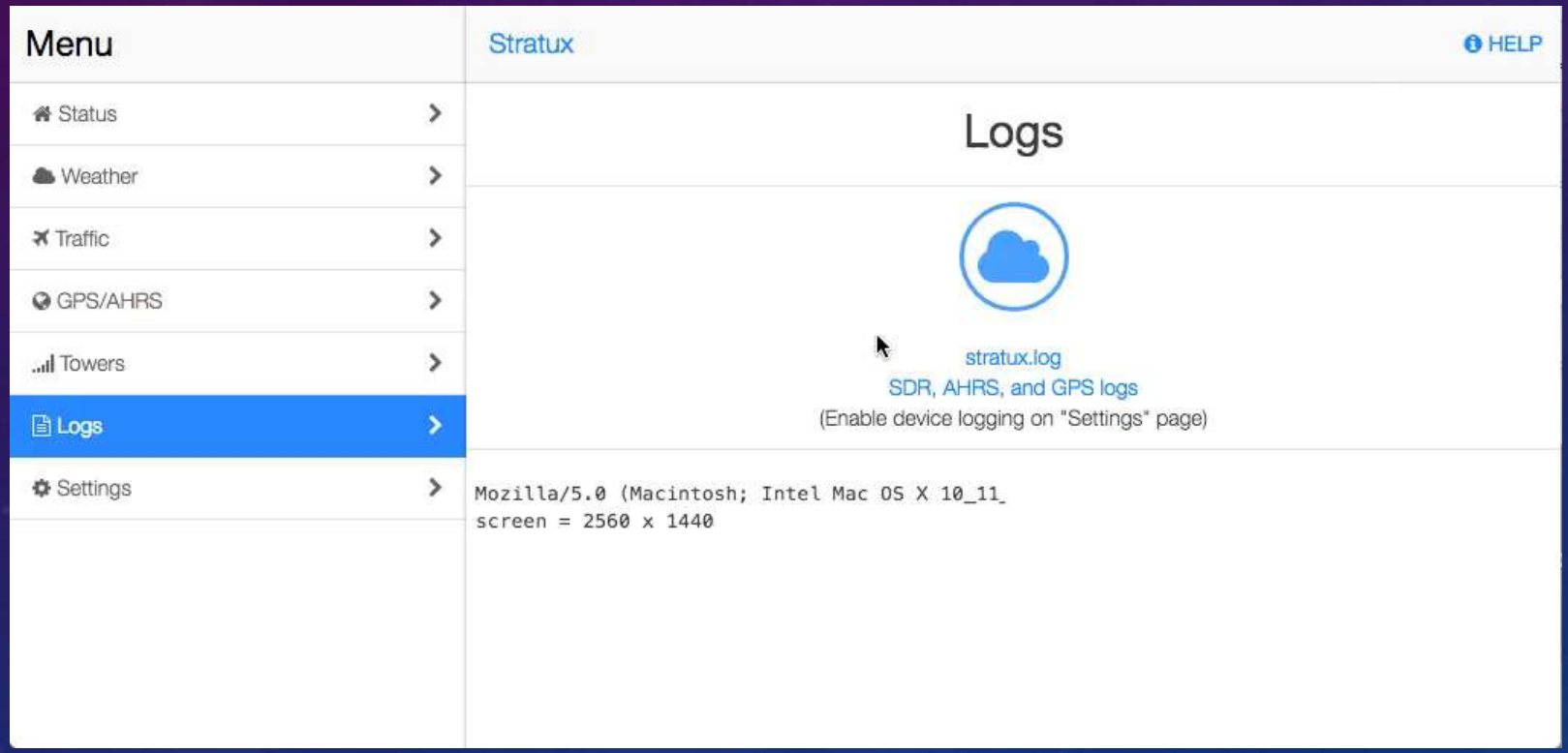
- Note responsive website
- Basic Mode S has no position



TOWERS


Menu
Stratux
HELP
Status
Weather
Traffic
GPS/AHRS
Towers
Logs
Settings
Towers
Location
Current Power (dB)
Avg Power (dB)
Max Power (dB)
Msgs Last Minute
41° 40' 41" -88° 12' 30"
-26.20
-27.60
-25.51
172

