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Earth Science Technology Office

WISM – A Wideband Instrument for Snow Measurement Past Accomplishments, Current Status, and Path Forward

by:

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HARRIS

NUVOTRONICS

W

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Presentation Outline



❖ **Project Overview**

❖ **GSFC Accomplishments**

❖ **Science Experiment I**

❖ **Science Experiment II**

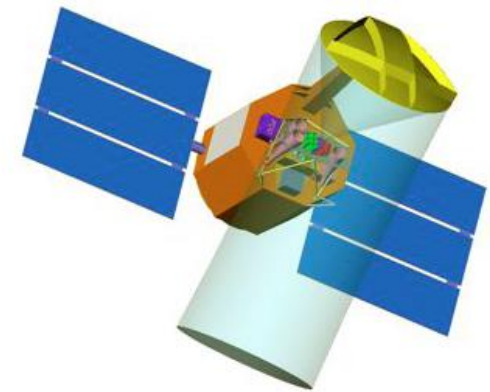
❖ **Current Status & Path Forward**



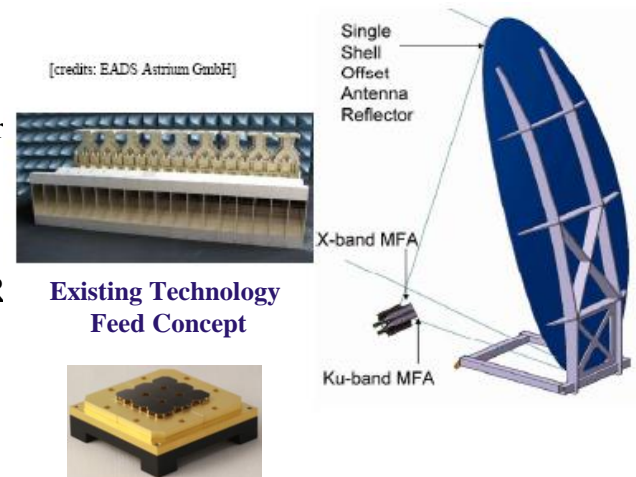
Project Overview: NASA ROSES IIP

Objectives, Motivation, and Approach

- ❖ **NASA ROSES IIP** (Research Opportunities in Space and Earth Sciences Instrument Incubator Program) Currently in second round of funding
- ❖ **Objective** Develop the Science and Technology to carry out snow remote sensing missions to make snow measurements on
 - Airborne platforms
 - Space platforms
- ❖ **Motivation** SCLP mission will include four instruments to gather data on snow pack extent, depth and mass
 - X-band SAR
 - Ku-band SAR
 - Ku-band radiometer
 - Ka-band radiometer
 - X-Band radiometer
- ❖ **Current State of the Art Limitations**
 - Existing antenna concept uses reflector antennas fed by individual feeds for each frequency/beam
 - Multi-element feeds produce offset beams, which impede the science
- ❖ **The WISM Approach** Demonstrated the technology to replace the feed manifold with a single array feed capable of supporting both SAR and radiometry
 - Performance improvement (i.e. co-boresighting)
 - Significant size, weight, power advantages
 - Enables enhanced SWE algorithm development



Notional SCLP Spacecraft



Existing Technology Feed Concept

WISM IIP Feed

Project Overview: Science Implications and Broader Impact

Importance of Seasonal Snow

Supplies 50% to 80% of the yearly water supply in the Western United States

Accurate measurement of the snow water equivalent (SWE), are needed to effectively manage water resources

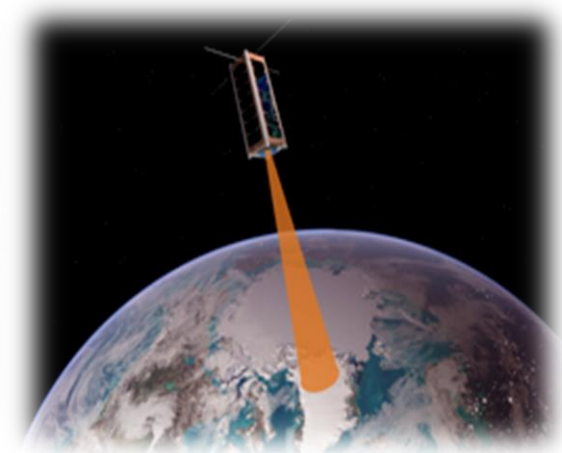
Challenge: on the very small spatial scales over which the snowpack varies.



Highly variable snowpack



Ground truth experiments are conducted in parallel with airborne SWE measurements



Conceptualization of the measurement of SWE and other snow parameters from space

Project Overview: GSFC's Role – The WISM Radiometer

1. GSFC Team

- RF: 555
- Data-System: 587
- Thermal System: 545
- Power System: 563

1. Instrument Subsystems

- RF: 3x Radiometer Bands; Ku, Ka and X
- Data-System
- Four Zone Thermal System
- Power System

2. Calibration

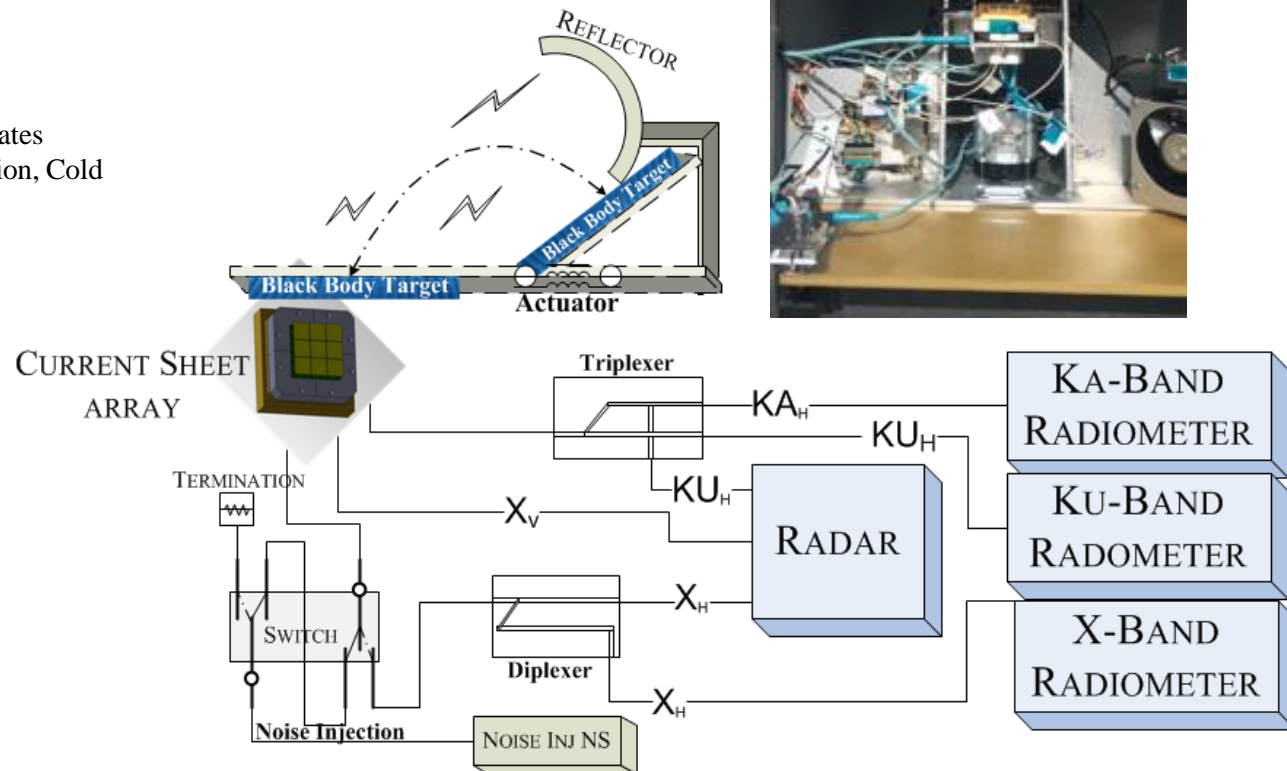
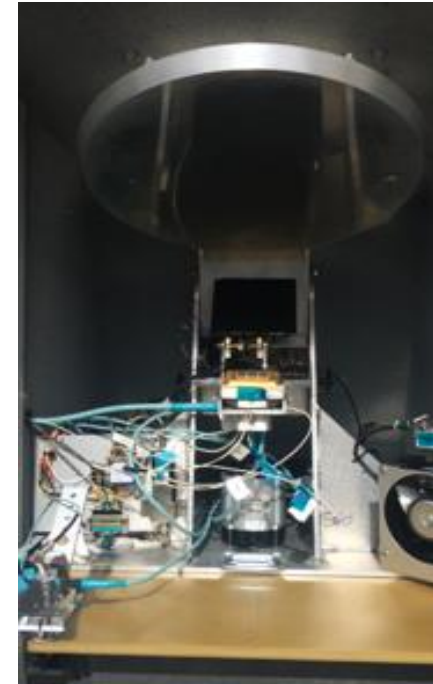
- Internal Calibration via 6x Calibration States
- Calibration Standards: Ambient termination, Cold Termination, 2x Noise sources
- External Pre-Flight Calibration
- Noise Source
- External Black Body Target

