Edwards “Have DRAGON” Flight Test (Detection Recognition and Adaption to GPS Overt Noise)

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Working Group C – Resiliency Subgroup

Test Pilot School 2019: Have DRAGON

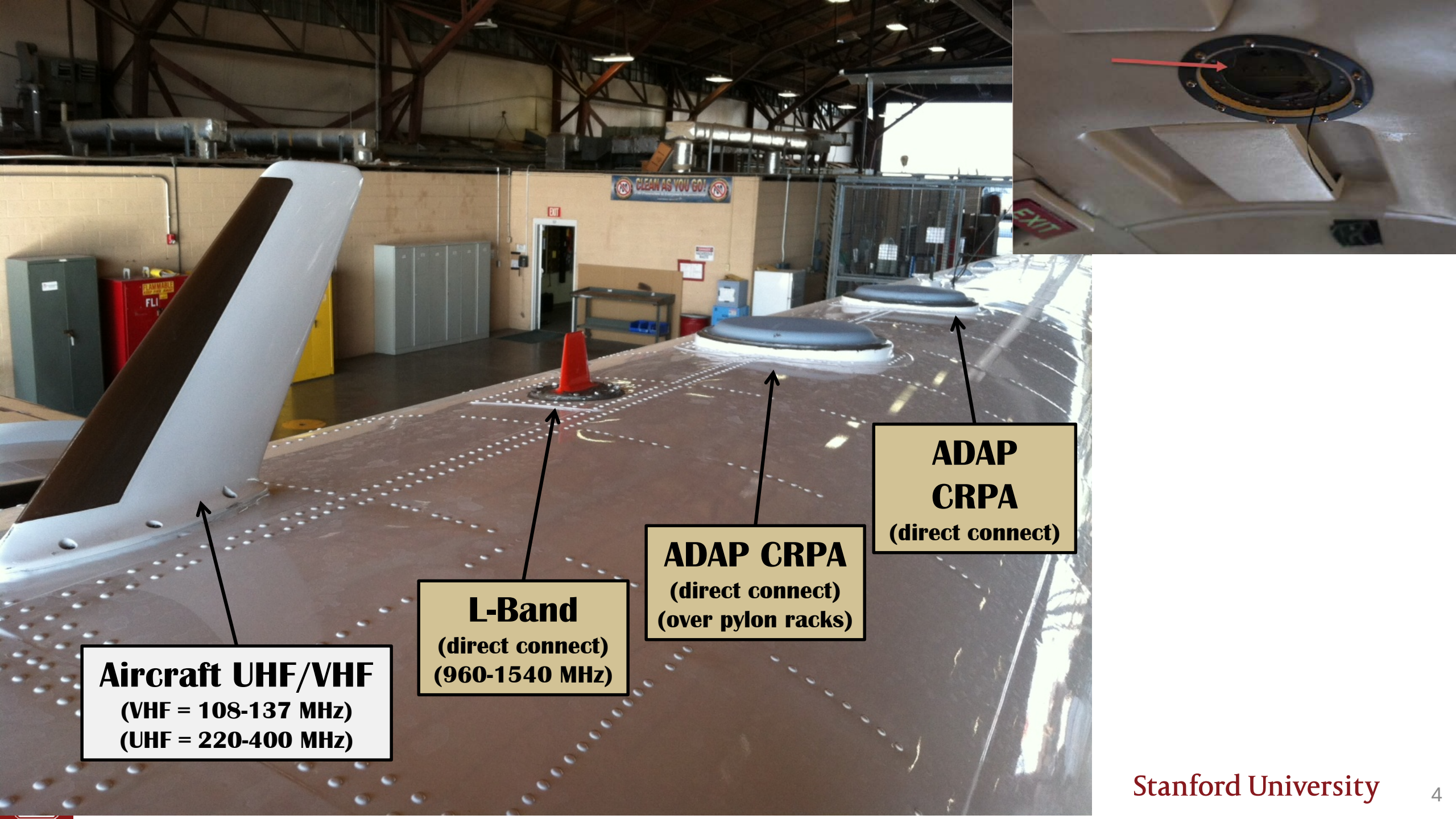
- Test Pilot School Program at Edwards Air Force Base; Provide experiments to test (our experiment designated Have DRAGON):
  - Advanced Receiver Autonomous Integrity Monitoring (ARAIM)
  - Dual Polarization Antenna (DPA)

- Test dates: 8 flight days, 2 hr flights Sept 9-13, 16-19; Ground test Sept 6 with 3 days overlap with DT-NAVFEST (jamming)

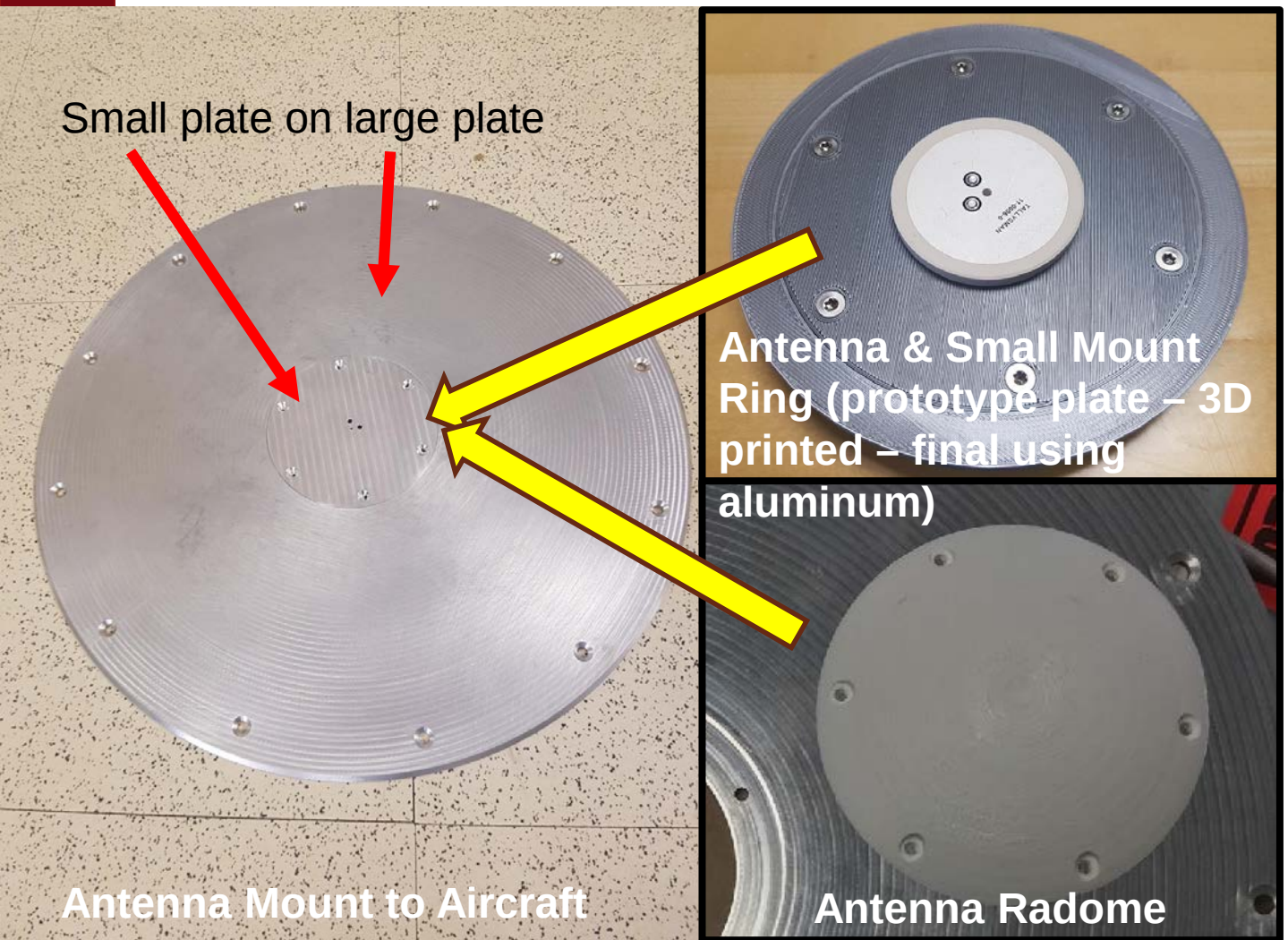
- Flight vehicle military C-12J (King Air/Beechcraft 1900) 586th FLTS Mable