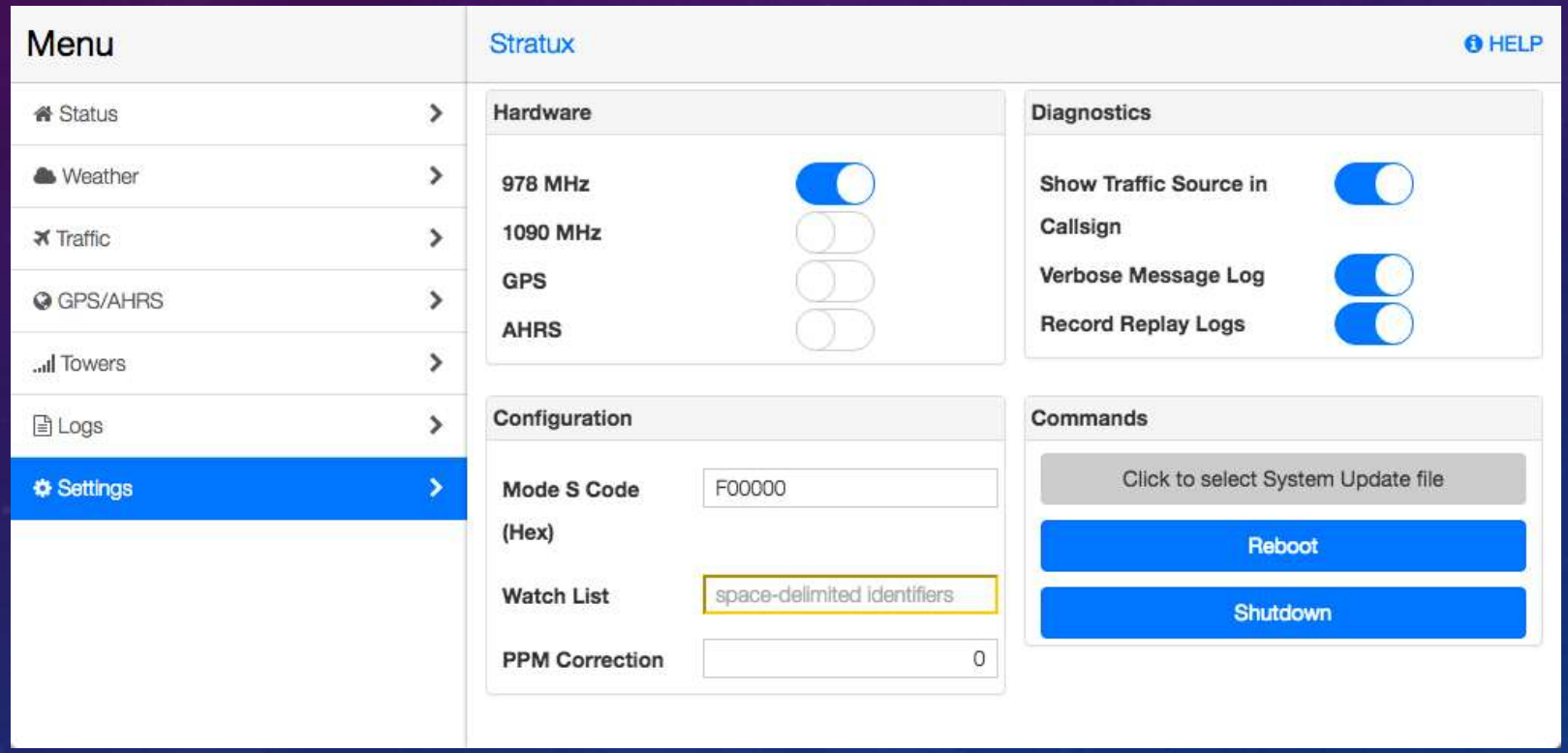
LOGS


Menu
Status
Weather
Traffic
GPS/AHRS
Towers
Logs
Settings
Stratux
HELP
Logs
stratux.log
SDR, AHRS, and GPS logs
(Enable device logging on "Settings" page)
Mozilla/5.0 (Macintosh; Intel Mac OS X 10_11_
screen = 2560 x 1440

