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

by:

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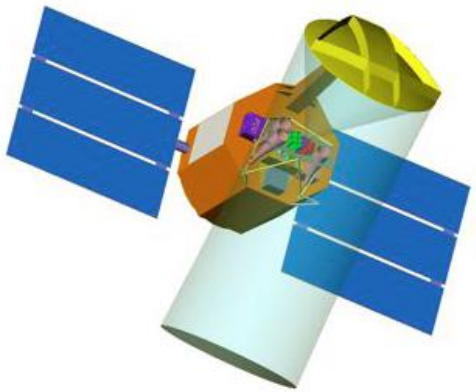
Presentation Outline

- Project Overview
- GSFC Accomplishments
- Science Experiment I
- Science Experiment II
- Current Status & Path Forward

Project Overview: NASA ROSES IIP Objectives, Motivation, and Approach

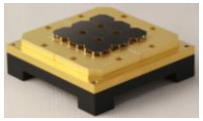
- **NASA ROSES IIP** (Research Opportunities in Space and Earth Sciences Instrument Incubator Program) Currently in second round of funding
- **Objective** Develop the Science and Technology to carry out snow remote sensing missions to make snow measurements on
  - Airborne platforms
  - Space platforms
- **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



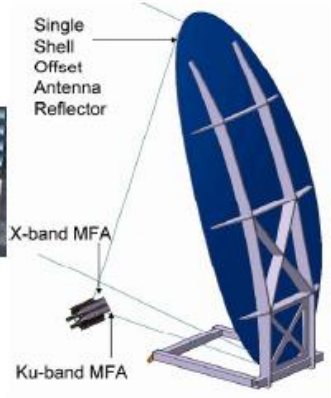
Notional SCLP Spacecraft

[credits: EADS Astrium GmbH]

Existing Technology Feed Concept



WISM IIP Feed



Project Overview:
Science Implications and Broader Impact

Importance of Seasonal Snow

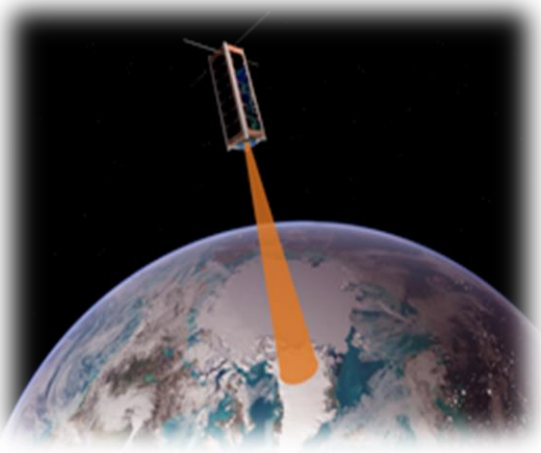
Supplies 50% to 80% of the yearly water supply in the Western United States

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

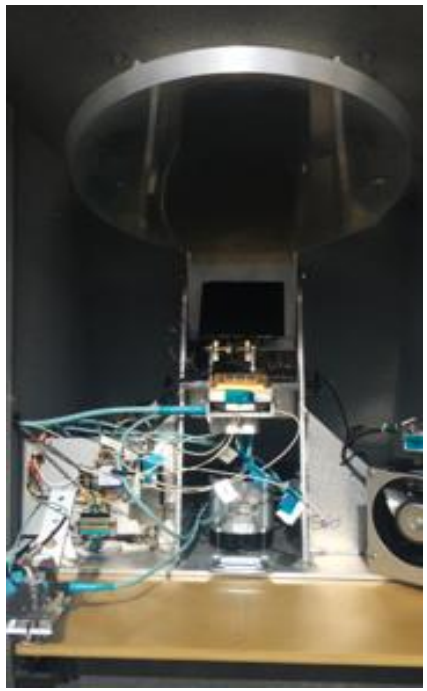
1. **GSFC Team**
   a. RF: 555
   b. Data-System: 587
   c. Thermal System: 545
   d. Power System: 563

