# Microcontroller Radar Stations utilizing Software Defined Radio (SDR)

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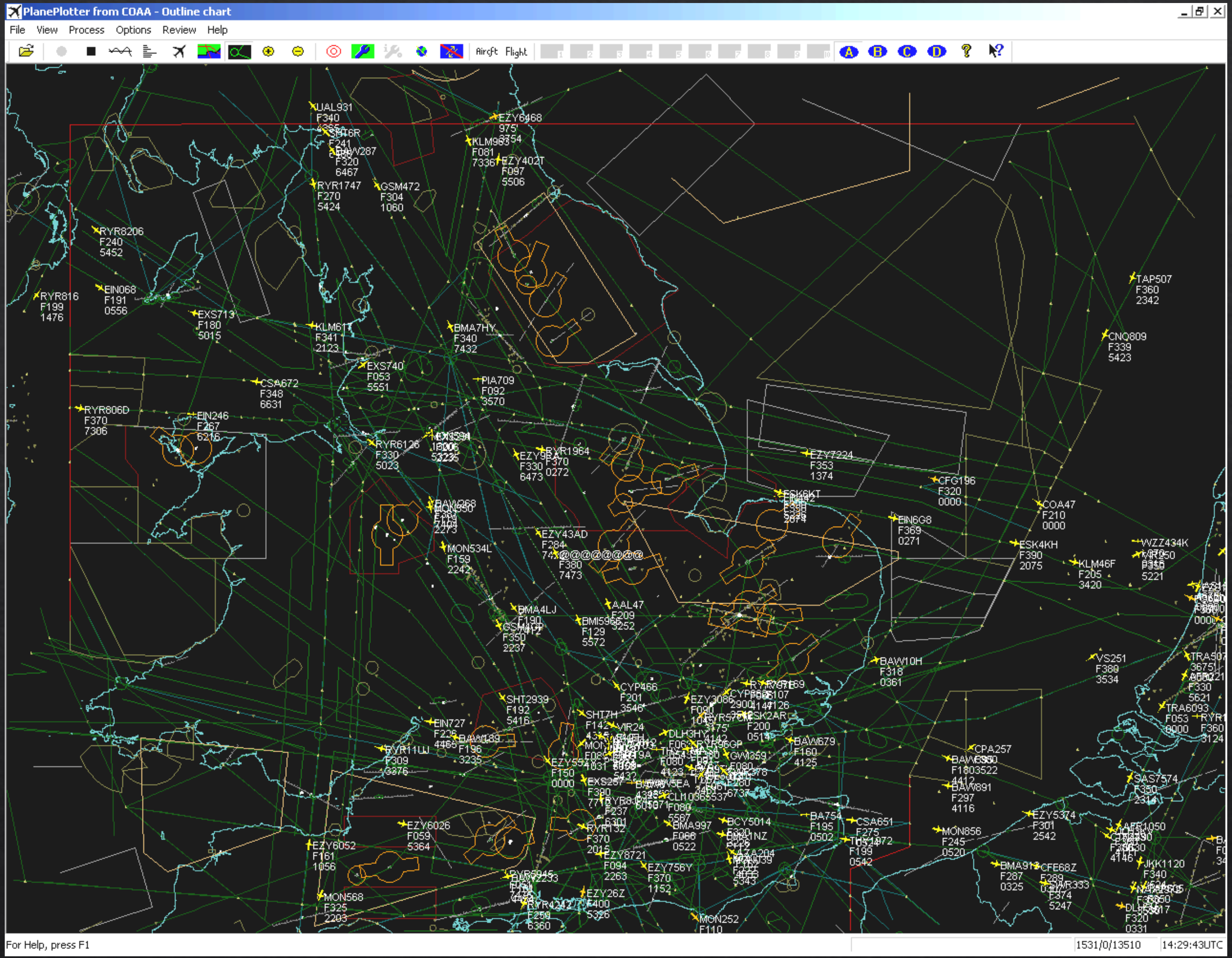
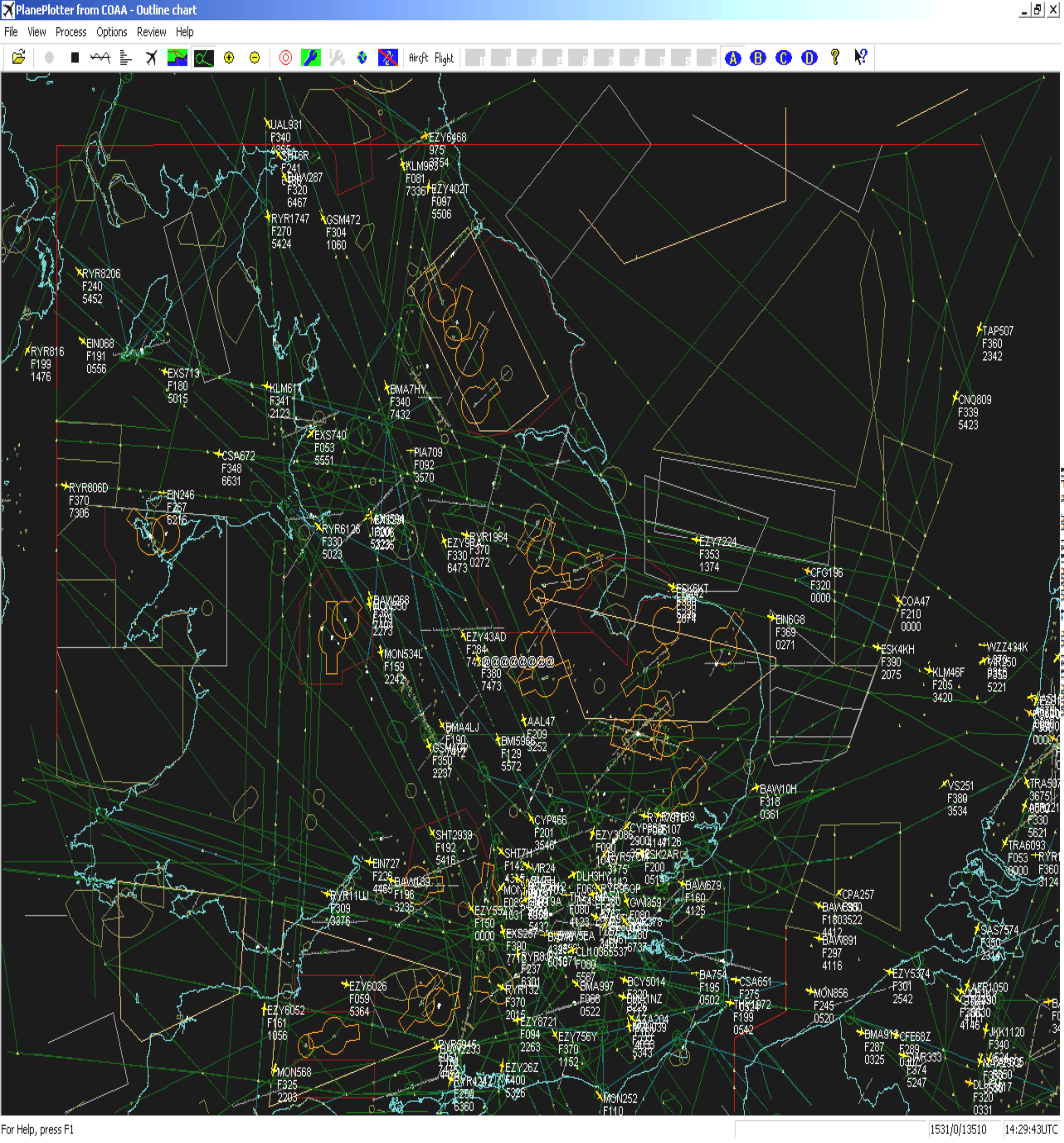
# Purpose