3. Frequency Bands

- Ku 18.6 GHz – 18.8 GHz
- Ka 36.0 GHz – 37.0 GHz
- X 10.6GHz – 10.7GHz

4. Key Specifications

- Horizontal Polarization
- Spatial Resolution: 93m
- Uncertainty: $< 0.5 \text{ }^\circ\text{K}$
- Temp Resolution NeDT $< 0.5 \text{ }^\circ\text{K}$





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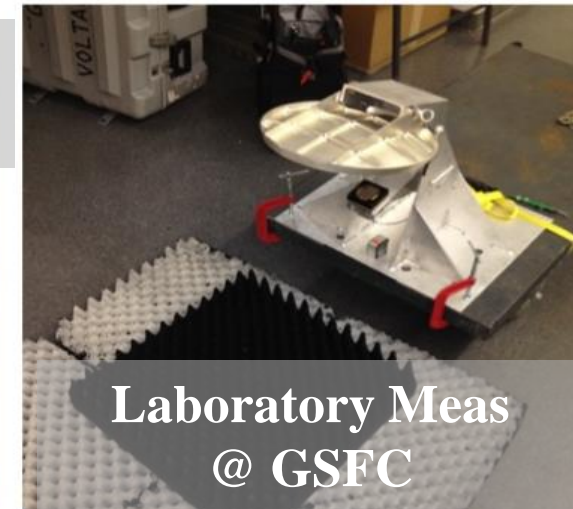
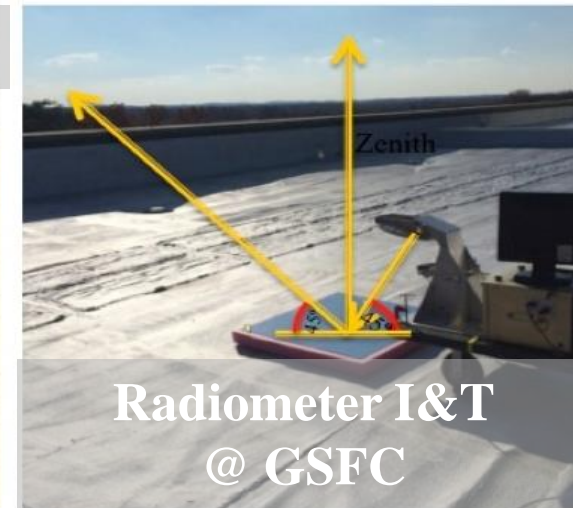
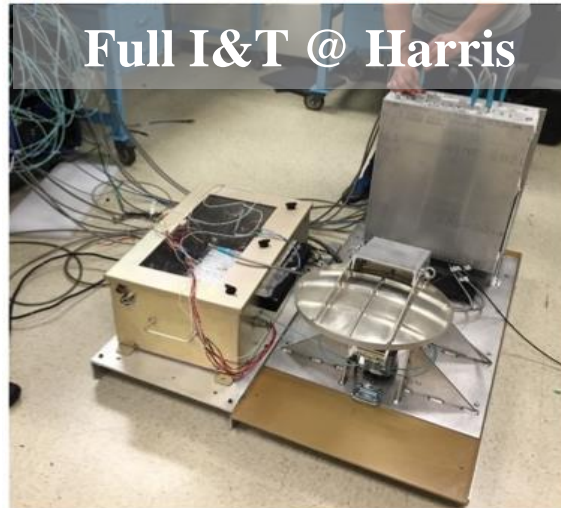
GSFC ACCOMPLISHMENTS



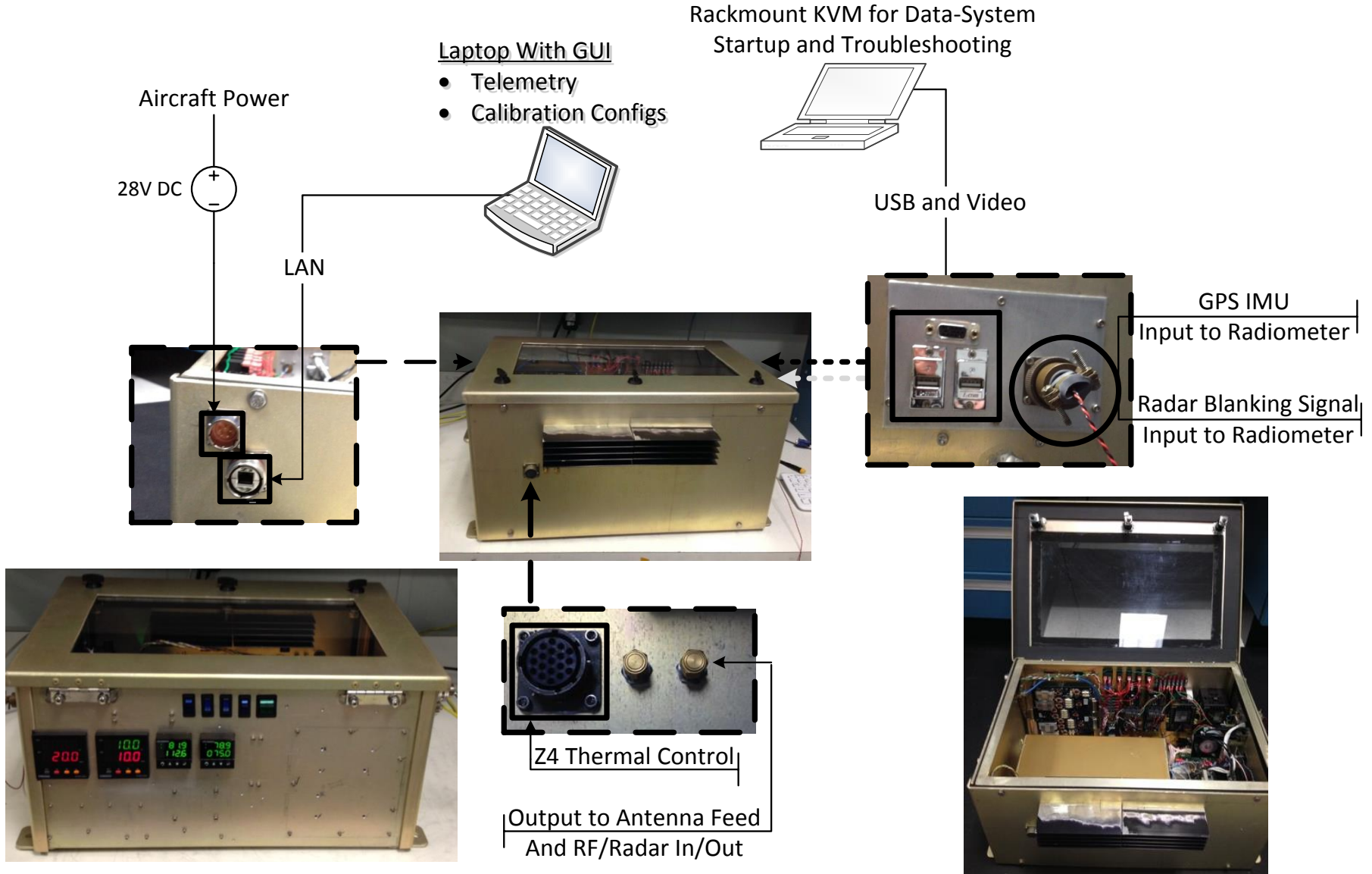
GSFC Accomplishments: Overview

GSFC Team Accomplishments

1. Completed engineering integration and test (I&T) radiometer
 - a. Measurement test bench configuration
 - b. GSFC 1st order calibration
 - c. GSFC laboratory measurements and data analysis
 - d. GSFC SIRF lab snow measurement
2. Completed I&T of radiometer with WISM antenna
 - a. GSFC SIRF lab snow measurement
 - b. GSFC BLD 33 rooftop measurements
 - c. Noise inject test
3. Completed I&T of radiometer, radar and antenna @ Harris
 - a. Validated instrument (radar - radiometer) operation, power, etc.
 - b. Tested radar blanking signal
 - c. Tested Zone 4 thermal assembly
 - d. Configured and test GPS/IMU
 - e. No radar transmit interference
 - f. Enhanced flightworthiness of cables and harnessing
4. Data Post-Processing Program (DPP) Development
 - a. DPP Development
 - i. LIA completed
 - ii. LIB In progress
 - b. Pre-flight calibration application
 - i. Cold sky calibration
 - ii. Cold and hot target calibration
5. Science Experiment I Completed
 - a. Viable data received on all flights
 - b. Calibrated radiometer data delivered
 - c. Correction in progress
6. WISM II Enhancements
 - a. Enhanced calibration via external noise injection
 - b. Additional radiometer band
 - c. Enhanced the DPPs'
7. Science Experiment II Completed
 - a. Viable data received on all flights except X-band
 - b. Results promising
 - c. Correction in progress
8. Q.Bonds secured supplemental funding via SECP and IRAD



GSFC Accomplishments: Radiometer System Design



GSFC Accomplishments: Radiometer System Design

Internal Calibration interleaved with science data

Two 50Ω waveguide terminations; primary, long averages

Two noise sources (NS); secondary

Radiometer Box Input

Room temperature termination

LN2 Dewar

Antenna Calibration (sheet array)

