IIP-13: Signals of Opportunity Airborne Demonstrator (SoOp-AD)

Earth Science Technology Forum 2014

October 28-30, 2014

National Conference Center (NCC)

Leesburg, VA

Outline

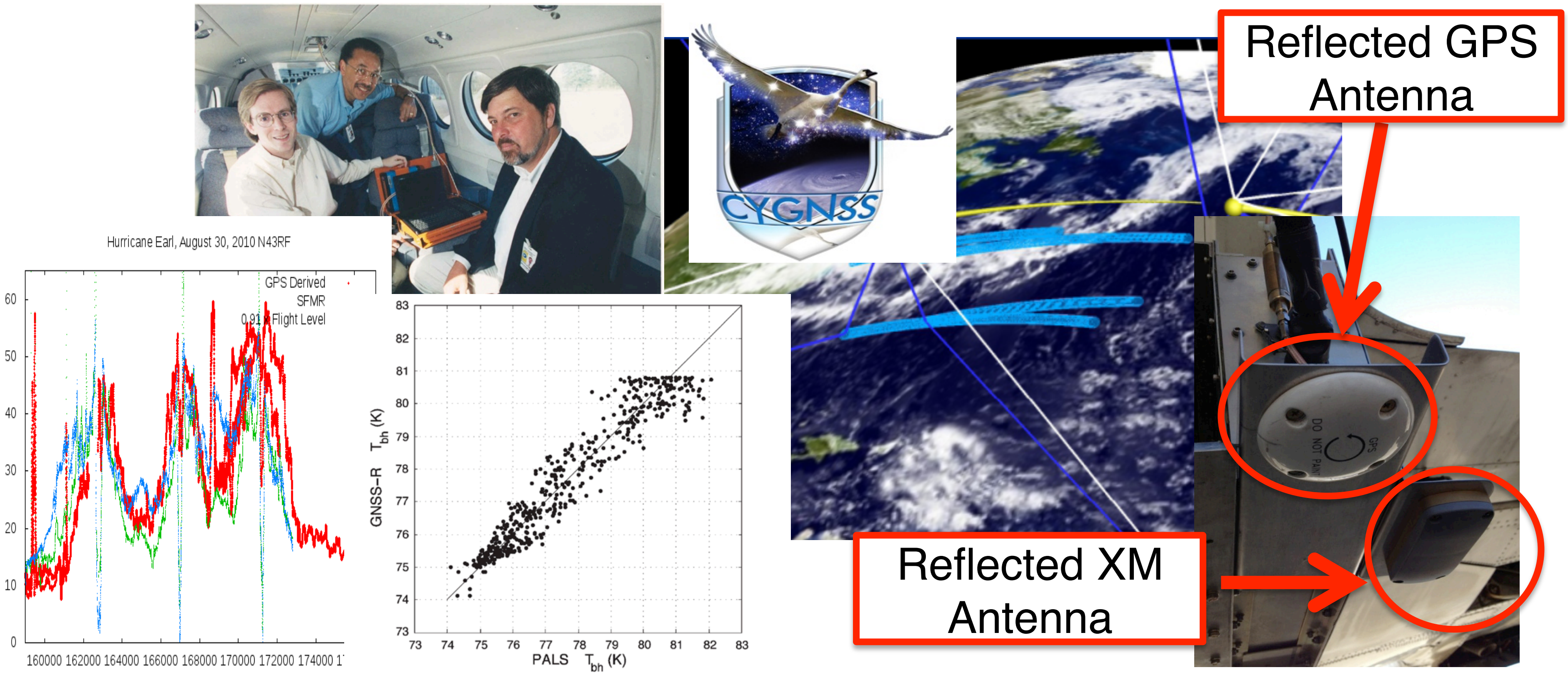
- Introduction:
  - Motivation: the problem of Root-Zone Soil Moisture (RZSM) sensing
  - The promise of SoOp
  - SoOp-AD Goals and Objectives
- Project Team
- Technology Development
  - Measurement simulation
  - Antenna Design
  - RF section Design
  - Digital Section Design
  - Aircraft Integration
- Schedule

Motivation

- Root Zone Soil Moisture (RZSM):
  - Water in top ~meter of soil
  - Critical link between surface hydrology and deeper process
  - Drainage and absorption by plant roots
  - Connection between near-term precipitation and long-term availability of fresh water
- L-band penetrates only few cm of soil
- SMAP Level 4 data product to estimate RZSM
- P-band radar –difficult to find allocation in heavily utilized spectrum
  - ESA-BIOMASS cannot operate in North America or Europe due to interference with Space Object Tracking Radar
  - 4G mobile network may also cause problems