AIRCRAFT DATA IN LOG

```
2016/02/26 01:30:28  - Network data messages sent: 2918 total, 1955 nonqueueable.  Network data bytes sent: 822816 total, 36870
nonqueueable.
2016/02/26 01:30:28 Writing 48 rows
2016/02/26 01:30:28 Writing finished. 48 rows in 0.06 seconds (800.0 rows per second).
2016/02/26 01:30:31 List of all aircraft being tracked:
2016/02/26 01:30:31 ================================================================
2016/02/26 01:30:31 27025E =>
{"Icao_addr":2556510,"Reg":"","Tail":"ut","Emitter_category":0,"OnGround":false,"Addr_type":3,"TargetType":4,"SignalLevel":-26.5
58042841285648,"Squawk":0,"Position_valid":true,"Lat":41.668503,"Lng":-87.58942,"Alt":2900,"GnssDiffFromBaroAlt":0,"AltIsGNSS":f
alse,"NIC":6,"NACp":7,"Track":314,"Speed":157,"Speed_valid":true,"Vvel":0,"Timestamp":"2016-02-
26T01:30:19.200638412Z","Age":12.36,"AgeLastAlt":12.36,"Last_seen":"0001-01-01T00:11:48.58Z","Last_alt":"0001-01-
01T00:11:48.58Z","Last_GnssDiff":"0001-01-01T00:00:00Z","Last_GnssDiffAlt":0,"Last_speed":"0001-01-
01T00:11:48.58Z","Last_source":2,"ExtrapolatedPosition":false,"Bearing":0,"Distance":0}
2016/02/26 01:30:31 270AF8 =>
{"Icao_addr":2558712,"Reg":"","Tail":"ut","Emitter_category":0,"OnGround":false,"Addr_type":3,"TargetType":4,"SignalLevel":-26.7
44843366368517,"Squawk":0,"Position_valid":true,"Lat":41.73088,"Lng":-87.68054,"Alt":1900,"GnssDiffFromBaroAlt":0,"AltIsGNSS":fa
lse,"NIC":6,"NACp":8,"Track":341,"Speed":173,"Speed_valid":true,"Vvel":-896,"Timestamp":"2016-02-
26T01:30:21.789923776Z","Age":9.77,"AgeLastAlt":9.77,"Last_seen":"0001-01-01T00:11:51.17Z","Last_alt":"0001-01-
01T00:11:51.17Z","Last_GnssDiff":"0001-01-01T00:00:00Z","Last_GnssDiffAlt":0,"Last_speed":"0001-01-
01T00:11:51.17Z","Last_source":2,"ExtrapolatedPosition":false,"Bearing":0,"Distance":0}
2016/02/26 01:30:32 Average sendable queue is 0 messages. Changing queue timer to 0.100000 seconds
2016/02/26 01:30:37 Average sendable queue is 0 messages. Changing queue timer to 0.100000 seconds
2016/02/26 01:30:38 Writing 26 rows
2016/02/26 01:30:38 Writing finished. 26 rows in 0.33 seconds (78.8 rows per second).
2016/02/26 01:30:42 Average sendable queue is 0 messages. Changing queue timer to 0.100000 seconds
2016/02/26 01:30:43 On  192.168.10.11:4000,  Queue length = 0 messages / 0 bytes
2016/02/26 01:30:43 On  192.168.10.10:4000,  Queue length = 1826 messages / 803987 bytes
2016/02/26 01:30:46 List of all aircraft being tracked:
2016/02/26 01:30:46 ================================================================
2016/02/26 01:30:46 27025E =>
{"Icao_addr":2556510,"Reg":"","Tail":"ut","Emitter_category":0,"OnGround":false,"Addr_type":3,"TargetType":4,"SignalLevel":-26.5
58042841285648,"Squawk":0,"Position_valid":true,"Lat":41.668503,"Lng":-87.58942,"Alt":2900,"GnssDiffFromBaroAlt":0,"AltIsGNSS":f
alse,"NIC":6,"NACp":7,"Track":314,"Speed":157,"Speed_valid":true,"Vvel":0,"Timestamp":"2016-02-
```