Room temperature blackbody

LN2 blackbody

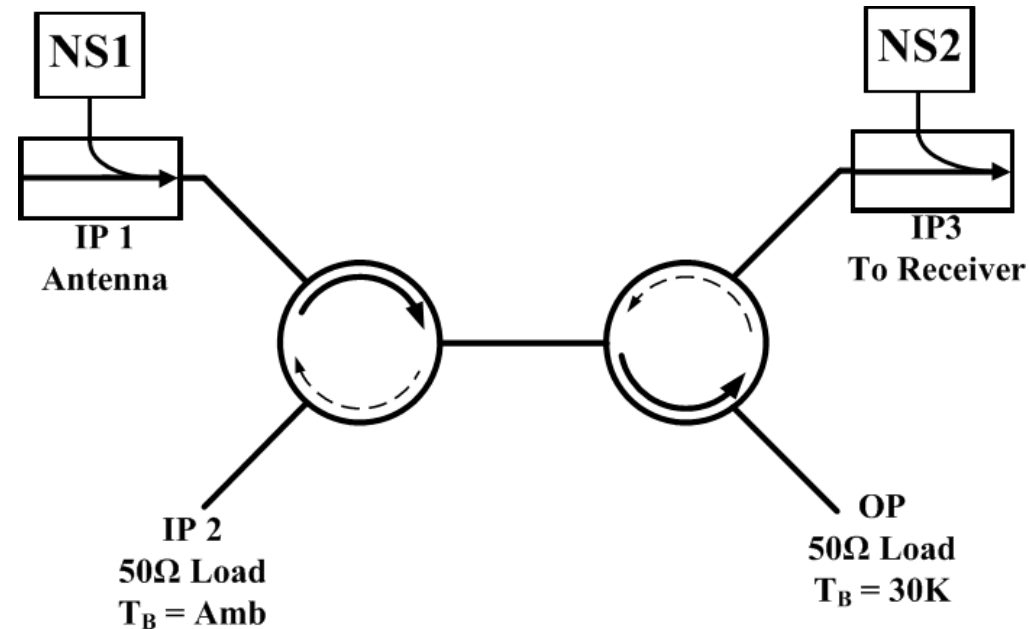
Pre-flight calibration

Ambient blackbody box over
sheet array

Flight Data Calibration

Antenna Pattern Correction

Internal calibration + thermal correction of front-end
losses (sheet array, triplexer)



GSFC Accomplishments: Integration and Test (I&T)

Functional Testing

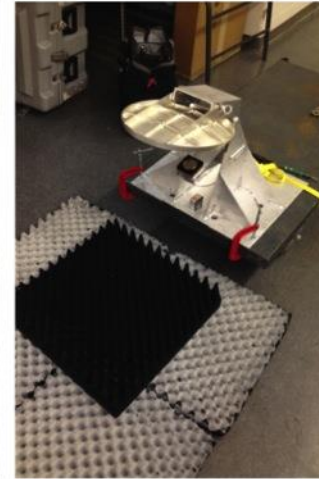
- Data digitization
- Calibration state sequencing
- Noise source switching
- Thermal control and stability
- Thermal control
- Radar blanking signal



GSFC Accomplishments: Integration and Test (I&T)

Task: WISM Antenna Integration with Radiometer

- Install measurement grade test tables
- Configure mobile test bench
- Install WISM antenna feed into the reflector assembly
 - Feed angle of critical importance
 - Reflector angle of critical importance
- Integrate radiometer with WISM antenna



Task: Preliminary Lab Tests to Confirm System Functionality

- Data-system sampling
- Instrument control
- Recording of science and telemetry
- Thermal system

Task: SIRF Lab Meas with WISM Antenna

- Performed with Ludovic Brooker, Code 615 Scientist
- Data-system sampling
- Instrument control



GSFC Accomplishments: Integration and Test (I&T)

Task: Performance Validation via Cold-Sky Measurements on Bld 33 Roof

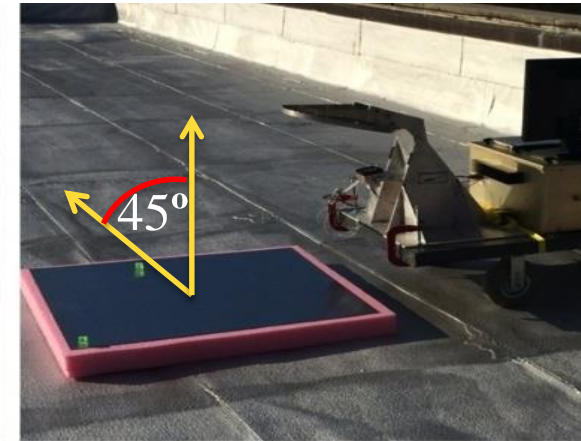
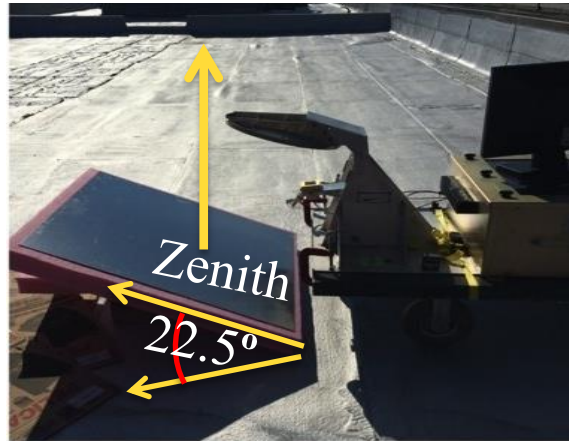
Objective: Final Step Before Radar Integration at Harris in Melbourne

Radiometer preliminary performance analysis to quantify:

- Stability
- Resolution - NeDT
- Data-system sampling and timing
- Impact of the radome

BLD 33 Roof: Unobstructed View of Known Targets

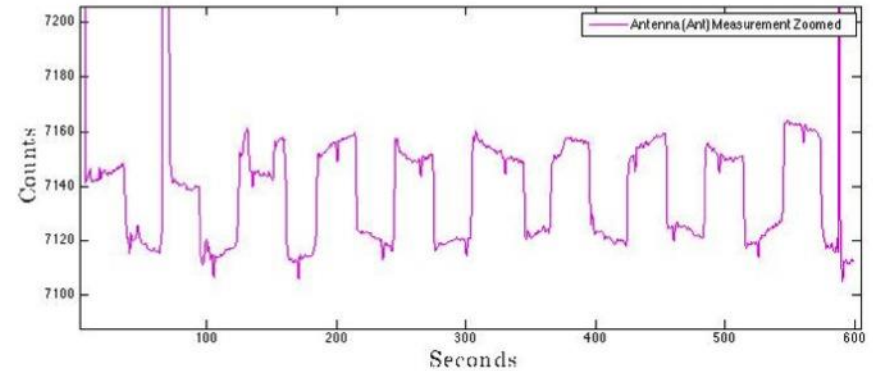
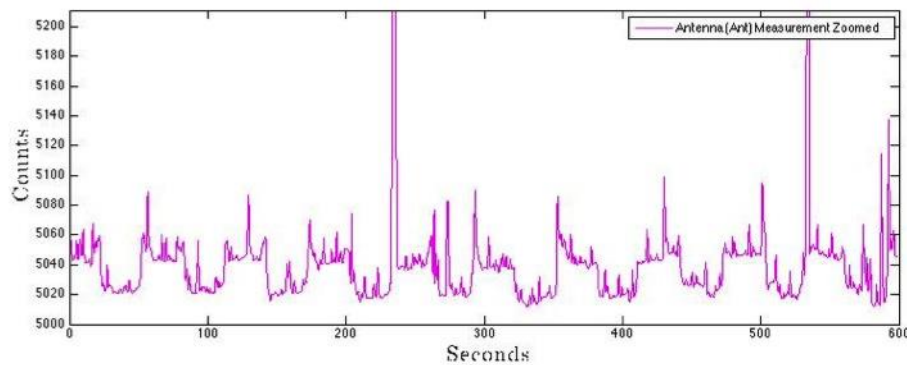
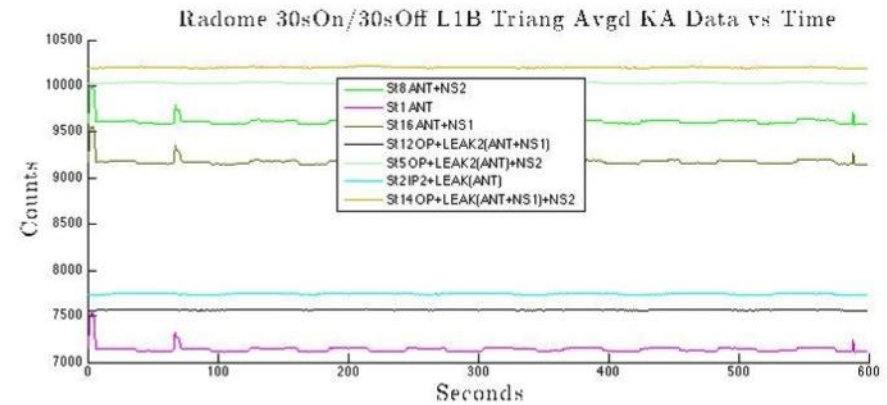
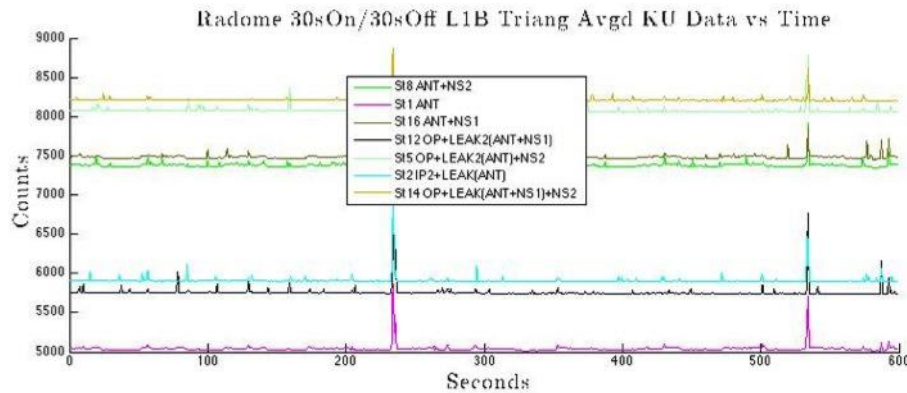
- Zenith
- 45 degrees
- Cold black body
- Warm black body
- Radome measurements