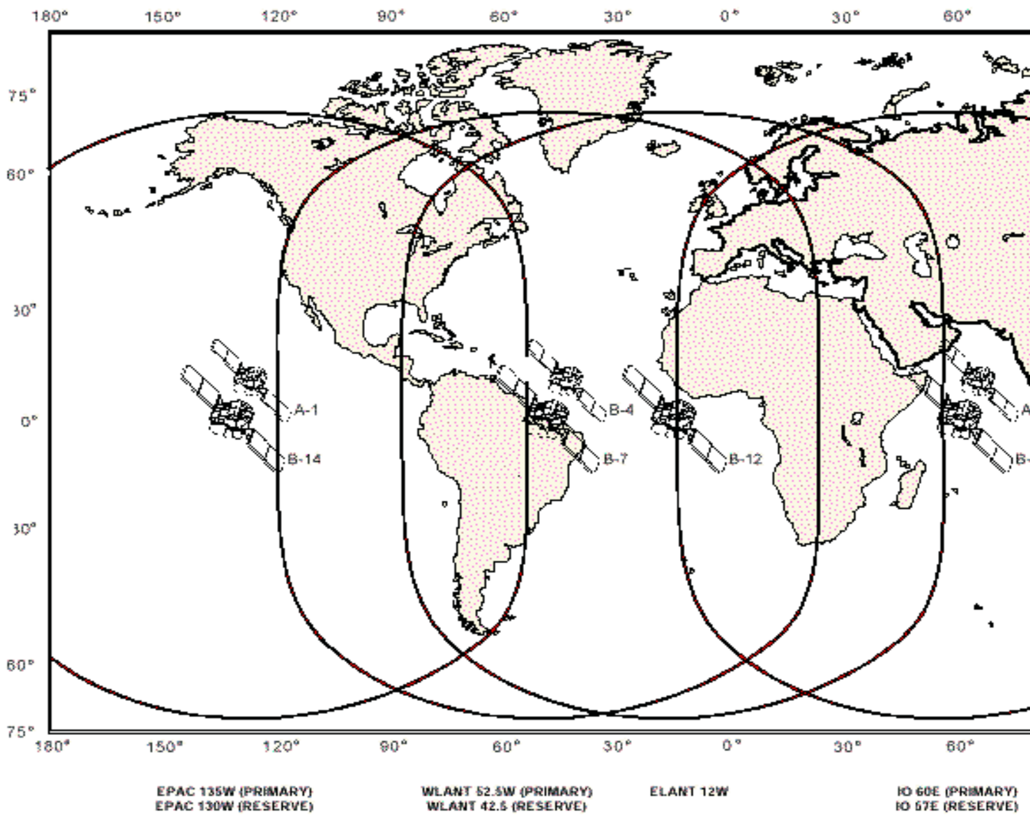
The promise of SoOp

- Signals of Opportunity (SoOp):
  - GNSS Reflectometry (GNSS-R): Ocean winds, soil moisture
  - UK-DMC (2003), TechDemoSat-1 (2014) and CYGNSS (2016)
  - Recent demonstration with S-band communication satellites



The promise of SoOp

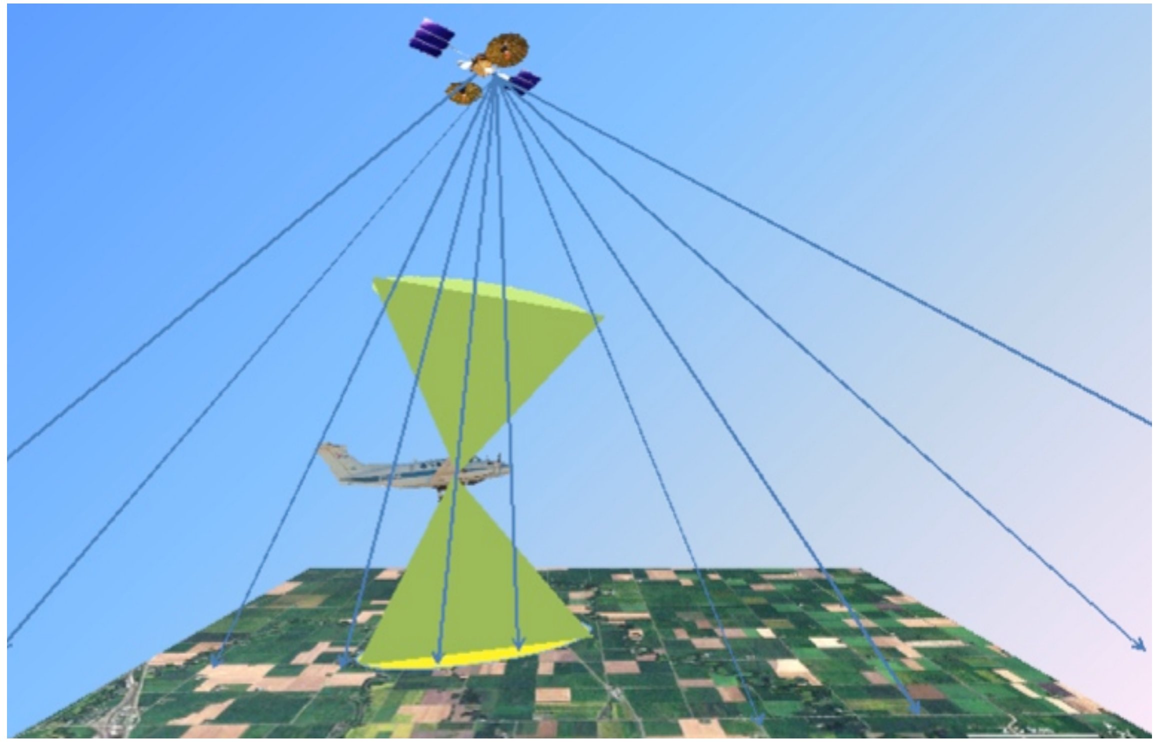
- 225–420 MHz allocation for defense/government use
  - Continuous use by US since 1978
  - Other systems: Skynet (UK) ComsatBw (Germany ?) Sicral (Italy)
  - Public signal specification and well studied by hams (and pirates!)



"The Great Brazilian Sat-Hack Crackdown"
wired.com 4/20/2009

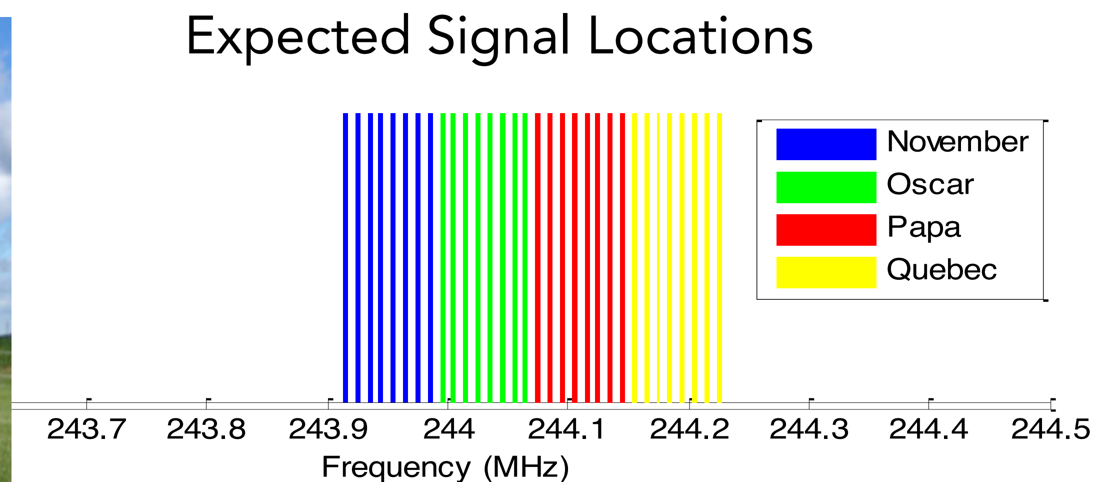
SoOp-AD (IIP-13 Award)