- No classification concerns are expected/Project will be releasable to public


586 FLT TEST SQ

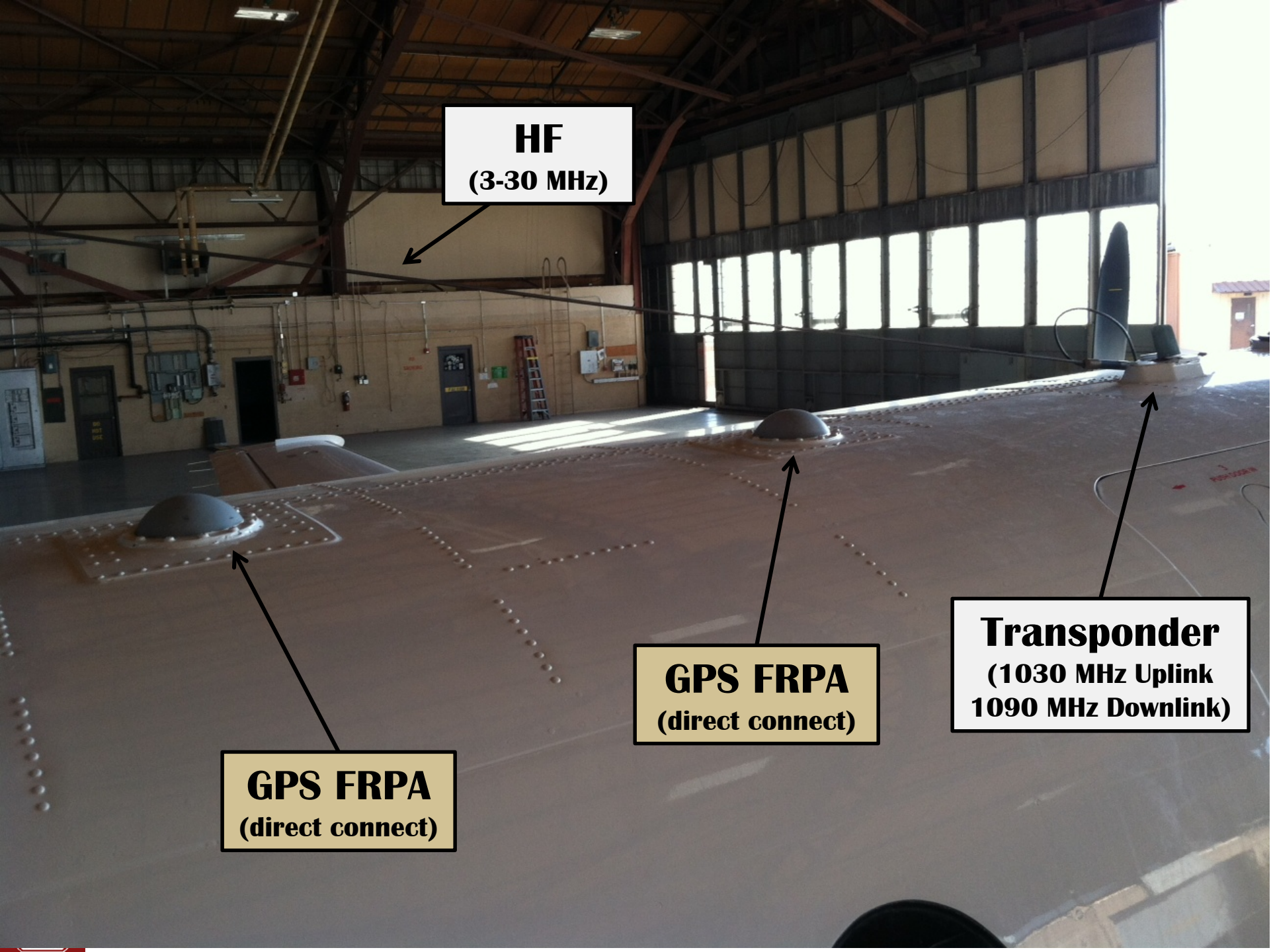

Aircraft UHF/VHF
(VHF = 108-137 MHz)
(UHF = 220-400 MHz)
L-Band
(direct connect)
(960-1540 MHz)
ADAP CRPA
(direct connect)
(over pylon racks)
ADAP
CRPA
(direct connect)

Dual Polarization Antenna for Flight: Mount and Housing



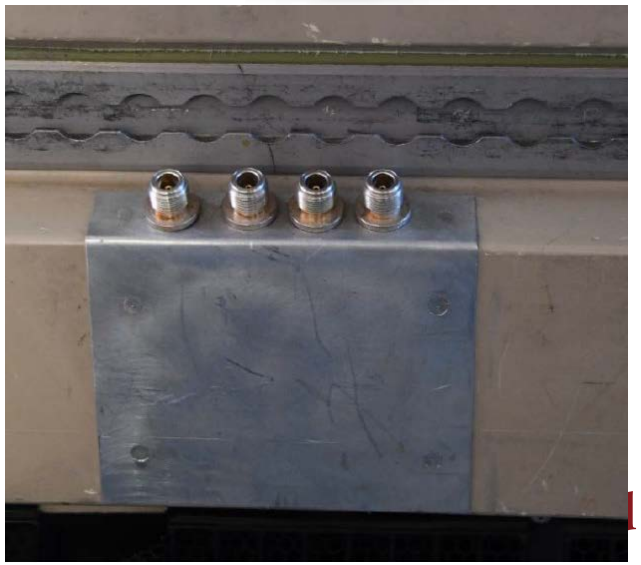
- Antenna mounted on a small circular aluminum plate that screws onto larger mounting plate via 6 screws
- Large aluminum mount fits C-12 aircraft & provide ground plane for DPA
- Radome created to go over antenna on smaller plate using the 6 screw points. It is made using 3-D print using PETG
- Air worthiness tested August 2019 at Holloman

DPA Mounted on Aircraft Top and Bottom


HF
(3-30 MHz)
GPS FRPA
(direct connect)
GPS FRPA
(direct connect)
Transponder
(1030 MHz Uplink
1090 MHz Downlink)

