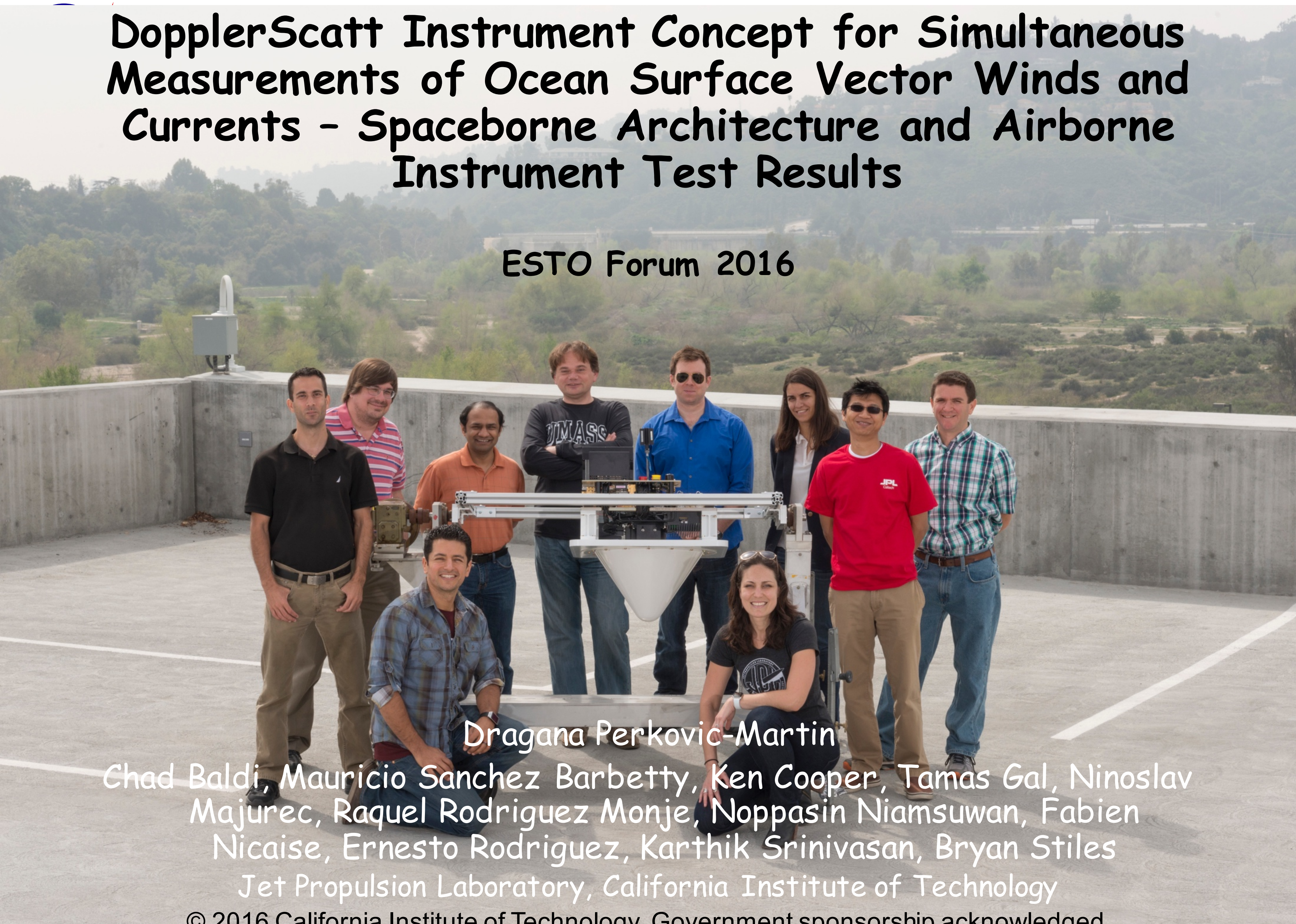
DopplerScatt Instrument Concept for Simultaneous Measurements of Ocean Surface Vector Winds and Currents – Spaceborne Architecture and Airborne Instrument Test Results

ESTO Forum 2016

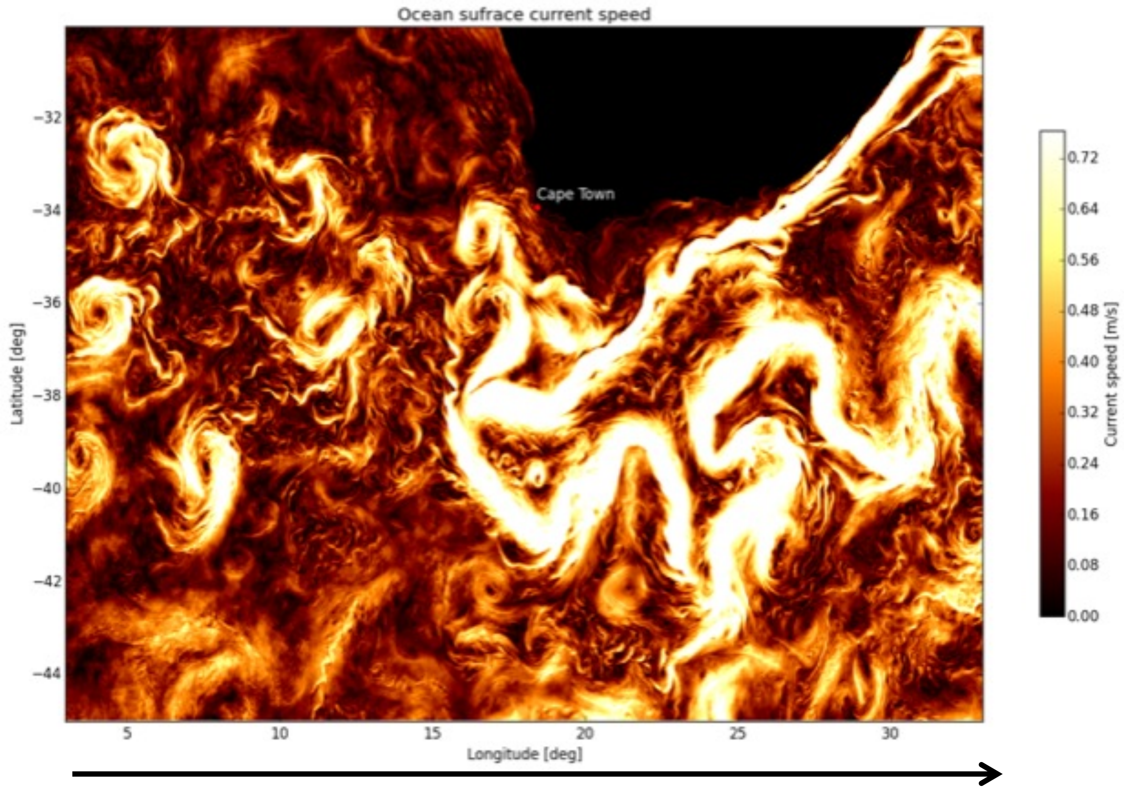


Dragana Perkovic-Martin

Chad Baldi, Mauricio Sanchez Barbetty, Ken Cooper, Tamas Gal, Ninoslav Majurec, Raquel Rodriguez Monje, Noppasin Niamsuwan, Fabien Nicaise, Ernesto Rodriguez, Karthik Srinivasan, Bryan Stiles

Jet Propulsion Laboratory, California Institute of Technology

Why Measure Ocean Currents?



~2400km

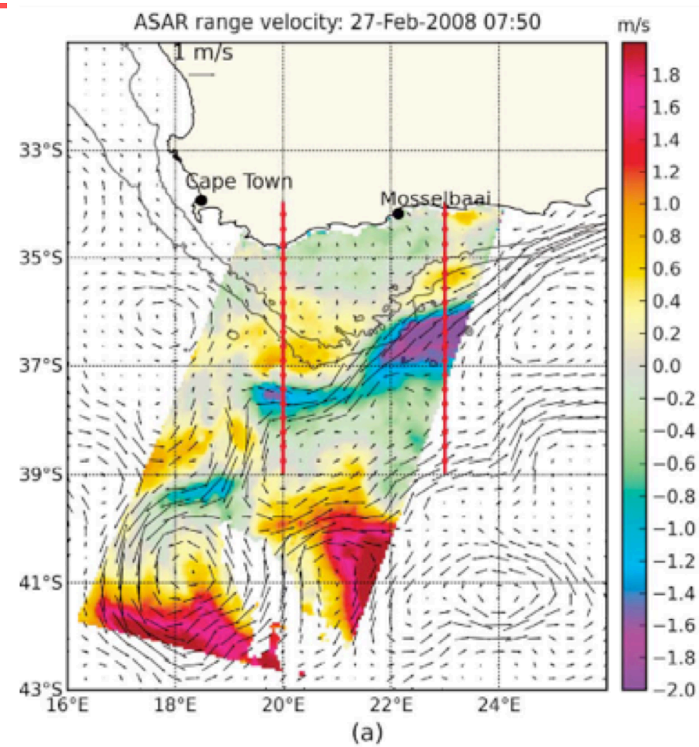
Image of modeled ocean surface currents from the high resolution ECCO2 model.

Currently, we have no way to validate these results at high resolution.

- Ocean surface currents are an essential climate variable
- Knowledge of ocean surface currents will improve our knowledge of energy transfer between the atmosphere and the ocean and our understanding of the advection of heat, nutrients, and pollutants in the ocean.
- Ocean surface currents are a unique complement to the geostrophic currents measured by the forthcoming SWOT mission.