GSFC Accomplishments: Integration and Test (I&T)

Measurements Taken

- Zenith, 45 Degrees, Cold Black Body, Warm Black Body , Radome Measurements
- Ku vs Ka Radome Measurements Below



GSFC Accomplishments: Full Instrument Integration and Test (I&T)

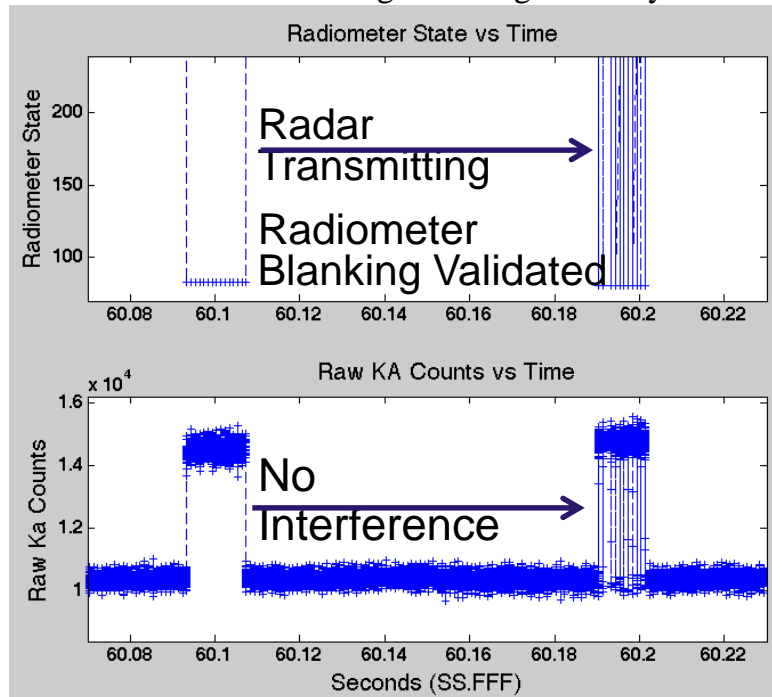
Full Instrument I&T at Harris

Results: Confirmed with good confidence: The radar will not interfere with or damage the radiometer

1. Final updates to the data-system
2. Integration of radar and radiometer
3. Validate instrument (radar - radiometer) operation, power, etc.
4. Test radar blanking signal
5. Test Zone 4 thermal assembly
6. Configure and test GPU/IMU
7. No radar transmit interference
8. Cables harnessing more flight worthy



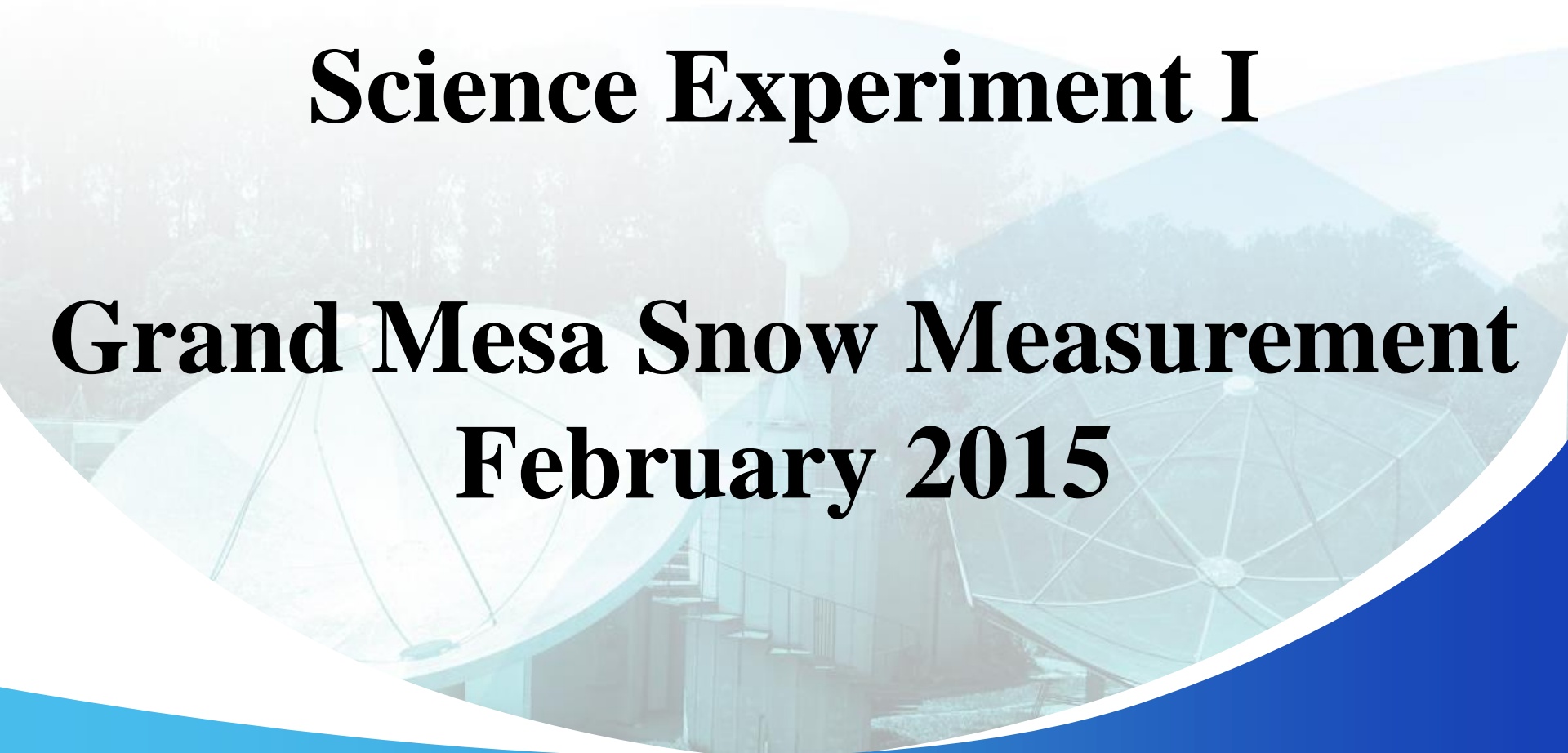
In the Lab @ Harris





Science Experiment I

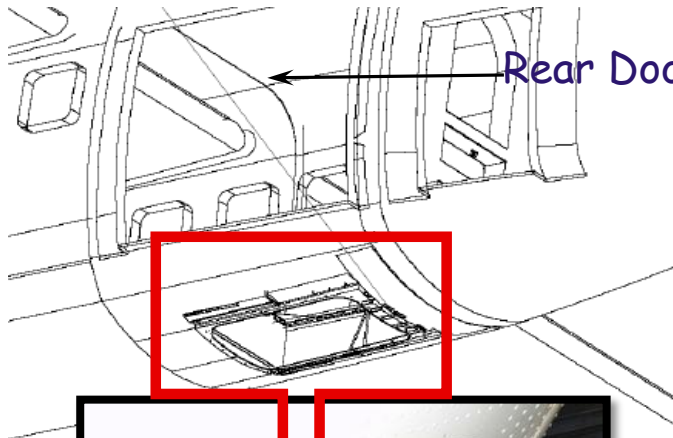
Grand Mesa Snow Measurement February 2015