ARAIM Antenna

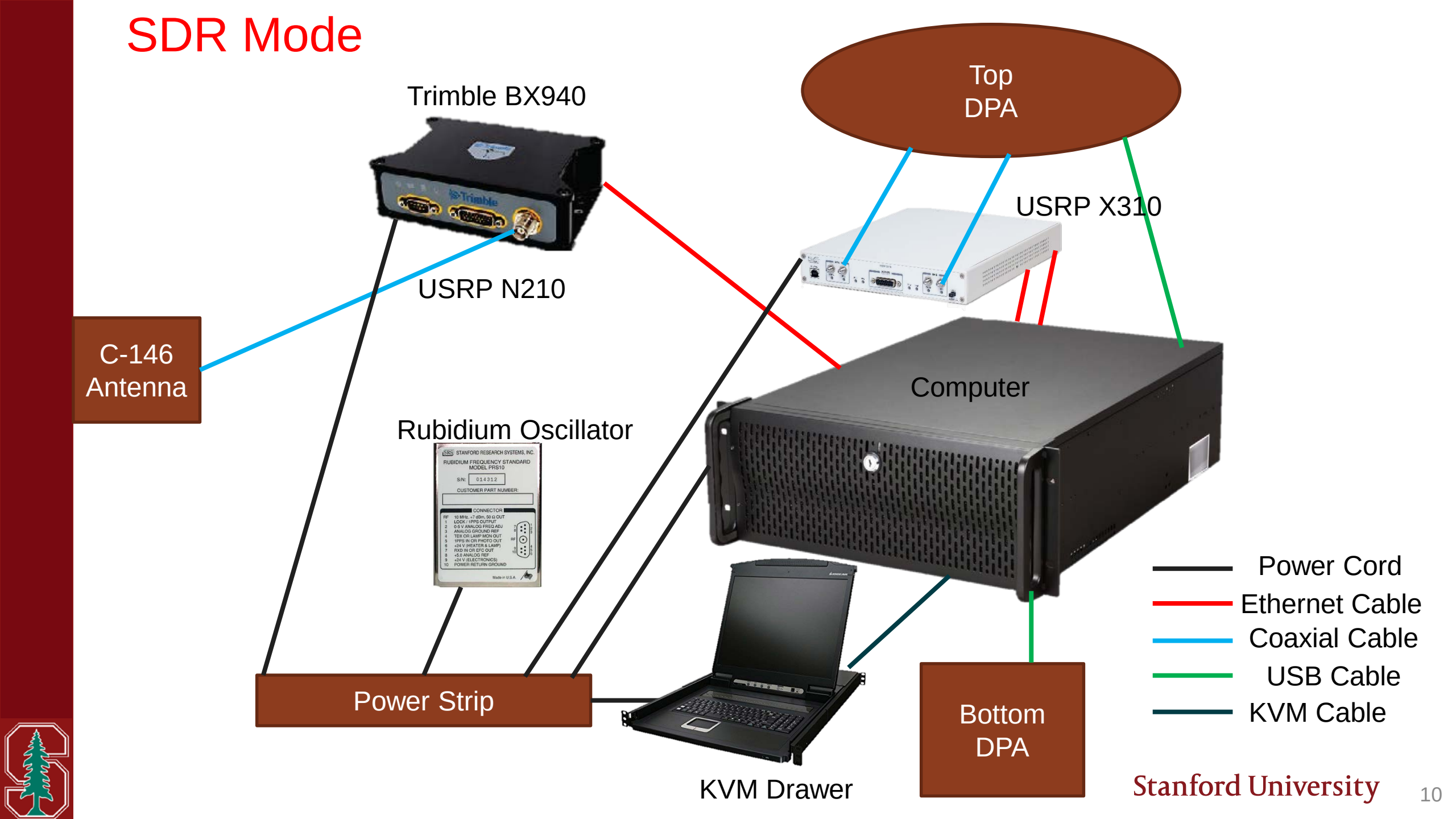
- Current antenna is L1/L2 Harris C 146
- Turns out that the C-146 is wideband and can support L5 as well
- Connect to Trimble receiver and SDR for ARAIM testing and raw data collection



Experiment Equipment

- Multi-frequency antenna (C-146 L1/L2/L5)
- Two Dual Polarization Antenna (top and bottom)
- Trimble BX940: GNSS and Inertial
- Raw data collection system: 2 USRPs
  - Shared 1 USRP between the C-146 Antenna and DPA
- Data collection computer (4U Rack mount)
- Truth System: FINS or UHARS
  - Fighter Instrumentation Navigation System
  - Ultra high accuracy reference system

SDR Mode


Top
DPA
Trimble BX940
USRP X310
USRP N210
C-146
Antenna
Computer
Rubidium Oscillator
Power Cord
Ethernet Cable
Coaxial Cable
USB Cable
KVM Cable
Power Strip
KVM Drawer
Bottom
DPA

Flight Equipment Rack

- All data collection equipment and receivers strapped down to flight rack
- Flight rack tested for airworthiness

Flight Test Profiles

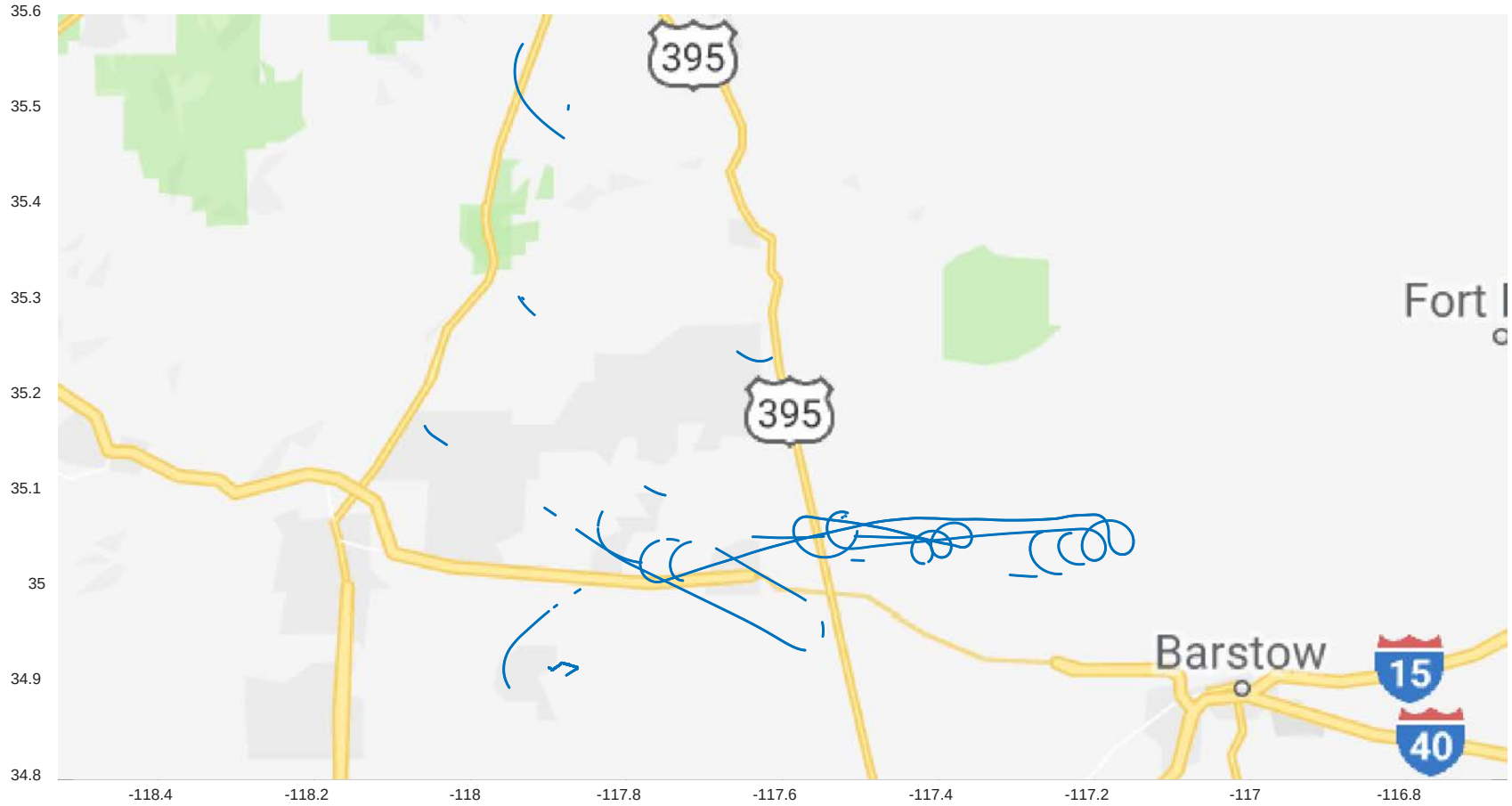
- Test DPA direction of arrivals in flight environment
- Test ARAIM performance in flight, particularly approach, high bank and other more difficult conditions
- Test DPA & ARAIM in interference

- Straight level flights, climbs, descents
- Spiral climbs, descents
- Cruise and Dynamic Maneuvering
- Low Level through canyons (terrain masking)
- Over water (500 ft, multipath)
- GPS jamming (DT NAVFEST, L1/L2)