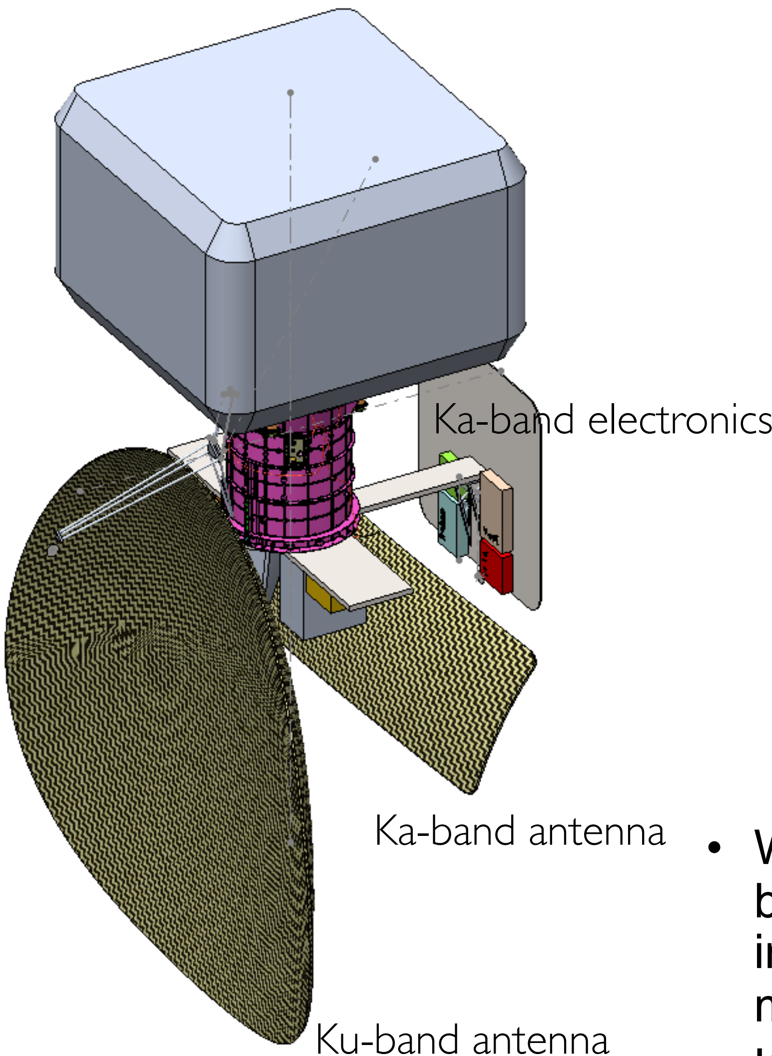
The DopplerScatt Concept

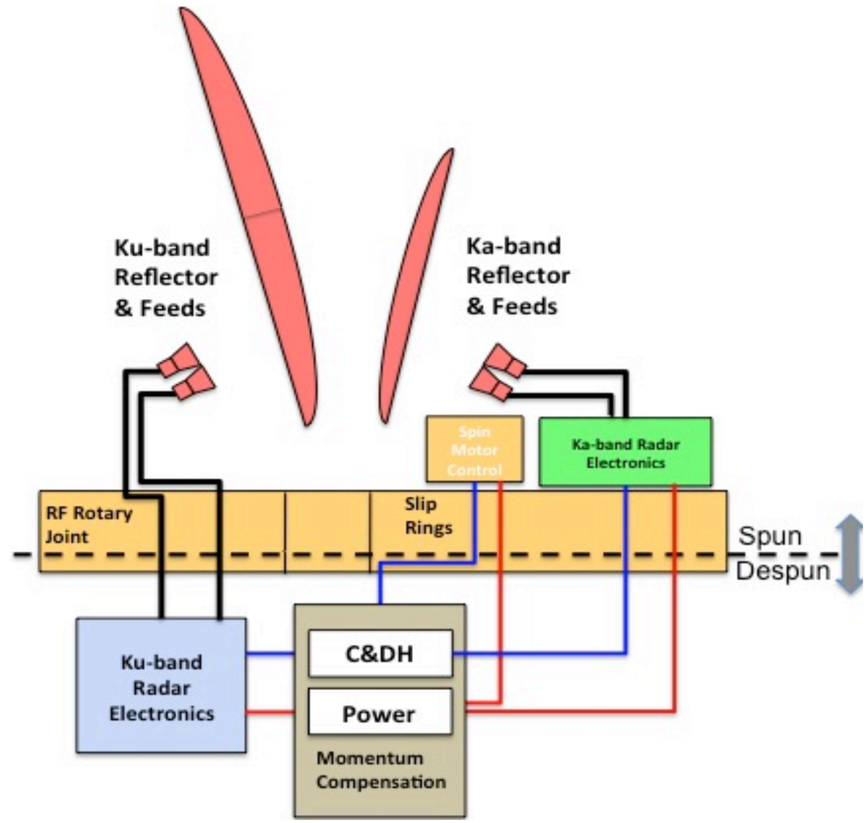
- Coherent radars can measure radial velocities by measuring Doppler shifts.
- The use of Doppler for one component of the surface current velocity has been demonstrated from space using SAR's.
  - Since SAR only looks in one direction, only one component of the velocity is retrieved.
  - Swath width and data rate limitations make SAR's impractical for global coverage
- Rodríguez (2012, 2014) has extended the concept to be able to measure ***both*** components by using a pencil-beam scanning scatterometer.
  - A wide swath coverage would enable global coverage in one day
  - The same instrument would also measure high resolution winds
- The DopplerScatt IIP will demonstrate the feasibility and accuracy of this concept using an airborne instrument and the results will be applicable to future spaceborne missions.



Comparison of surface current radial component measured by ASAR and geostrophic currents from the AVISO altimetry product. Rouault, M. J., Mouche, A., Collard, F., Johannessen, J. A. & Chapron, B. Mapping the Agulhas Current from space: An assessment of ASAR surface current velocities. Journal of Geophysical Research 115, (2010).

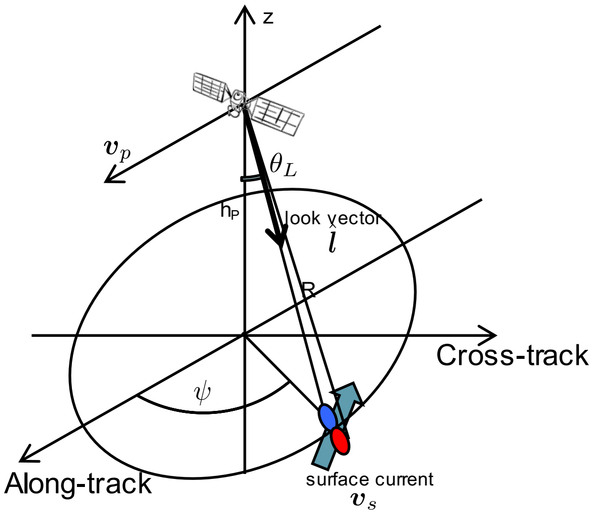
Spaceborne Instrument Concept



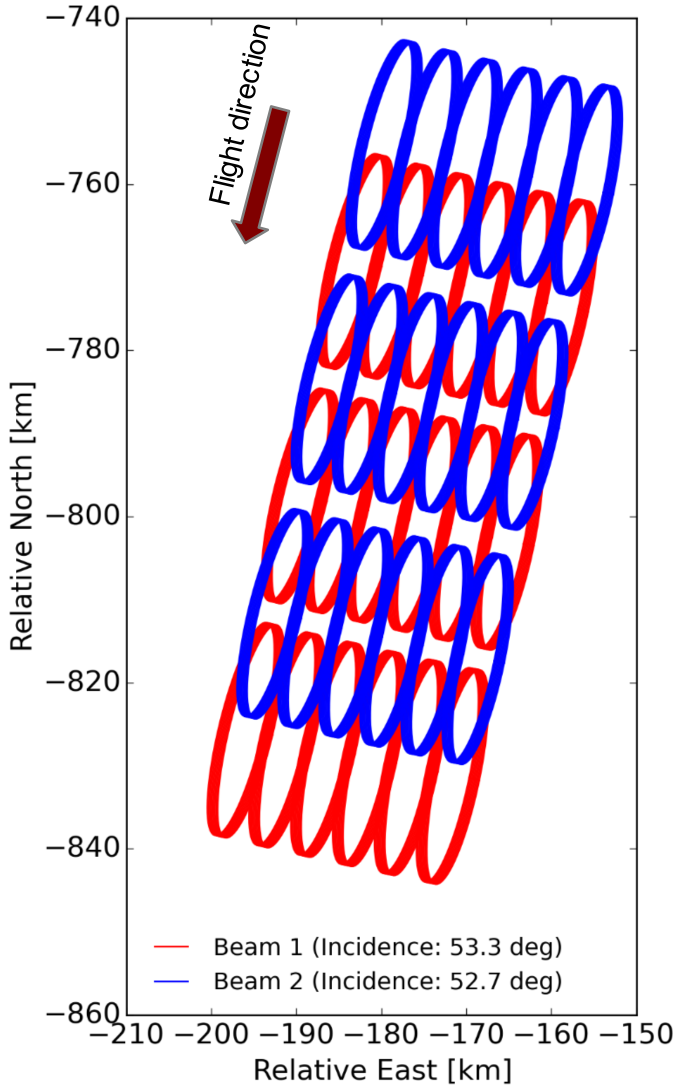


- Winds and Currents mission functional electrical block diagram, showing Ku- and Ka-band radar interfaces to the spacecraft and the spin mechanism.
- Ka-band Doppler Scatterometer electronics all reside on the spun side

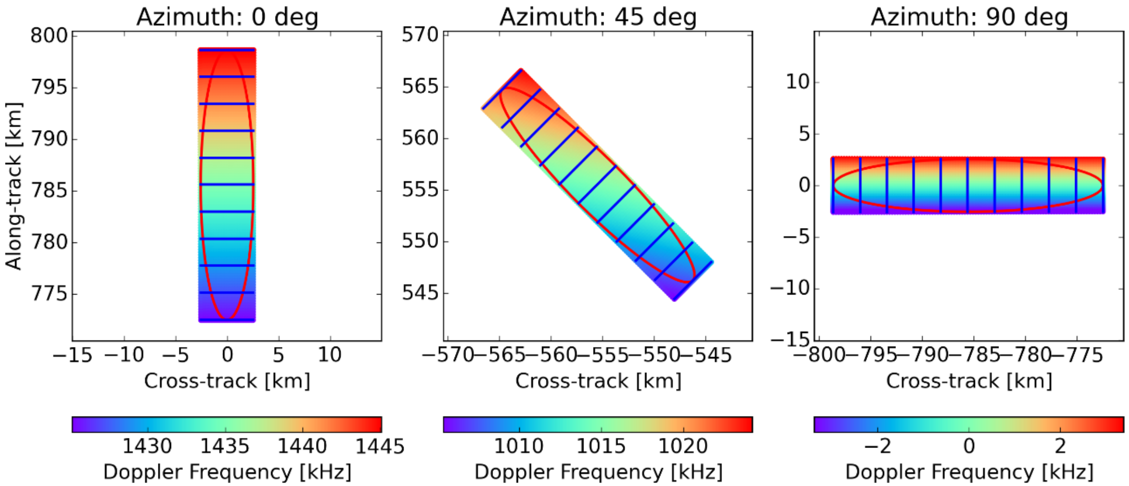
Space-borne Concept
Doppler and Range Coordinates