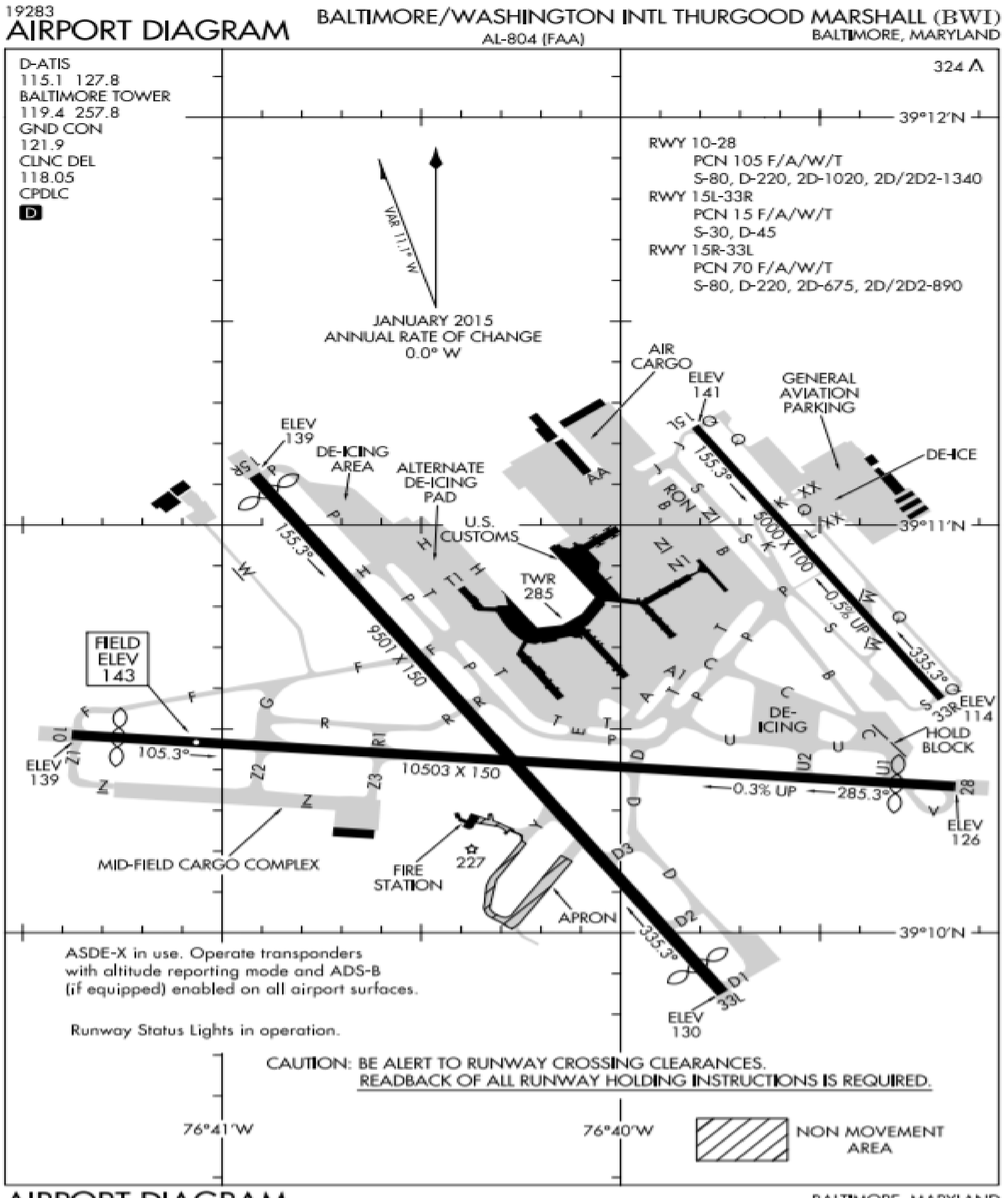
- The goal of this research is to create portable radar systems that can be used in real life applications. This would allow in many fields of study to use very small microcontrollers to complete everyday task. Many devices would benefit of having an alternative portable system compared to a bulkier design. My goal is to create a reliable radar that can run nonstop without much down time and push the limits of how far different microcontrollers can perform in different real-world applications.

# What is SDR?

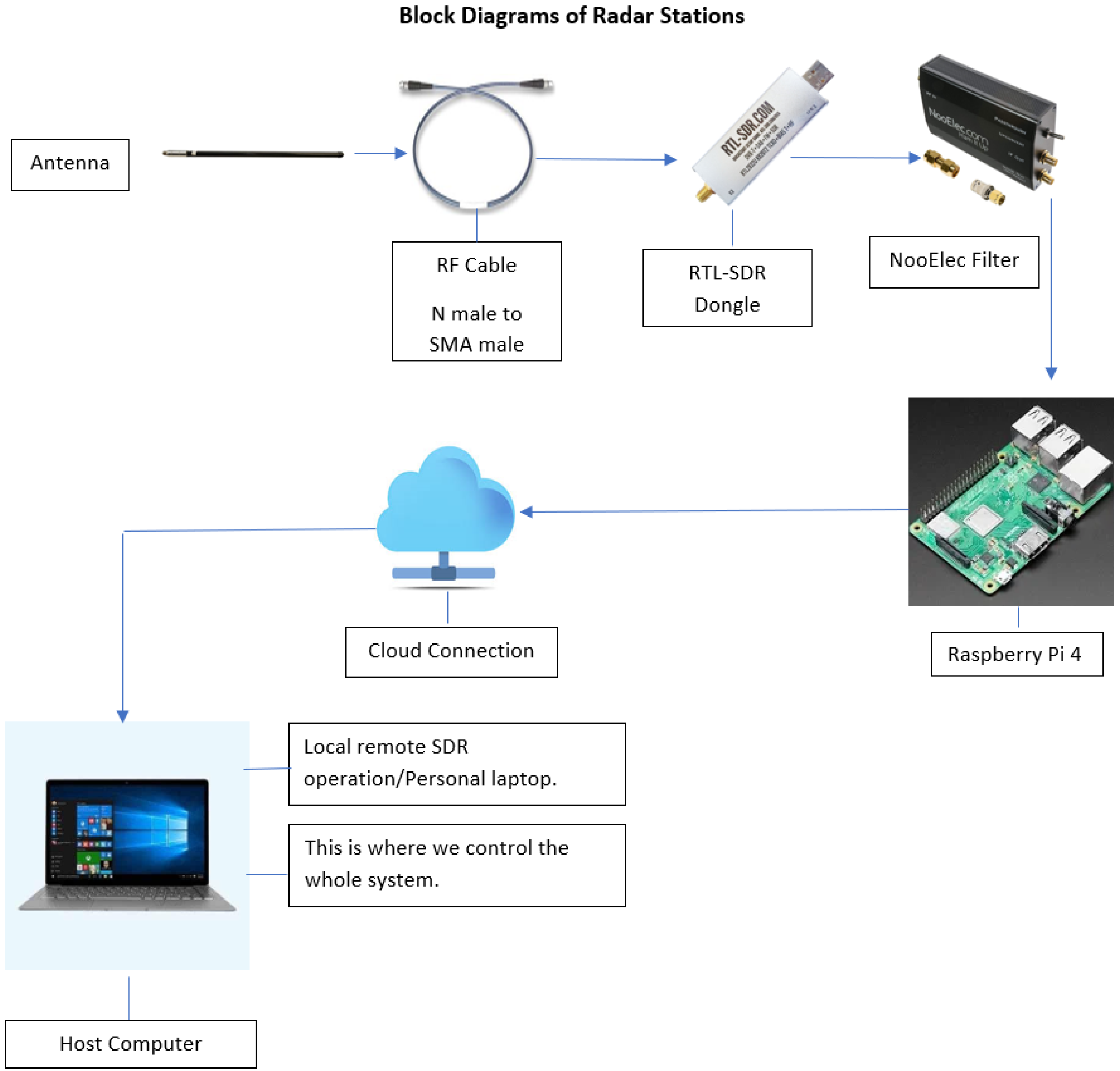
- Software Defined Radio is a radio communication system where components that have been traditionally implemented in hardware are instead implemented by means of software on a personal computer or embedded system.
- ADS-B is a surveillance technology in which an aircraft determines its position via satellite navigation and periodically broadcasts it, enabling it to be tracked.
- MLAT system is a navigation and surveillance technique based on measurement of the *times of arrival (TOAs)* of energy waves (radio, acoustic, seismic, etc.)




