

The background features a dark blue gradient with a subtle pattern of white dots. Overlaid on this are several circular and semi-circular white lines of varying thicknesses and styles (solid, dashed, dotted). A prominent feature is a large circular scale on the left side, with numerical markings from 140 to 260 in increments of 10. The text is centered in the right half of the image.

AIRBORNE WEATHER AND TRAFFIC INFO USING RASPBERRY PI

CHICAGO UNIFORM – 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

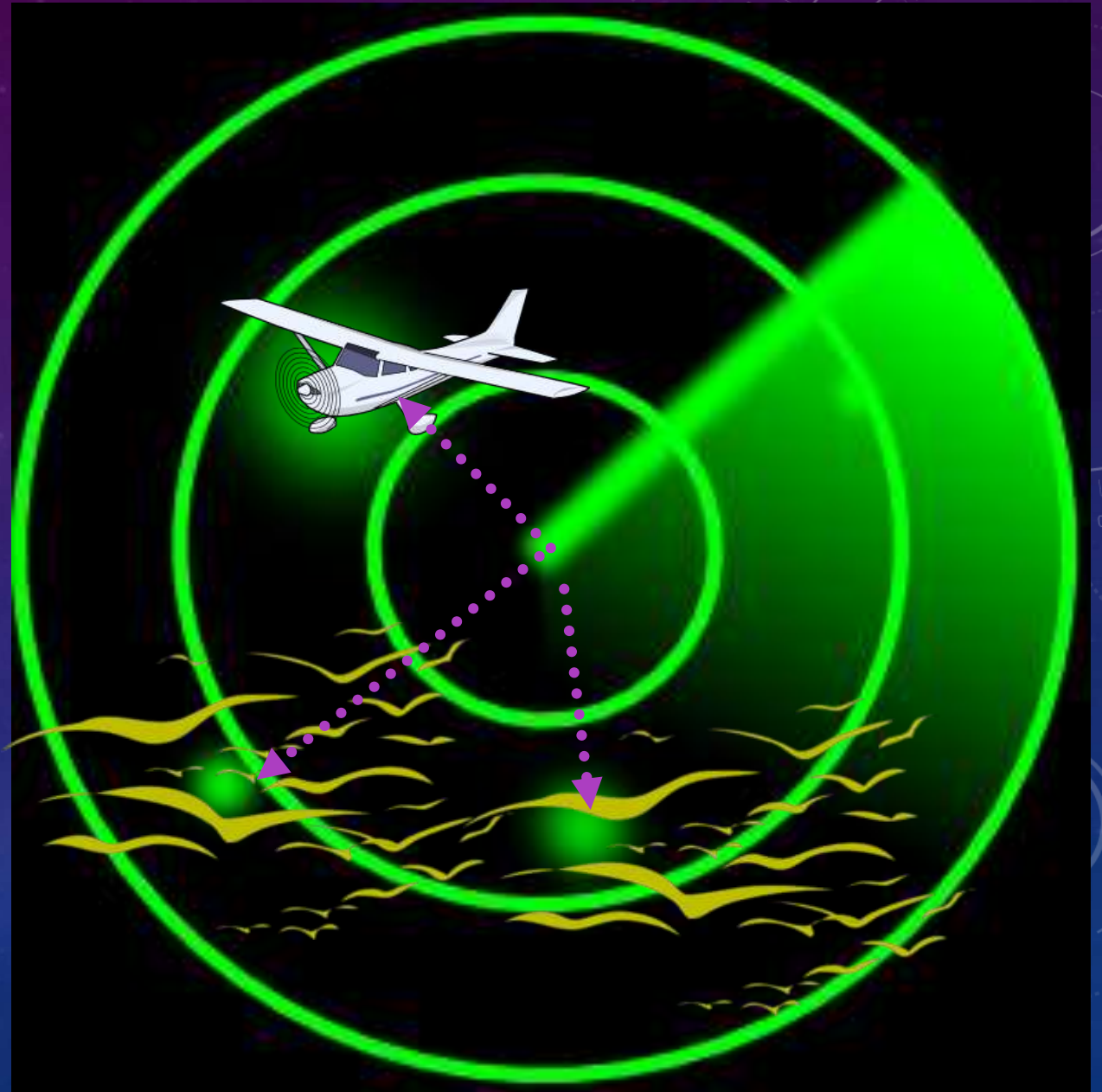
WHAT WE'LL COVER

- 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



SECONDARY RADAR

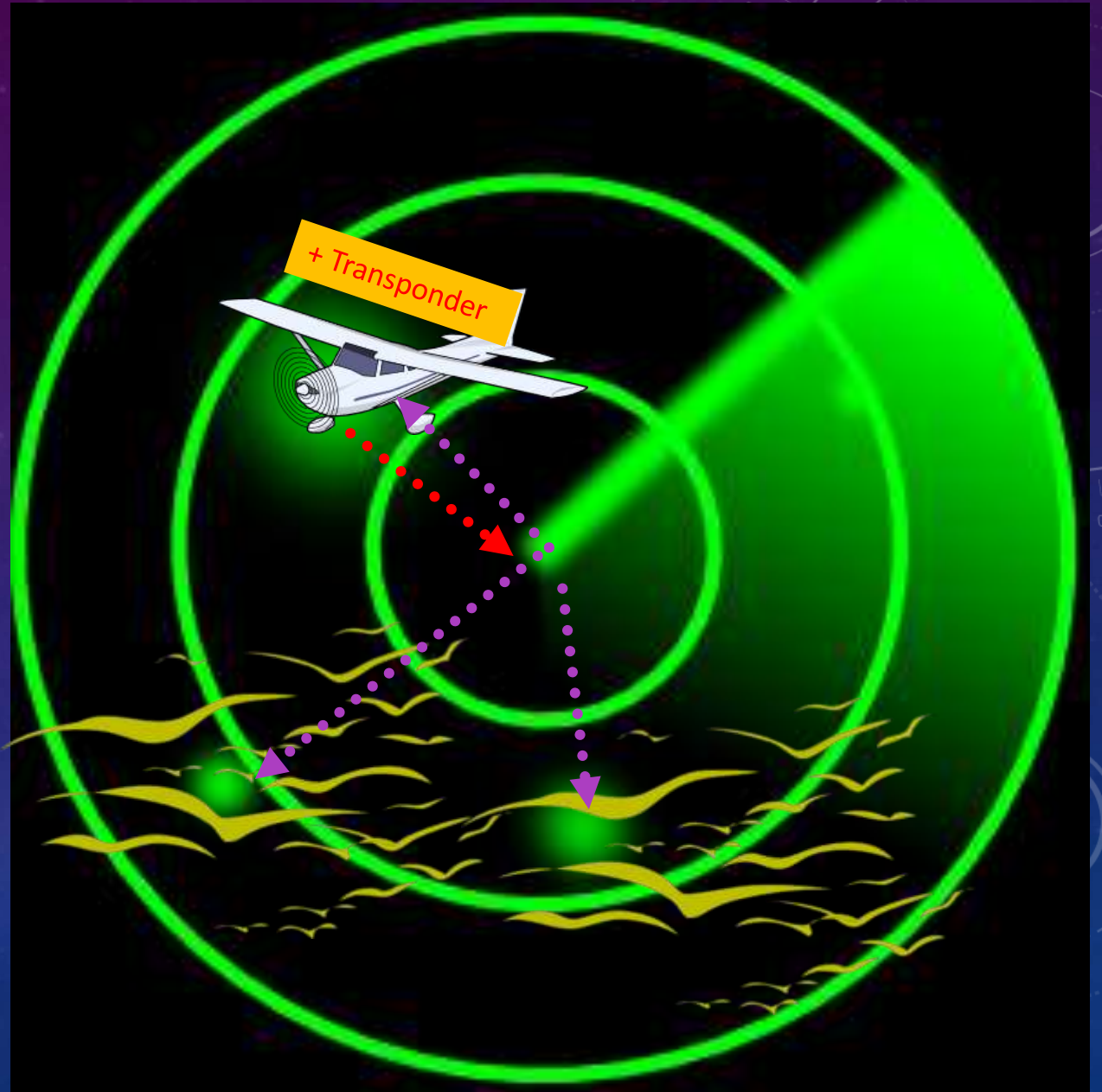
Transponder Types:



Mode A : 4 digit code
Mode C : + altitude



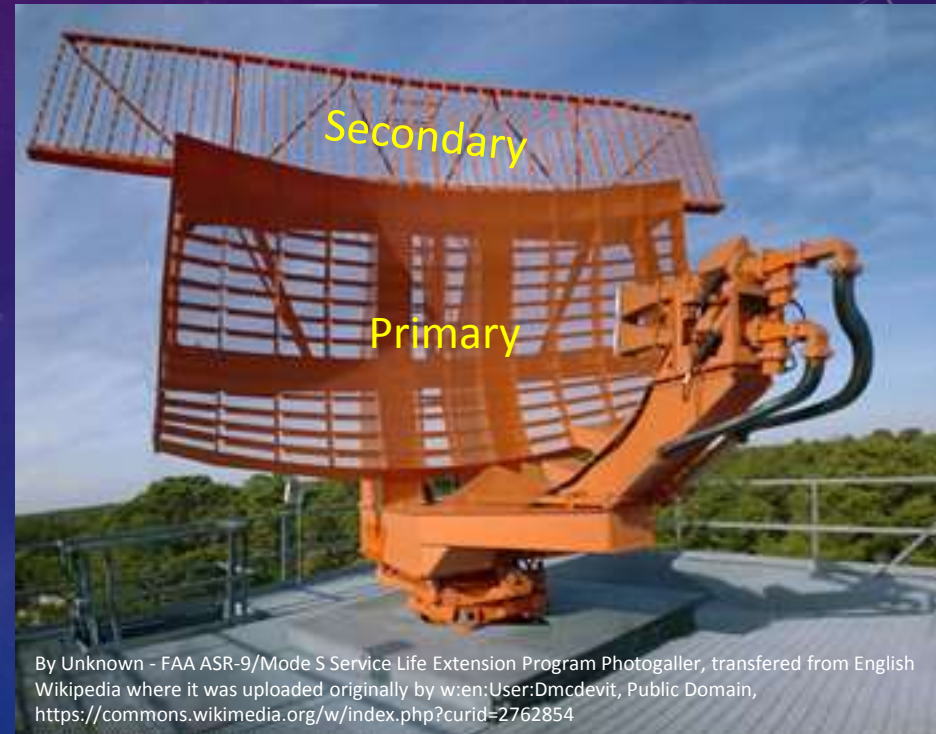
Mode S : + aircraft call sign, fixed 24-bit address



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, transferred 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

- A**utomatic – No interrogation
- D**ependent – Rely on others
- S**urveillance – Who and where
- B**roadcast – Party line