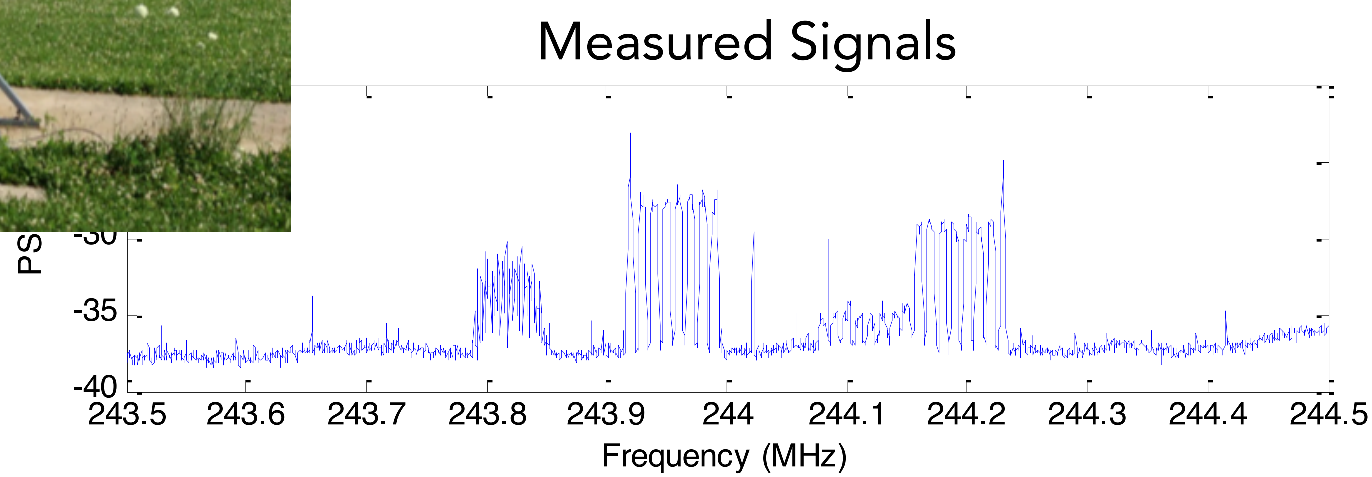
- Entry **TRL 3** (April 2014)
- Exit **TRL 5** (March 2017)
- Partnership:
  - Purdue University
  - NASA GSFC
  - Exelis, Inc
  - NASA LaRC
  - Dr. Steve Katzberg



Measurement Model & Simulation

- Measurements of available UHF SoOps:





Measurement Model & Simulation

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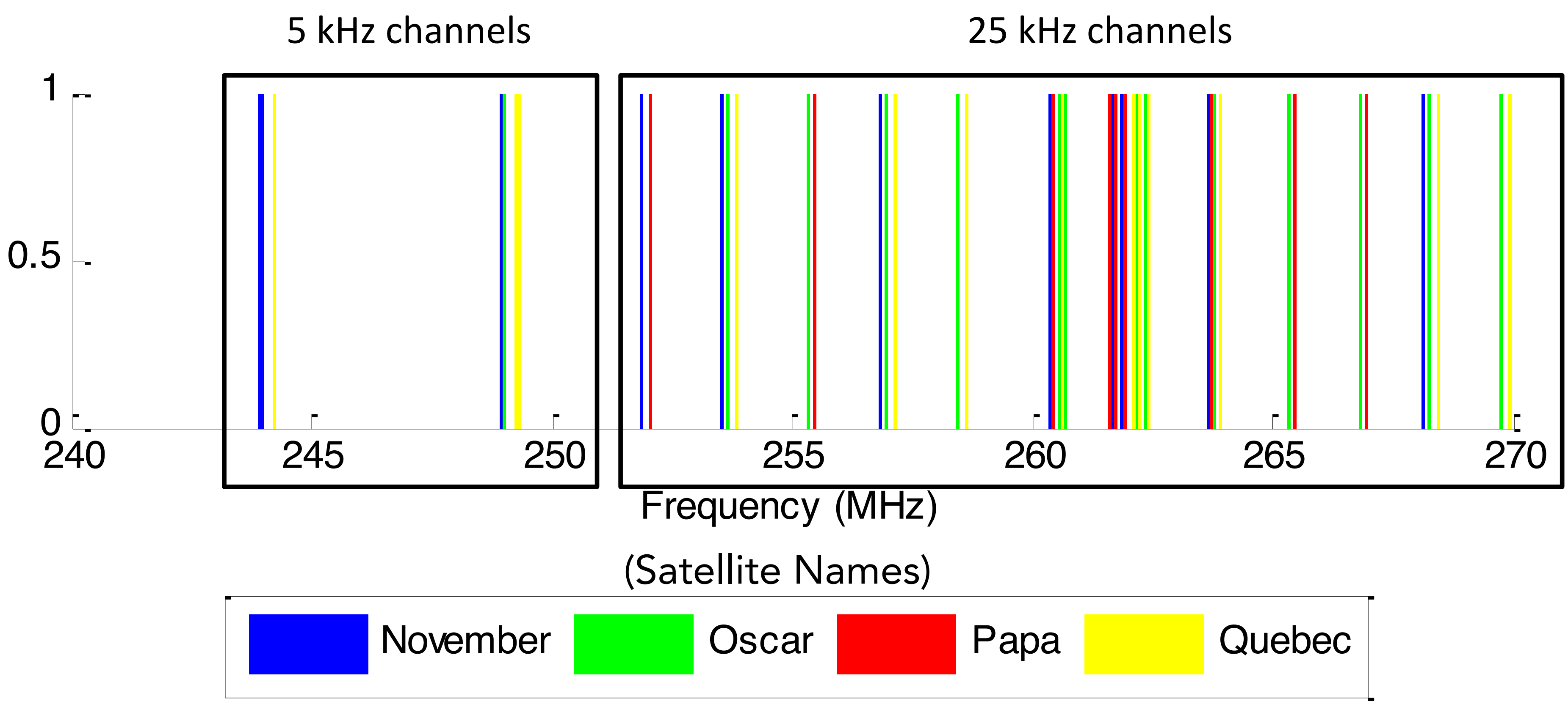