PlanePlotter from COAA - Outline chart
File View Process Options Review Help
Airfgt Flight
For Help, press F1
1531/0/13510
14:29:43UTC


19283
AIRPORT DIAGRAM
BALTIMORE/WASHINGTON INTL THURGOOD MARSHALL (BWI)
AL-804 (FAA)
BALTIMORE, MARYLAND
D-ATIS
115.1 127.8
BALTIMORE TOWER
119.4 257.8
GND CON
121.9
CLNC DEL
118.05
CPDLC
324
39°12'N
39°11'N
39°10'N
RWY 10-28
PCN 105 F/A/W/T
S-80, D-220, 2D-1020, 2D/2D2-1340
RWY 15L-33R
PCN 15 F/A/W/T
S-30, D-45
RWY 15R-33L
PCN 70 F/A/W/T
S-80, D-220, 2D-675, 2D/2D2-890
VAR 11.1° W
JANUARY 2015
ANNUAL RATE OF CHANGE
0.0° W
AIR CARGO
ELEV 141
GENERAL AVIATION PARKING
DE-ICE
ELEV 139
DE-ICING AREA
ALTERNATE DE-ICING PAD
U.S. CUSTOMS
TWR 285
FIELD ELEV 143
ELEV 139
105.3°
10503 X 150
9501 X 150
5000 X 100
0.3% UP
285.3°
335.3°
155.3°
DE-ICING
HOLD BLOCK
ELEV 114
ELEV 126
MID-FIELD CARGO COMPLEX
FIRE STATION
227
APRON
ELEV 130
ASDE-X in use. Operate transponders with altitude reporting mode and ADS-B (if equipped) enabled on all airport surfaces.
Runway Status Lights in operation.
CAUTION: BE ALERT TO RUNWAY CROSSING CLEARANCES. READBACK OF ALL RUNWAY HOLDING INSTRUCTIONS IS REQUIRED.
76°41'W
76°40'W
NON MOVEMENT AREA