ADS-B

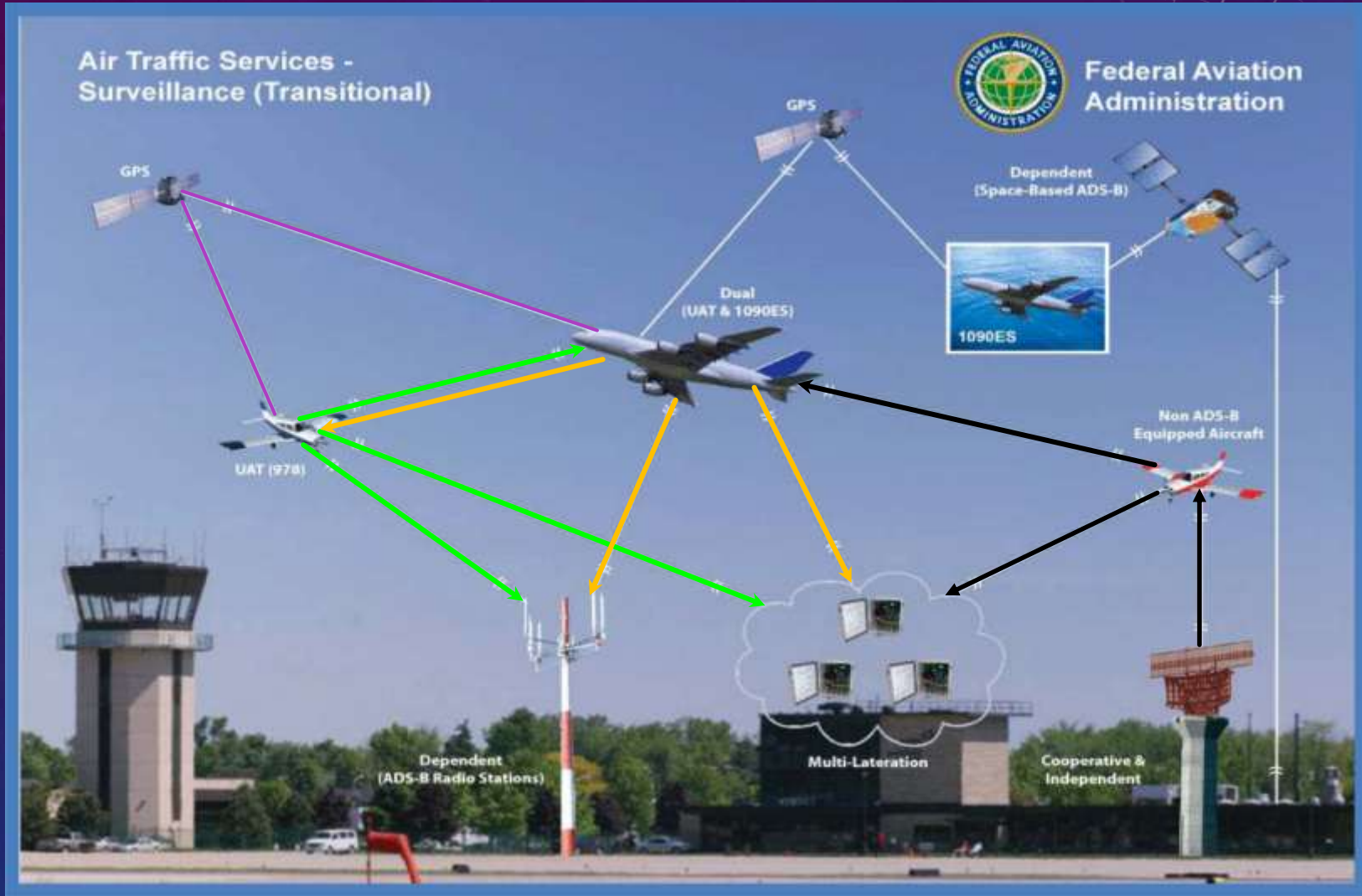
1090ES

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

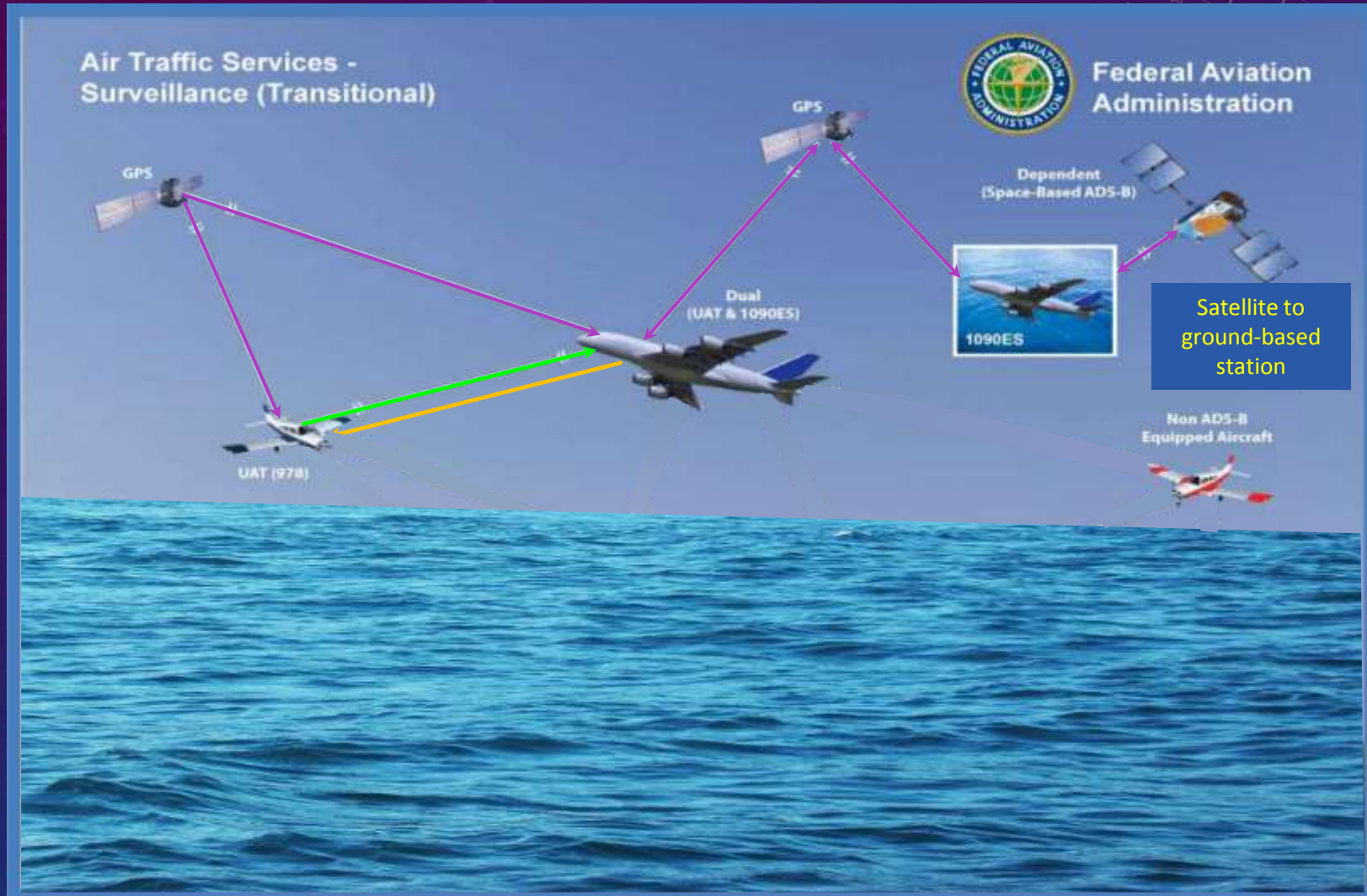
UAT

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

ADS-B OUT



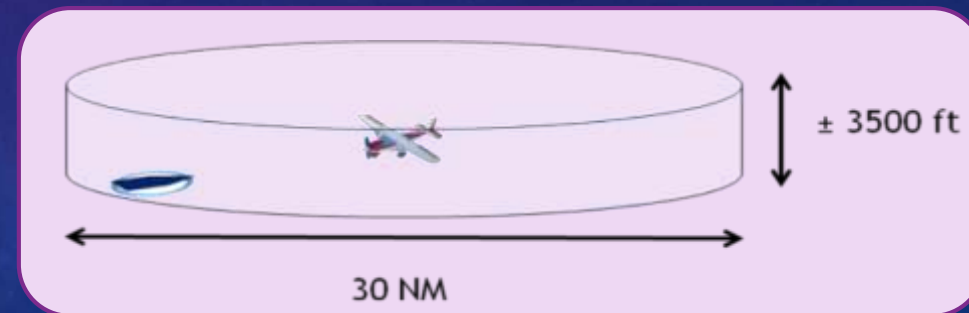
ADS-B OUT



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

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



Thingiverse DASHBOARD EXPLORE LEARN CREATE

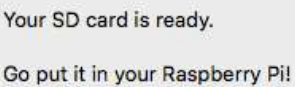
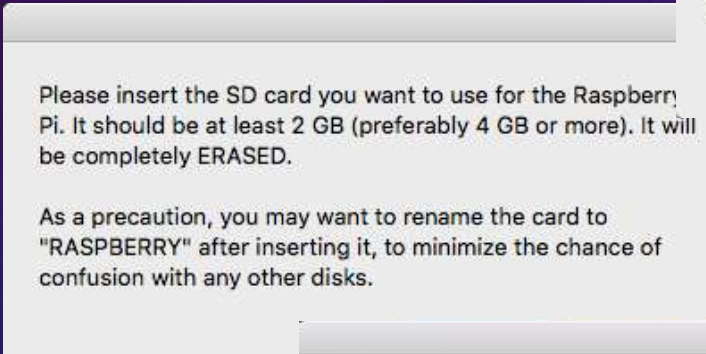
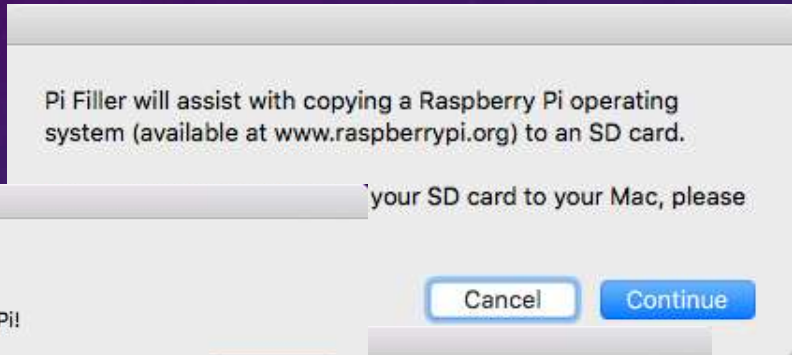
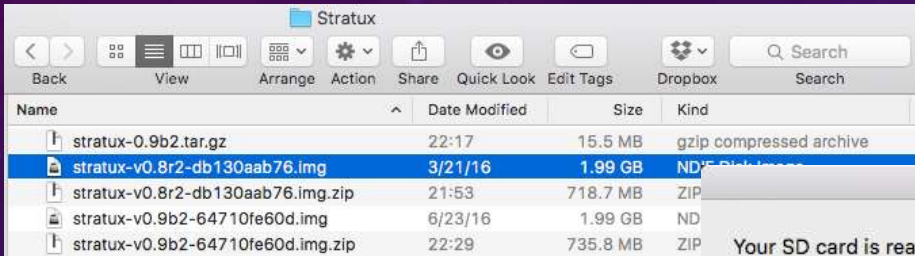
Stratux Dual Band ADS-B TuffCase