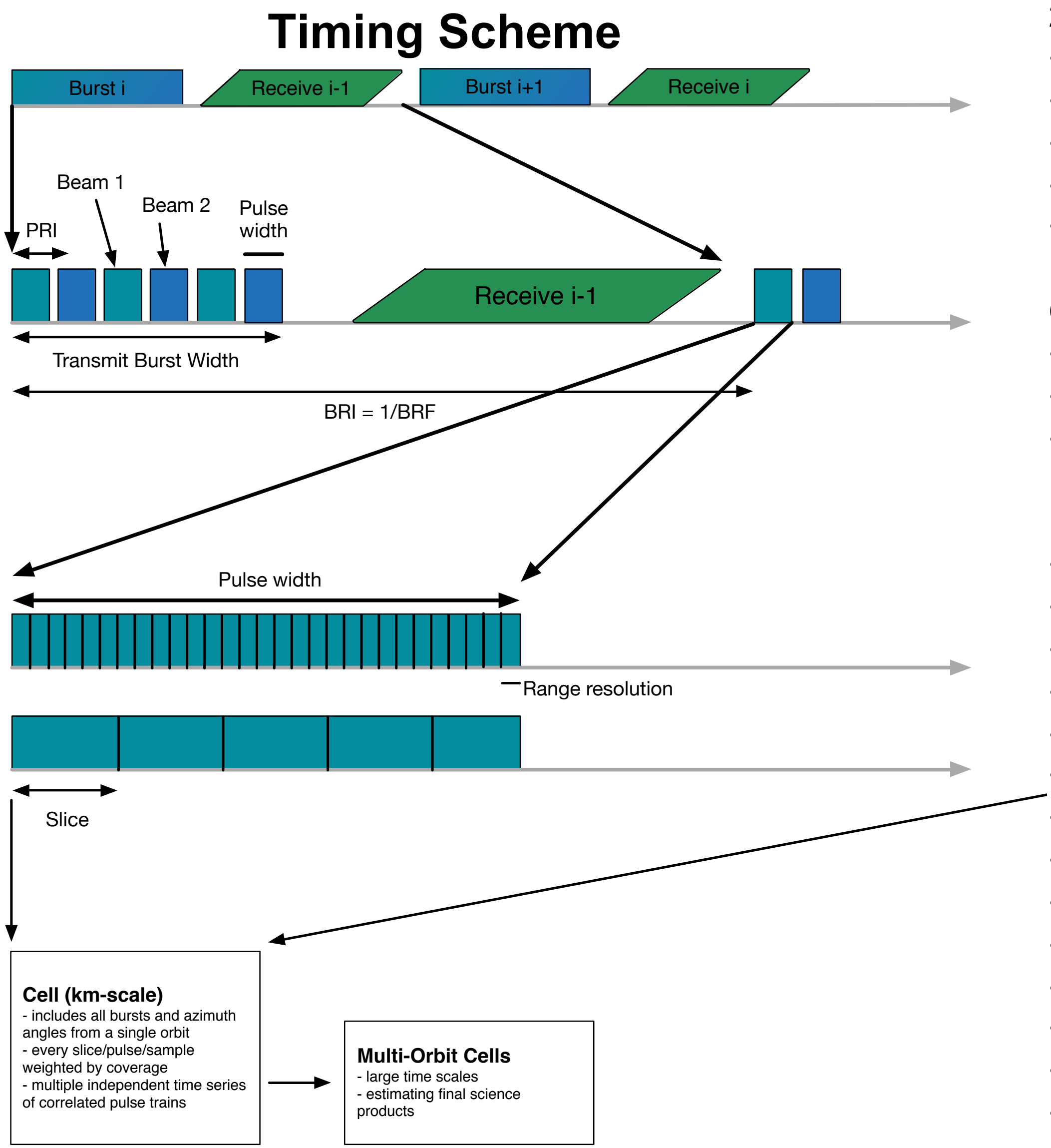
Footprints:
- Both beams
- 5 bursts per beam
- 8 pulses per burst



Footprints with Doppler Frequency and Iso Range:



Space-borne Concept Design



2 Ka-band beams

- Separated in frequency and incidence angles
- Burst-interleaved: 2 bursts in flight
- Beams: pulse-interleaved
- Slice processing
- Cell aggregation

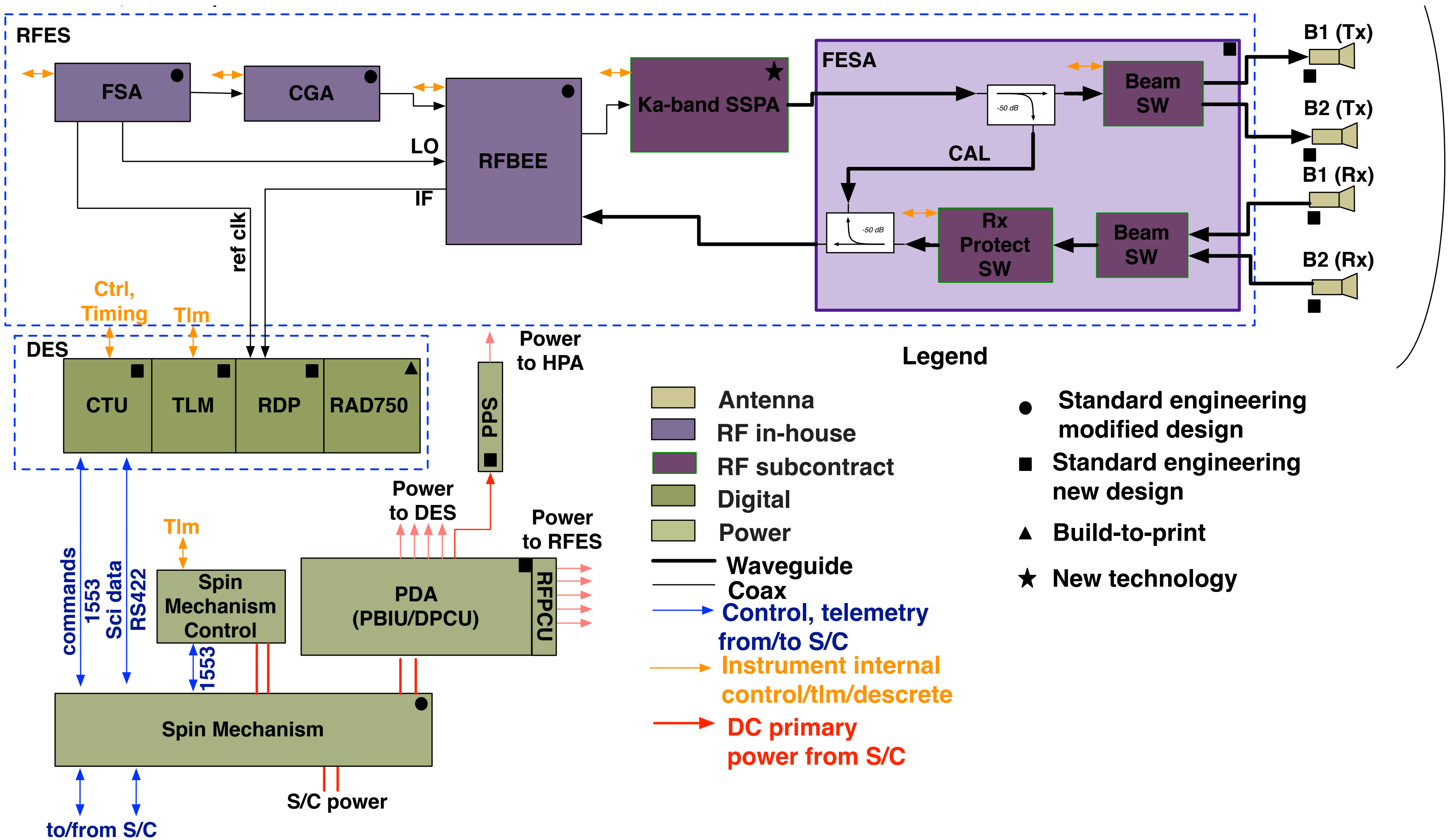
Orbit (sun-synchronous)

- Altitude: 705 km
- Inclination: 98.14 deg
- Velocity: 7560 m/s

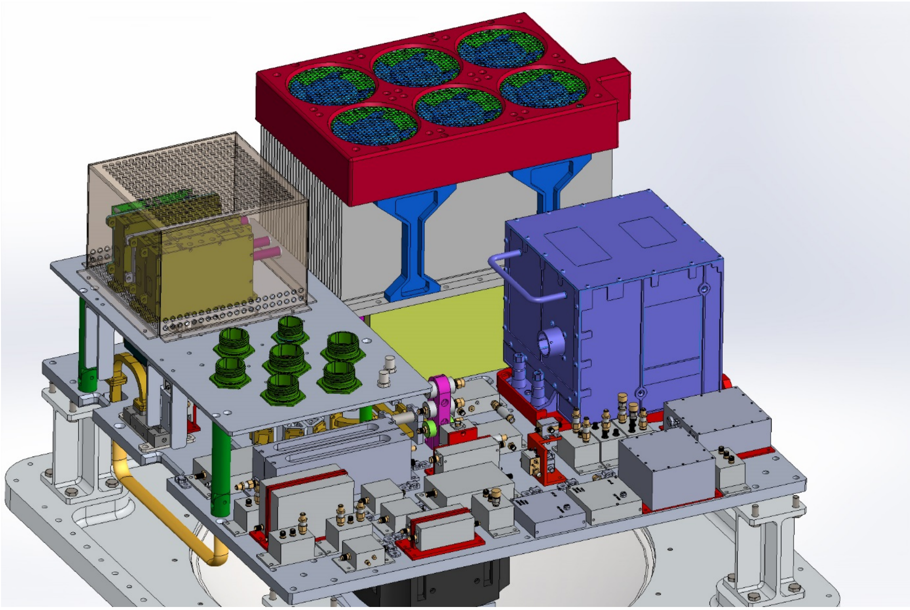
Ka-band configuration:

- Look angle: 45.72 and 46.18 deg
- Incidence: 52.66 and 53.25 deg
- Frequency: 35.75 GHz
- Pulse width: 65 us
- Burst width: 1.2 ms
- Burst Repetition Interval: 4.3 ms
- Number of pulses: 8 pairs
- Rotation rate: 14 rpm
- Beamwidth: 0.83 x 0.27 deg
- Resolution: 0.3 x 5 km
- Footprint: 26 x 5 km
- Slice size: 3.7 x 5 km
- Cell size: 5 x 5 km
- Swath: 1,589 km

Ka-band Instrument Block Diagram



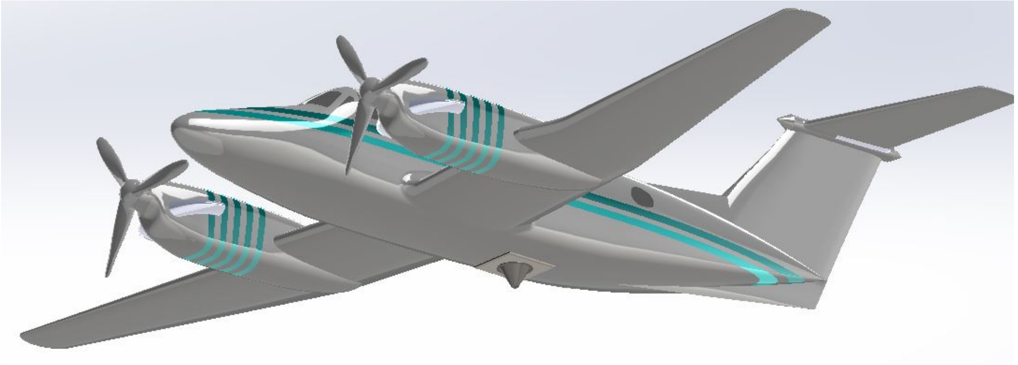
- Ka Doppler Radar block diagram showing its subsystems (PIA, DES, RFES, antenna and spin mechanism), electrical interfaces and hardware maturity levels.

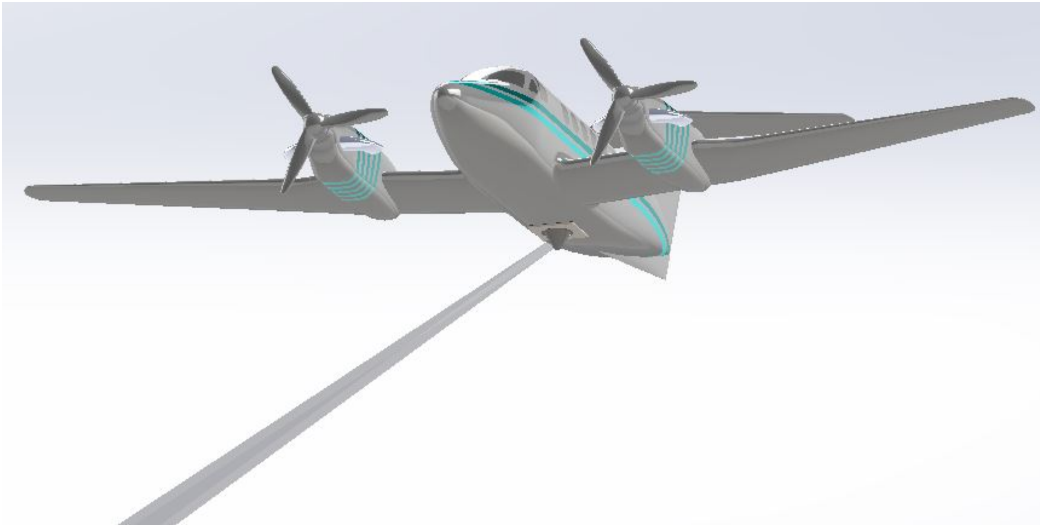
 

AIRBORNE RADAR HARDWARE STATUS AND TESTS

Driving Requirements

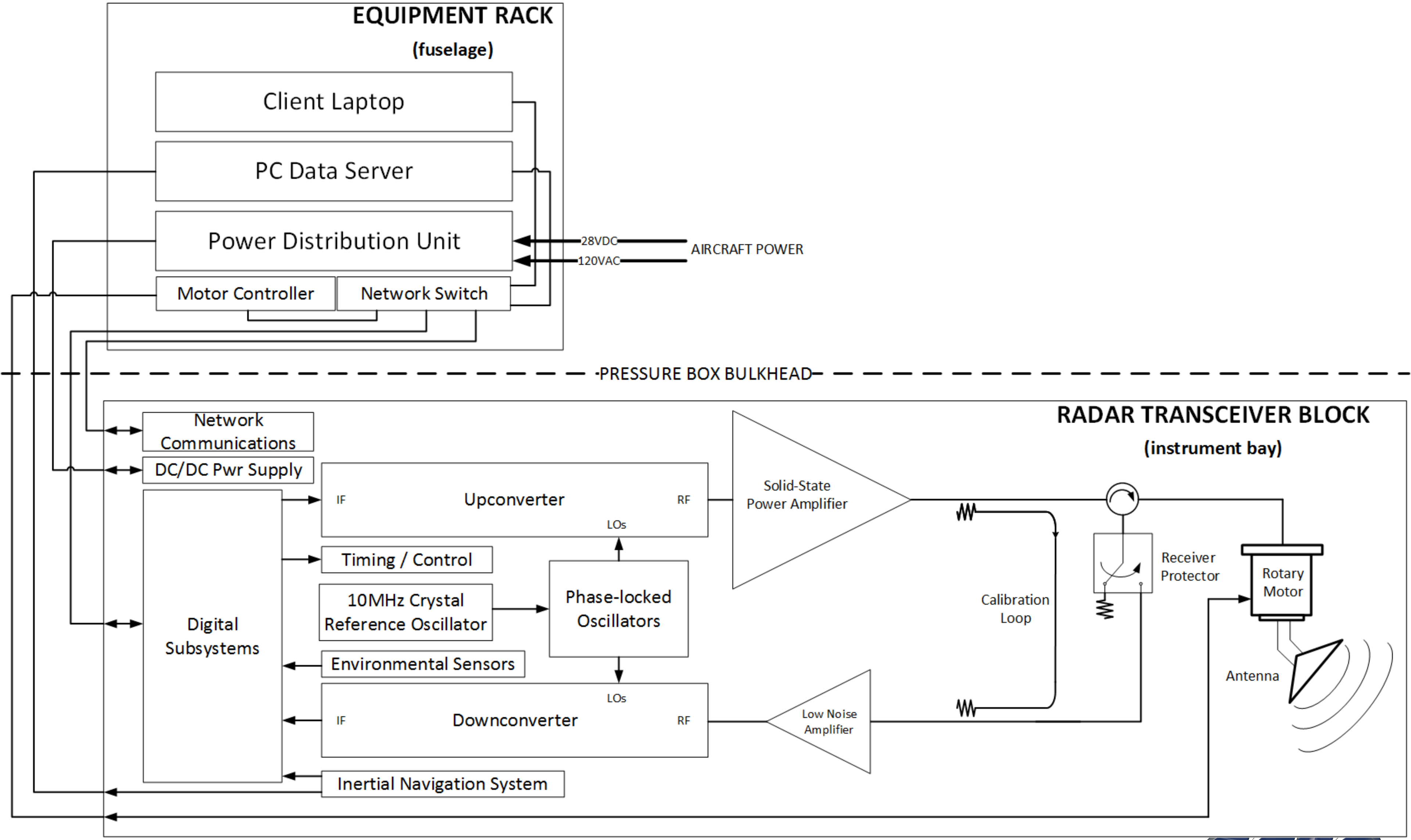
Parameter	Value (CBE)
Center Frequency	35.75 GHz
Peak Transmit Power	90 W (110W)
Burst Repetition	8 kHz (4.7 kHz)
System Noise Figure	10 dB (6 dB)
Antenna Rotation Rate	5-25 rpm (12.5 rpm)
Antenna Beamwidth	2.9 deg
Velocity Bias	1.0 cm/s
Velocity Precision	10 cm/s
Wind Speed Accuracy	2 m/s (3-20 m/s) 10 % (20-30 m/s)
Wind Direction Accuracy	20 deg
Resolution cell size	5 km