# Block Diagram of Radar Stations



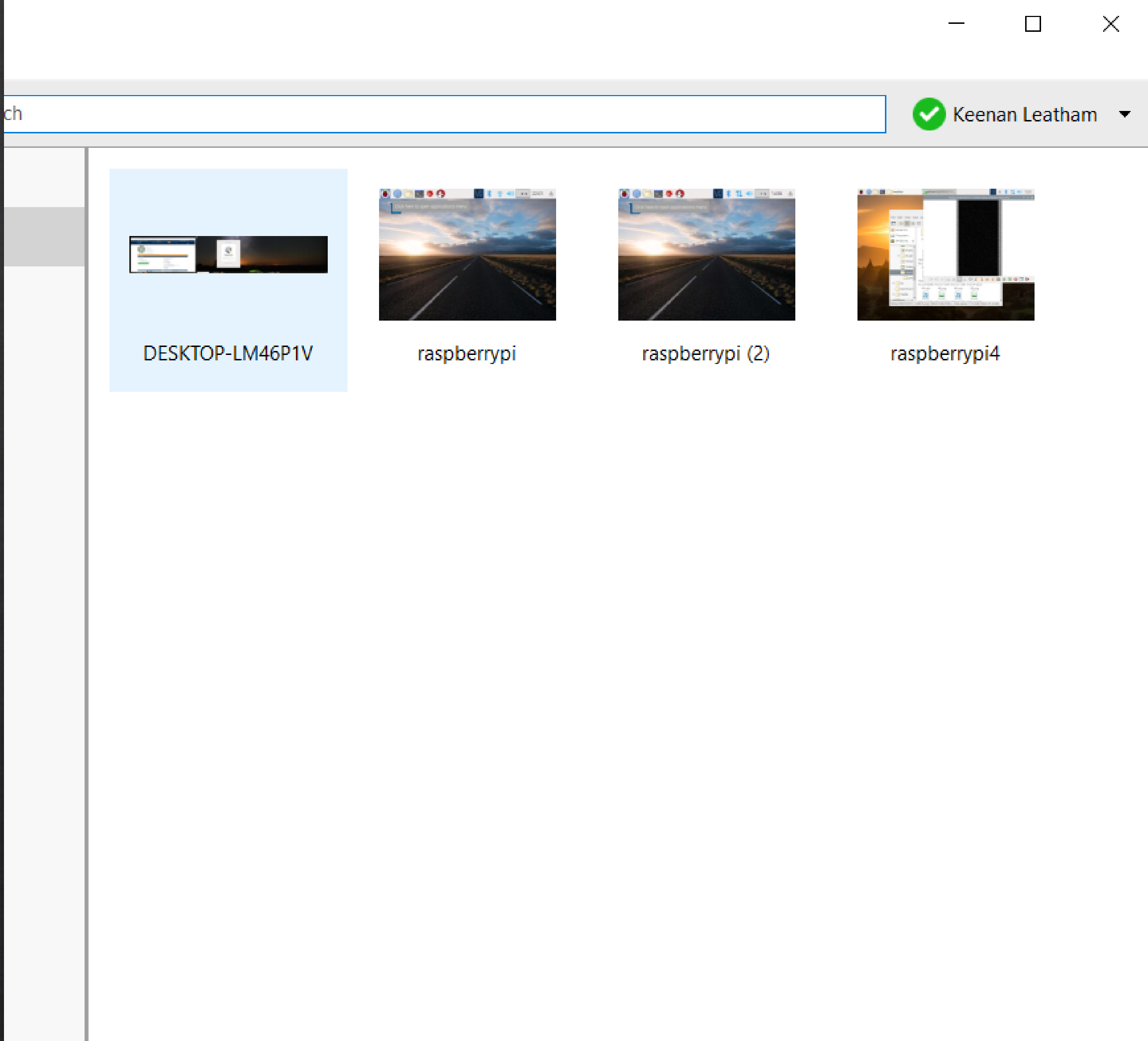
# Radar Stations

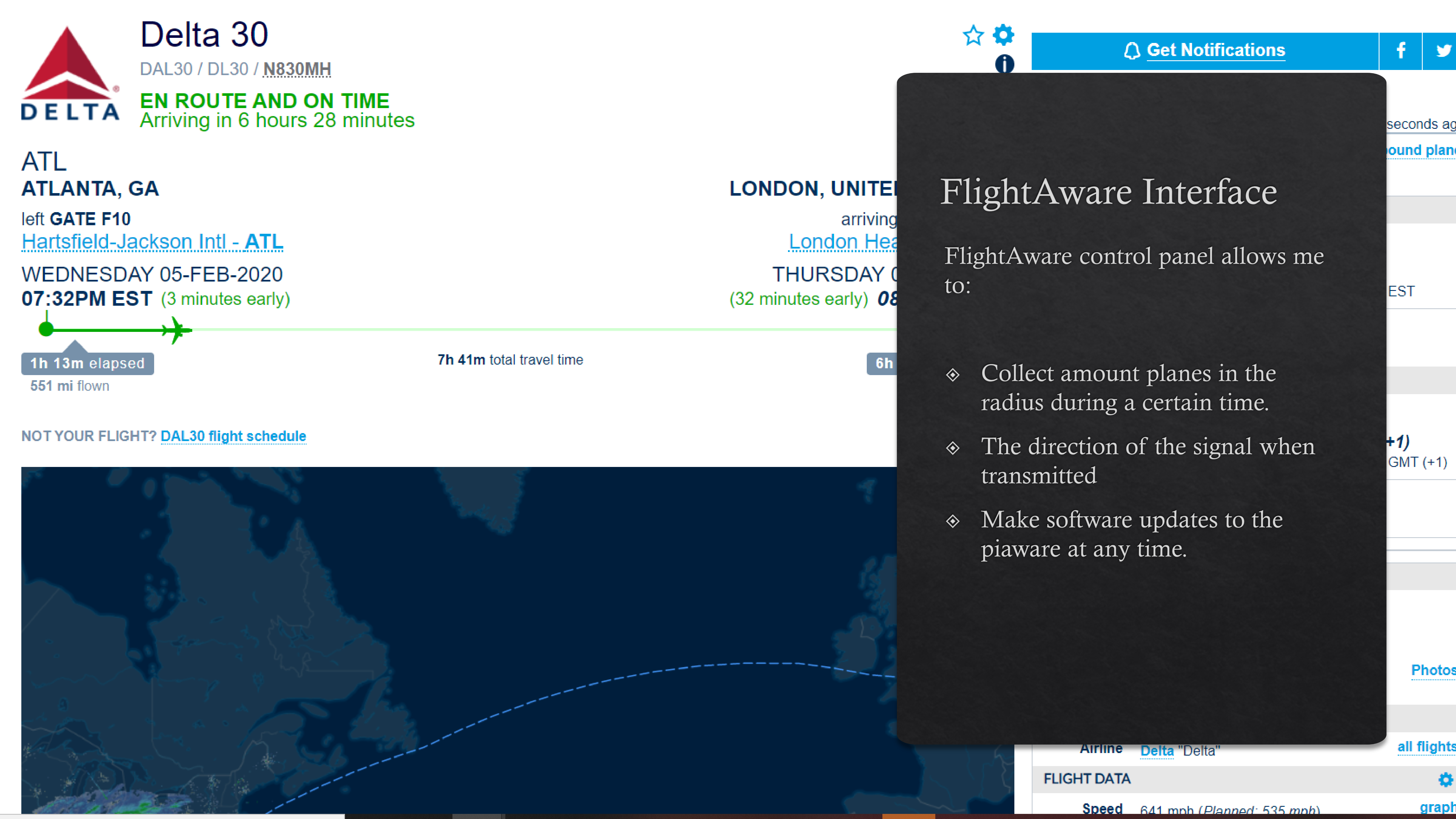
# Remote Cloud Connections

VNC Viewer allows me to have access to any device on the cloud at any time.

Advantages of Creating my own Cloud:

- All devices can be updated simultaneously
- Can spot any errors or Security vulnerabilities in the software.
- Have access to any command window to any device.






# FlightAware Interface

FlightAware control panel allows me to:

- Collect amount planes in the radius during a certain time.
- The direction of the signal when transmitted
- Make software updates to the piaware at any time.