by PCF/yr, published Dec 4, 2015



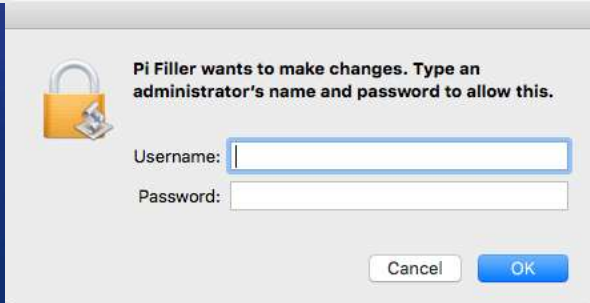
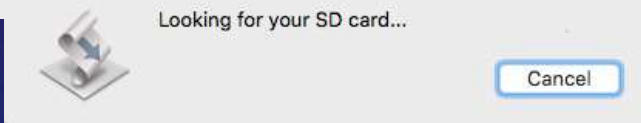
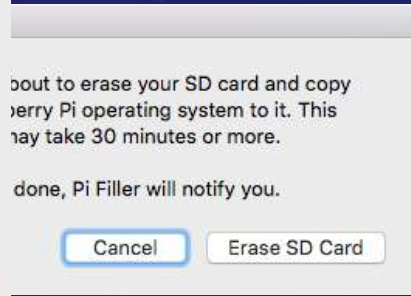
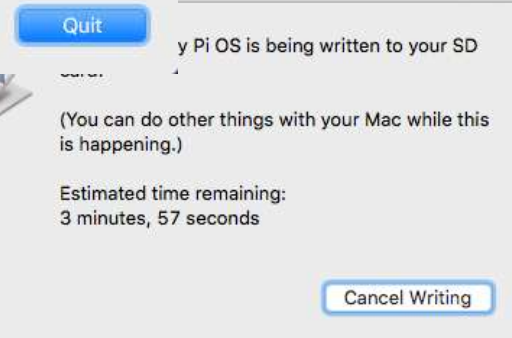
BUILDING STRATUX – AVIATION RTL-SDR

- 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



Please insert the SD card into the Raspberry Pi. Do not remove the SD card while the program is running.

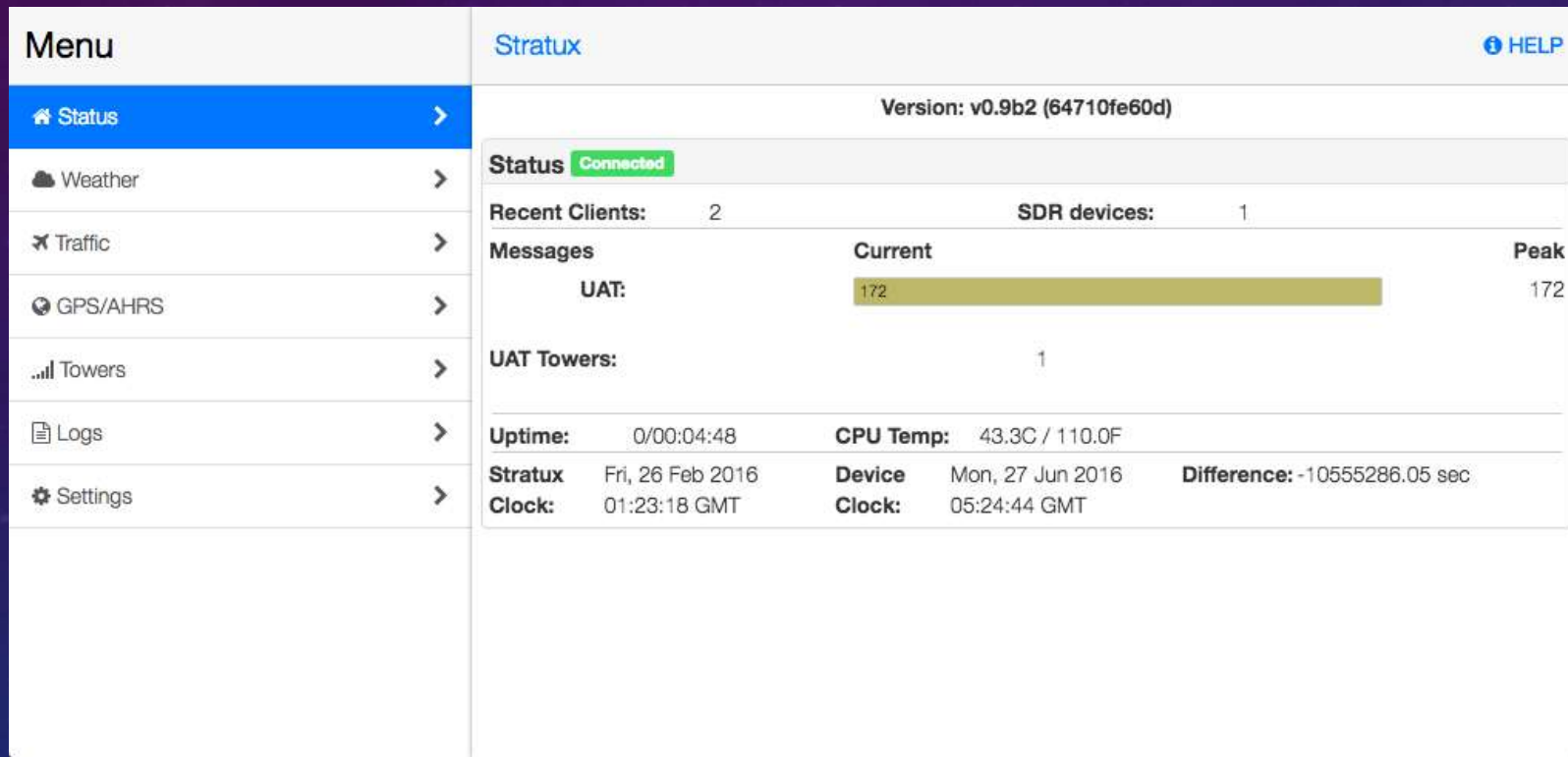


START UP

- 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



Menu

- Status
- Weather
- Traffic
- GPS/AHRS
- Towers
- Logs
- Settings

Stratux [HELP](#)