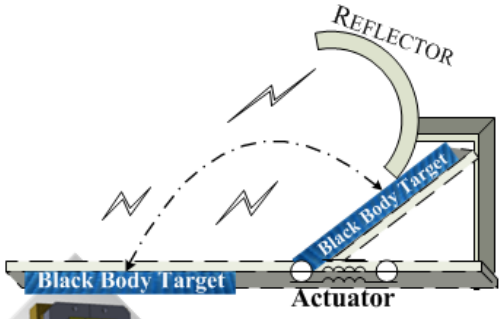
1. **Instrument Subsystems**
   a. RF: 3x Radiometer Bands; Ku, Ka and X
   b. Data-System
   c. Four Zone Thermal System
   d. Power System

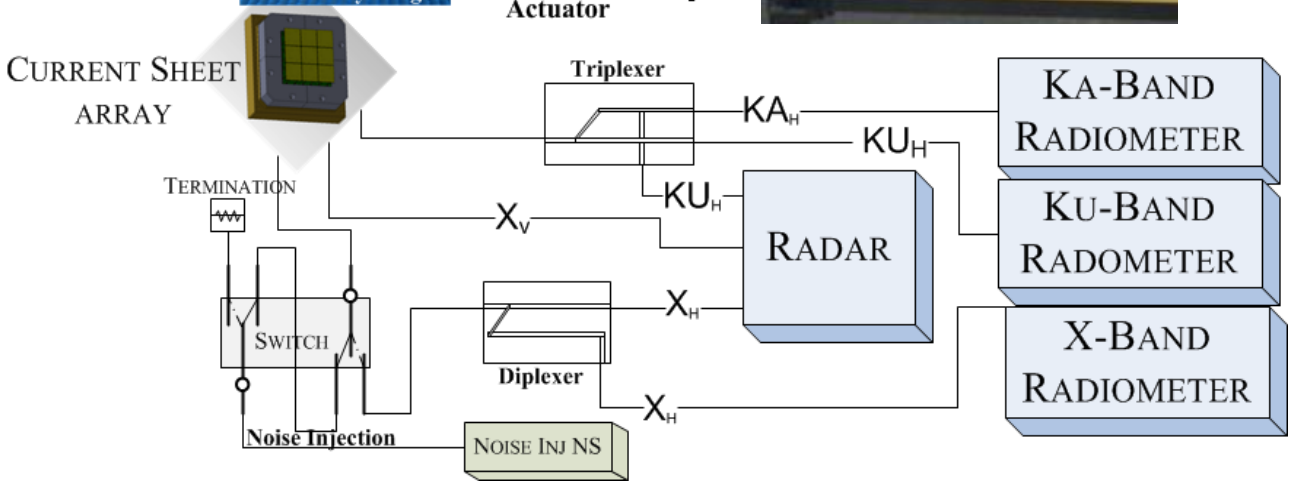
2. **Calibration**
   a. Internal Calibration via 6x Calibration States
   b. Calibration Standards: Ambient termination, Cold Termination, 2x Noise sources
   c. External Pre-Flight Calibration
   d. Noise Source
   e. External Black Body Target

3. **Frequency Bands**
   a. Ku 18.6 GHz – 18.8 GHz
   b. Ka 36.0 GHz – 37.0 GHz
   c. X 10.6Ghz – 10.7GHz

4. **Key Specifications**
   a. Horizontal Poliarization
   b. Spatial Resolution: 93m
   c. Uncertainty: < 0.5 ºK
   d. Temp Resolution NeDT < 0.5 ºK