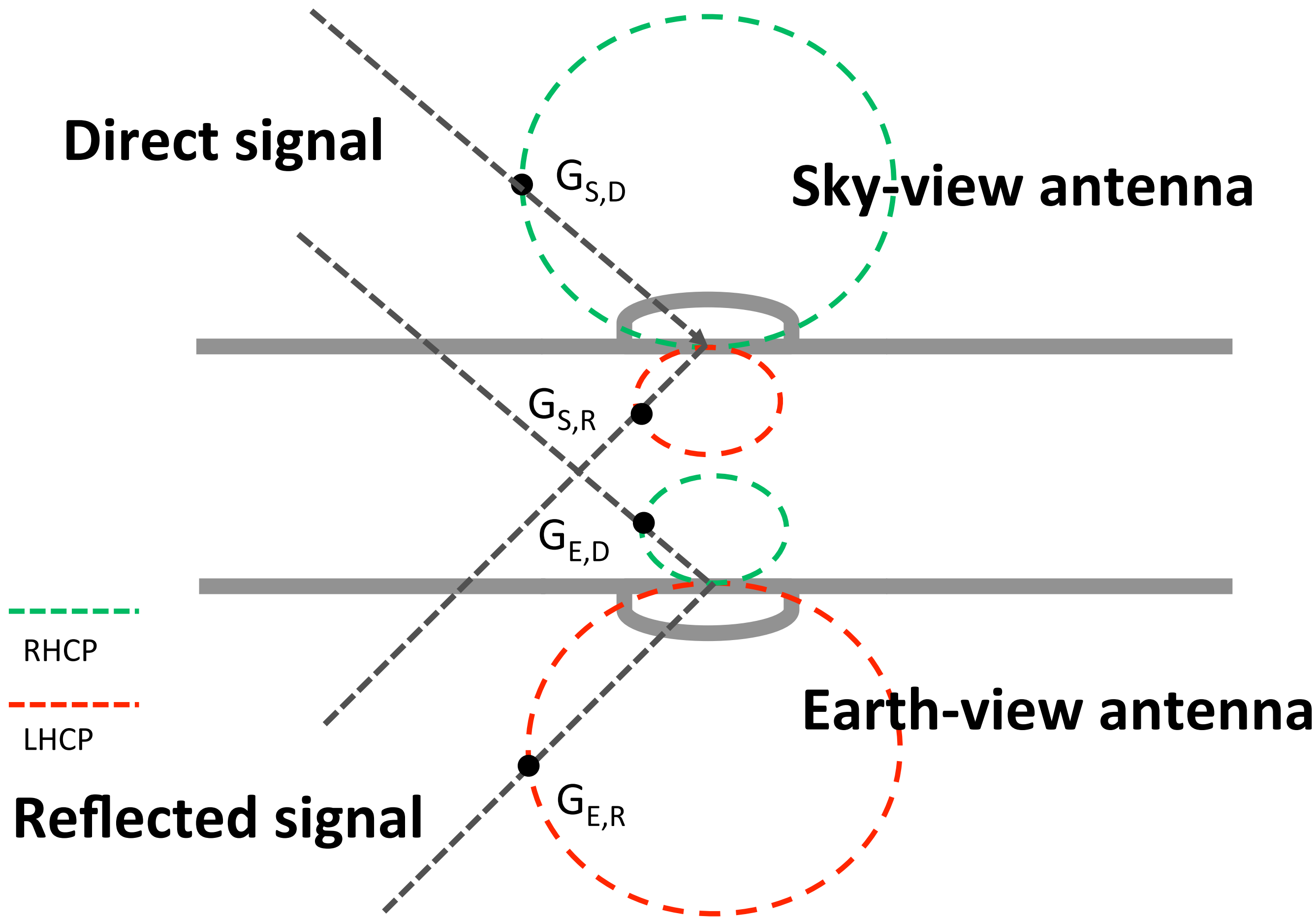
Measurement Model & Simulation

Nomenclature:

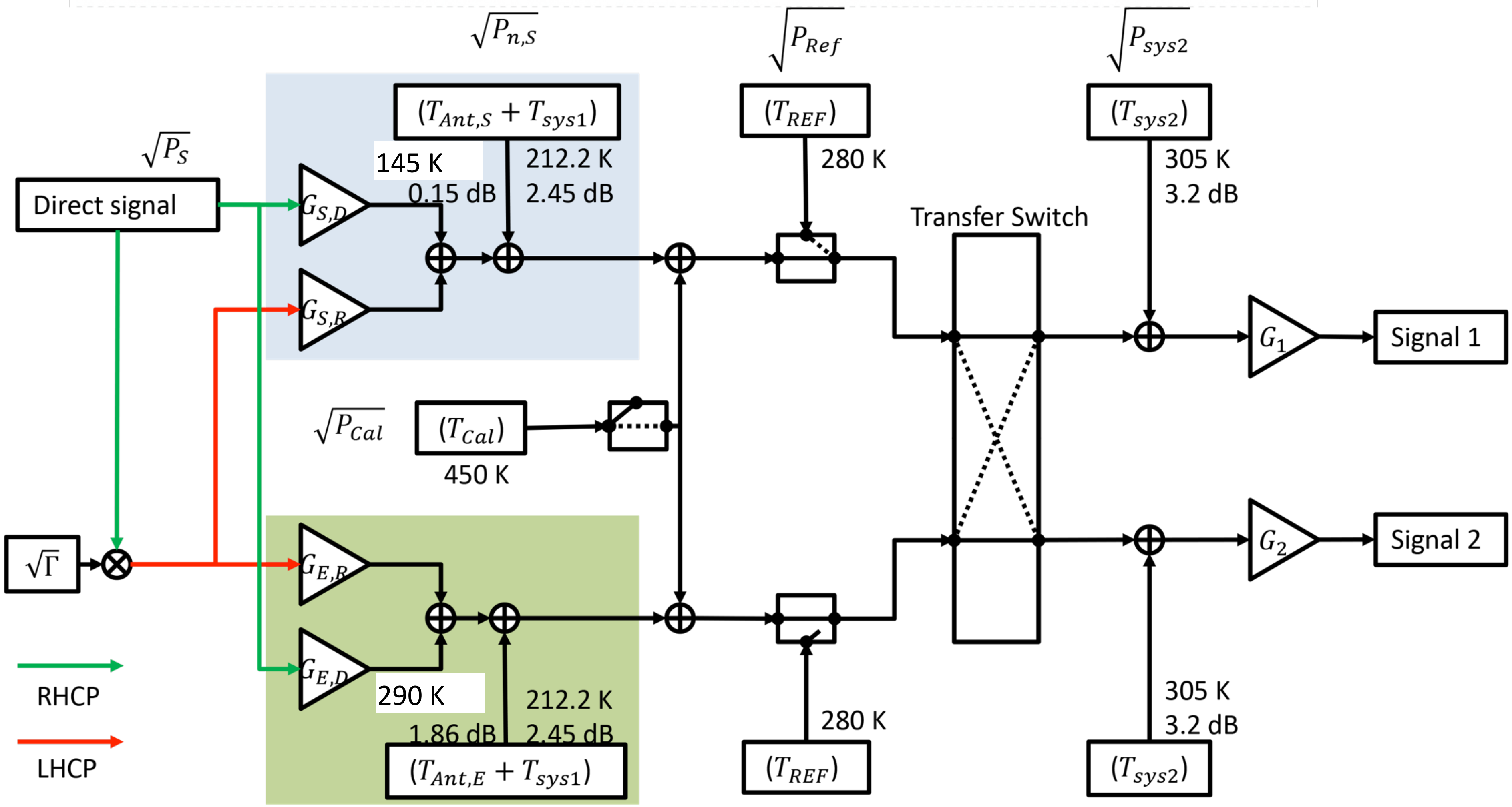
Antennas:
(S) Sky-view
(E) Earth-view

Signals:
(D) Direct
(R) Reflected

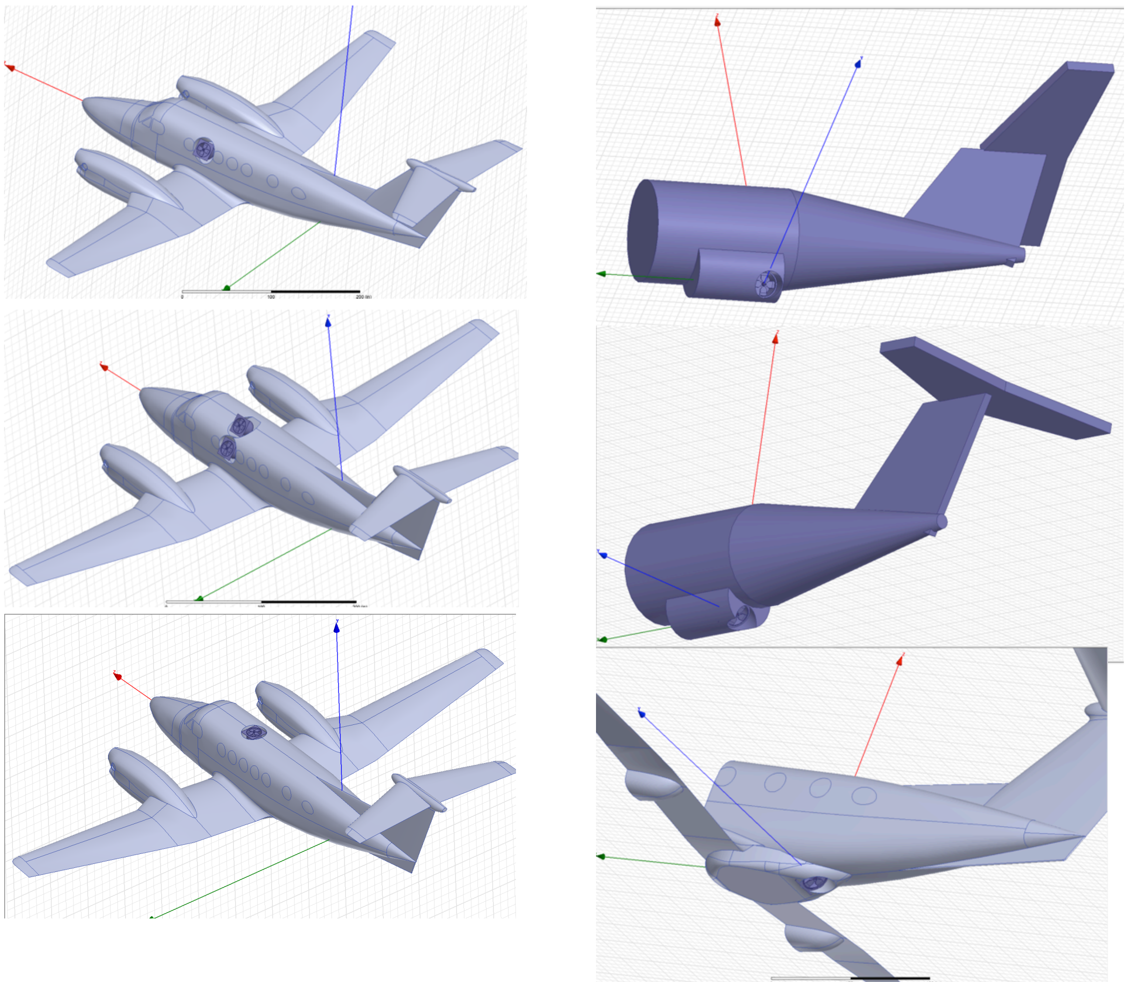
Receiver signal paths:
(1) and (2)