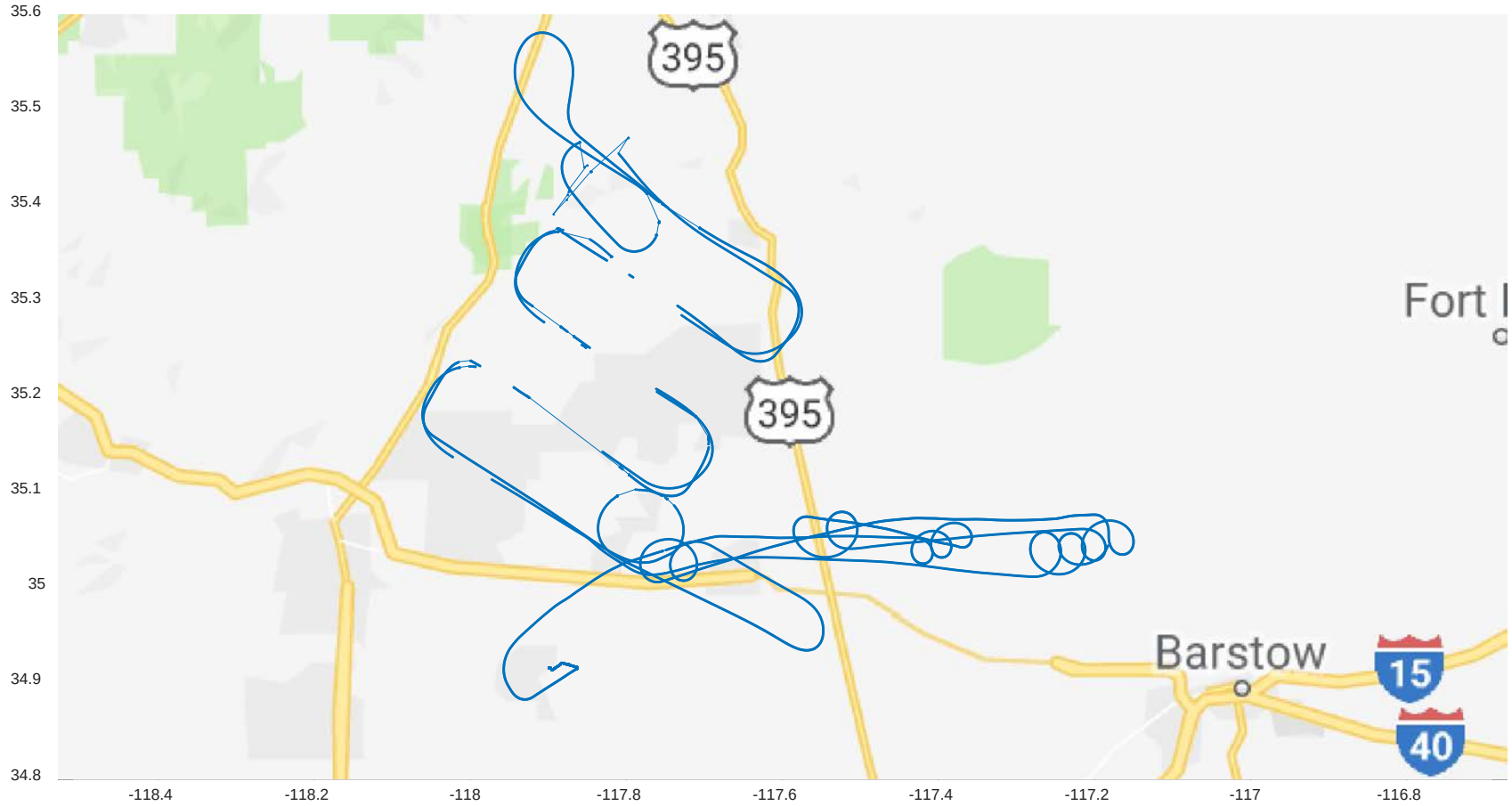
Experiment #1 ARAIM

- Flight test of ARAIM in various environments to examine performance and potential faults (multipath, etc.)
- Will extreme flight conditions may be problematic for ARAIM availability or other performance metrics
- For resiliency, this test allow us to record receiver and raw flight data to characterize nominal conditions and effects of aircraft body

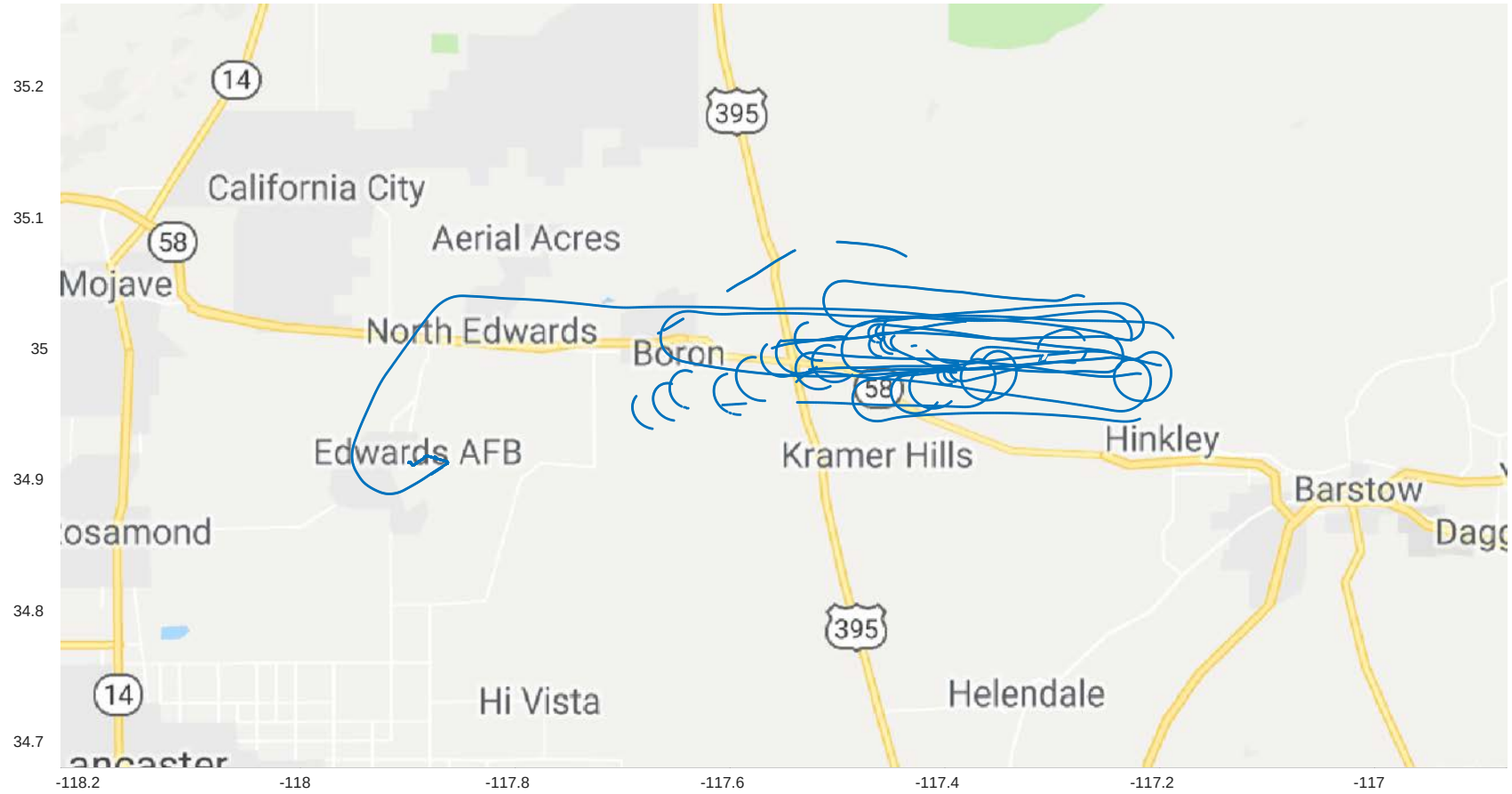
GPS only positions during DT NAVFEST (9-17)