Earth Science Technology Office

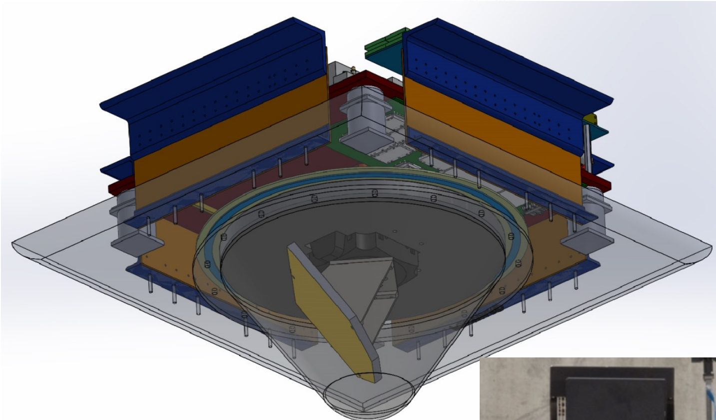
System Architecture Block Diagram



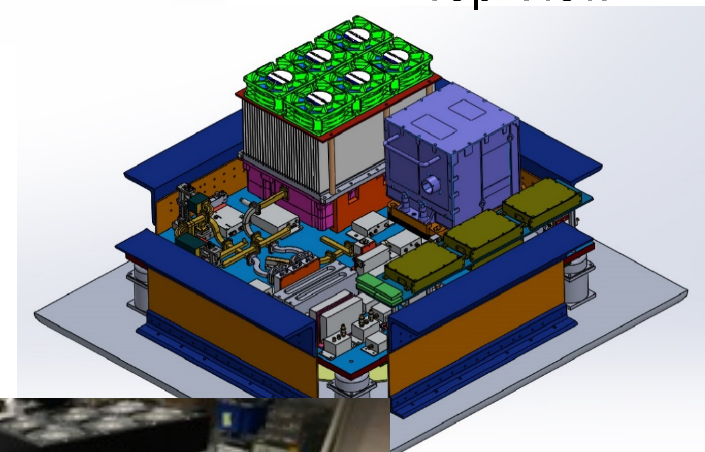
ESTO Earth Science Technology Office

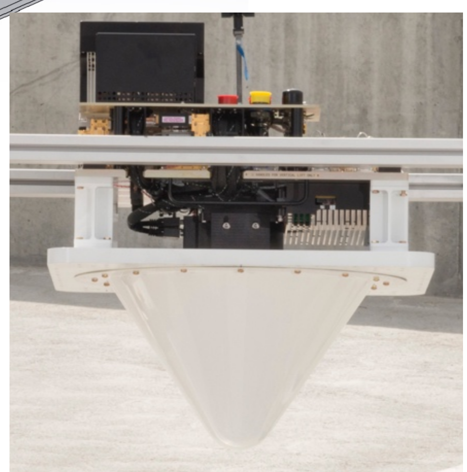
Mechanical Layout

Bottom View

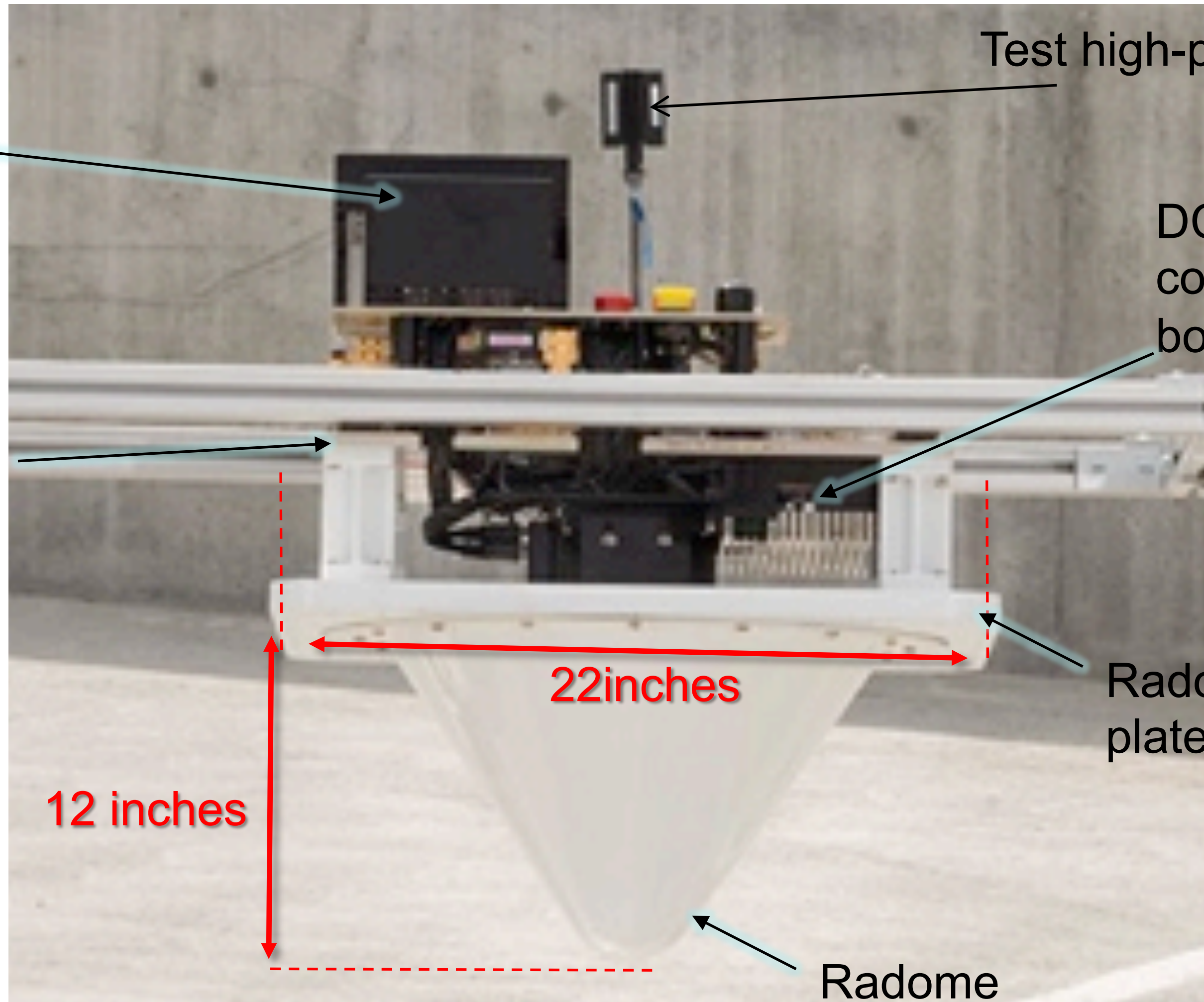


Top View





Completely Integrated DopplerScatt



Earth Science Technology Office

Bottom View

Antenna

Spinning motor

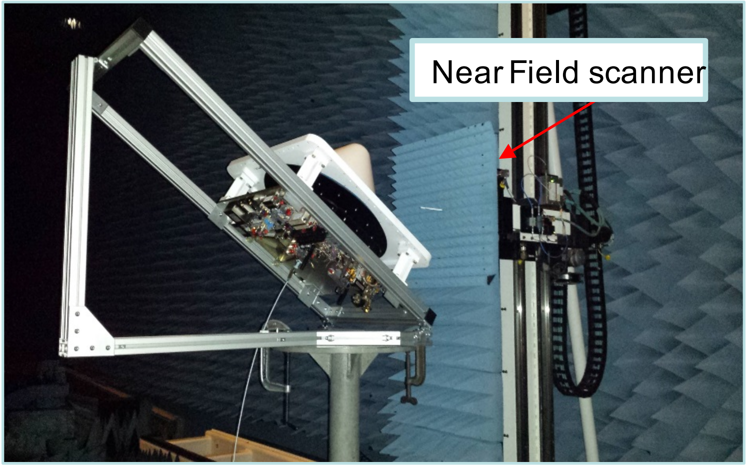
DC/DC converter board

Test high-power loaod

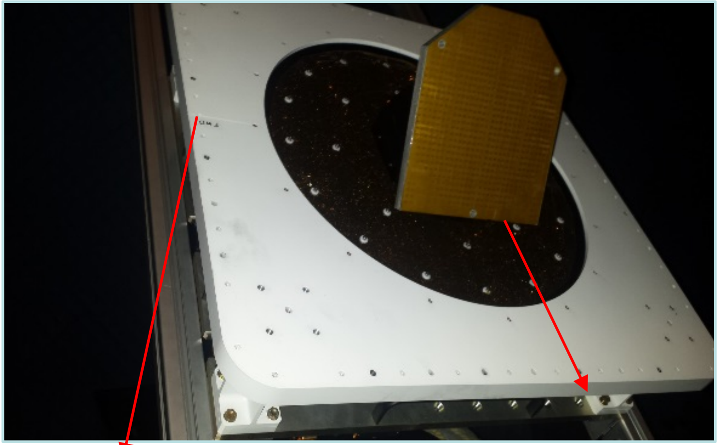
SSPA stack

Antenna Measurements

- Goals of antenna range measurements:
  - Characterize the antenna pattern and its geometric relation to the center of navigation.
  - Verify radome insertion loss vs azimuth angle
  - Identify variations of the radome vs azimuth angle due to material or manufacturing irregularities.