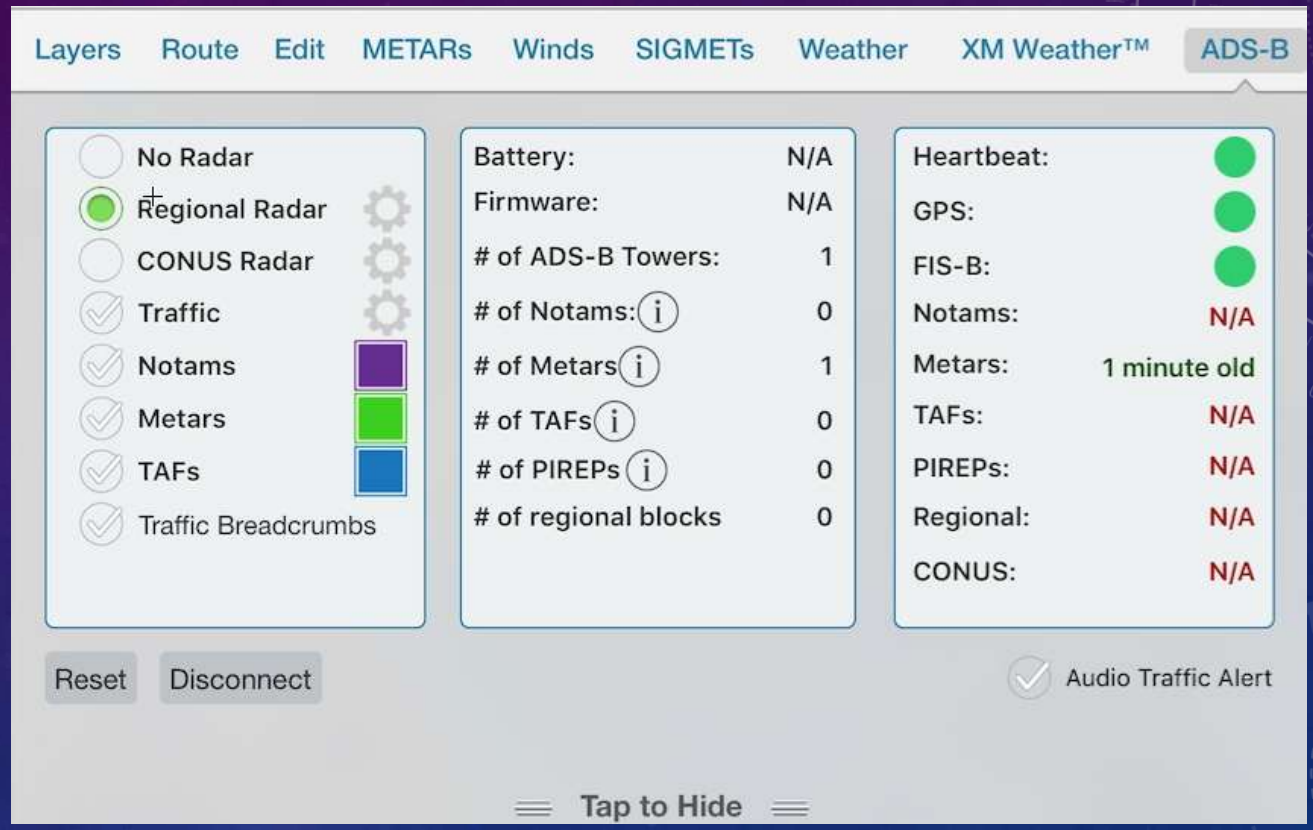
SETTINGS


Menu
Status
Weather
Traffic
GPS/AHRS
Towers
Logs
Settings
Stratux
HELP
Hardware
978 MHz
1090 MHz
GPS
AHRS
Diagnostics
Show Traffic Source in Callsign
Verbose Message Log
Record Replay Logs
Configuration
Mode S Code (Hex)
F00000
Watch List
space-delimited identifiers
PPM Correction
0
Commands
Click to select System Update file
Reboot
Shutdown

CONFIGURATION/STATUS AND FIS-B

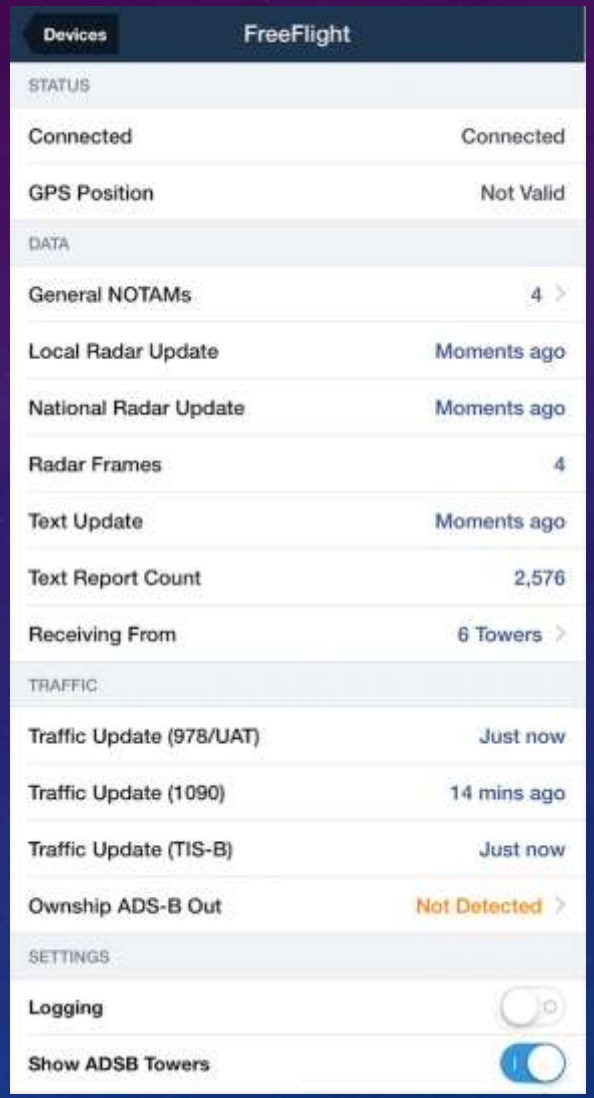
FLTPLAN GO ADS-B SETTINGS

- Control what you want added to map screen
- See current status
- See age of data