Version: v0.9b2 (64710fe60d)

Status Connected

Recent Clients: 2 SDR devices: 1

Messages	Current	Peak
UAT:	172	172

UAT Towers: 1

Uptime: 0/00:04:48 CPU Temp: 43.3C / 110.0F

Stratux	Fri, 26 Feb 2016	Device	Mon, 27 Jun 2016	Difference: -10555286.05 sec
Clock:	01:23:18 GMT	Clock:	05:24:44 GMT	

WEATHER

Menu Stratux [HELP](#)

- Status >
- Weather >**
- Traffic >
- GPS/AHRS >
- Towers >
- Logs >
- Settings >

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

The screenshot shows the Stratux mobile application interface. At the top, it displays the time 7:49 PM and battery level 77%. The main content is divided into two sections: 'ADS-B and TIS-B Traffic' and 'Basic Mode S and No-Position Messages'. The first section has a 'Connect' status and a table of traffic data. The second section has a table of messages. At the bottom, there is a note about ADS-B position transmissions.

ADS-B and TIS-B Traffic Connect

Callsign	Code	Location	Altitude	Speed	Course	Power	Age
✓ SWA133E	ABD19E	42° 15' -87° 40'	36,000	385 _{ms}	260°	-33.32 _{db}	5.1s
✓ 908	ABG2AD	41° 35' -88° 03'	3,950	235 _{ms}	060°	-24.37 _{db}	0.1s
✓ N322LV	A276DC	42° 07' -87° 40'	18,325 _{ft}	295 _{ms}	330°	-34.11 _{db}	13.2s
✓ N832SD	ABG2DG	41° 54' -88° 42'	19,750 _{ft}	405 _{ms}	290°	-33.42 _{db}	29.5s
✓ 2049	ABEGDH	41° 13' -87° 44'	20,000 _{ft}	420 _{ms}	175°	-34.48 _{db}	49.0s
✓ N3896S	A49136	41° 56' -88° 01'	5,350 _{ft}	260 _{ms}	270°	-33.88 _{db}	59.5s
✓ N25201	A2815E	41° 52' -87° 38'	10,850	305 _{ms}	305°	-33.00 _{db}	16.5s
✓ SWA461	ABEF16	41° 26' -88° 22'	6,900 _{ft}	280 _{ms}	060°	-28.97 _{db}	0.0s
✓ UAL1742	A20433	41° 47' -88° 57'	26,650	---	---	-34.83 _{db}	21.1s
✓ UAL1839	A28810	41° 35' -87° 46'	11,325 _{ft}	390 _{ms}	170°	-32.69 _{db}	2.8s

Show Tail Show Squawk Show Distance
Number N/A

Basic Mode S and No-Position Messages


Callsign	Code	Squawk	Altitude	Speed	Course	Power	Age
✓ N15966	ADEFJD	----	12,850	---	---	-28.67 _{db}	0.1s
✓ N17560	A12F03	7215	13,950	---	---	-31.11 _{db}	0.1s
✓ N412WN	A4E146	----	3,925	---	---	-35.13 _{db}	12.1s
✓ N603CZ	A7D2AE	----	7,850	---	---	-34.76 _{db}	5.0s
✓ N662EH	ABBC13	----	6,900	---	---	-34.21 _{db}	0.0s
✓ N772SK	AA72DF	----	17,275	---	---	-31.43 _{db}	1.8s
✓ N821SK	ABG2DC	----	9,900	---	---	-35.00 _{db}	9.8s
✓ N891AT	AC49TD	----	34,000	---	---	-33.54 _{db}	1.2s
✓ N963SW	AD68FD	----	15,925	---	---	-31.67 _{db}	0.7s

Stratux has not received valid ADS-B position transmissions from the aircraft in this section. They will not appear on your EFB map. See help page for details.

TOWERS

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

LOGS

Menu	Stratux HELP
✈ Status >	<h2>Logs</h2>  <p>stratux.log SDR, AHRS, and GPS logs (Enable device logging on "Settings" page)</p>
☁ Weather >	
✈ Traffic >	
📍 GPS/AHRS >	
📶 Towers >	
📄 Logs >	Mozilla/5.0 (Macintosh; Intel Mac OS X 10_11_ screen = 2560 x 1440
⚙ Settings >	

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):
- Watch List:
- PPM Correction:

Commands

-
-
-

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

Layers Route Edit METARs Winds SIGMETs Weather XM Weather™ ADS-B

No Radar
 Regional Radar
 CONUS Radar
 Traffic
 Notams
 Metars
 TAFs
 Traffic Breadcrumbs

Battery: N/A
Firmware: N/A
of ADS-B Towers: 1
of Notams: 0
of Metars: 1
of TAFs: 0
of PIREPs: 0
of regional blocks: 0

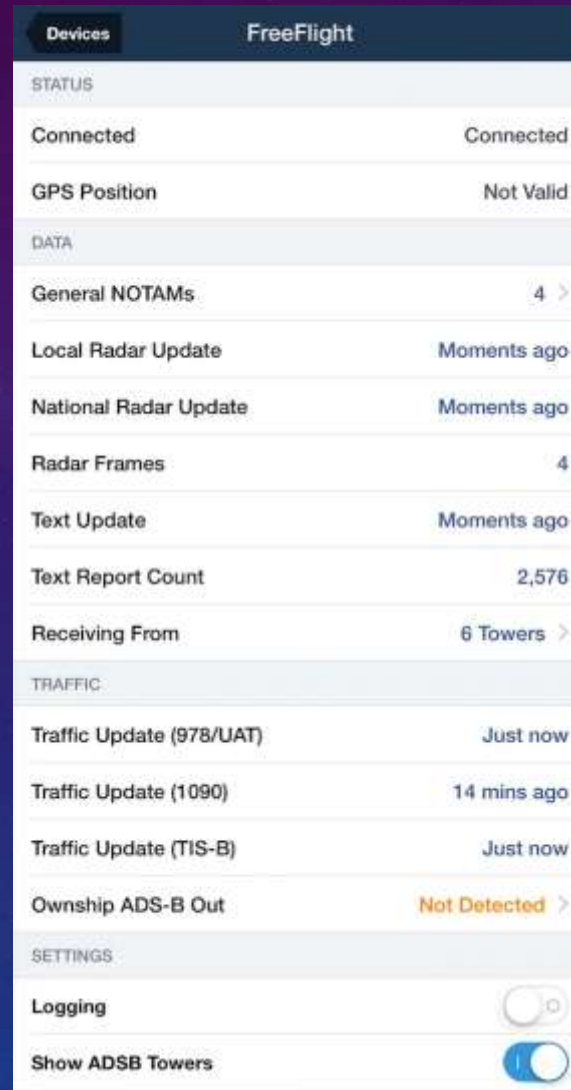
Heartbeat: ●
GPS: ●
FIS-B: ●
Notams: N/A
Metars: 1 minute old
TAFs: N/A
PIREPs: N/A
Regional: N/A
CONUS: N/A