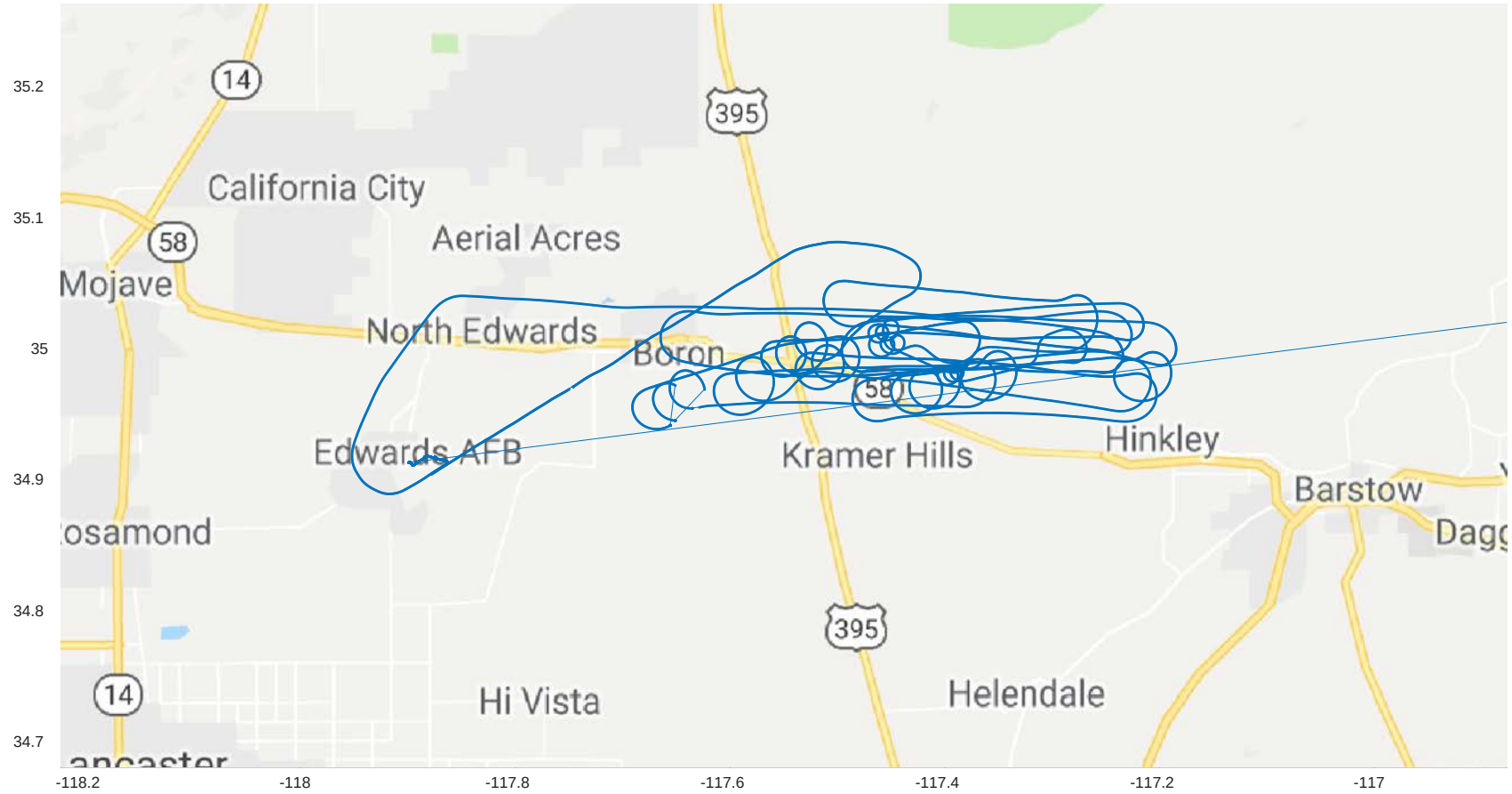
GNSS positions during DT NAVFEST (9-17)



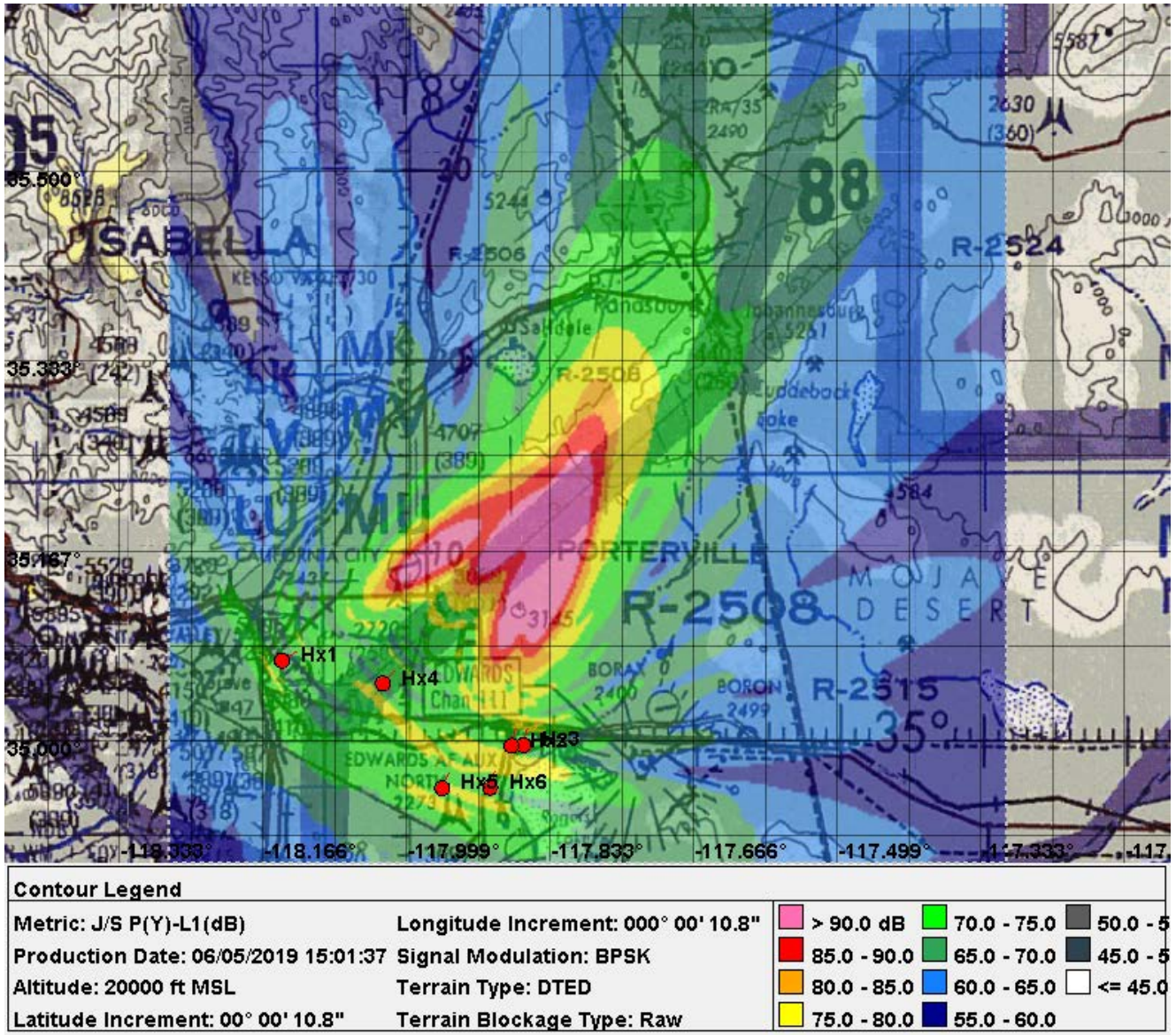
GPS only positions during DT NAVFEST (9-19)



GNSS positions during DT NAVFEST (9-19)