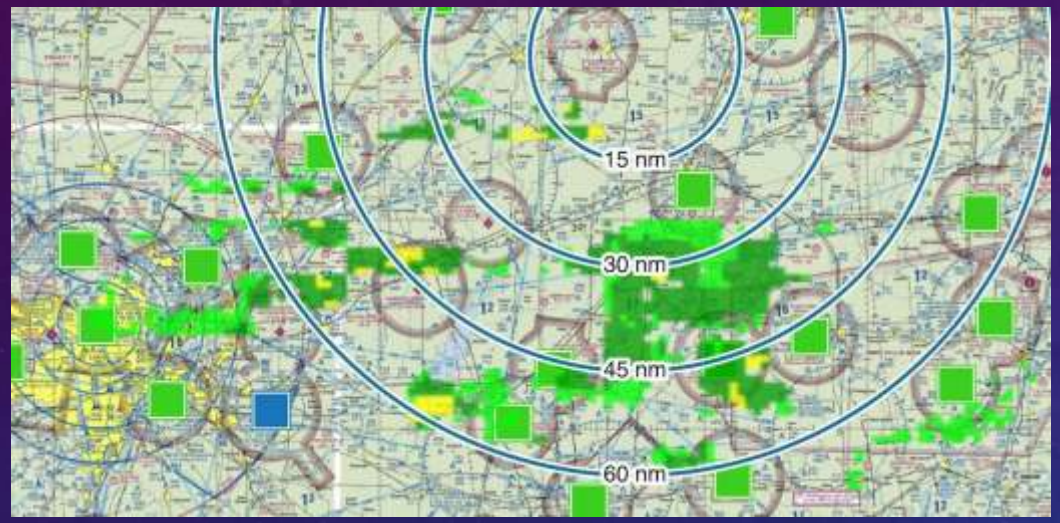


FOREFLIGHT ADS-B STATUS PAGE

Limited settings

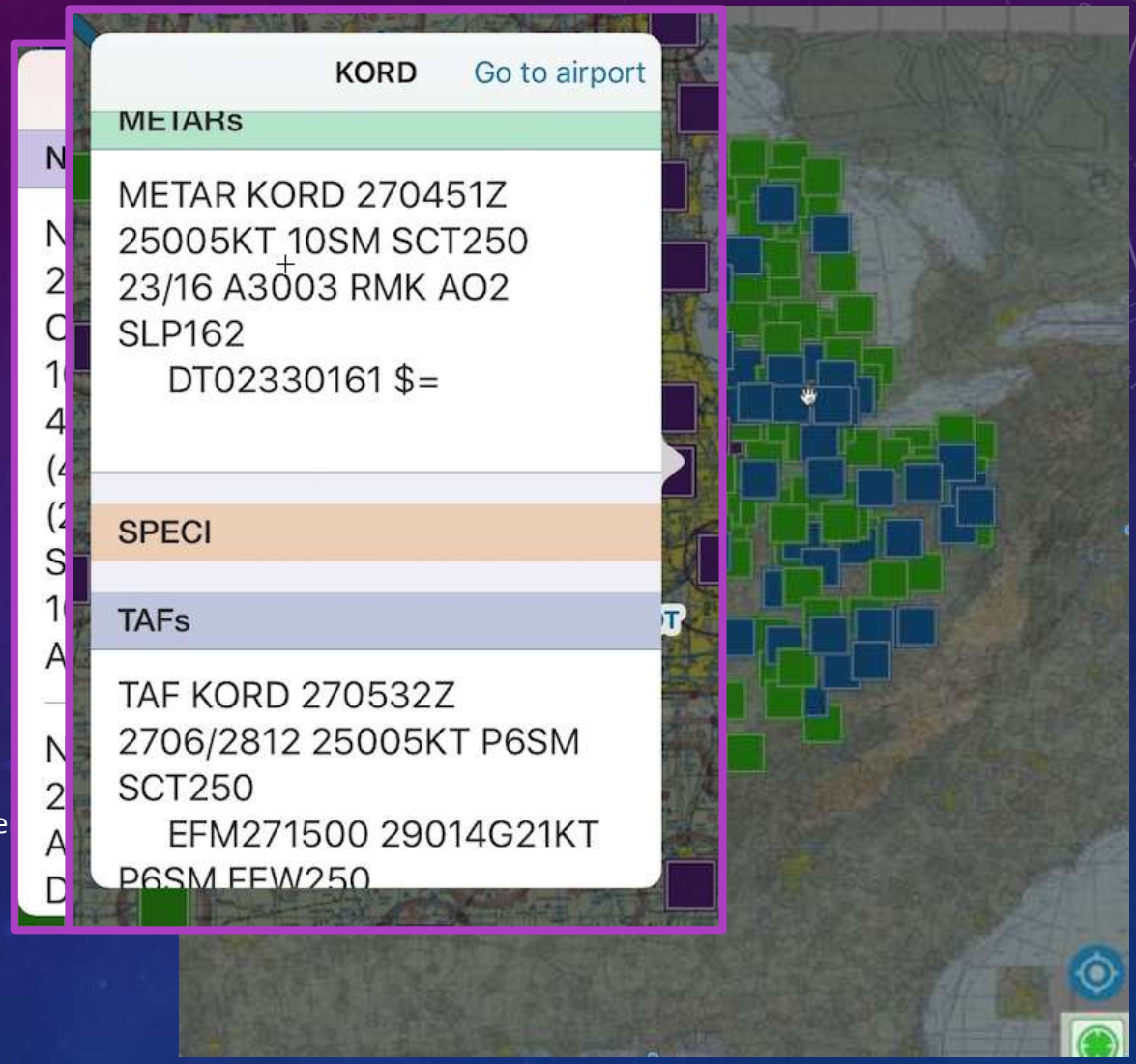


CONUS VS REGIONAL RADAR



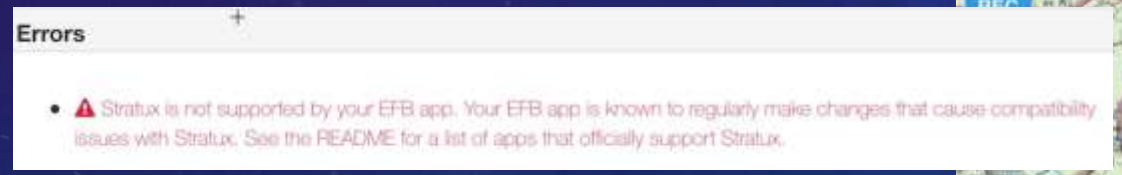
NOTAMS AND TEXT WEATHER

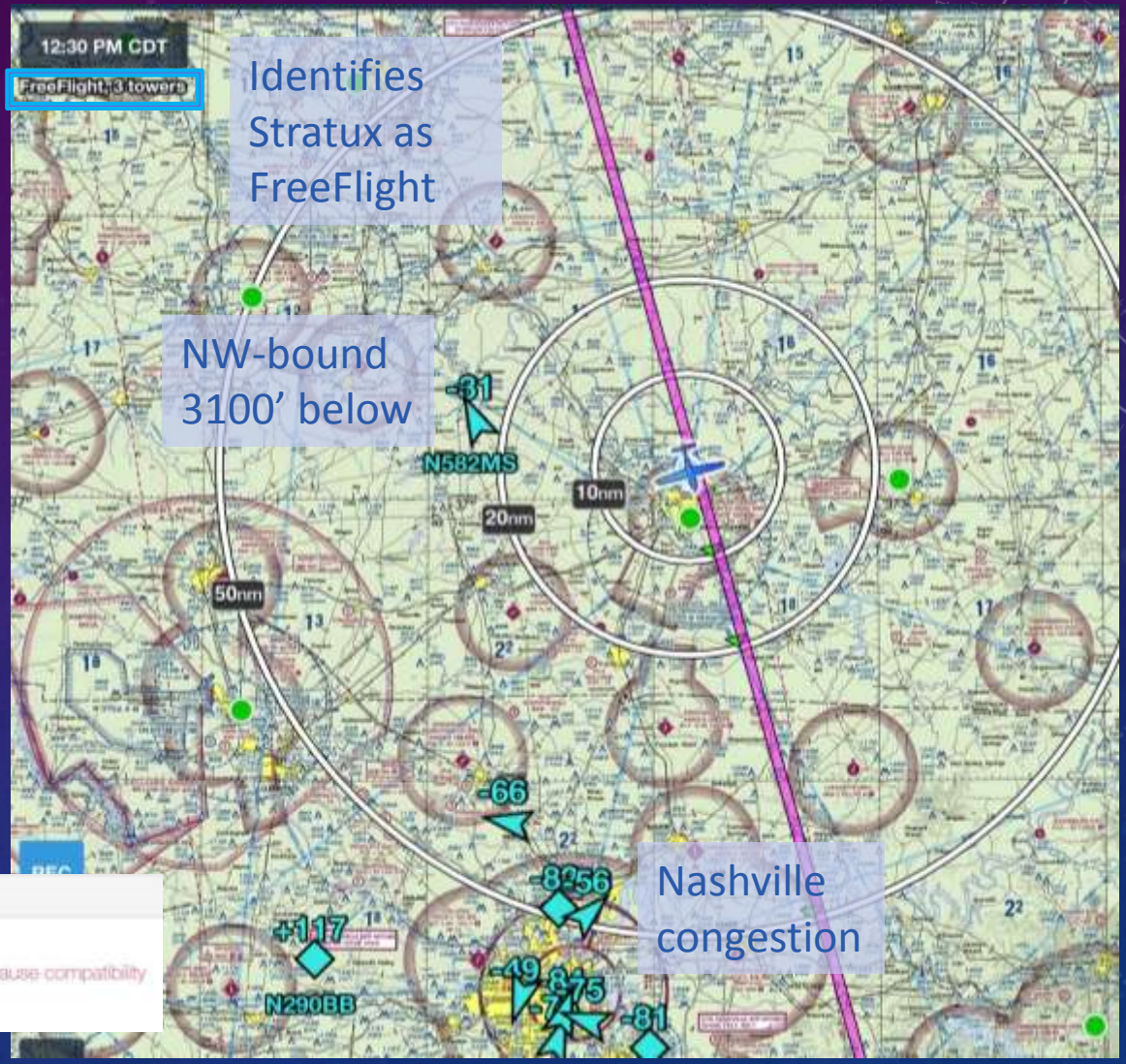
- **NOT**ices to **A**ir**M**en (purple)
  - Within about 100nm
- Textual weather
  - **MET**eorological **A**viation **R**eports (METARs - Gree
  - **T**erminal **A**rea **F**orecasts (TAFs - blue)
  - Within about 300nm
- Depiction on FltPlan Go