Reset Disconnect Audio Traffic Alert

≡ Tap to Hide ≡

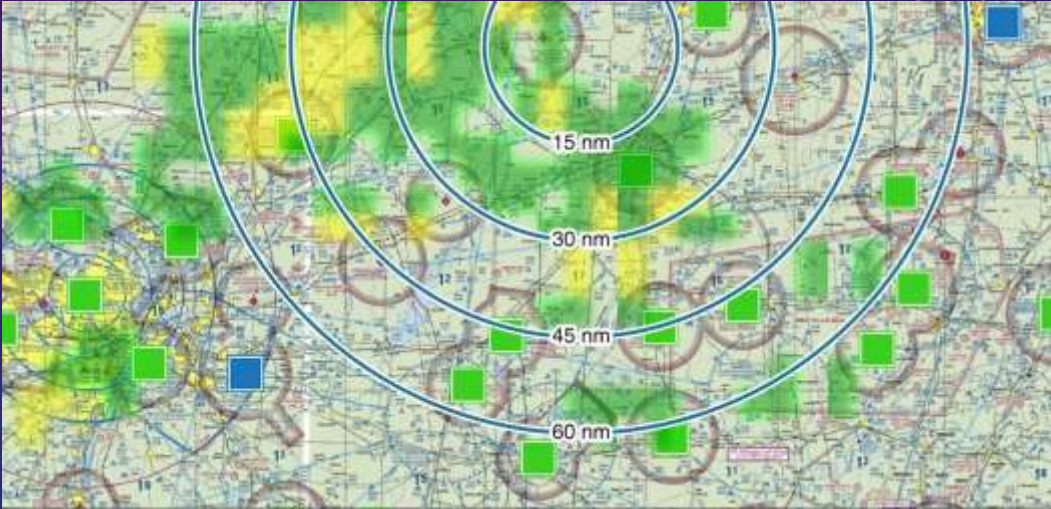
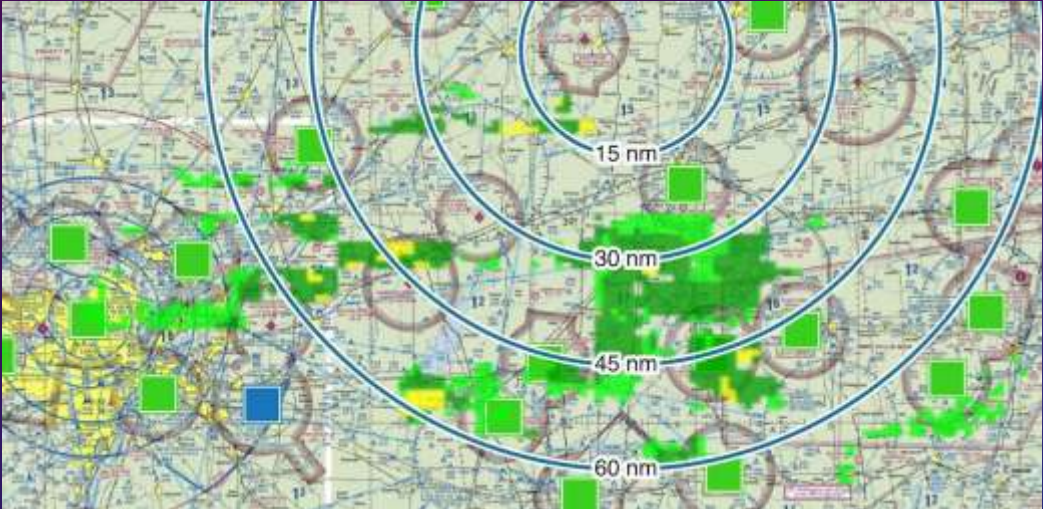
FOREFLIGHT ADS-B STATUS PAGE