Science Experiment I: Aircraft Procurement and Mechanical Integration



Twin Otter – DC6



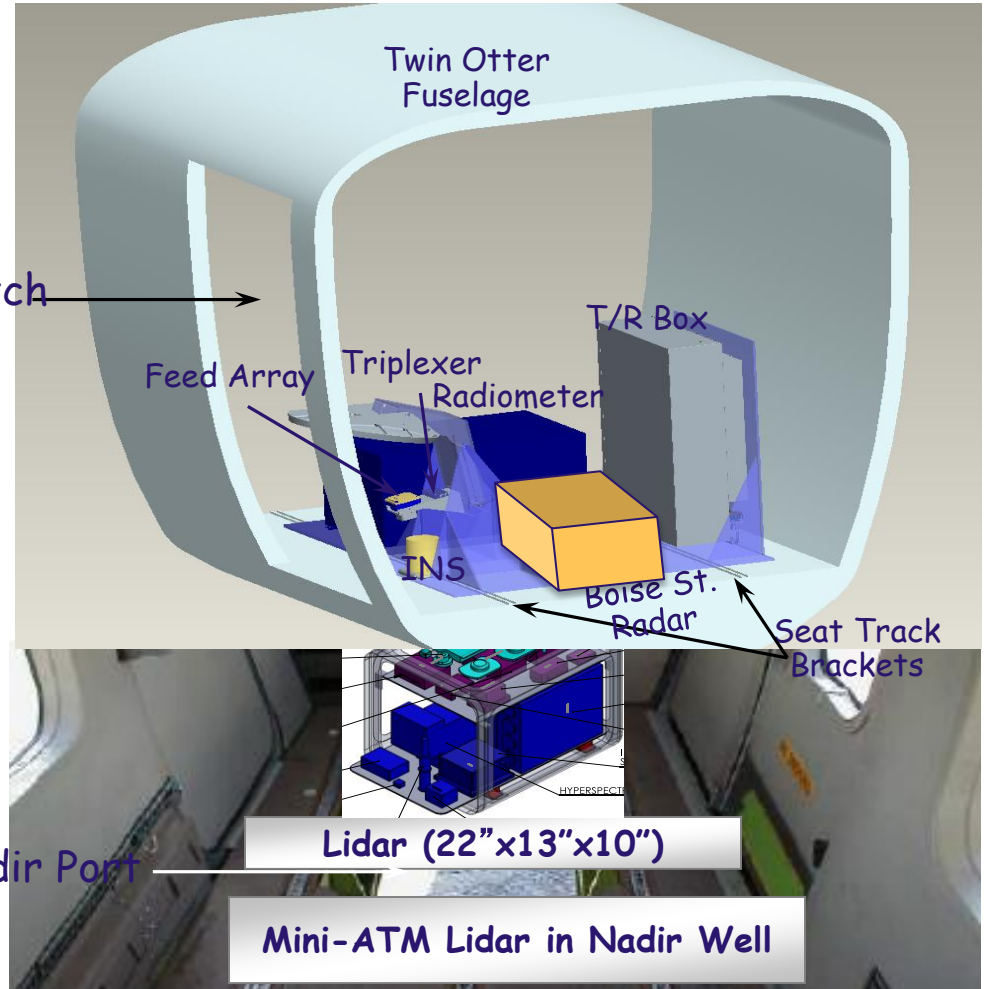
Rear Door Hatch



Rear Nadir Port

Nadir Port (36"x23"x13"|15")

Approx. Position in Fuselage



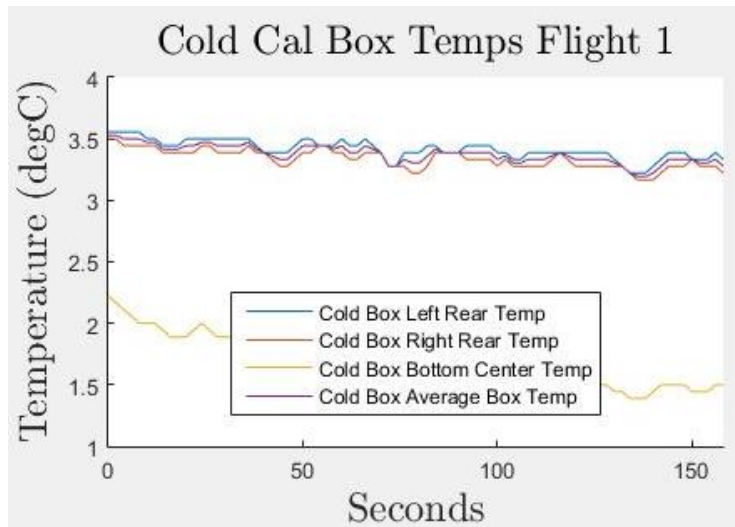
Science Experiment I: Aircraft Measurements

Science Experiment: Grand Mesa Colorado

Pre-Flight Calibration Before Each Flight

- Hot target (kept outside, temp $\sim 17\text{C}^\circ - 19\text{C}^\circ$)
- Cold target (kept outside, temp $\sim 2\text{C}^\circ - 3.5\text{C}^\circ$)
- Hot and cold targets were cycled onto the calibration structure
- Zenith (Cold Sky)
- 45° (Cold Sky)

Measurements: SWE at 3 altitudes above the Grand Mesa; 1500ft, 3000ft, 5000ft



Science Experiment I: Aircraft Measurements

Science Experiment: Grand Mesa Colorado

4 Flights

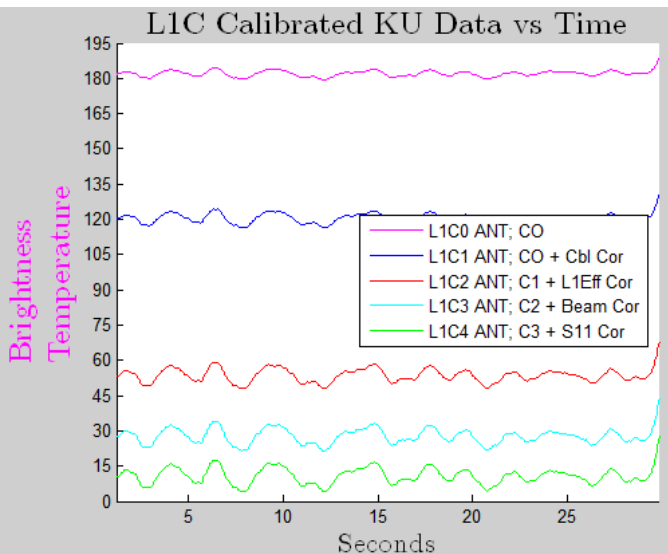
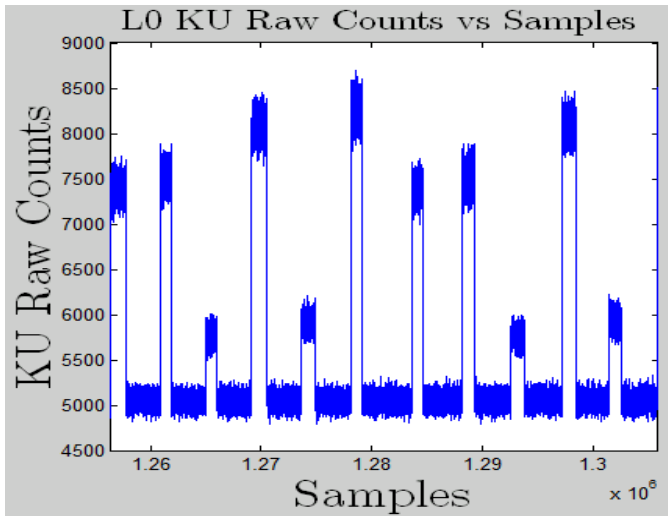
- 2/21/2015 Mesa
- 2/22/2015 GJT Airport (Lidar/Radar) Cal
- 2/24/2014 Mesa morning & Mesa afternoon

Ground Truth Site Visit with HP Marshall, PhD and Kelly Elder, PhD

- Surveyed area of investigation
- Dug and surveyed snow pit
- Analyzed snow crystals at microscopic level



Science Experiment I: Data Post-Processing



Prev DPP Design

**Process Raw Data:
Bin to Dec**

**Remove Spikes
Avg Per Cycle 240ms**

**Apply Triangular
Mov Avg**

Apply Calibration

Enhanced Design

**Process Raw Data:
Bin to Dec**

**Remove Spikes
Avg Per State Change,
10ms to 30ms**

Apply Calibration

**Apply Triangular Mov
Avg**

**Apply Model to
Correct for Loss**

**Calibrate Flight Data
with Pre-Flight**

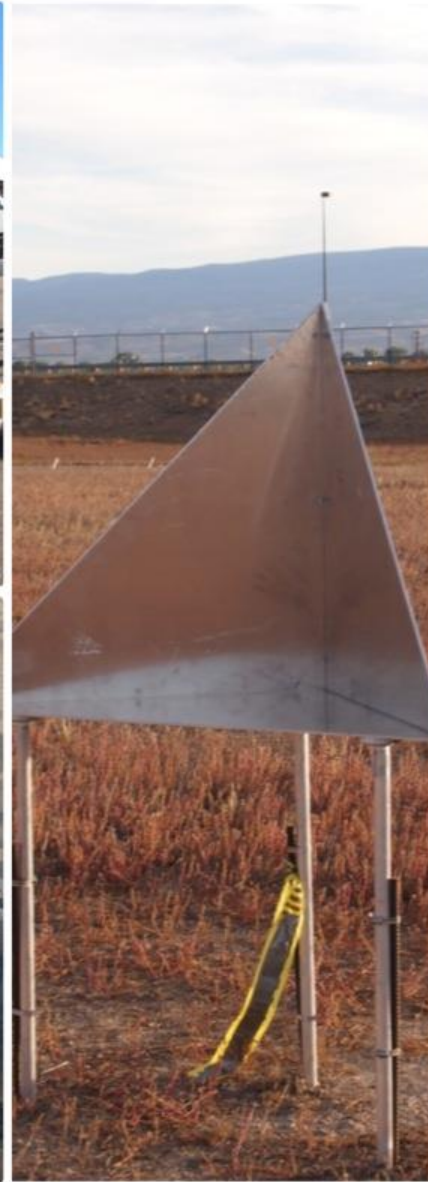
**Perform Optimization
on Model Parameters**