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

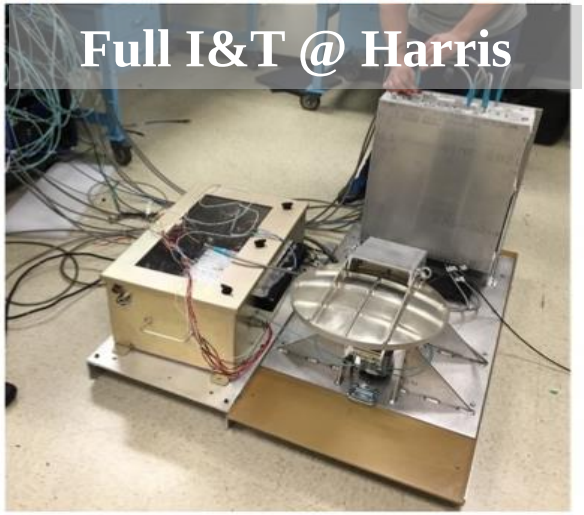
4. Data Post-Processing Program (DPP) Development
   a. DPP Development
      i. L1A completed
      ii. L1B In progress
   b. Pre-flight calibration application
      i. Cold sky calibration
      ii. Cold and hot target calibration

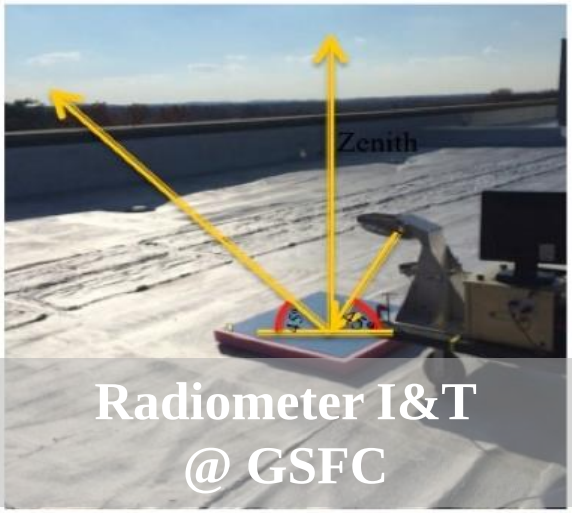
5. Science Experiment I Completed
   a. Viable data received on all flights
   b. Calibrated radiometer data delivered
   c. Correction in progress

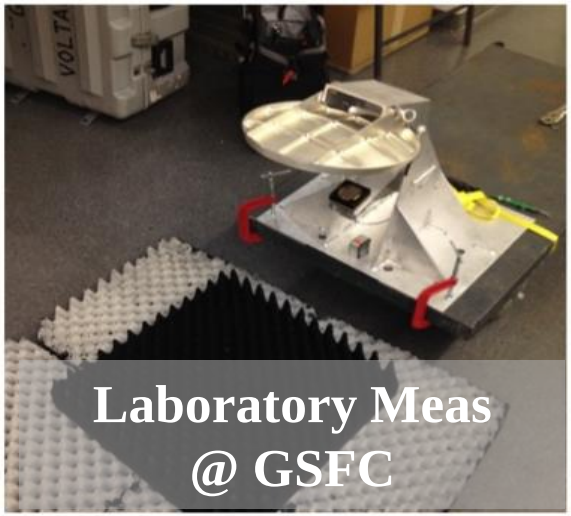
6. WISM II Enhancements
   a. Enhanced calibration via external noise injection
   b. Additional radiometer band
   c. Enhanced the DPPs'

7. Science Experiment II Completed
   a. Viable data received on all flights except X-band
   b. Results promising
   c. Correction in progress