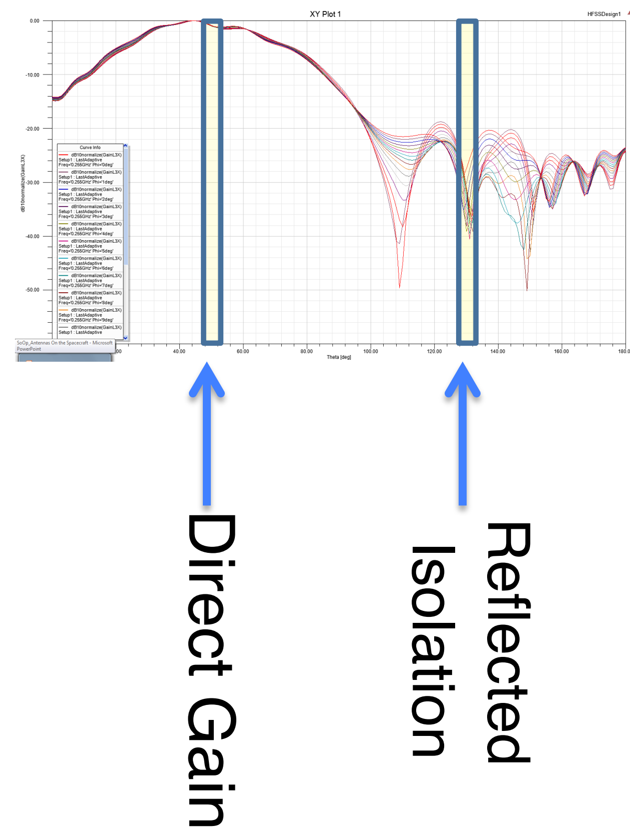
Measurement Model & Simulation



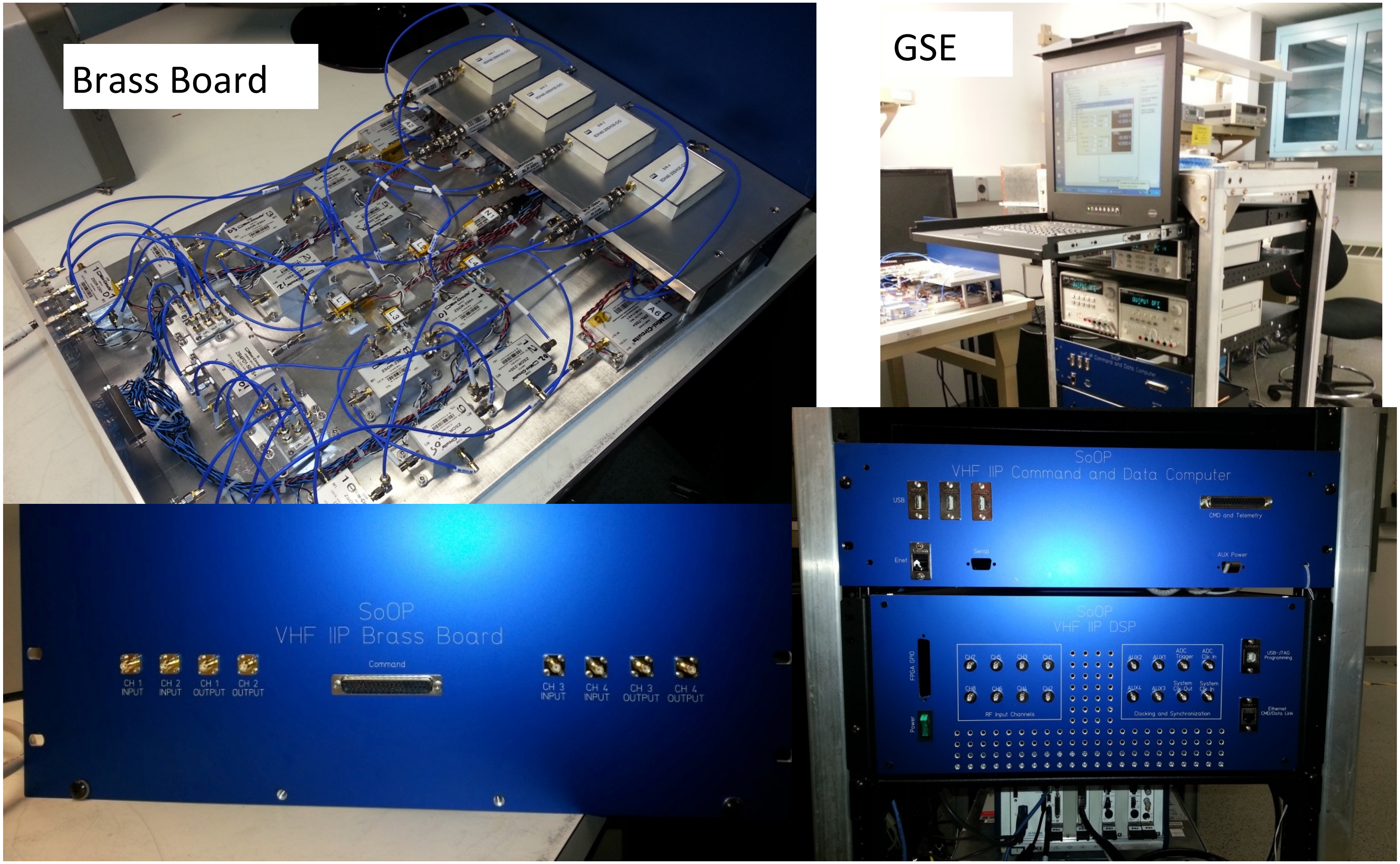
Antenna Design Trade Studies



Simulated Patterns

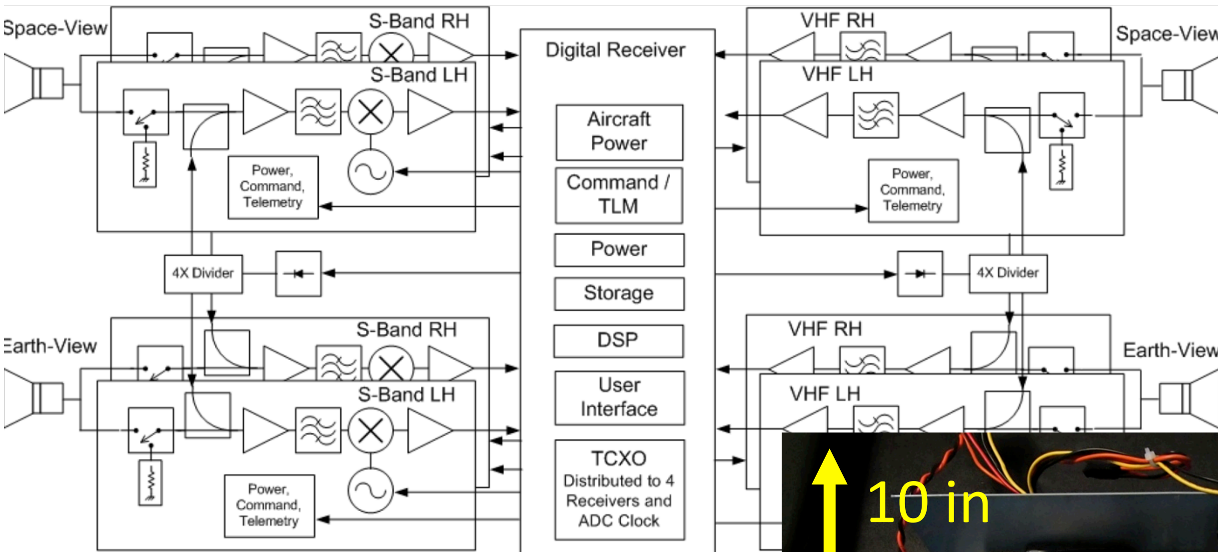