Limited settings



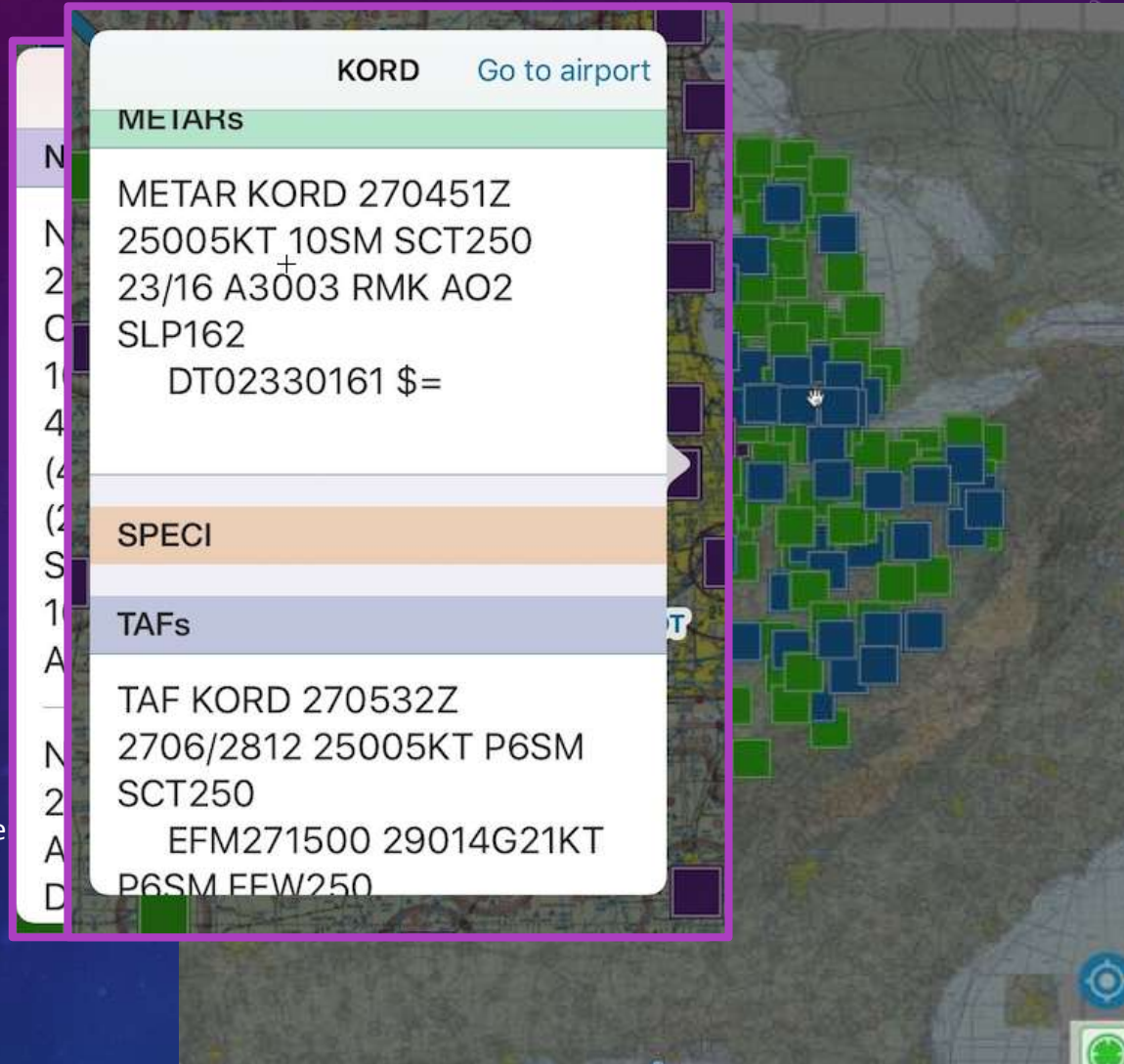
Devices		FreeFlight
STATUS		
Connected		Connected
GPS Position		Not Valid
DATA		
General NOTAMs		4 >
Local Radar Update		Moments ago
National Radar Update		Moments ago
Radar Frames		4
Text Update		Moments ago
Text Report Count		2,576
Receiving From		6 Towers >
TRAFFIC		
Traffic Update (978/UAT)		Just now
Traffic Update (1090)		14 mins ago
Traffic Update (TIS-B)		Just now
Ownship ADS-B Out		Not Detected >
SETTINGS		
Logging		<input type="checkbox"/>
Show ADSB Towers		<input checked="" type="checkbox"/>

CONUS VS REGIONAL RADAR



NOTAMS AND TEXT WEATHER

- **NOT**ices to **AirMen** (purple)
 - Within about 100nm
- Textual weather
 - **ME**teorological Aviation Reports (METARs - Green)
 - Terminal **A**rea Forecasts (TAFs - blue)
 - Within about 300nm
- Depiction on FltPlan Go