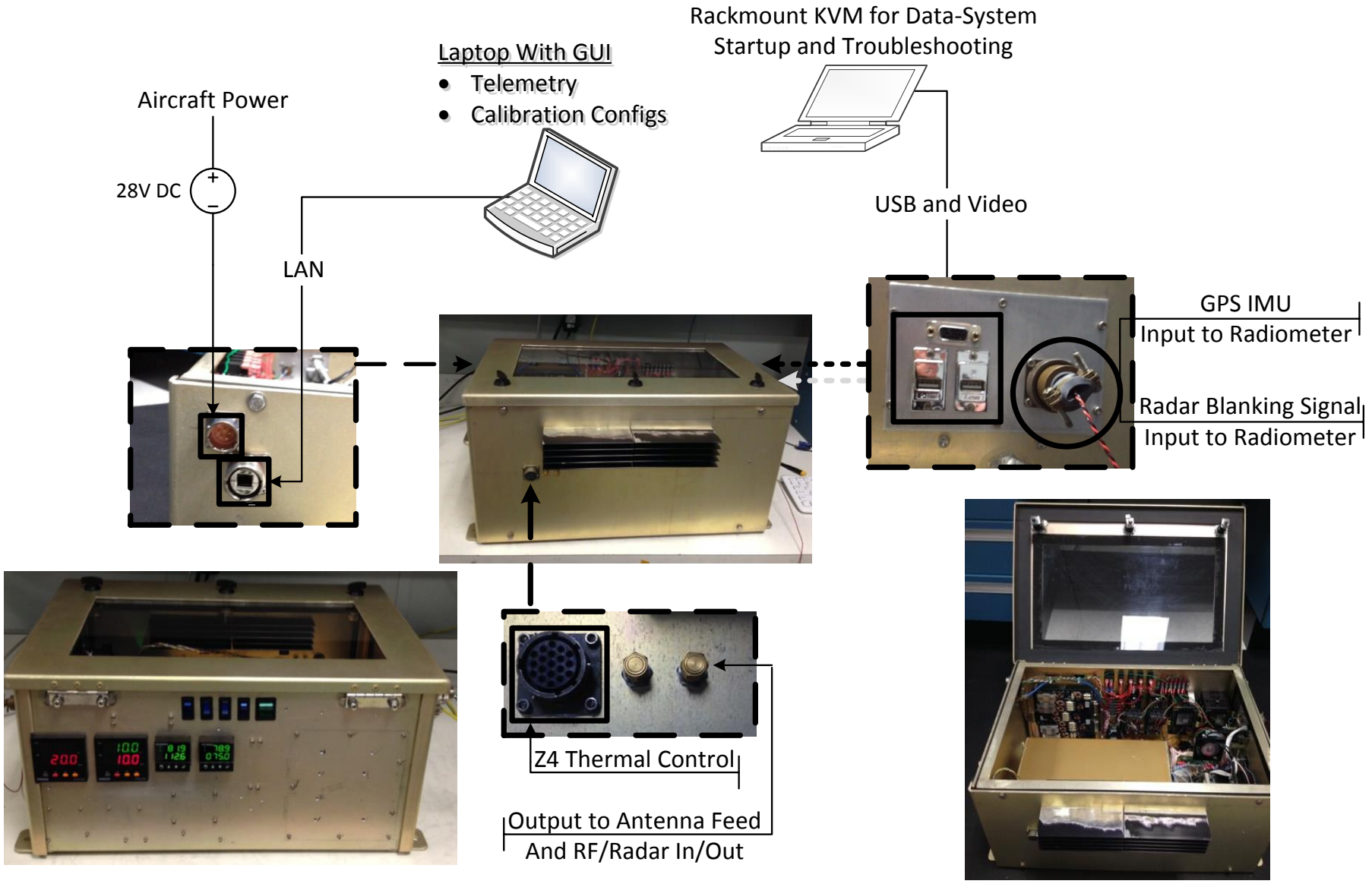
8. Q.Bonds secured supplemental funding via SECP and IRAD