DT (Developmental Test) NAVFEST 2019



40 to 90 dB of jamming

Compare radiated and anticipated interference power with measured power

Experiment #2 DPA

- Flight test of dual polarization antenna in flight environments to examine performance at speed and in interference
- Aviation test of two versions of DPA processing: using COTS GNSS chipset and using software defined radio (SDR)
- Test of DPA in mitigating interference

DPA Direction of Arrival (DOA) Detection

Phase difference between RHCP and LHCP signal to estimate DOA

Need ground plane and signal propagation along ground plane

Measured phase diff = 2*DOA + offset = 2*(heading + sat azimuth) + offset

180 degree ambiguity

GNSS COTS chipset examines phase shifted combination of RHCP and LHCP and finds phase shift that causes null or peak (takes time > 2.4 sec)

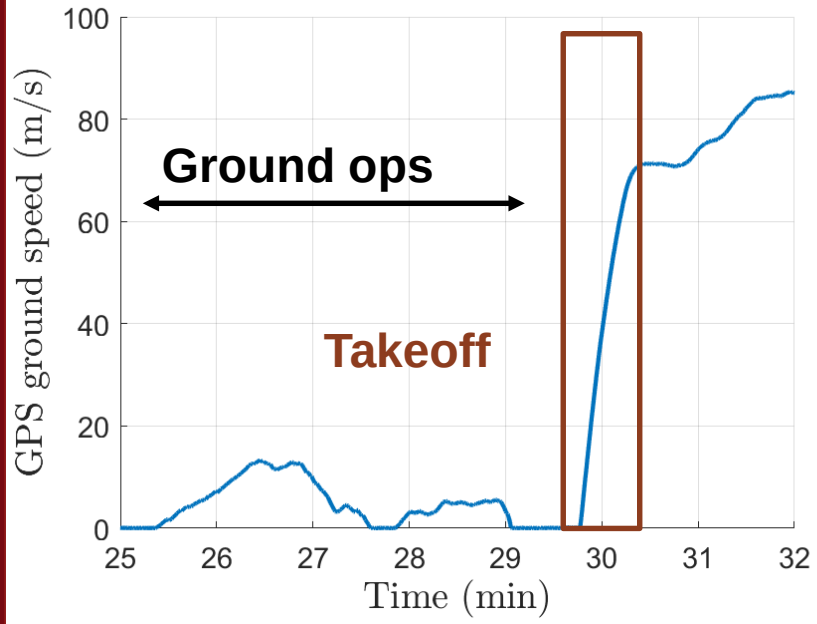
SDR can calculate phase difference directly – more frequent measurements (> 10 Hz) and anti-jam processing

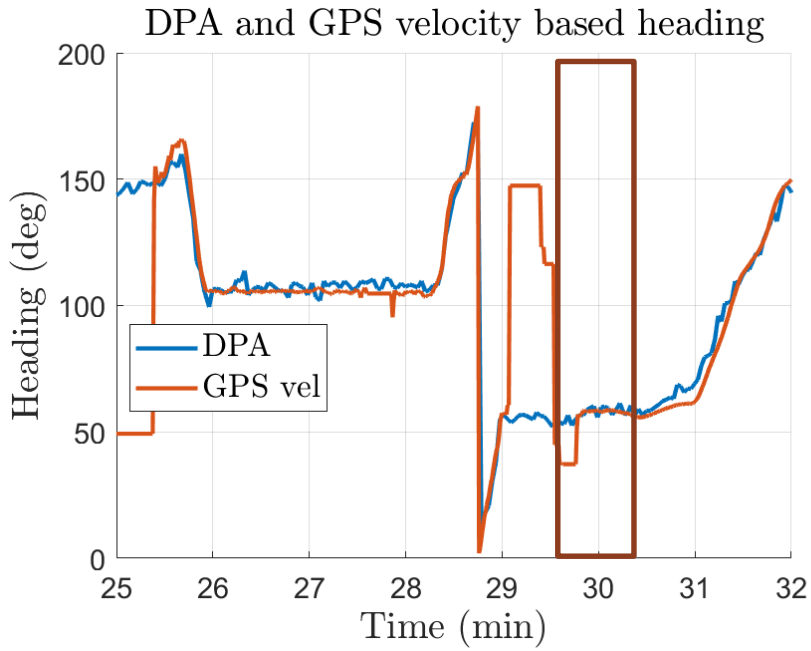
DPA with COTS receiver: Two examples from in flight heading estimation

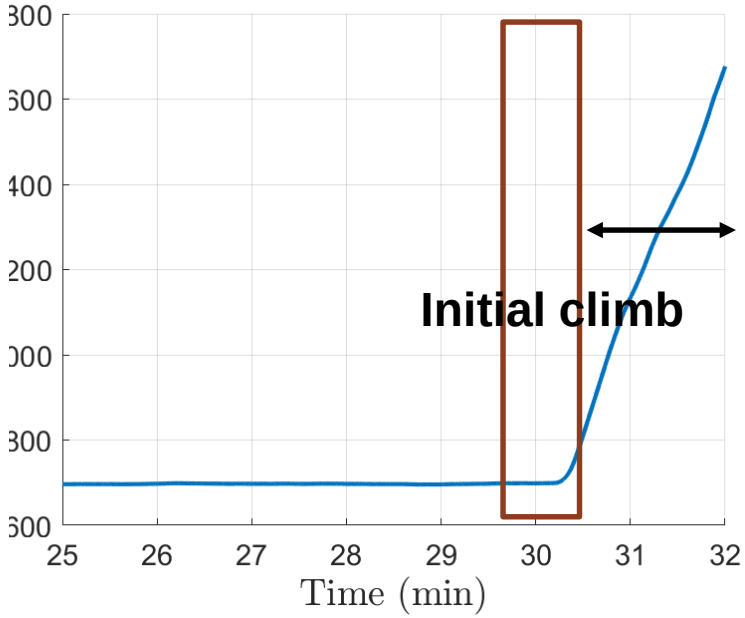
1) Ground ops and take-off

2) Climbing turns, cruise flight

Ground ops and takeoff (2019/09/19)