Geolocate Data

Science Experiment II

Grand Mesa Snow Free Measurement October 2015

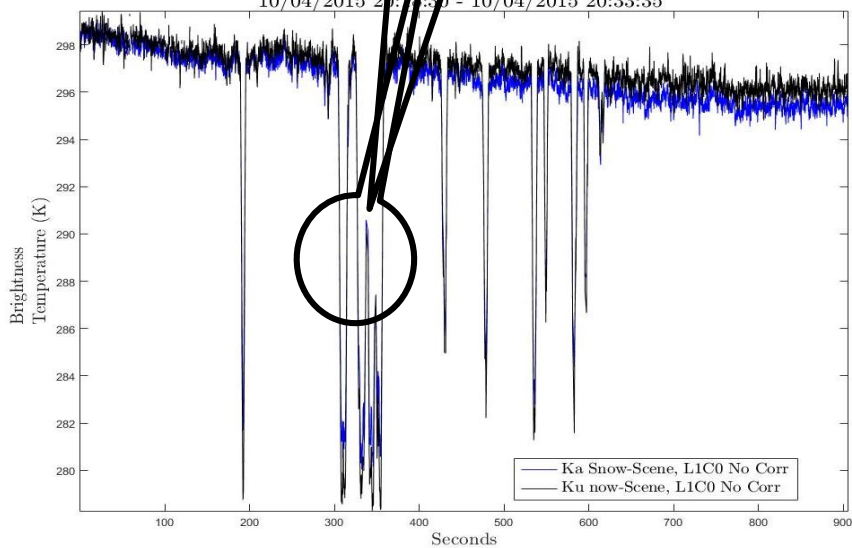
Science Experiment II: Pre-Flight



Science Experiment II: Flight






Sci Exp2 Flt1 1500ft Pass1 Est Ka-Blue/Ku-Black
10/04/2015 20:32:30 - 10/04/2015 20:33:35



Science Experiment II: Flight Measurement Summary

| Flt # | Date | Duration (hours) | Radiometer | | | Radar | | miniATM | Notes |
|-------|-------|---------------------|----------------|----------------|----------------|----------------|----------------|----------------|--|
| | | | X | Ku | Ka | X | Ku | | |
| 1 | 4-Oct | 2.0 | No Usable Data | Validated Data | Validated Data | No Usable Data | No Usable Data | Validated Data | miniATM foresight calibration and miniATM/radiometer flight over Mesa at 1.5kft. Radiometer and miniATM reported normal operation. Poor connection on X-band radiometer. No radar. |
| 2 | 6-Oct | 1.1 | Validated Data | Validated Data | Validated Data | No Usable Data | No Usable Data | Validated Data | Local flight over airport to test radar. Radar sampling window set wrong, no useful data. |
| 3 | 7-Oct | 0.7 | No Usable Data | Validated Data | Validated Data | No Usable Data | No Usable Data | Validated Data | Local flight over airport for radar. CW leakage signal corrupted radar data. |
| 4 | 8-Oct | 0.9 | No Usable Data | Validated Data | Validated Data | Validated Data | Validated Data | No Usable Data | Local flight over airport for radar. Radar reported normal operation. miniATM removed from aircraft |
| 5 | 8-Oct | 2.3 | No Usable Data | Validated Data | Validated Data | Validated Data | Validated Data | No Usable Data | Local flight and then over Mesa at 5kft. Radar and radiometer reported normal operation. No miniATM. |
| 6 | 9-Oct | 2.7 | No Usable Data | Validated Data | Validated Data | Validated Data | Validated Data | No Usable Data | Local flight and then over Mesa at 5kft. Radar and radiometer reported normal operation. No miniATM. |

| | |
|---|---|
|  | Validated Data |
|  | Unsure: Data received but not processed |
|  | No Usable Data |



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Current Status and Path Forward

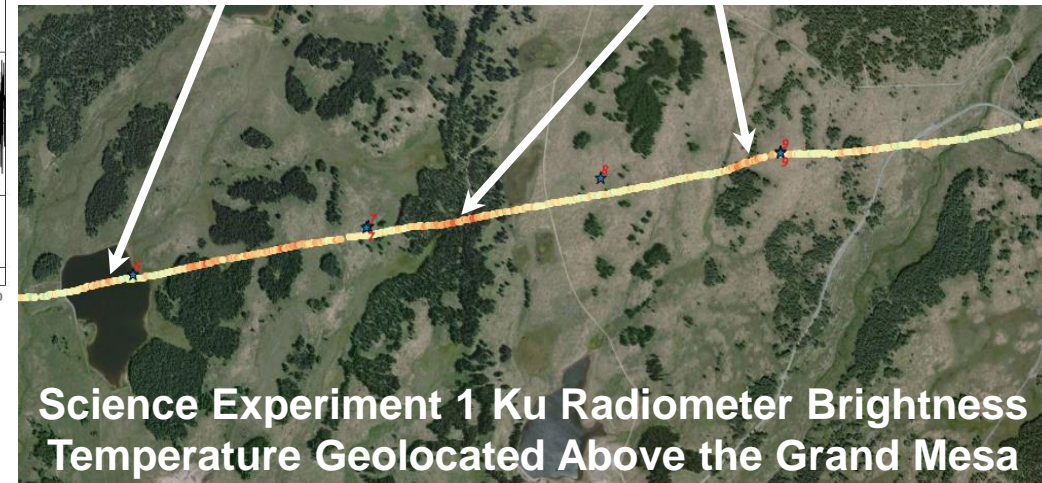
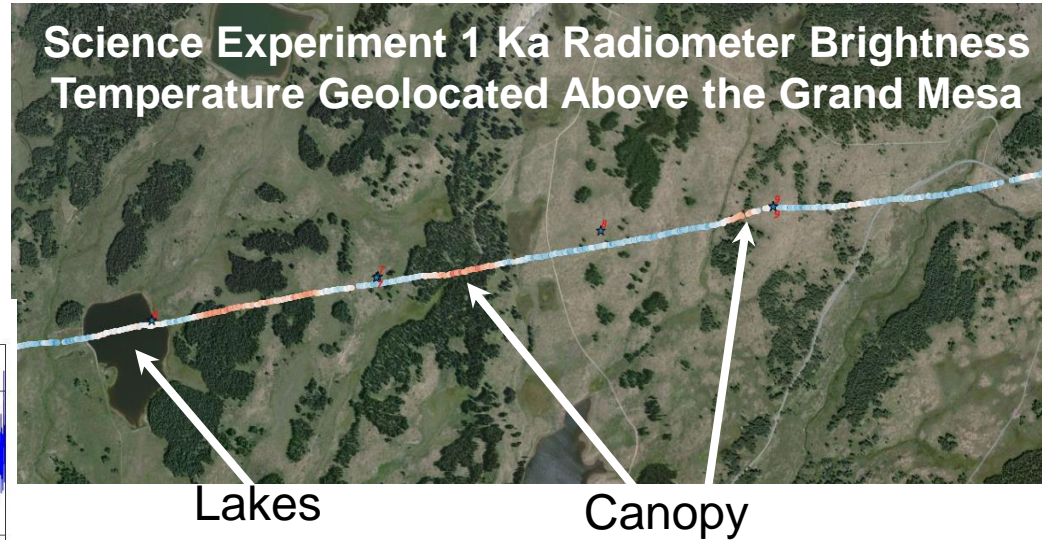
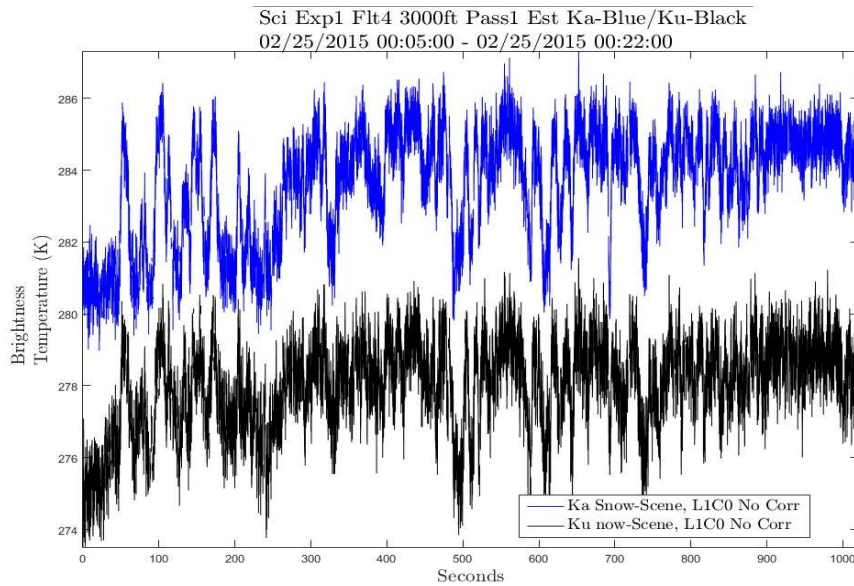