FOREFLIGHT TRAFFIC

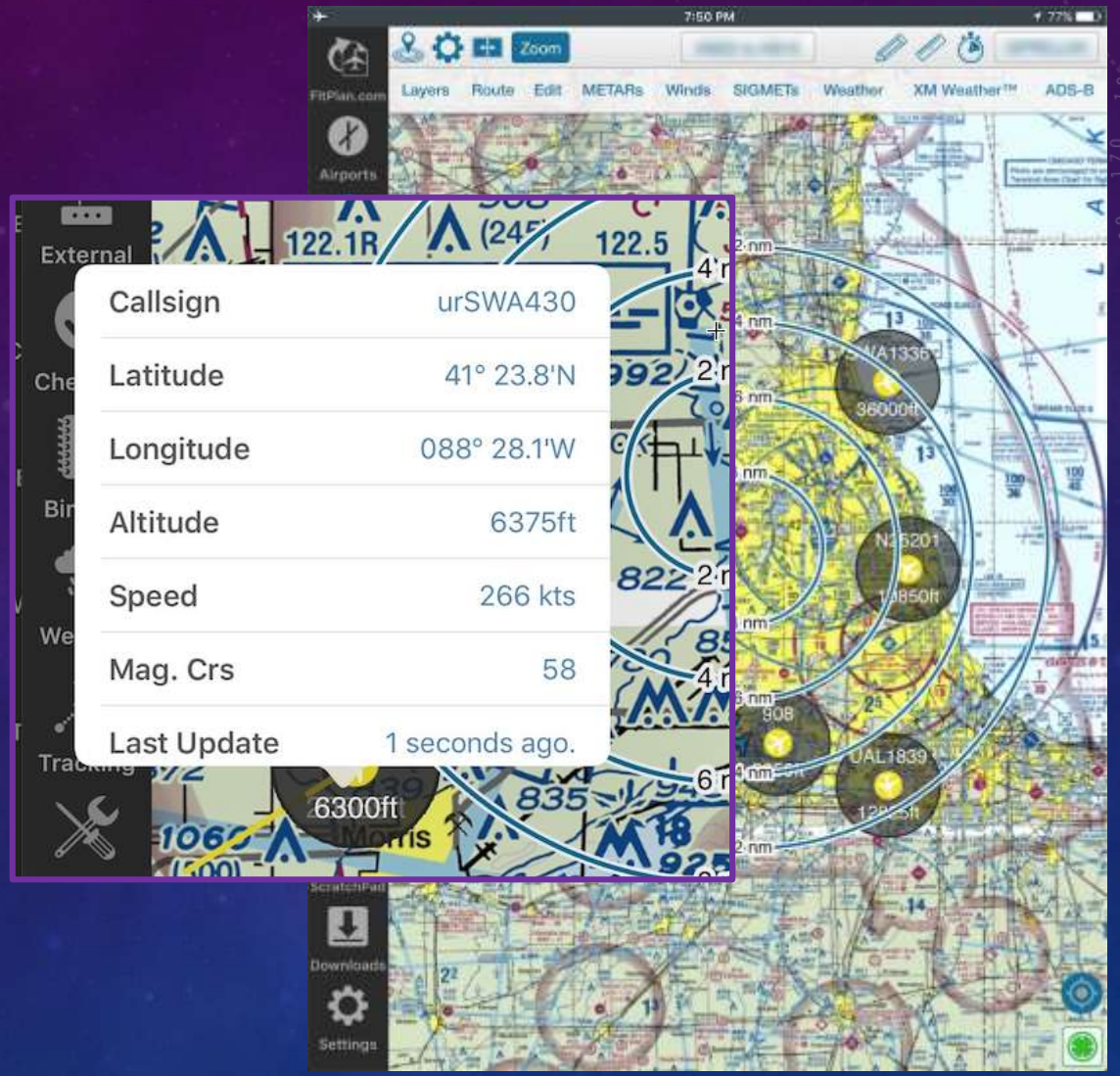
- Not limited to nearby traffic (optional)
- Display information
  - Direction of flight, Altitude difference
  - Tail number sometimes
- ForeFlight not completely supported