GSFC Accomplishments: Radiometer System Design



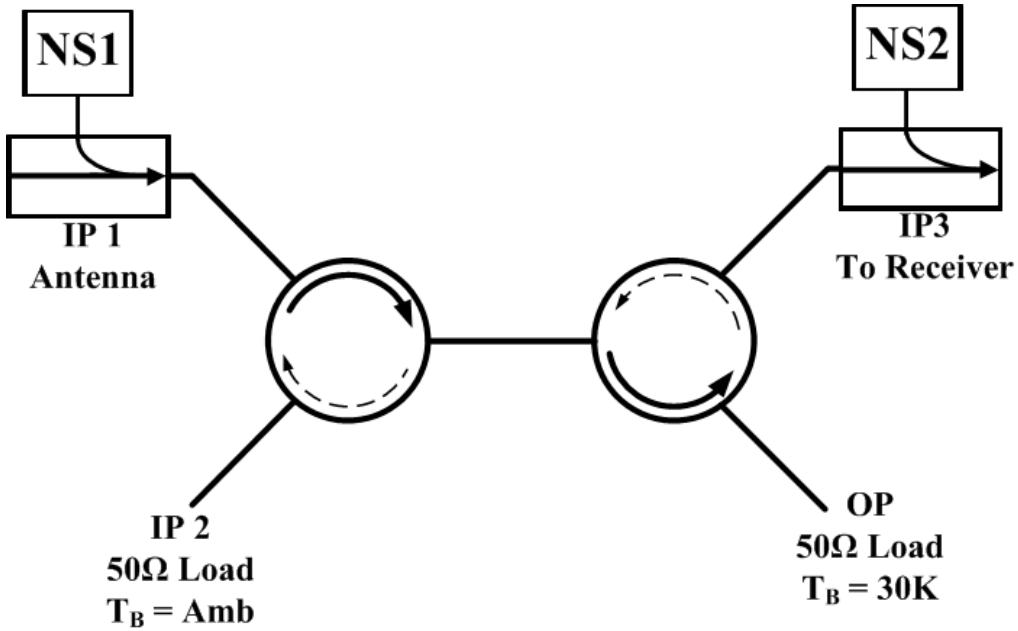
GSFC Accomplishments: Radiometer System Design

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)

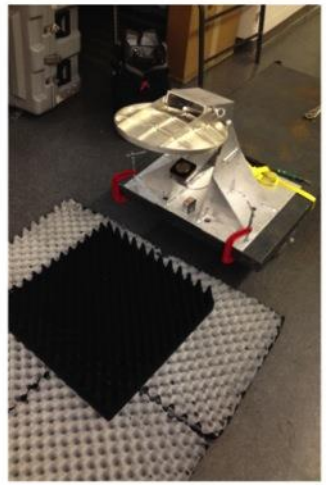
Functional Testing

- 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

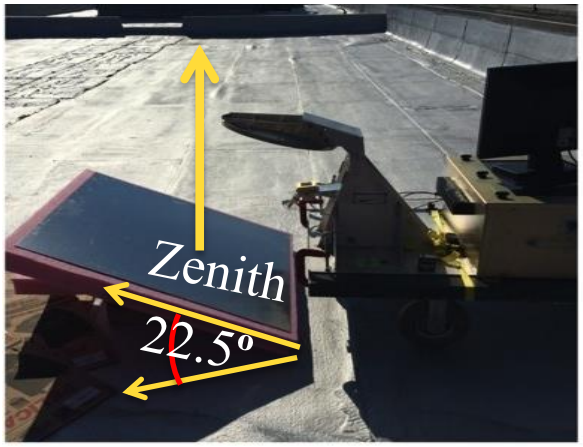
Objective: Final Step Before Radar Integration at Harris in Melbourne

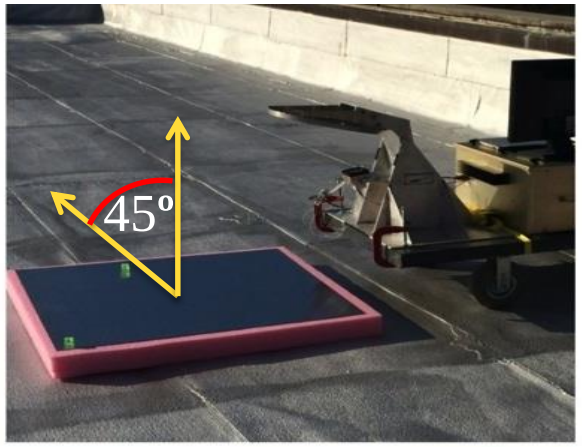
Radiometer preliminary performance analysis to quantify:

- 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

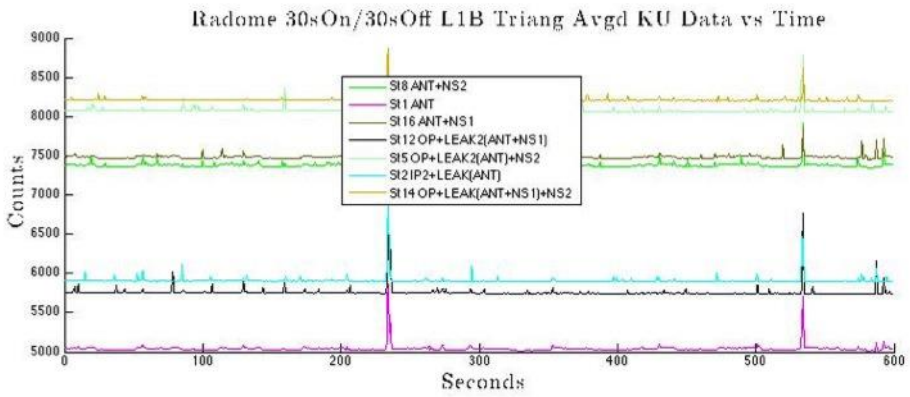


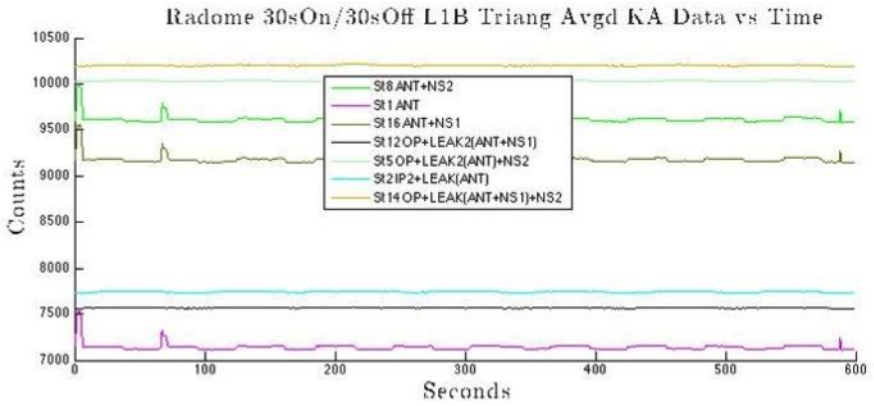


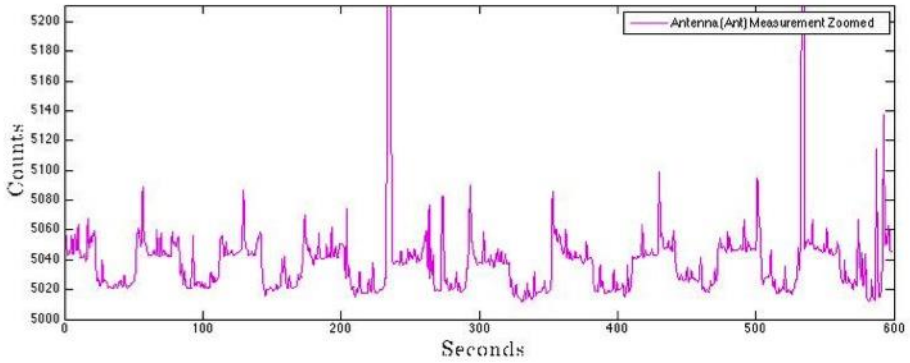
GSFC Accomplishments: Integration and Test (I&T)