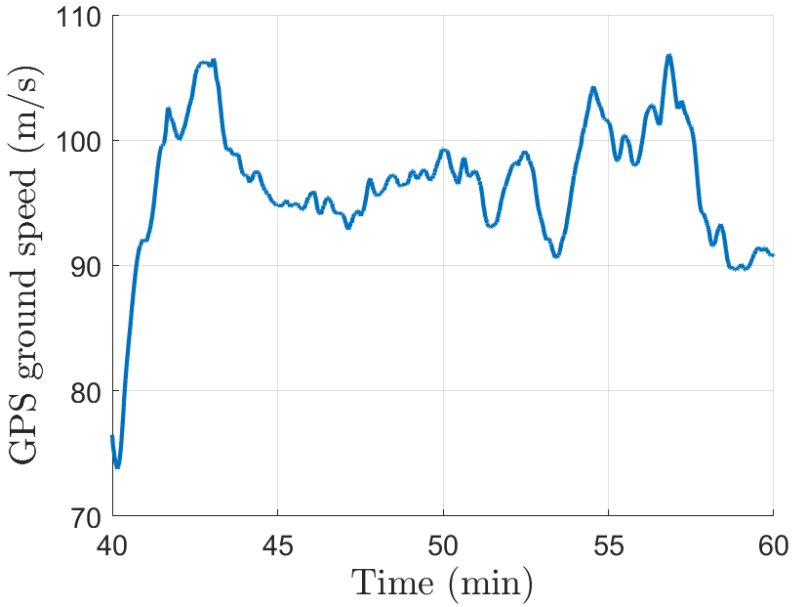


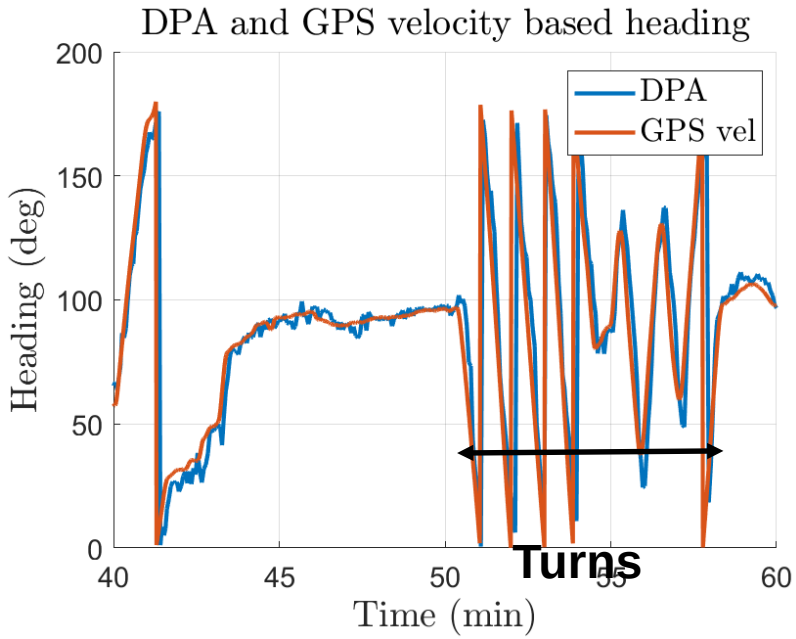


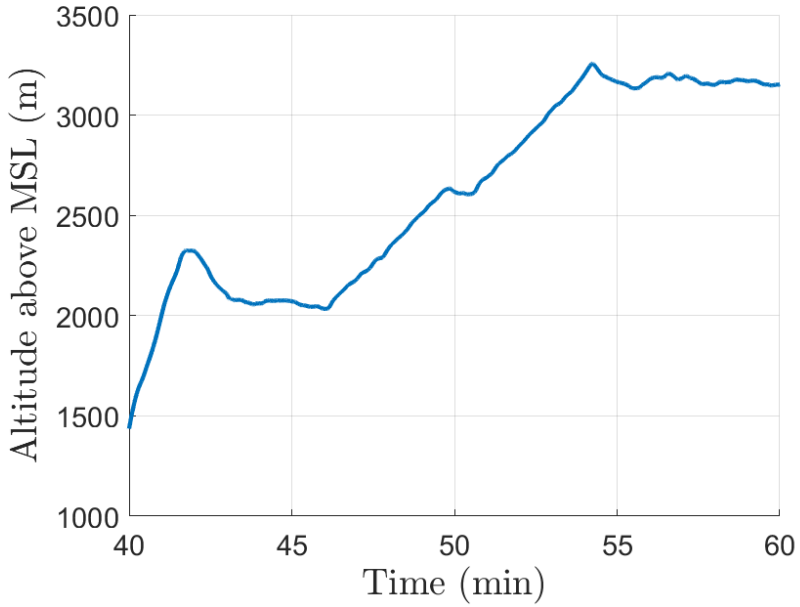


- Heading closely tracked on the ground and in the air
- Stable heading during low velocity periods

Climbing turns, straight & level flight (2019/09/18)

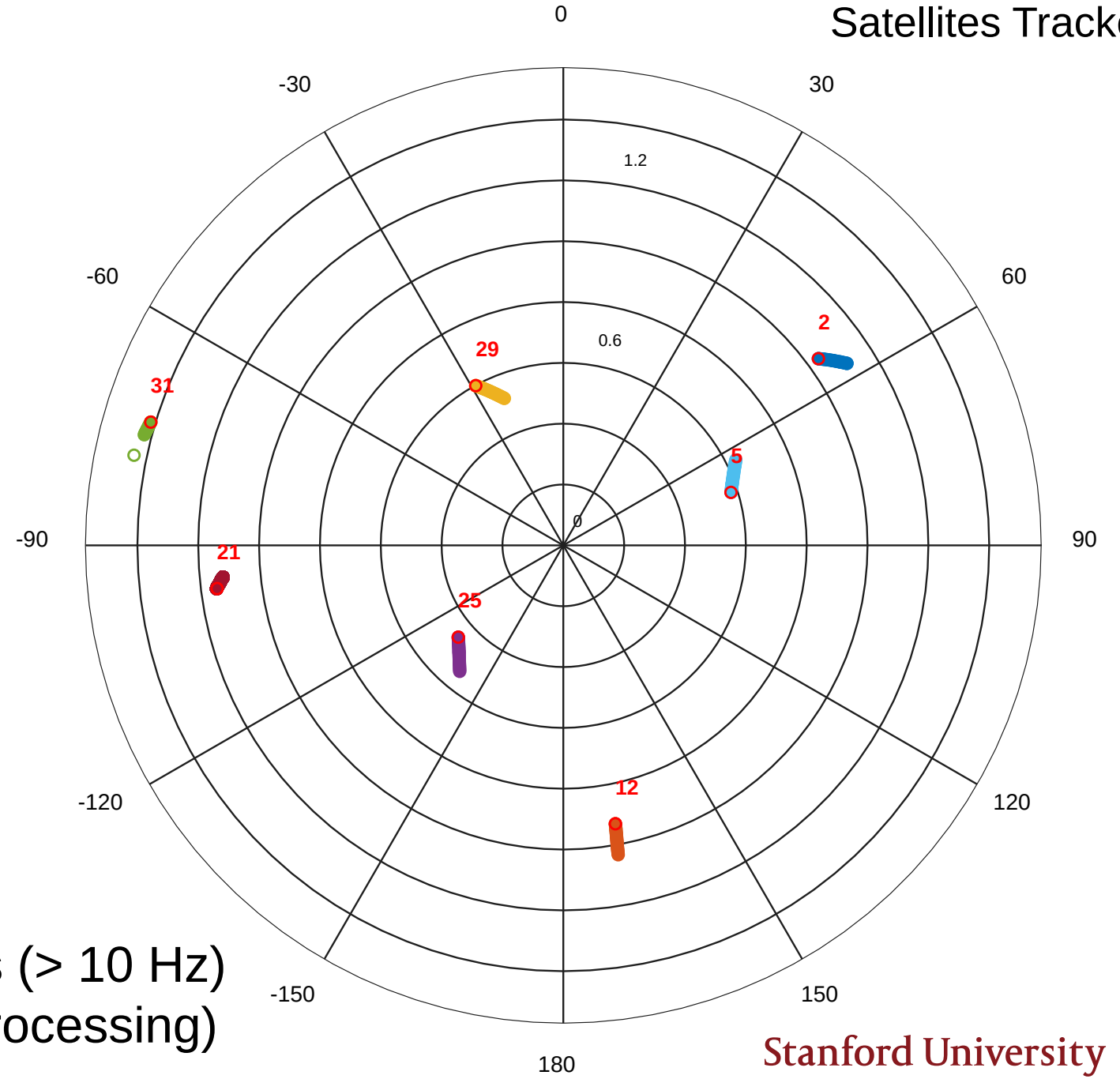






- Heading closely tracked during straight and turning climb
- Filtering, smoothing and a rate gyro can improve the result