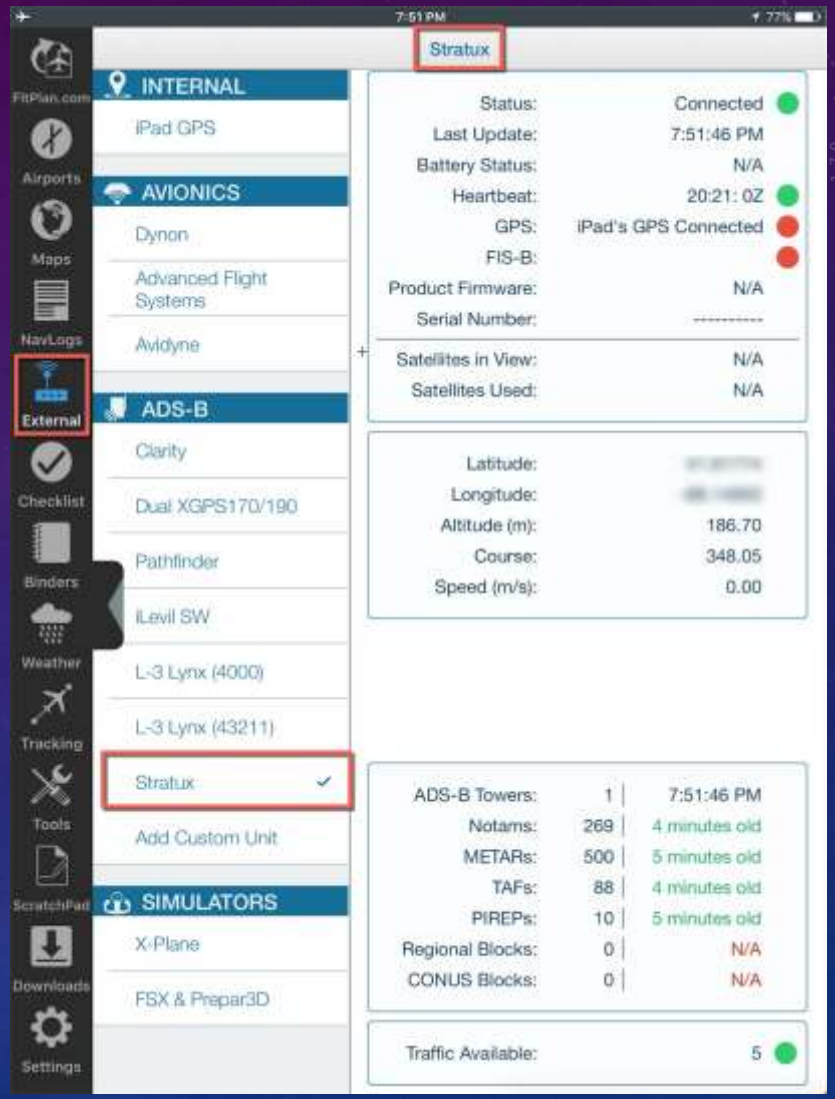
FLTPLAN GO TRAFFIC

- Example shows 1090
- Note IDs with airplanes indicating direction of flight
- Altitude not relative
- Optional track breadcrumbs
- Click for additional detail



FLTPLAN GO HARDWARE CONFIGURATION

- Free product
- Explicitly supports Stratux



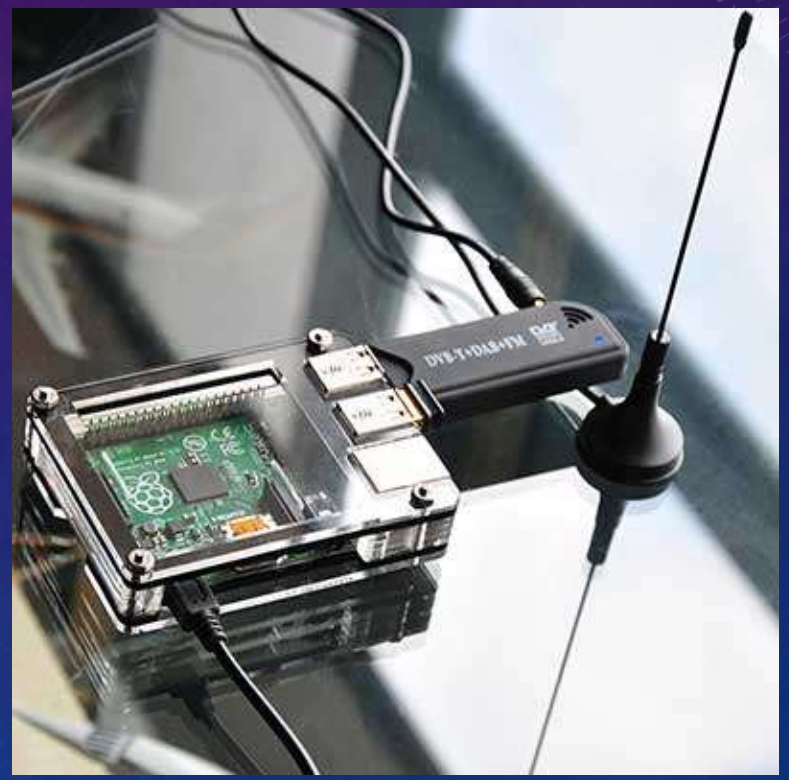
FLIGHTAWARE

FLIGHTAWARE

- FlightAware is worldwide flight tracking site
- Incorporates feeds from 70+ sources, including ADS-B
  - ASDI (Aircraft Situation Display for Industry) decommissioned April 29, 2016
  - TFMData only includes instrument flight plans
  - Position Only Flight Tracking (opt-in) displays ADS-B and Mode S info without ATC involvement
- http://flightaware.com

PIAWARE

- Crowdsourced data using PiAware
- Placement
  - Proximity to airport ideal
  - High in house
- Similar or identical hardware to Stratux
- Free enterprise account to contributors ($90/mo value)
- http://flightaware.com/adsb/piaware/



Questions?

Grant Prellwitz

1C5Pilot@comcast.net or gprellwitz@acm.org

@1C5Pilot