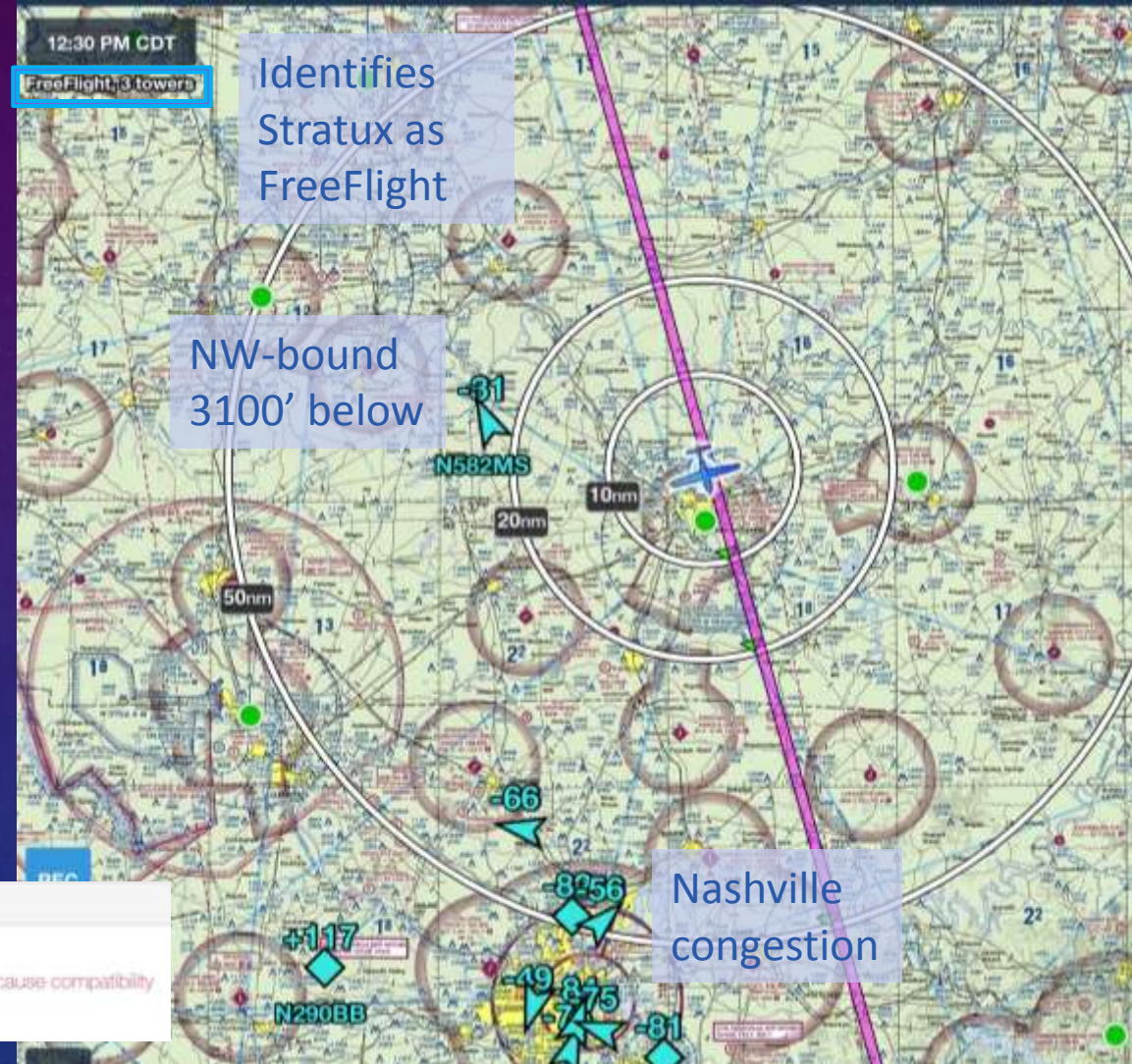


FOREFLIGHT TRAFFIC

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

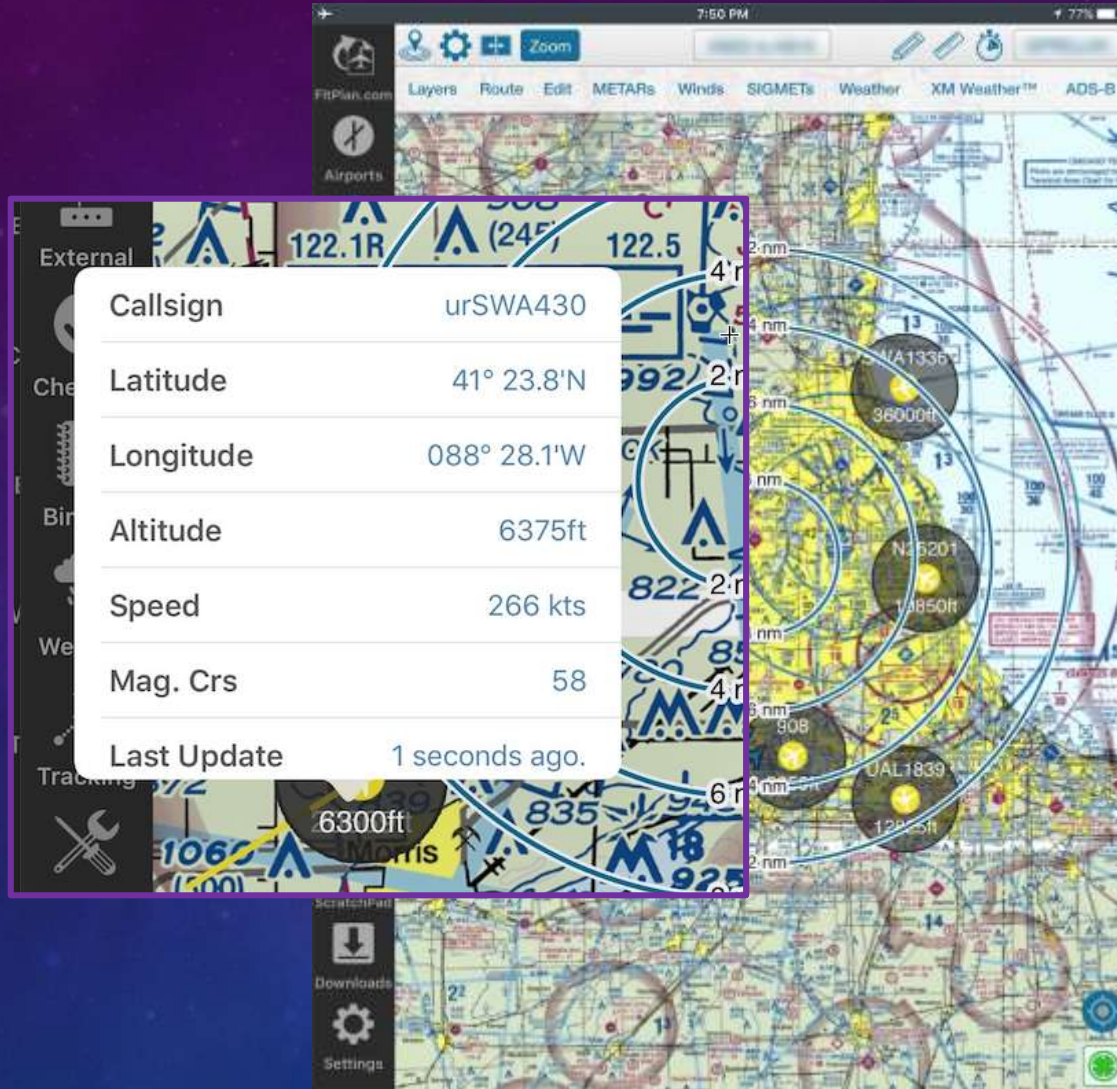
Errors

- ⚠ Stratux is not supported by your EFB app. Your EFB app is known to regularly make changes that cause compatibility issues with Stratux. See the README for a list of apps that officially support Stratux.



FLTPLAN GO TRAFFIC

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

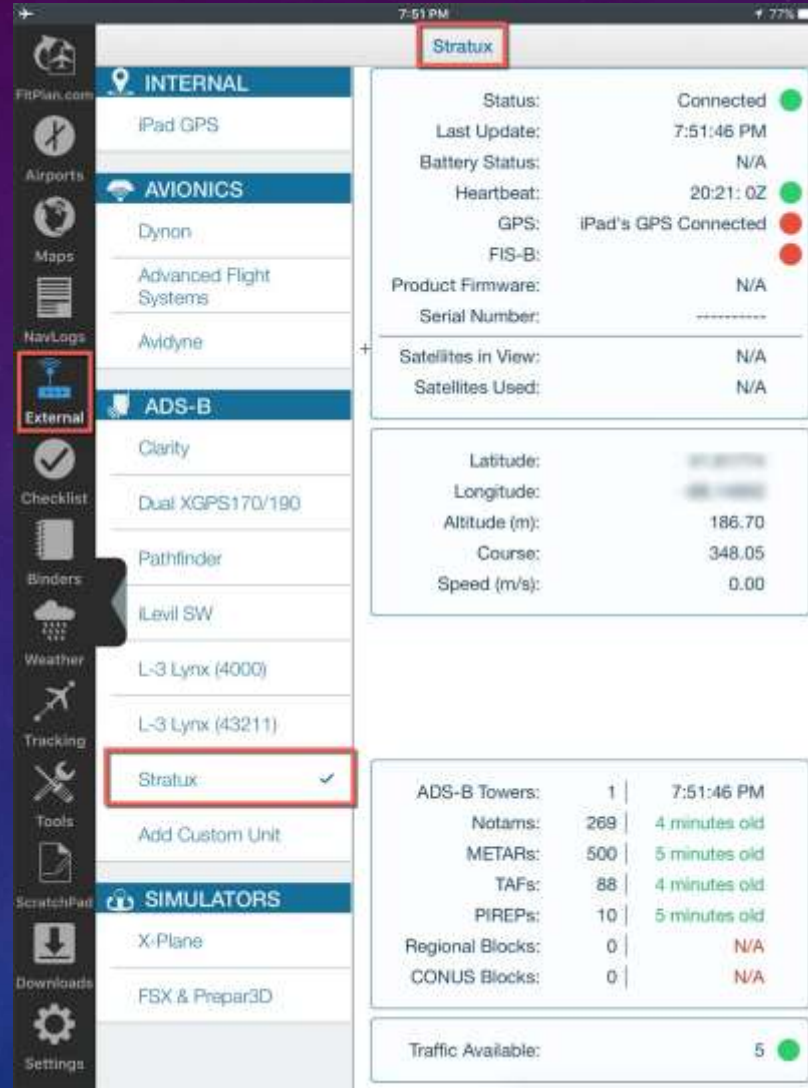


The screenshot shows the FLTPLAN GO TRAFFIC application interface. The main display is a map showing various aircraft tracks and altitudes. A pop-up window is overlaid on the map, displaying detailed information for a specific aircraft.

Callsign	urSWA430
Latitude	41° 23.8'N
Longitude	088° 28.1'W
Altitude	6375ft
Speed	266 kts
Mag. Crs	58
Last Update	1 seconds ago.

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?

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