Current Status:

Science Experiment I Data Post Processing and Analysis

Science Experiment 1 – Snow: Data Analysis

- Data Collect: Sci Exp-1 Flt-4 3000ft Pas-1 Eastbound
- Calibration with No Correction
- Correlated to TB via Q.Bonds/555, Geolocated via K.Speed/Harris, Mapped and via L.Brucker/GSFC 615

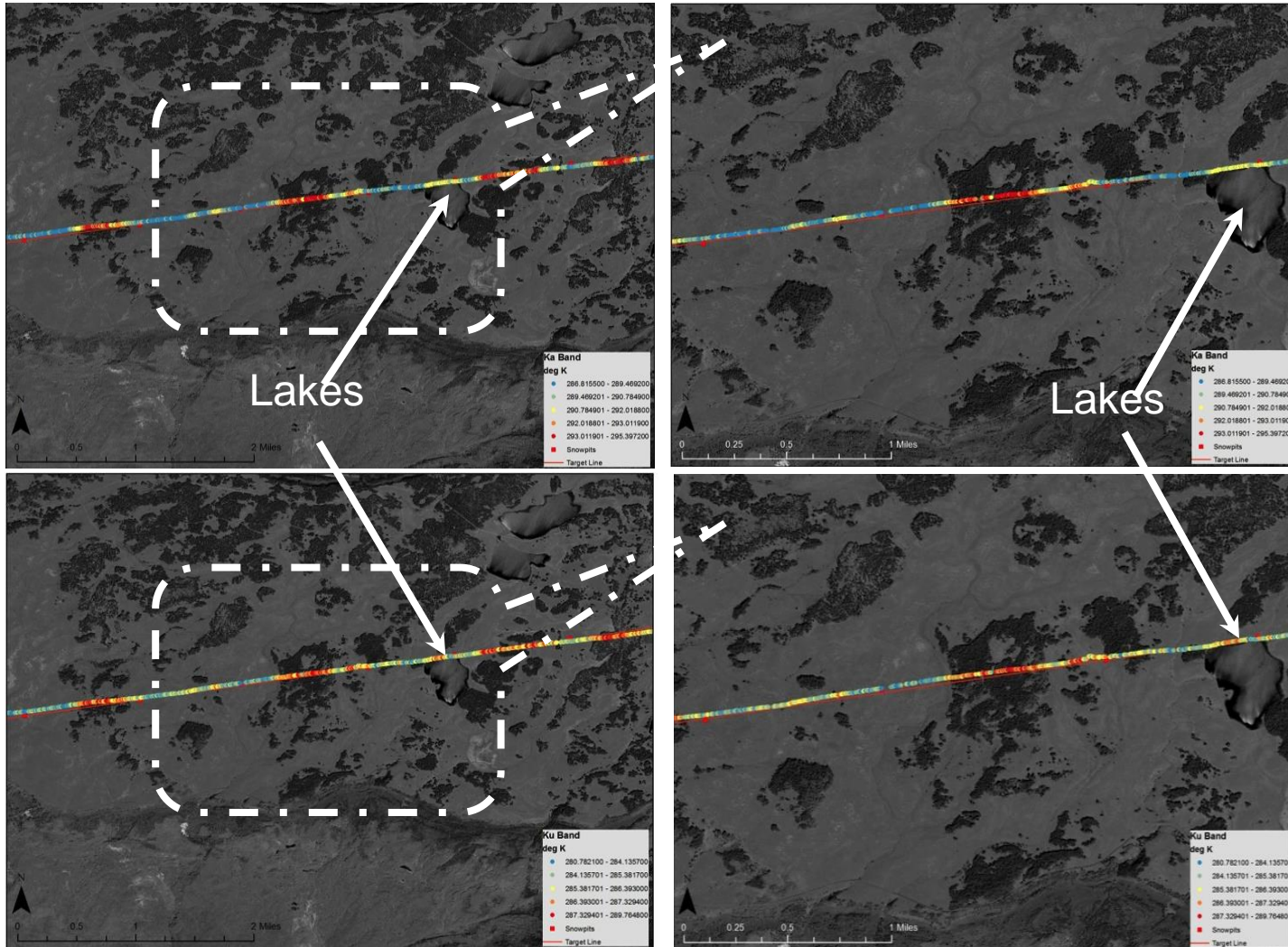


Current Status:

Science Experiment I Data Post Processing and Analysis

Sci Exp-1 Flt-4 3000ft Pas-1 Eastbound: Tb Over Lakes Plotted on World Map Actual vs Zoomed Scale

T_B of Lakes vs Canopy Demonstrate the Desired Trend Over the Grand Mesa

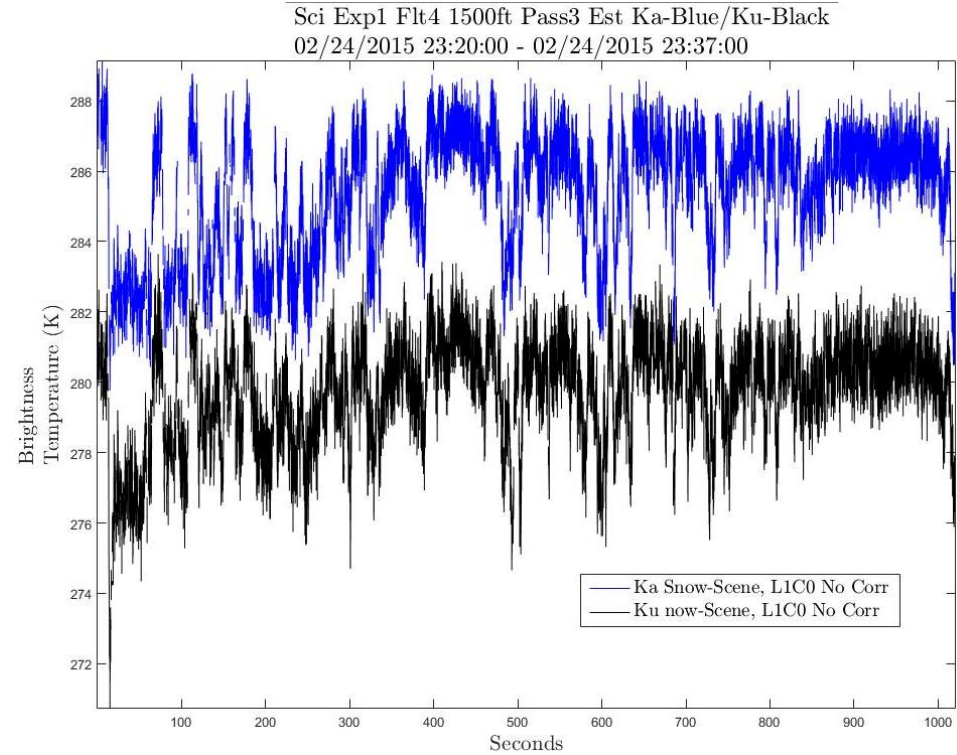
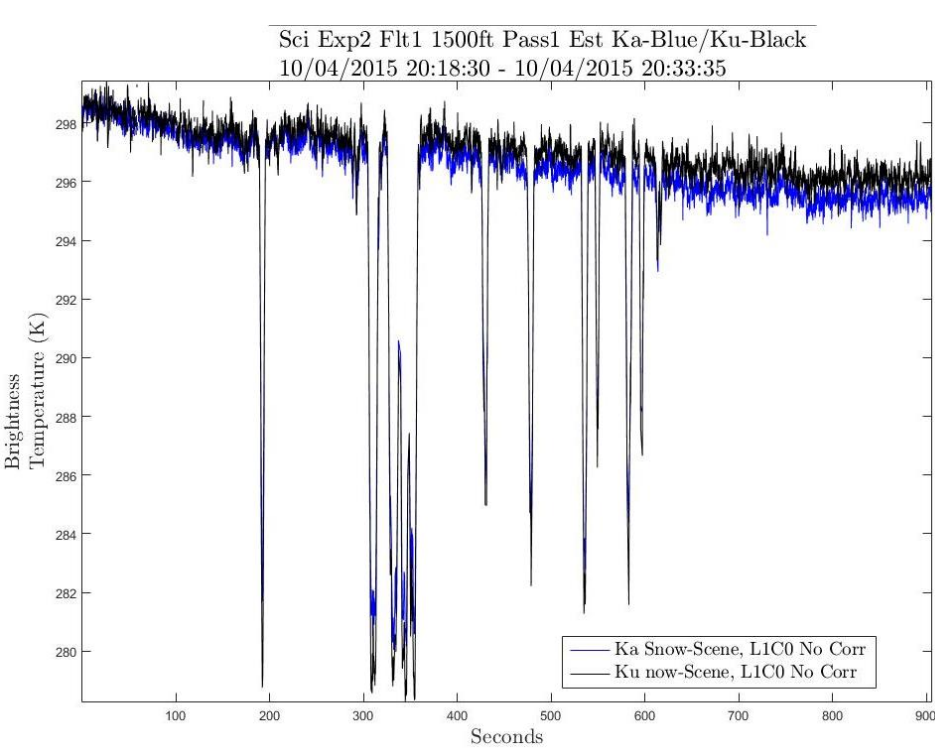