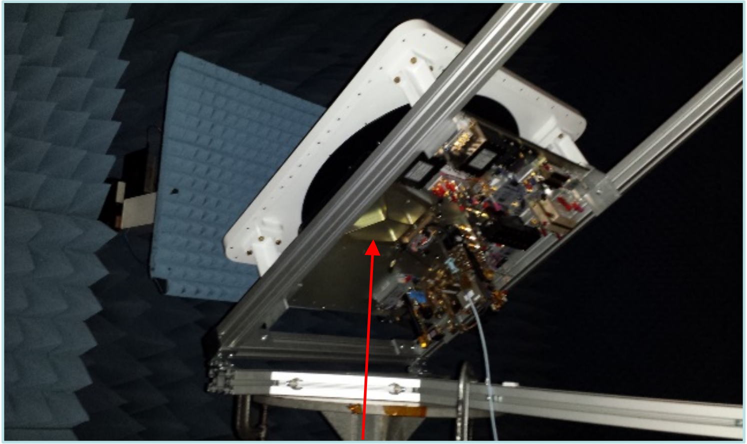


Configuration with Radome



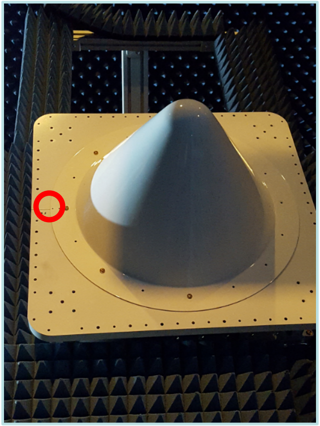
FWD marker

Antenna position during measurements

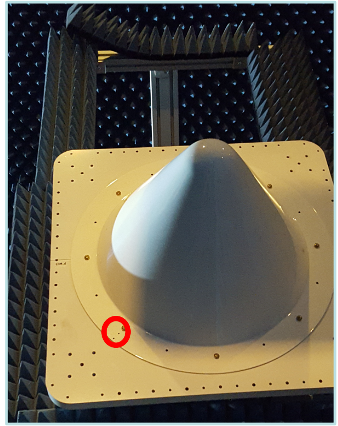


IMU tray

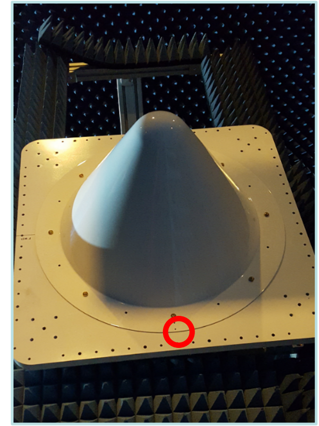
Radome Positions



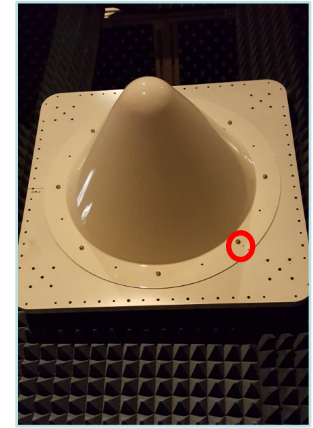
Nominal



+45º

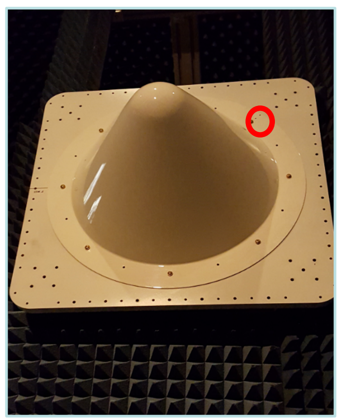


+90º

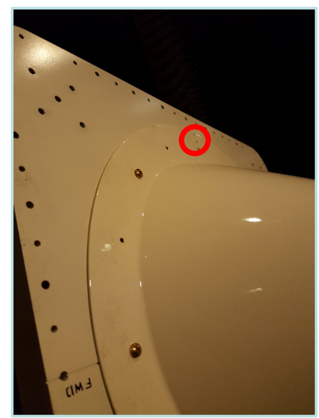


+135º

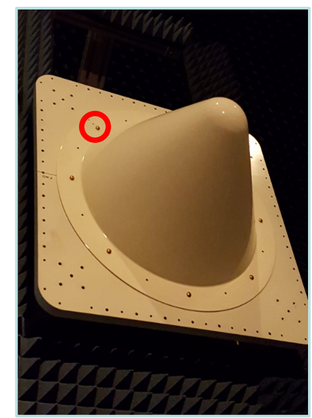
+180º



+225º

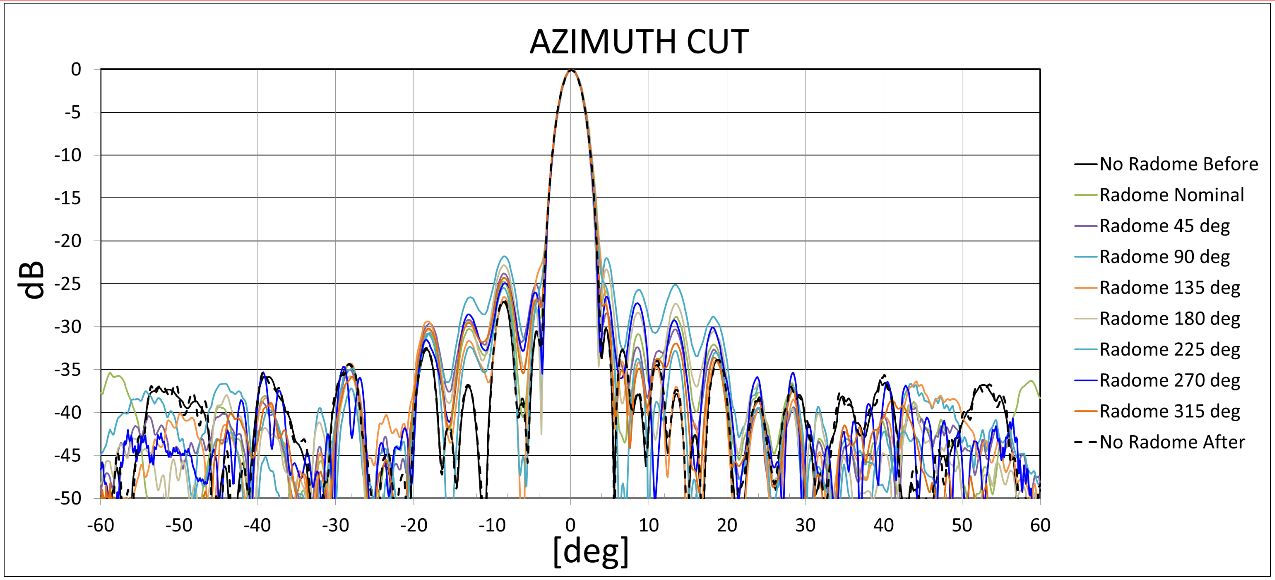


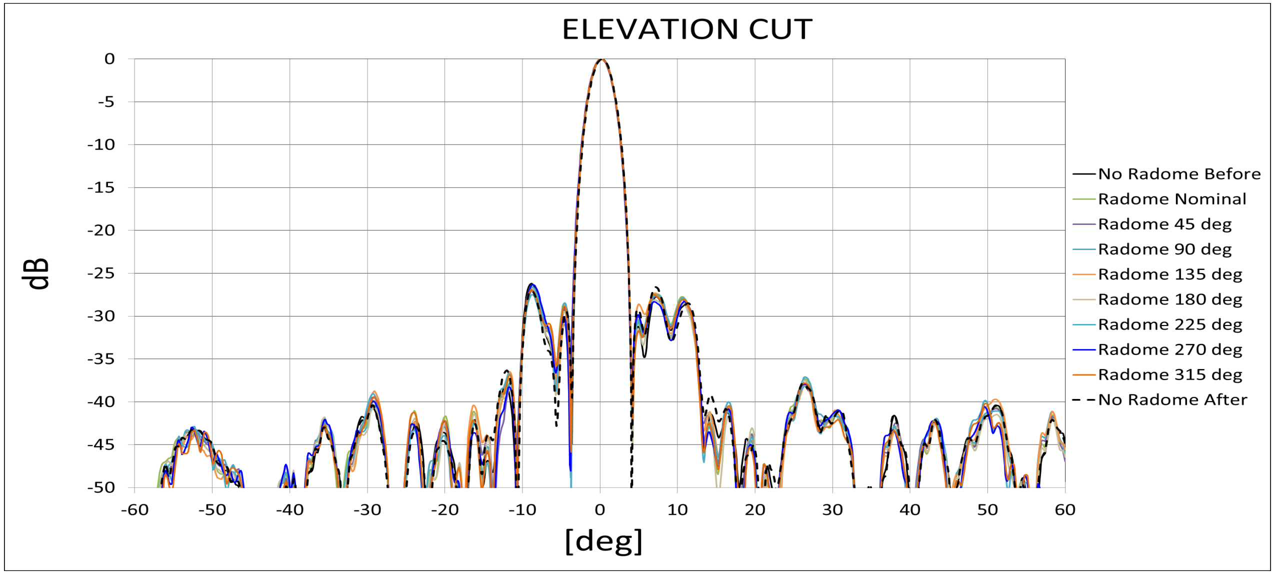
+270º



+315º

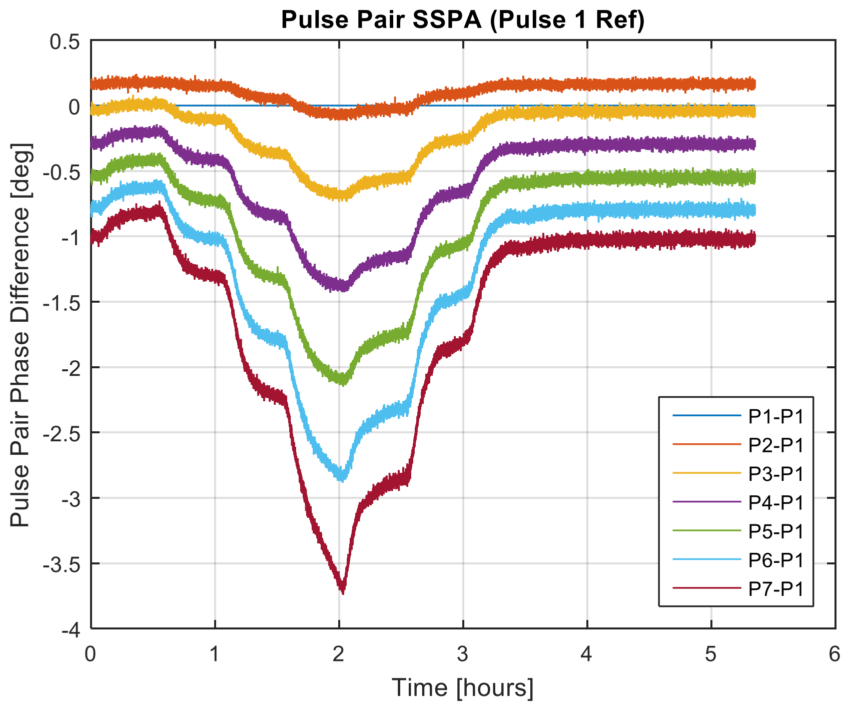
Radiation Pattern wrt Azimuth Angle with Radome