RF Section Design

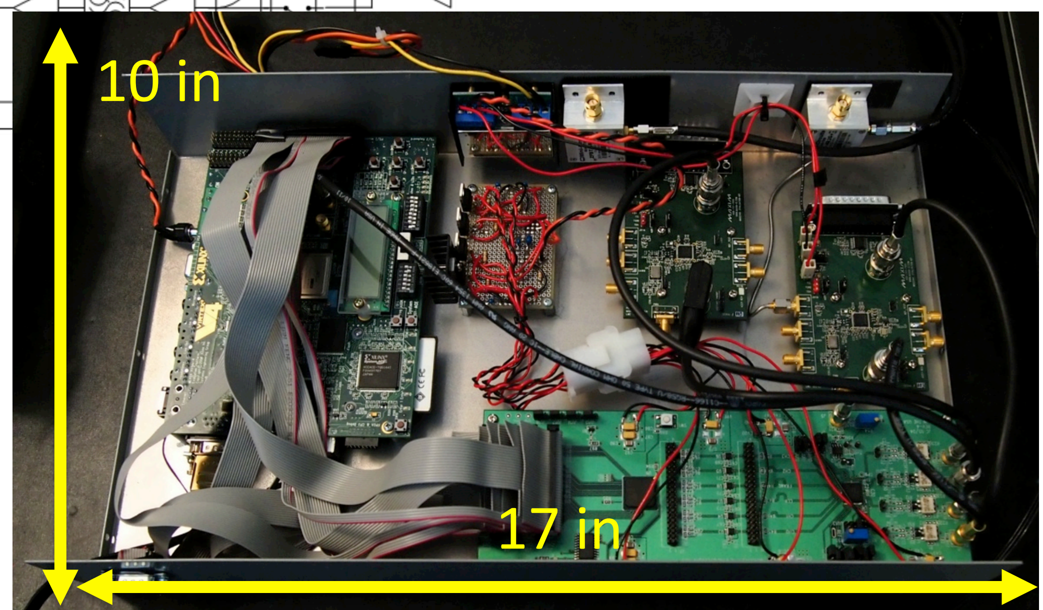


Digital Receiver

- Prototype Design (Exelis)



- Heritage: FPGA Airborne Prototype for XM Radio (S-band) (ITT/Exelis IRAD with Purdue)