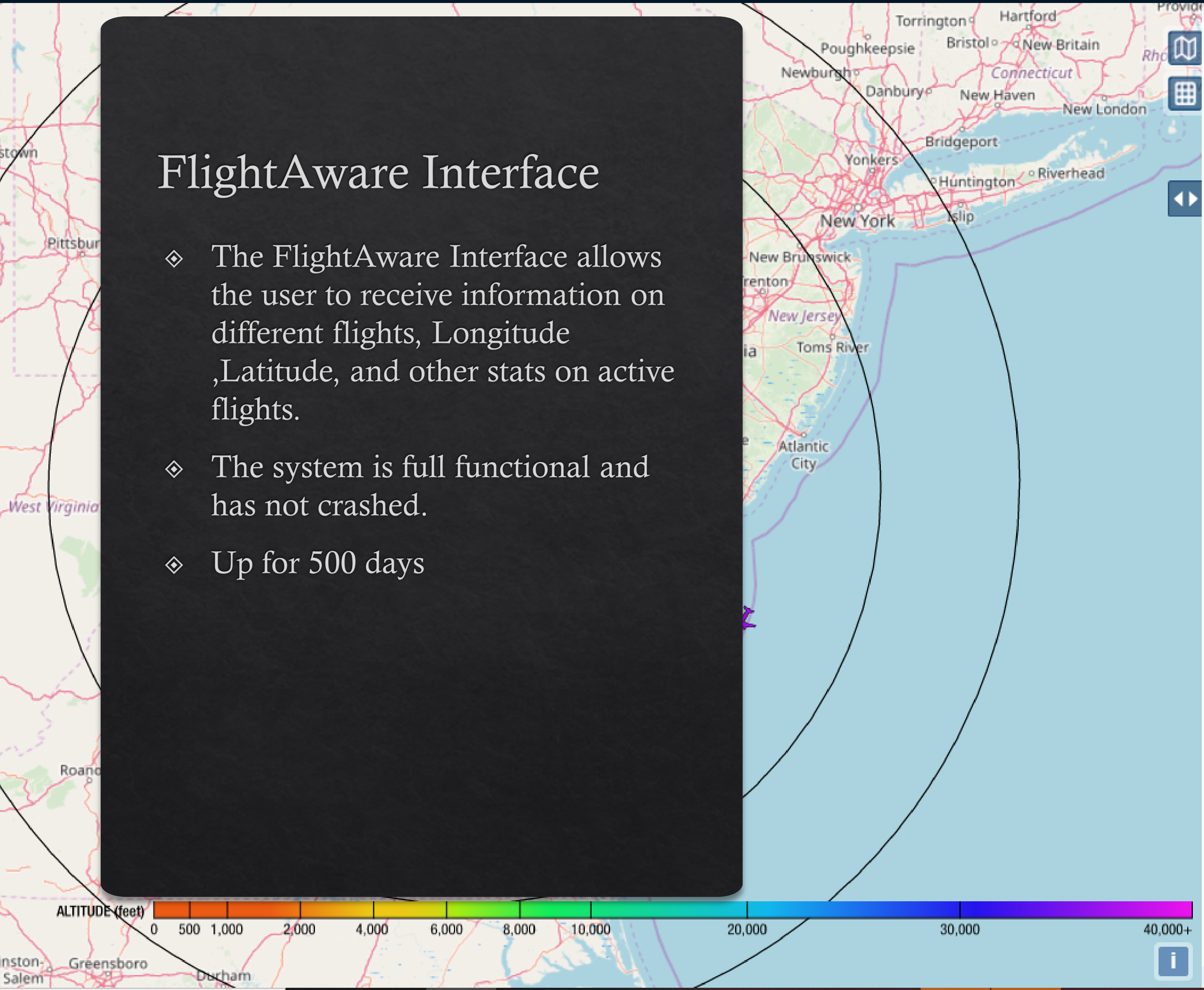
# FlightAware Interface

- The FlightAware Interface allows the user to receive information on different flights, Longitude ,Latitude, and other stats on active flights.
- The system is full functional and has not crashed.
- Up for 500 days

PiAware SkyAware

1/20/2020, 10:34:50 AM

Reset Map | Show All Tracks | Hide All Tracks




3.7.2

**Total Aircraft:** 44
**With Positions:** 38
**Messages:** 237.2/sec
**History:** 1648 positions

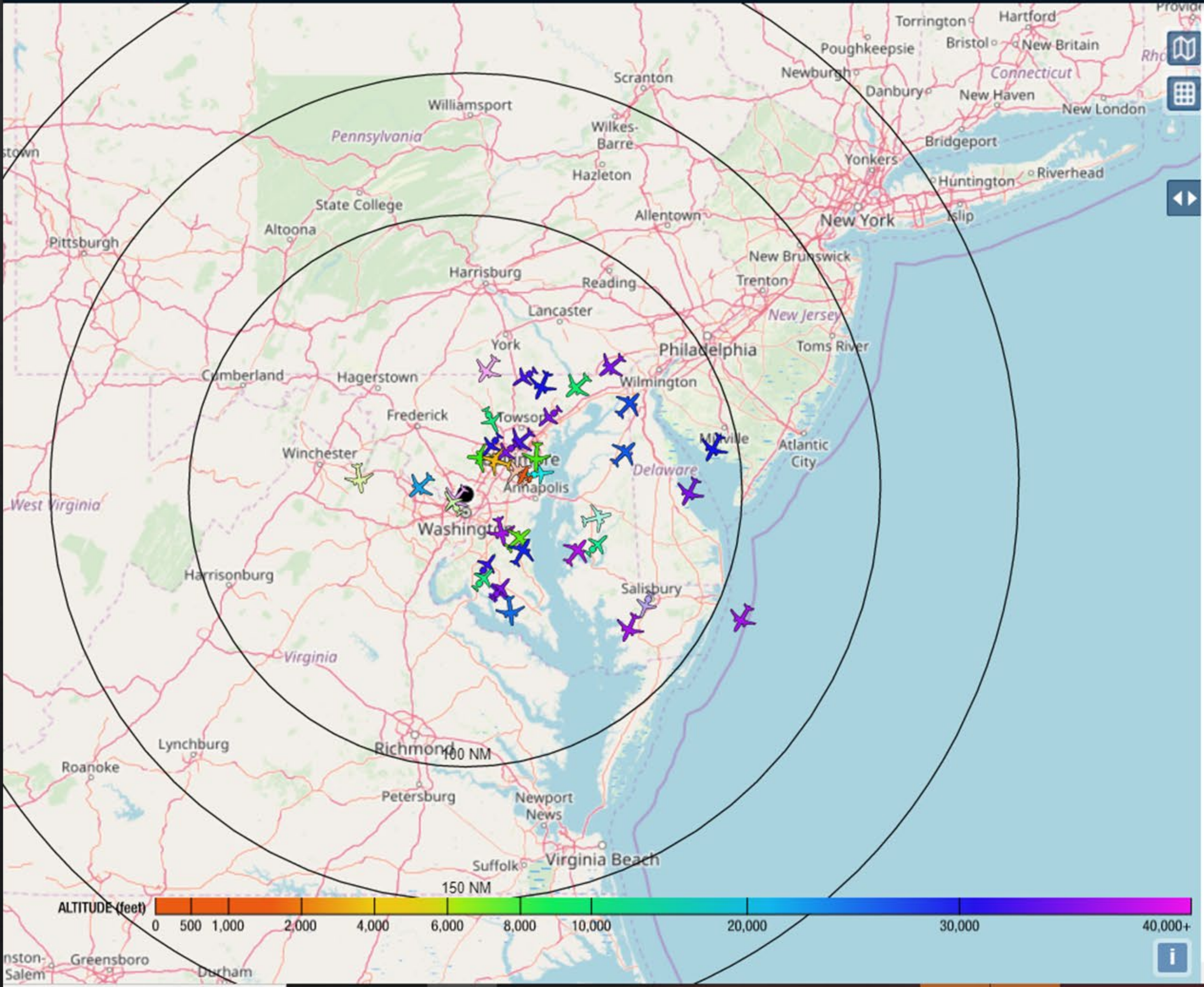
**Filter by Altitude:** ft to ft Filter Reset