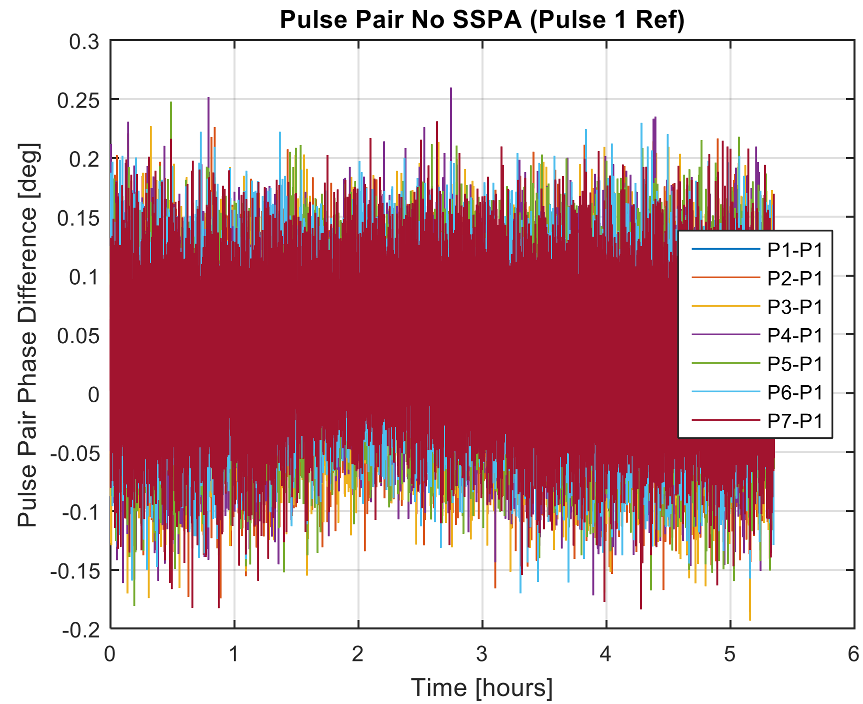




SSPA ulse-Pair Phase Difference Testing

Previous Results: Phase Comparison

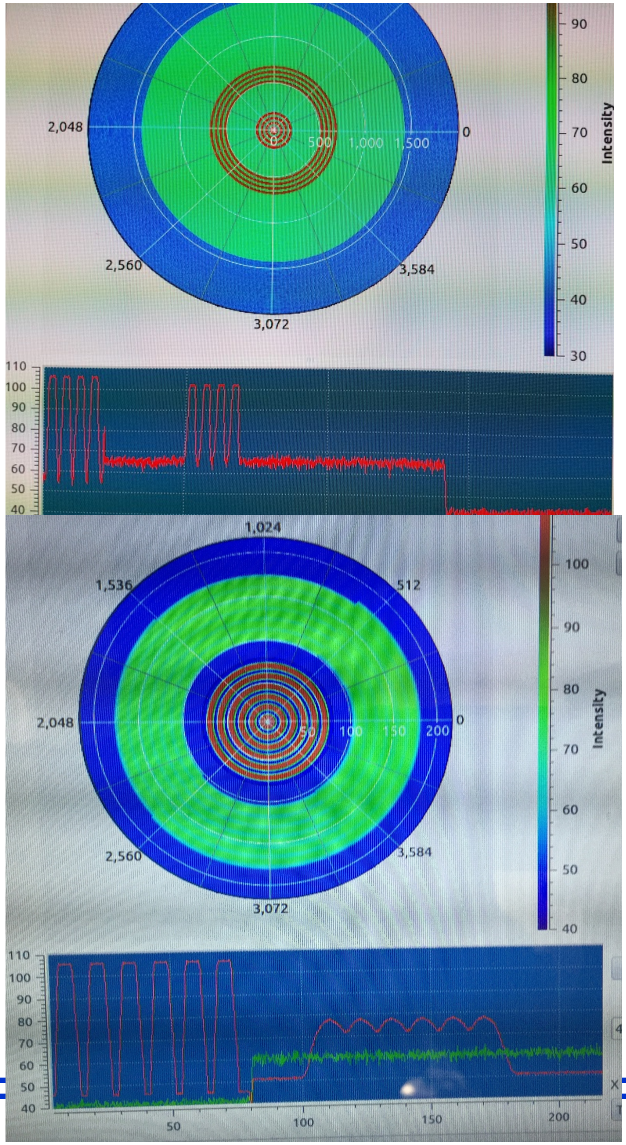


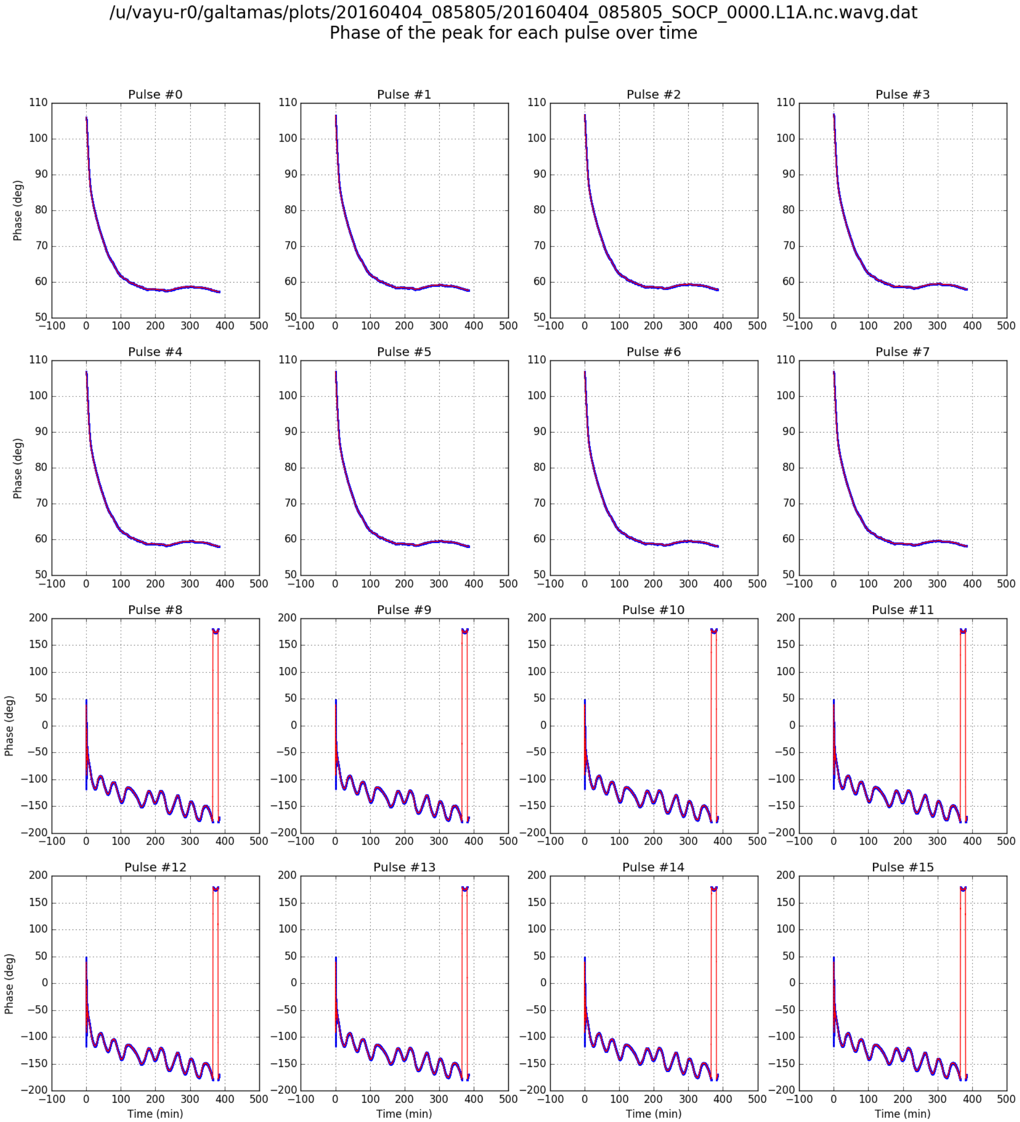


- Pulse-pair phase difference, with Pulse 1 (beginning of the burst) as a reference. Nominally, this should be 0 deg.
- In SSPA case, there is progressively larger phase difference, as the pulse separation within the burst increases. Effect seems more pronounced at low temperatures, less at room or hotter temperatures.
- No such effect visible in No SSPA case.