Current Status:

Science Experiment II Data Post Processing and Analysis

SE1 vs SE 2 @1500Ft Eastbound: Data Analysis

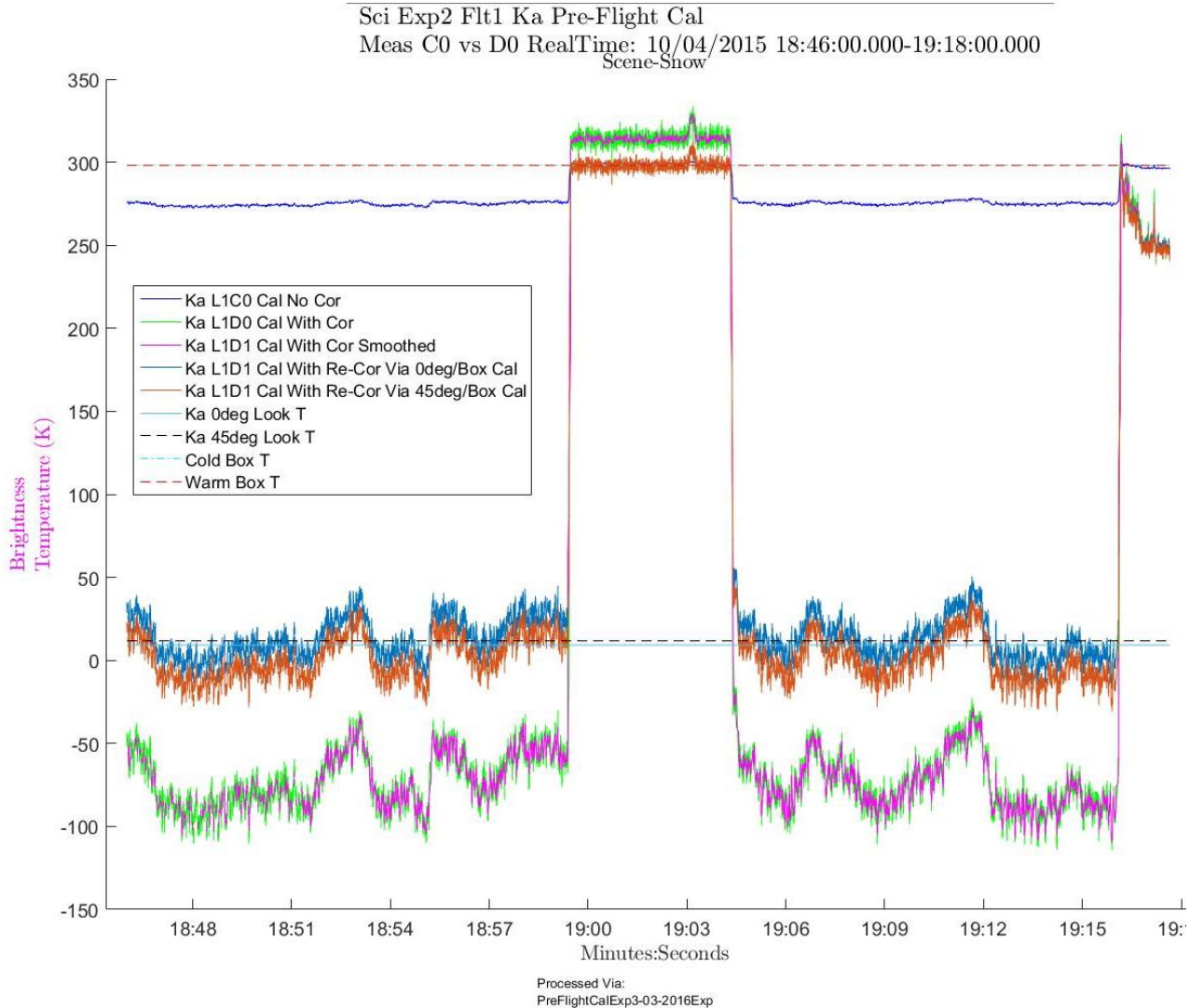
Calibration with No Correction



Current Status: Calibration Correction

SE1 Flight 1 Ka Calibrated Via Preflight Data (light blue/orange)

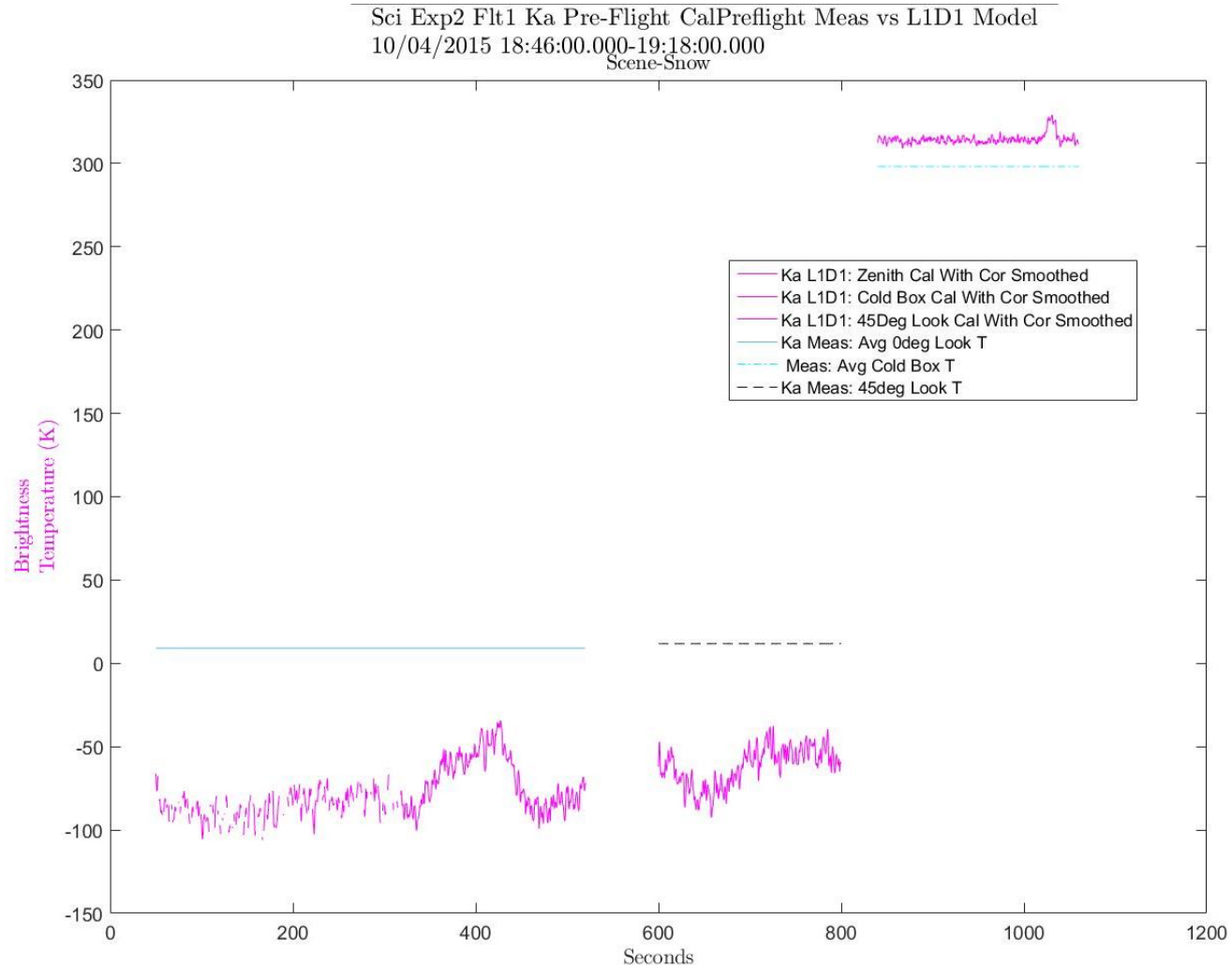
Radiometer data before (blue) and after (pink/green) the model is applied



Current Status: Model Optimization to Correct the Calibration

SE1 Flight 1 Ka Preflight Calibration References (blue/blue dashed/black dashed) Versus Model Predictions (pink)

Optimization Setup



Processed Via:
PreFlightCalExp3-03-2016Exp
ModelCaldViaPreCal

Path Forward:

Marginal Updates Prior to Next Science Experiment

❖ Prior to Next Field Campaign

- Implement differential mode on A/D
- Fabricate insulated ambient target calibrators
- Update firmware on external calibrator
- Address X-band switch sequence issue

❖ Enhance Data Post Processing Programs

- Improved automation enabling faster post processing e.g. during the science experiment
- Calibrate radiometer science data using pre-flight calibration
- Enhanced calibration algorithms
- Provide calibrated and corrected TB to be applied to SWE algorithm