| ICAO | | Ident | Squawk | Altitude (ft) | Speed (kt) | Distance (NM) | Heading | Msgs | Age |
|---|---|---|---|---|---|---|---|---|---|
| AD3581 | | JBU6457 | | 38,025 | 410 | 4.0 | 221° | 5268 | 1 |
| A05AD1 | | UCA4884 | | 30,000 | 416 | 4.1 | 221° | 5861 | 4 |
| A537ED | | RPA4636 | | 6,700 ▲ | 231 | 5.5 | 326° | 78 | 2 |
| A29611 | | JBU823 | | 10,725 | | 8.0 | | 64 | 56 |
| ACB872 | | DAL2413 | 2446 | 7,975 ▲ | 270 | 14.5 | 274° | 1436 | 0 |
| AC91D4 | | AAL1227 | 2135 | 3,575 ▲ | 246 | 16.4 | 287° | 531 | 0 |
| AC59AA | | UAL566 | | 20,825 ▲ | 368 | 16.4 | 226° | 2236 | 0 |
| C0360E | | WJA2506 | 0572 | 35,875 ▲ | 462 | 18.6 | 167° | 3638 | 0 |
| A44A48 | | EDV5317 | 7141 | 30,025 | 444 | 19.9 | 219° | 1282 | 0 |
| ABF2C2 | | SWA887 | 7265 | 675 ▼ | 141 | 20.6 | 325° | 3754 | 10 |
| ABD41A | | RPA3717 | 2223 | 34,000 | 407 | 21.2 | 231° | 4647 | 0 |
| AD6DA6 | | FDY153 | 3015 | 1,700 ▼ | 128 | 22.6 | 298° | 288 | 0 |
| AAD32F | | SWA1457 | 7065 | 7,300 ▼ | 258 | 25.1 | 50° | 1647 | 0 |
| ABDB88 | | RPA3401 | 1777 | 31,000 | 493 | 27.1 | 36° | 233 | 0 |
| A8E2D6 | | DAL481 | 1754 | 32,000 | 431 | 27.8 | 231° | 7222 | 0 |
| A4C8DE | | RPA4406 | 6503 | 17,950 ▲ | 370 | 28.1 | 82° | 3777 | 0 |
| A97D63 | | JIA5487 | 5712 | 11,550 | 332 | 28.3 | 153° | 808 | 0 |
| AB400E | | RVJ824 | 4633 | 7,600 ▲ | 287 | 29.3 | 183° | 166 | 0 |
| AB0B09 | | EJM810 | 3733 | 27,925 ▼ | 478 | 29.3 | 30° | 1173 | 7 |
| ACAD4B | | | 7114 | 12,225 ▼ | 319 | 31.7 | 42° | 103 | 1 |
| A912DE | | N684JC | 6175 | 34,250 ▼ | 516 | 36.8 | 40° | 349 | 0 |
| AFEF10 | | | | 34,575 ▼ | 507 | 37.4 | 41° | 12 | 0 |
| A2882A | | | | 5,550 | 285 | 38.9 | 171° | 47 | 44 |
| A32BCB | | EDV4934 | 2726 | 34,000 | 415 | 41.1 | 230° | 4662 | 0 |
| A845F4 | | JBU752 | 0744 | 36,975 | 478 | 45.3 | 38° | 2417 | 0 |
| A86A28 | | NKS781 | 5654 | 23,875 ▲ | 417 | 45.5 | 173° | 5282 | 0 |
| AA1960 | | N75TG | 3545 | 40,000 | 399 | 45.7 | 215° | 228 | 0 |
| AEE447 | | RPA4408 | 3001 | 32,000 | 406 | 47.0 | 236° | 1078 | 6 |

PiAware SkyAware

1/20/2020, 10:34:50 AM

Reset Map | Show All Tracks | Hide All Tracks

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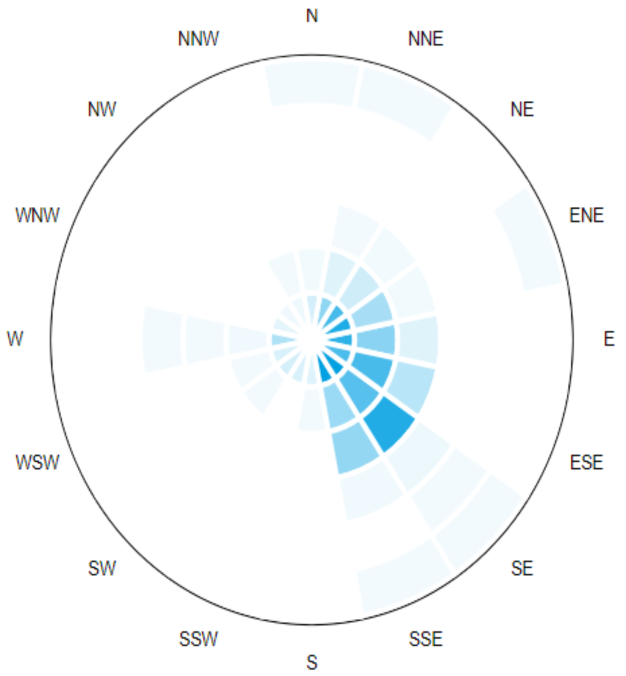
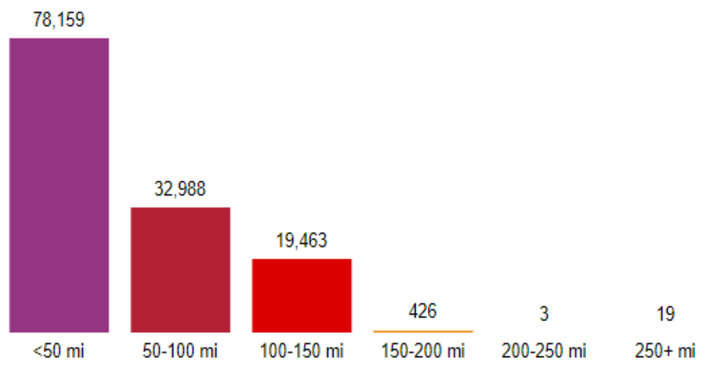
| AC91D4 | | AAL1227 | 2135 | 3,575 ▲ | 246 | 16.4 | 287° | 531 | 0 |
| AC59AA | | UAL566 | | 20,825 ▲ | 368 | 16.4 | 226° | 2236 | 0 |
| C0360E | | WJA2506 | 0572 | 35,875 ▲ | 462 | 18.6 | 167° | 3638 | 0 |
| A44A48 | | EDV5317 | 7141 | 30,025 | 444 | 19.9 | 219° | 1282 | 0 |
| ABF2C2 | | SWA887 | 7265 | 675 ▼ | 141 | 20.6 | 325° | 3754 | 10 |
| ABD41A | | RPA3717 | 2223 | 34,000 | 407 | 21.2 | 231° | 4647 | 0 |
| AD6DA6 | | FDY153 | 3015 | 1,700 ▼ | 128 | 22.6 | 298° | 288 | 0 |
| AAD32F | | SWA1457 | 7065 | 7,300 ▼ | 258 | 25.1 | 50° | 1647 | 0 |
| ABDB88 | | RPA3401 | 1777 | 31,000 | 493 | 27.1 | 36° | 233 | 0 |
| A8E2D6 | | DAL481 | 1754 | 32,000 | 431 | 27.8 | 231° | 7222 | 0 |
| A4C8DE | | RPA4406 | 6503 | 17,950 ▲ | 370 | 28.1 | 82° | 3777 | 0 |
| A97D63 | | JIA5487 | 5712 | 11,550 | 332 | 28.3 | 153° | 808 | 0 |
| AB400E | | RVJ824 | 4633 | 7,600 ▲ | 287 | 29.3 | 183° | 166 | 0 |
| AB0B09 | | EJM810 | 3733 | 27,925 ▼ | 478 | 29.3 | 30° | 1173 | 7 |
| ACAD4B | | | 7114 | 12,225 ▼ | 319 | 31.7 | 42° | 103 | 1 |
| A912DE | | N684JC | 6175 | 34,250 ▼ | 516 | 36.8 | 40° | 349 | 0 |
| *AFEF10* | | | | *34,575* ▼ | *507* | *37.4* | *41°* | *12* | *0* |
| A2882A | | | | 5,550 | 285 | 38.9 | 171° | 47 | 44 |
| A32BCB | | EDV4934 | 2726 | 34,000 | 415 | 41.1 | 230° | 4662 | 0 |
| A845F4 | | JBU752 | 0744 | 36,975 | 478 | 45.3 | 38° | 2417 | 0 |
| A86A28 | | NKS781 | 5654 | 23,875 ▲ | 417 | 45.5 | 173° | 5282 | 0 |
| AA1960 | | N75TG | 3545 | 40,000 | 399 | 45.7 | 215° | 228 | 0 |
| AFE447 | | RPA4498 | 3001 | 32,000 | 406 | 47.0 | 236° | 1078 | 6 |