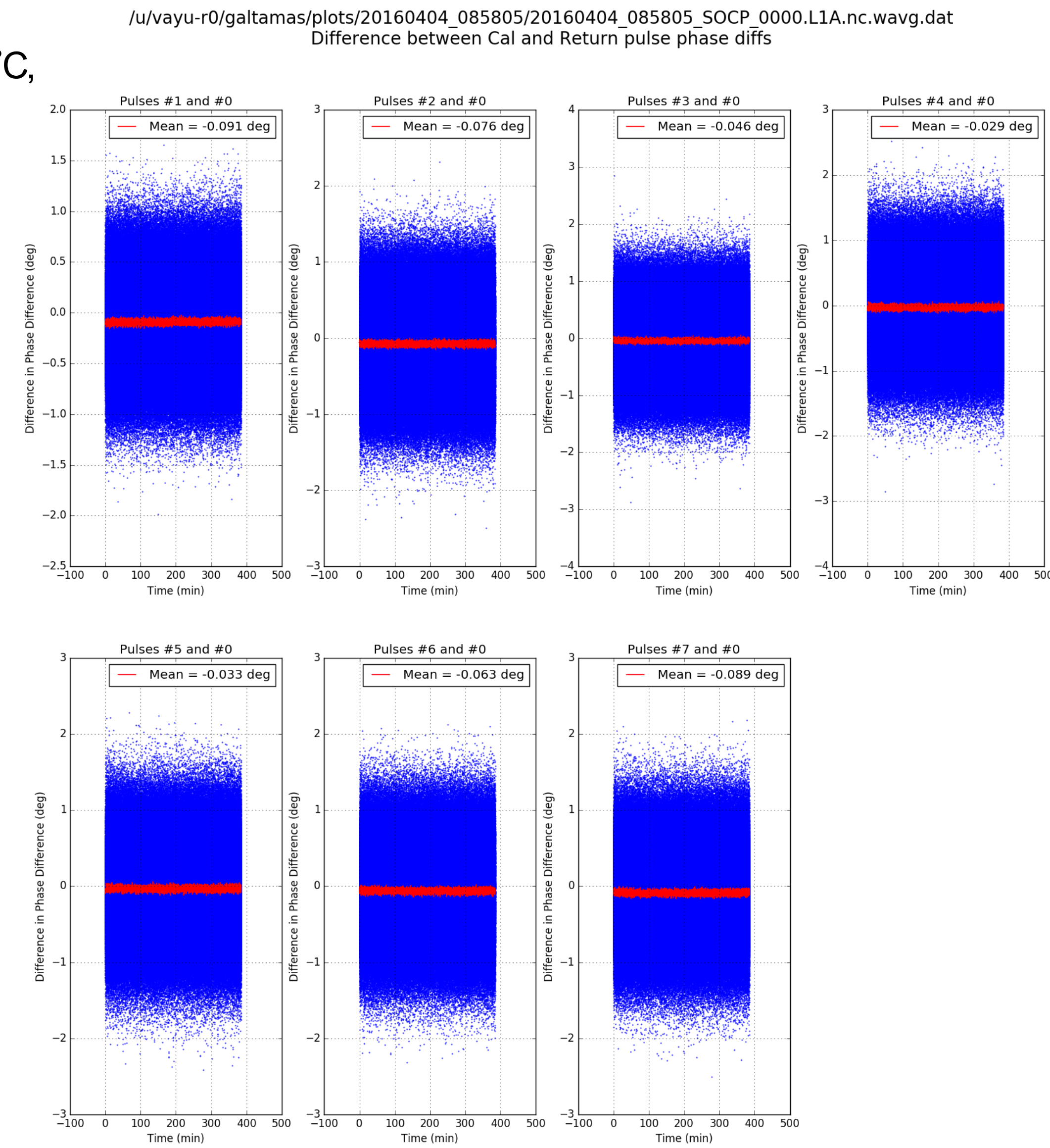
Earth Science Technology Office

Delay line, temperature control set to 26°C, then off after 1h

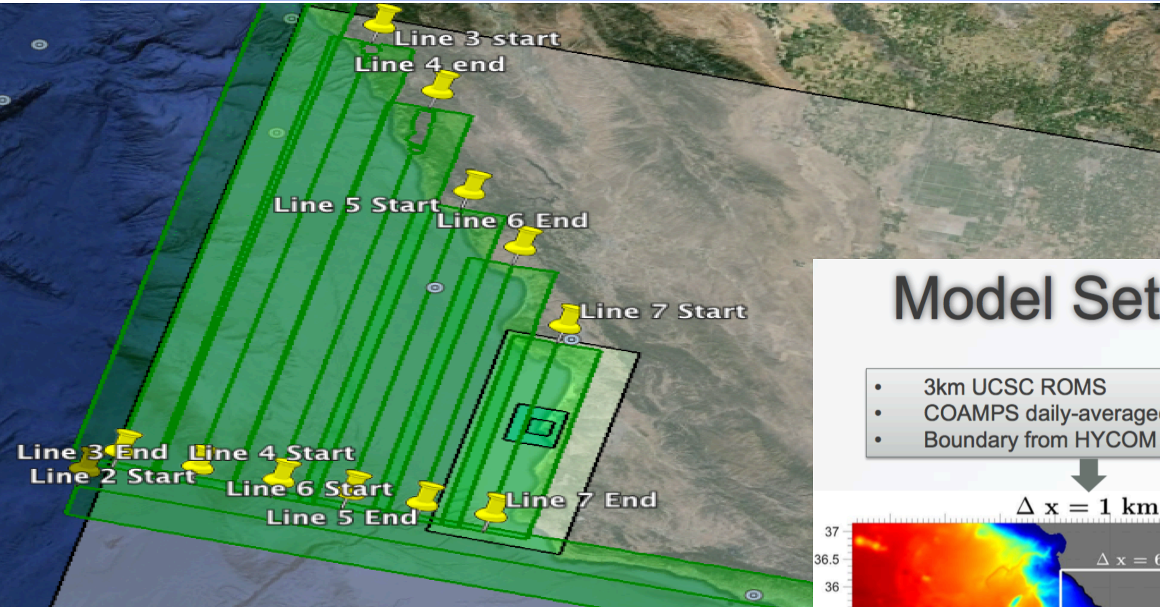


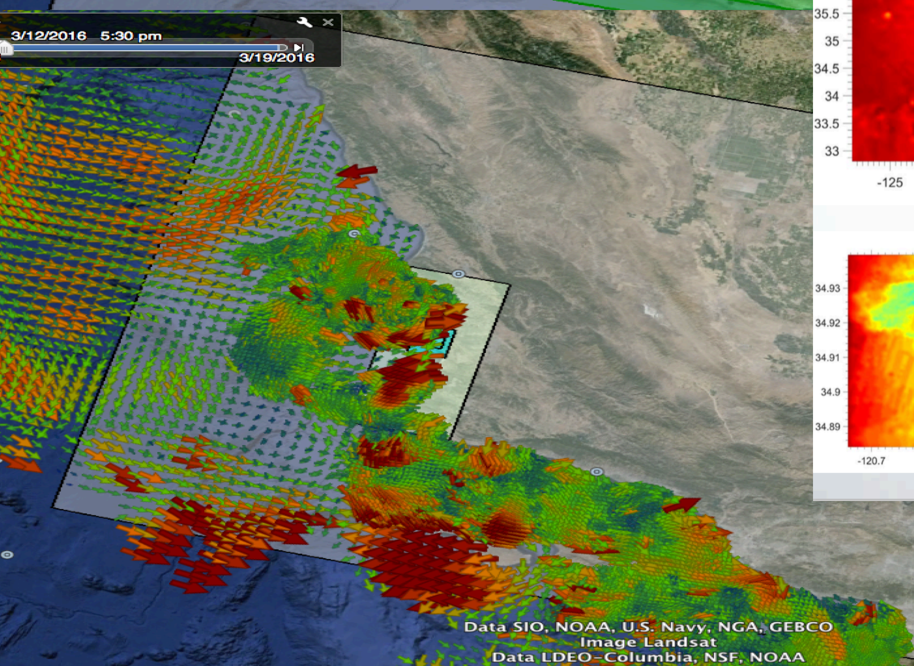


Delay line,
temperature control set to 26˚C,
then off after 1h

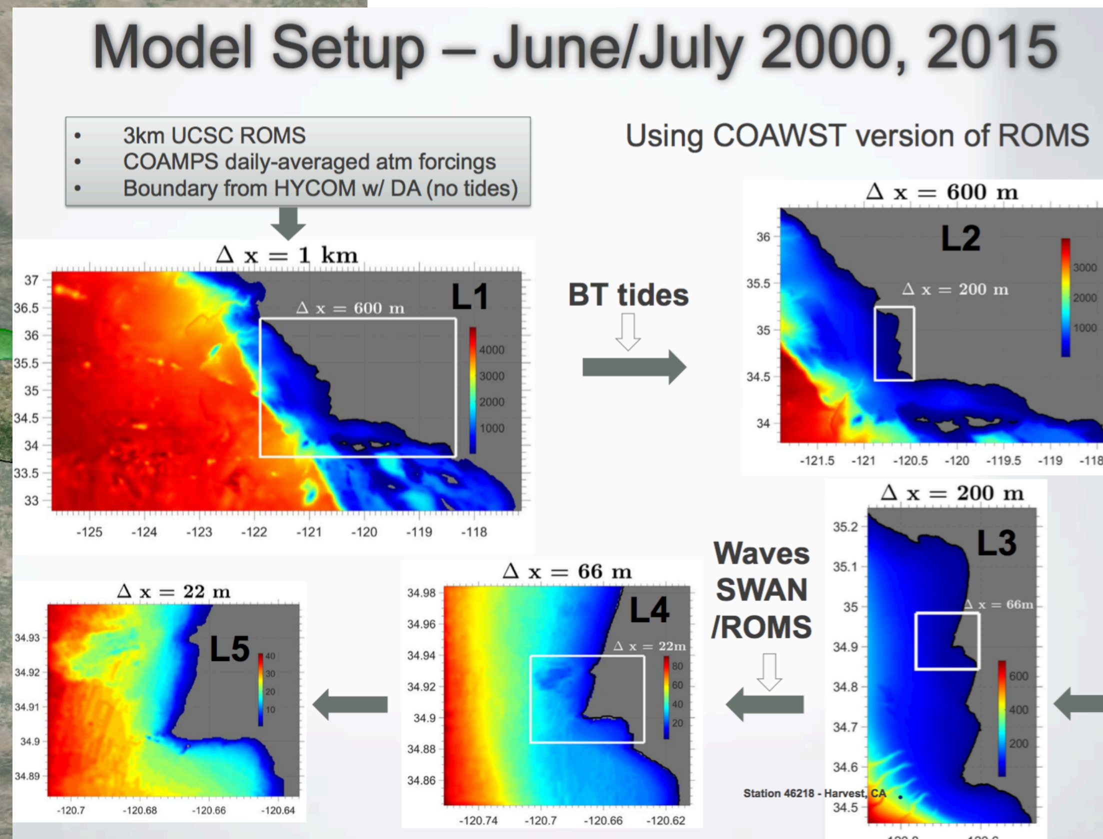


DopplerScatt Coverage/Verification experiment





Georgia Tech Model Physics & Resolution



Earth Science Technology Office

Summary

DopplerScatt from space

- Spaceborne DopplerScatt architecture has been defined as well as key driving requirements
- The TRLs of available technologies for space have been assessed and the Ka-band frequency has been chosen with the requirement on the peak transmit power of 100-200W for a fully spinning radar system.

Airborne DopplerScatt progress

- System is fully integrated into its flight configuration
- System post-processing calibration of SSPA behavior has been identified as one of the key efforts
- DopplerScatt has been tested end-to-end through the Optical Delay Line
- It has been integrated with the RSL's King Air B200 in the existing nadir port
- The engineering flights are on-going