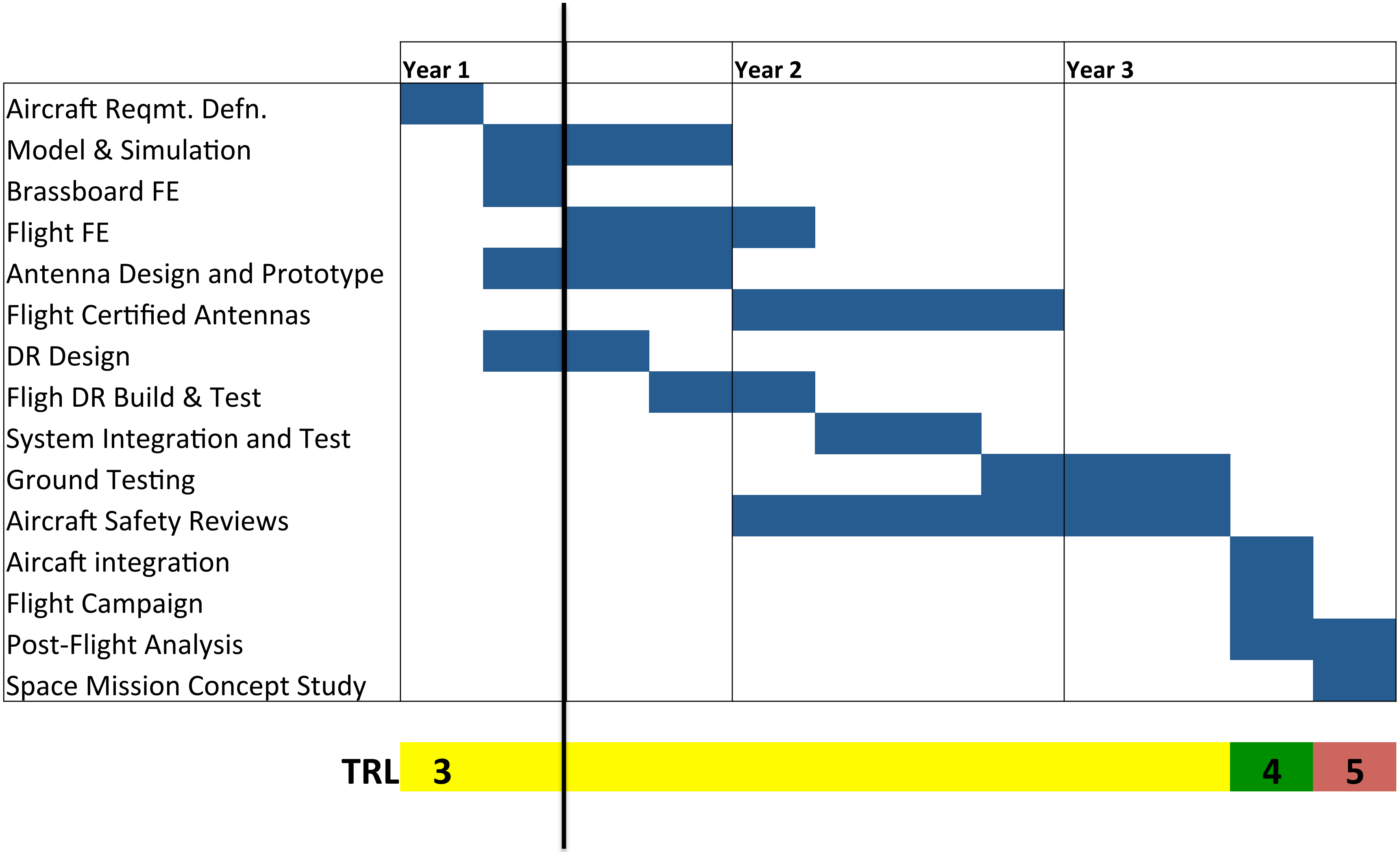


Aircraft Integration: Langley UC-12B

- SLAP Co-fly configuration

SLAP installed in UC-12B **SLAP Radome Will Share SoOp-AD Earth-View Antenna**

Schedule



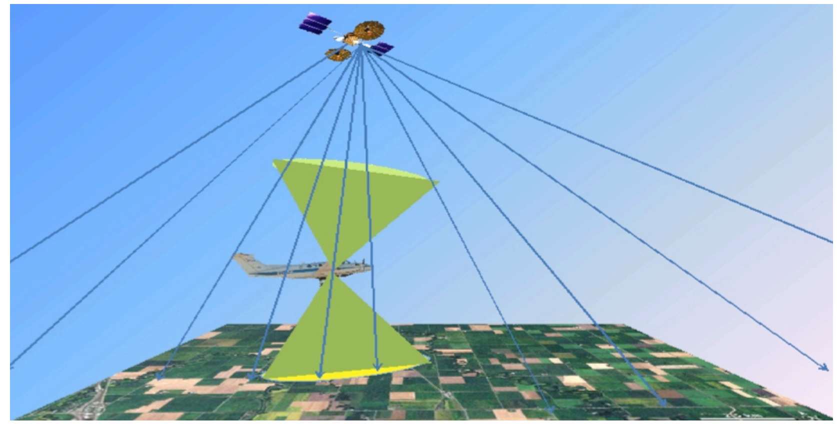
Year 1
Year 2
Year 3
Aircraft Reqmt. Defn.
Model & Simulation
Brassboard FE
Flight FE
Antenna Design and Prototype
Flight Certified Antennas
DR Design
Fligh DR Build & Test
System Integration and Test
Ground Testing
Aircraft Safety Reviews
Aircaft integration
Flight Campaign
Post-Flight Analysis
Space Mission Concept Study
TRL
3
4
5

SoOp-AD: Signals of Opportunity Airborne Demonstration

PI: James L. Garrison, Purdue University

Objective

- Develop new microwave remote sensing instrument to directly measure root zone soil moisture (RZSM) as opposed to currently derived RZSM products.
- Enable spaceborne Signals of Opportunity (SoOp) measurement technique that would lead to a substantially smaller antenna (75 x 75 cm) than a radiometer and require orders of magnitude lower power than radar while meeting 1 km resolution
- Develop an airborne instrument to demonstrate concepts of SoOp reflectometry at VHF and S-band frequency ranges for RZSM
- Measure soil moisture within 100 m resolution (airborne), 0-30 cm sensing depth (SMAP is 5-6 cm) and sensitivity of 0.04 (volumetric)



SoOp-AD will utilize reflected UFO and XM Radio signals to measure RZSM

Approach:

- Use radiometer architectures and digital cross-correlators as receivers and existing digital signal transmissions as illumination sources in a bistatic radar configuration
- Use transmissions in VHF with DoD's UHF Follow-on (UFO) satellite to demonstrate a frequency low enough to penetrate below first few cm of soil
- Use S-band (XM-Radio) to demonstrate adaptability of a common receiver core to multiple frequencies
- Perform remote sensing flight campaigns with SLAP instrument (Scanning L-Band Active Passive) for co-incidence measurements

Co-Is/Partners: Joseph Knuble, Jeffrey Piepmeier, Alicia Joseph, GSFC; George Alikakos, Exelis

Key Milestones

- Define measurement and instrument requirements 07/14
- Prototype RF receiver 09/14
- Design VHF and S-Band antennas 01/15
- Fabricate antennas and assemble digital correlators. 05/15
- Test processing algorithms with digital receiver 09/15
- Integrate antennas, RF receivers and digital receivers at GSFC. 02/16
- Install system on NASA Langley B200 aircraft 09/16
- Conduct flights over SMAP cal sites and St. Joseph Watershed in Indiana. 10/16

TRL_{in} = 3 $TRL_{current}$ = 3 TRL_{exit} = 5