# Flight Statistics




Positions Reported by Distance from Receiver

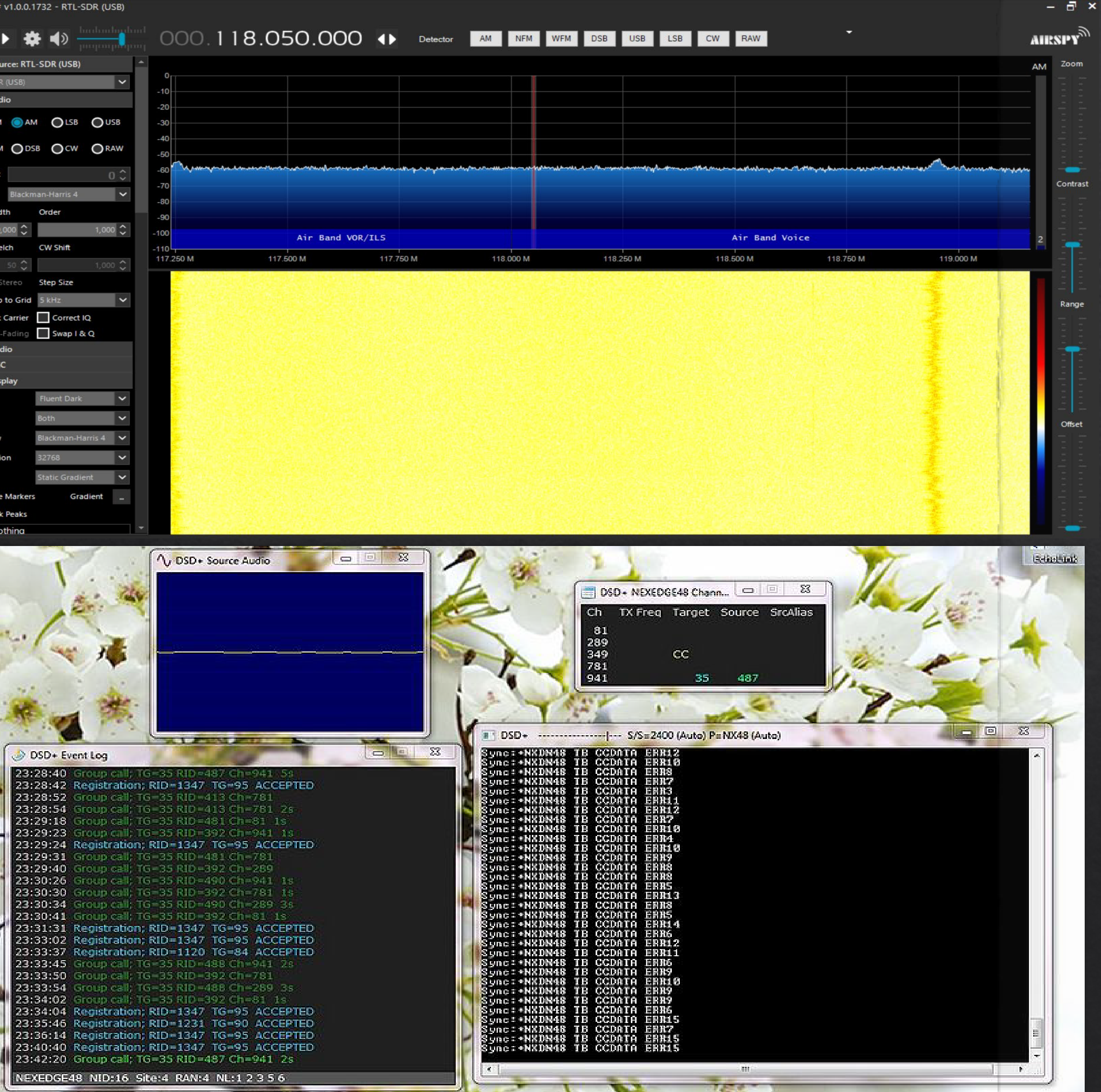



## AIRCRAFT REPORTED

| | 1/22/2020 | 1/21/2020 | 1/20/2020 | 1/19/2020 | 1/18/2020 | 1/17/2020 | 1/16/2020 |
|---|---|---|---|---|---|---|---|
| ADS-B Mode-S | 795 | 2,515 | 2,347 | 1,592 | 1,512 | 2,121 | 1,801 |
| MLAT | 49 | 112 | 78 | 36 | 47 | 130 | 104 |
| Other | 76 | 196 | 169 | 200 | 186 | 270 | 273 |
| Total | 920 | 2,823 | 2,594 | 1,828 | 1,745 | 2,521 | 2,178 |

## POSITIONS REPORTED

| | 1/22/2020 | 1/21/2020 | 1/20/2020 | 1/19/2020 | 1/18/2020 | 1/17/2020 | 1/16/2020 |
|---|---|---|---|---|---|---|---|
| ADS-B Mode-S | 34,869 | 180,671 | 157,371 | 61,644 | 56,871 | 108,003 | 70,750 |
| MLAT | 411 | 2,355 | 1,592 | 1,145 | 1,154 | 2,945 | 2,439 |
| Other | 15,550 | 85,094 | 71,797 | 39,226 | 38,019 | 69,549 | 53,251 |
| Total | 50,830 | 268,120 | 230,760 | 102,015 | 96,044 | 180,497 | 126,440 |




# SDR Sharp

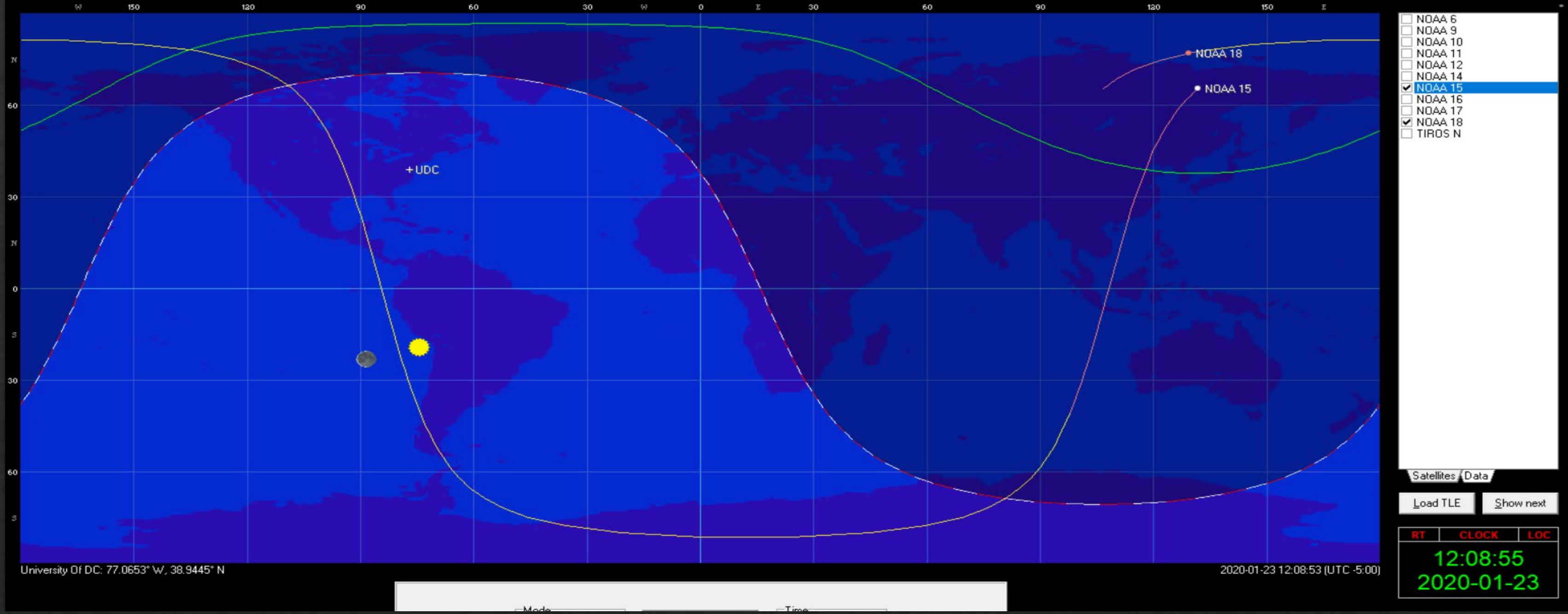
SDR# (read SDR Sharp) is a simple, intuitive, small and fast PC-based DSP application for Software Defined Radio. It's written in C# with both object design correctness and performance in mind. The main purpose is to offer a simple proof of concept application to get hands into DSP techniques.