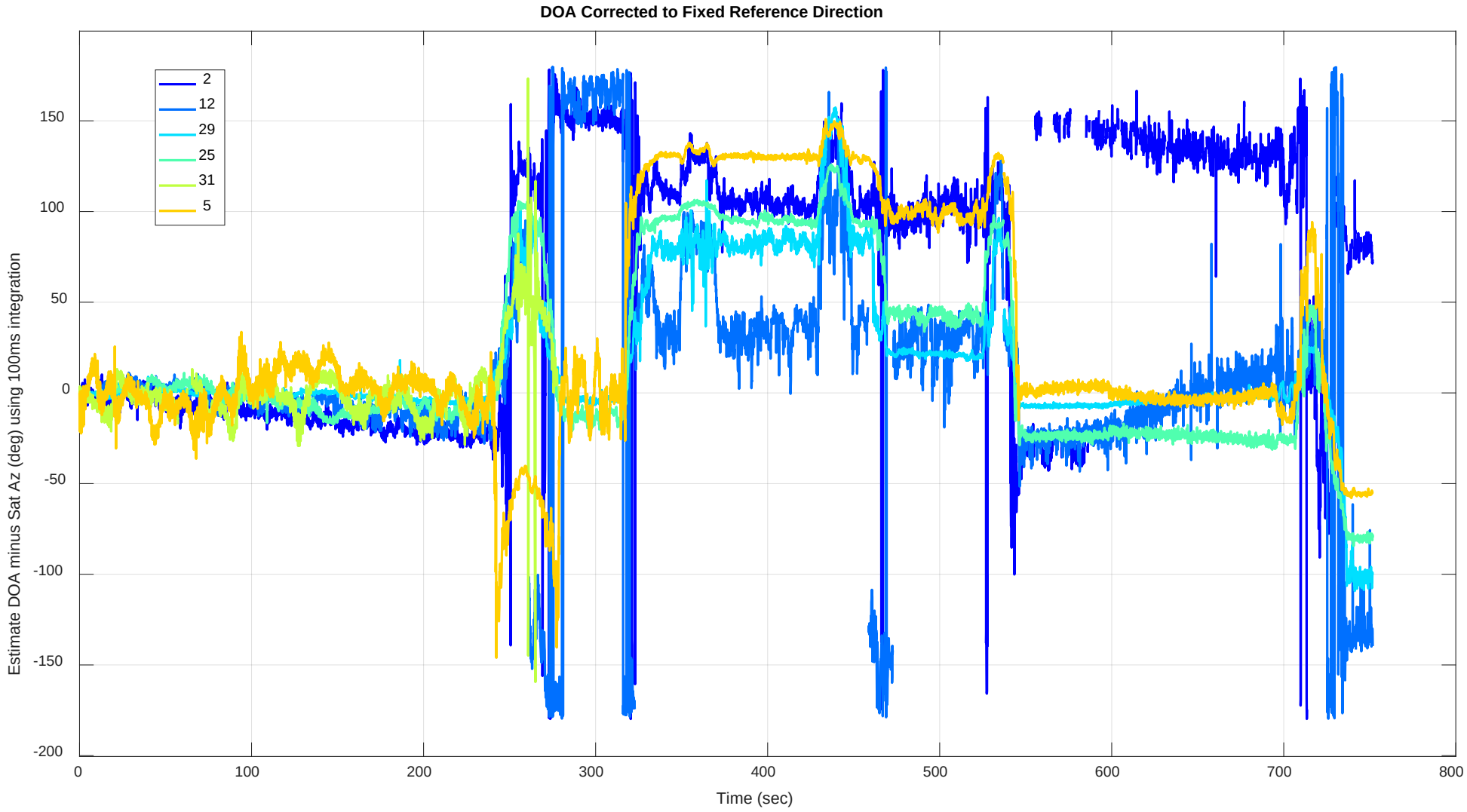
DPA with Software Defined Radio (SDR)



+ High update DOA estimates (> 10 Hz)
- Less sensitive (due to our processing)


Edwards AFB
34.928
34.926
34.924
34.922
34.92
34.918
34.916
34.914
34.912
-117.9
-117.895
-117.89
-117.885
-117.88
-117.875
-117.87
10.33
10.34
10.35
10.36
10.37
10.38
10.39
10.4
10.41
10.46
10.47

Verifying DPA SDR DOA measurements



DOA minus satellite azimuth, zero bias - essentially single satellite (negative) heading estimate


Edwards AFB
34.928
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10.39
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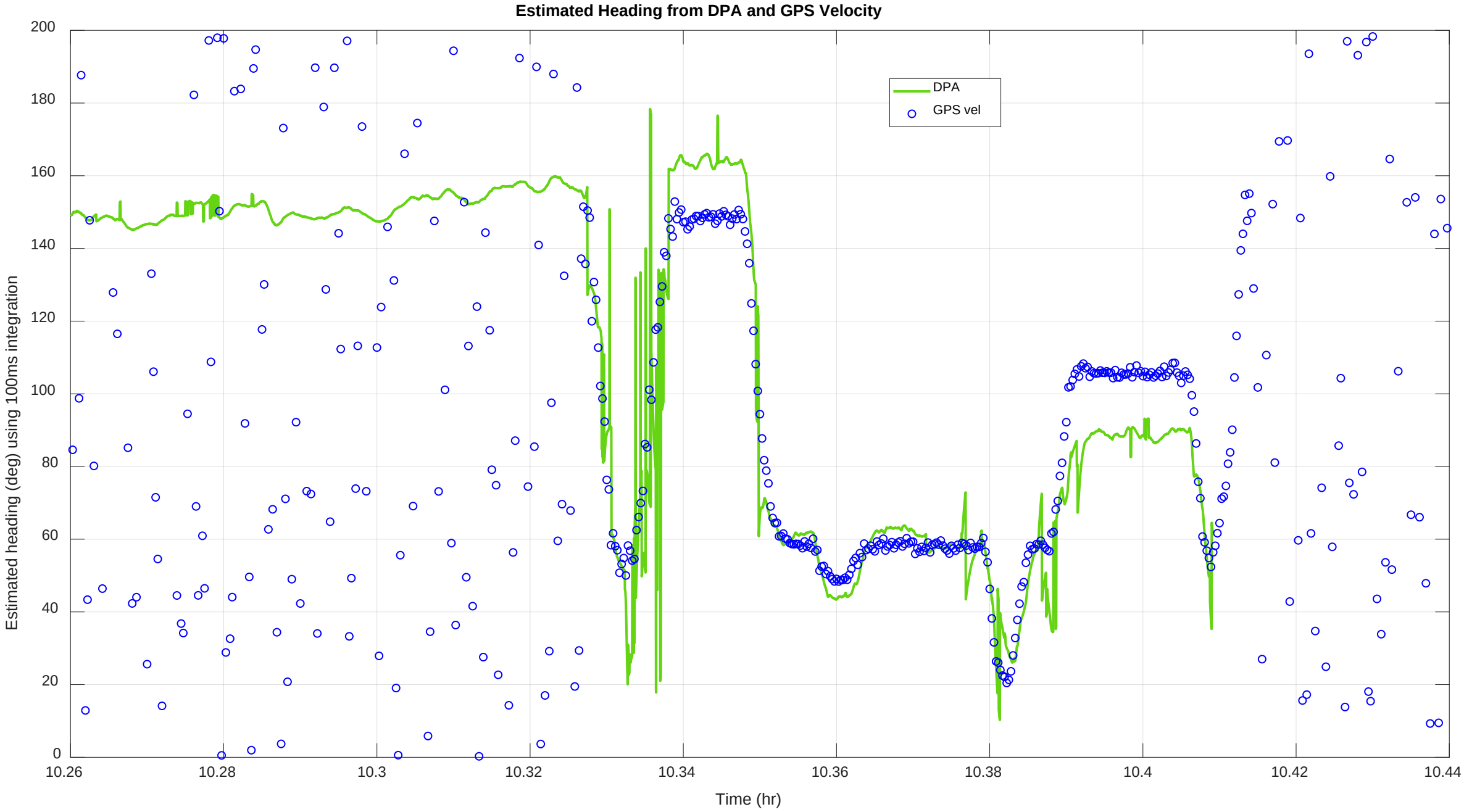
10.46
10.47


Estimated Heading from DPA and GPS Velocity
DPA
GPS vel
Estimated heading (deg) using 100ms integration
Time (hr)
0
20
40
60
80
100
120
140
160
180
200
10.26
10.28
10.3
10.32
10.34
10.36
10.38
10.4
10.42
10.44

Importance for Resiliency subgroup

- Opportunity to develop flight technology and understanding for GNSS resiliency
- Flight test resiliency technologies (DPA for spoof detection & interference mitigation)
- Record nominal flight conditions (thresholds), attenuation of interference by aircraft body
- While not always aligned with an interference event, airborne interference was seen
  - Several test aircraft observed interference; Trimble did not have outage but saw some drops in satellite available at indicated times

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