We can use SDR Sharp:

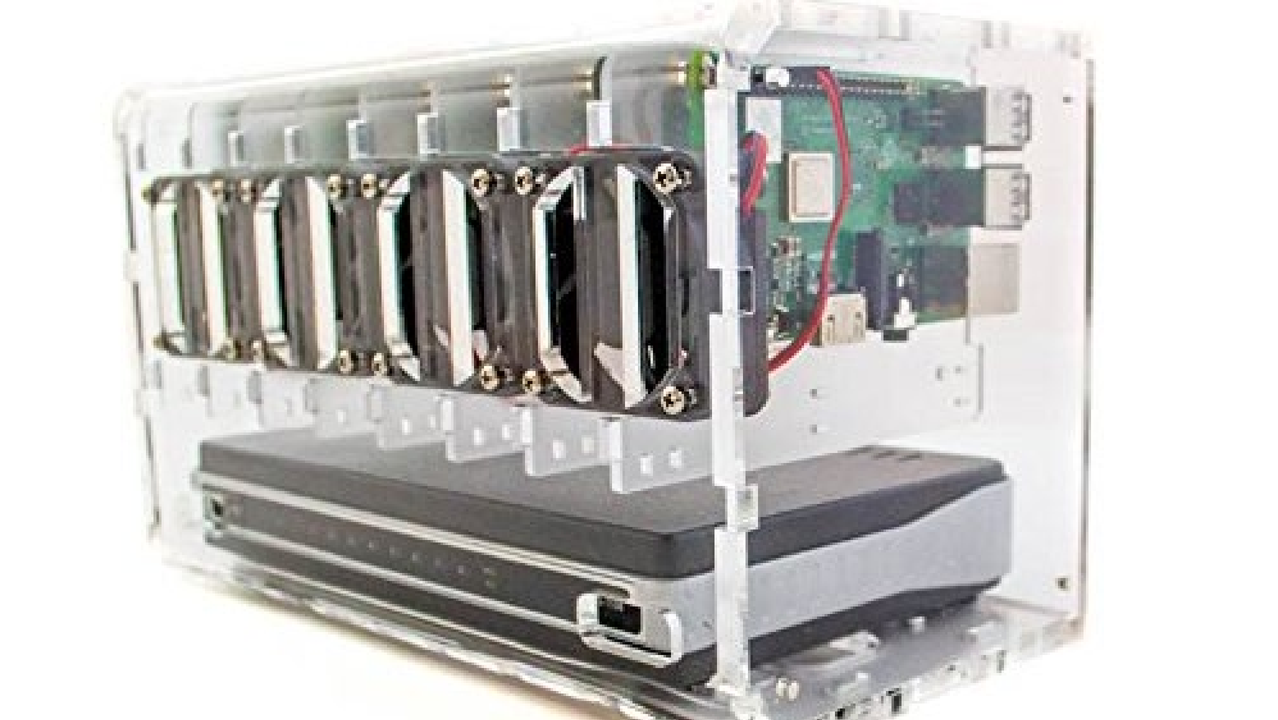
- Analyze signals
- Decode signals
- Spot Anomalies in signals

# Satellite Data

- On the right shows the simulation of the satellite passes.
- We can automatically send the data collected wherever you want.




```
#!/bin/bash

# Update Satellite Information

wget -qr https://www.celestrak.com/NORAD/elements/weather.txt -O /home/pi/weather/p
grep "NOAA 15" /home/pi/weather/predict/weather.txt -A 2 > /home/pi/weather/predict
grep "NOAA 18" /home/pi/weather/predict/weather.txt -A 2 >> /home/pi/weather/predic
grep "NOAA 19" /home/pi/weather/predict/weather.txt -A 2 >> /home/pi/weather/predic
grep "METEOR-M 2" /home/pi/weather/predict/weather.txt -A 2 >> /home/pi/weather/pre



#Remove all AT jobs

for i in `atq | awk '{print $1}'`;do atrm $i;done


#Schedule Satellite Passes:

/home/pi/weather/predict/schedule_satellite.sh "NOAA 19" 137.1000
/home/pi/weather/predict/schedule_satellite.sh "NOAA 18" 137.9125
/home/pi/weather/predict/schedule_satellite.sh "NOAA 15" 137.6200
```

# Future Work

In the Future we plan on creating supercomputers to handle bigger infrastructures to be used commercially.

# References

[1] Gianni Pasolini, Alessandro Bazzi, and Flavio Zabini, “A Raspberry Pi-Based Platform for Signal Processing Education” in IEEE Signal Processing Magazine, July. 2017

[2] “Signal Processing 101.” IEEE Signal Processing Society, 19 Apr. 2018, signalprocessingsociety.org/our-story/signal-processing-101.

If you have any more difficulties, just visit the websites underlined below. They will help you with your project. Otherwise, use your favorite search engine!

1. “Raspberry Pi as Remote Server for RTL2832u SDR.” Ham Radio Science, 28 Dec. 2012, hamradioscience.com/raspberry-pi-as-remote-server-for-rtl2832u-sdr/.
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3. “User Support.” Gqrx SDR, gqrx.dk/user-support
4. https://www.youtube.com/watch?v=1pr319FvOwI&t=303s
5. http://ranous.wordpress.com/
6. https://www.youtube.com/watch?v=AoXo0J6ZjiM

[3] M.G. Czerwinski, J.M. Usoff, "Development of the Haystack Ultrawideband Satellite Imaging Radar", Lincoln Laboratory Journal, vol. 1, no. 1, 2014.

[4] Pace. T (Ed. ): IEEE Aerospace and Electronic Systems Magazine, Special Issue on Passive Coherent Location Radar, October 2012, Vol. 27, No. 10, 2012.

[5] J. Mitola, "The Software Radio Architecture", IEEE Communications Magazine, vol. 33, no. 5, pp. 26-38, 1995.

# Acknowledgment

- University of the District of Columbia SEAS
- University of the District of Columbia STEM Center
- IEEE Institute of Electrical and Electronics Engineers

# Questions