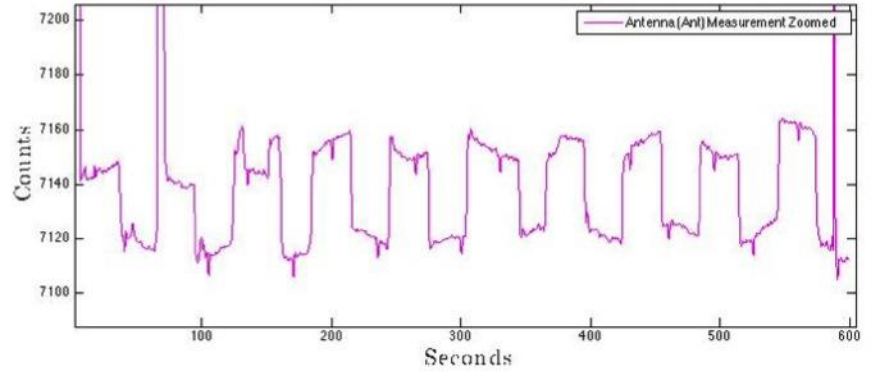
Measurements Taken

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







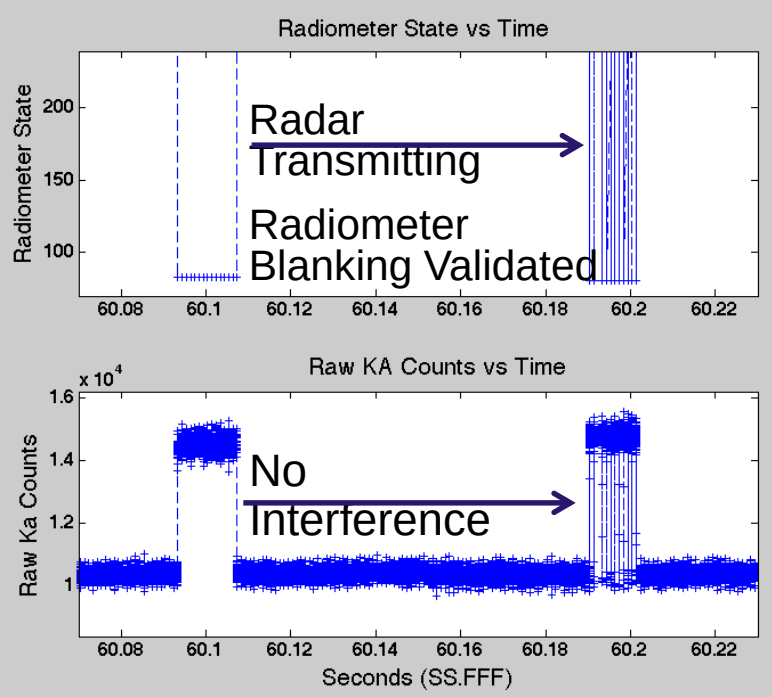


GSFC Accomplishments:
Full Instrument Integration and Test (I&T)

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



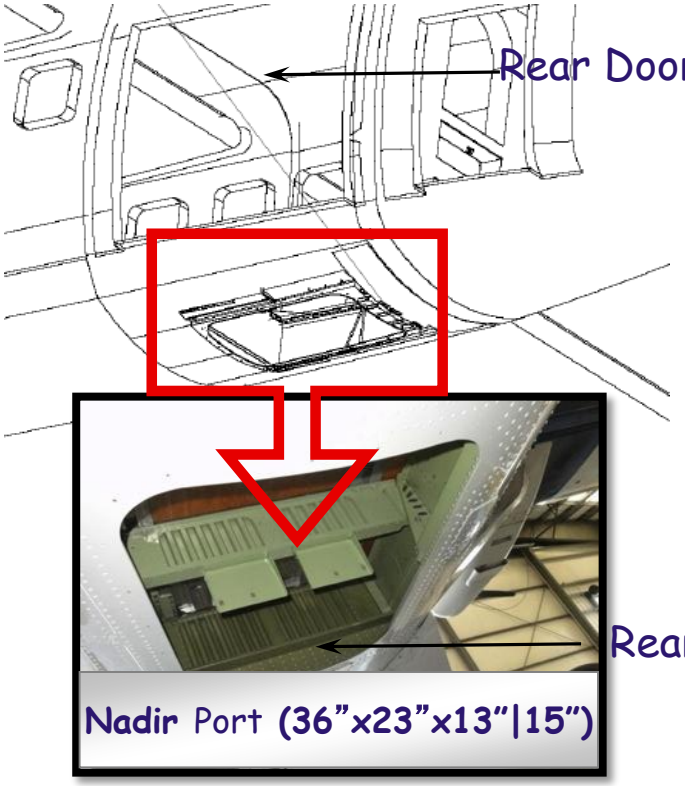
In the Lab @ Harris

Science Experiment I

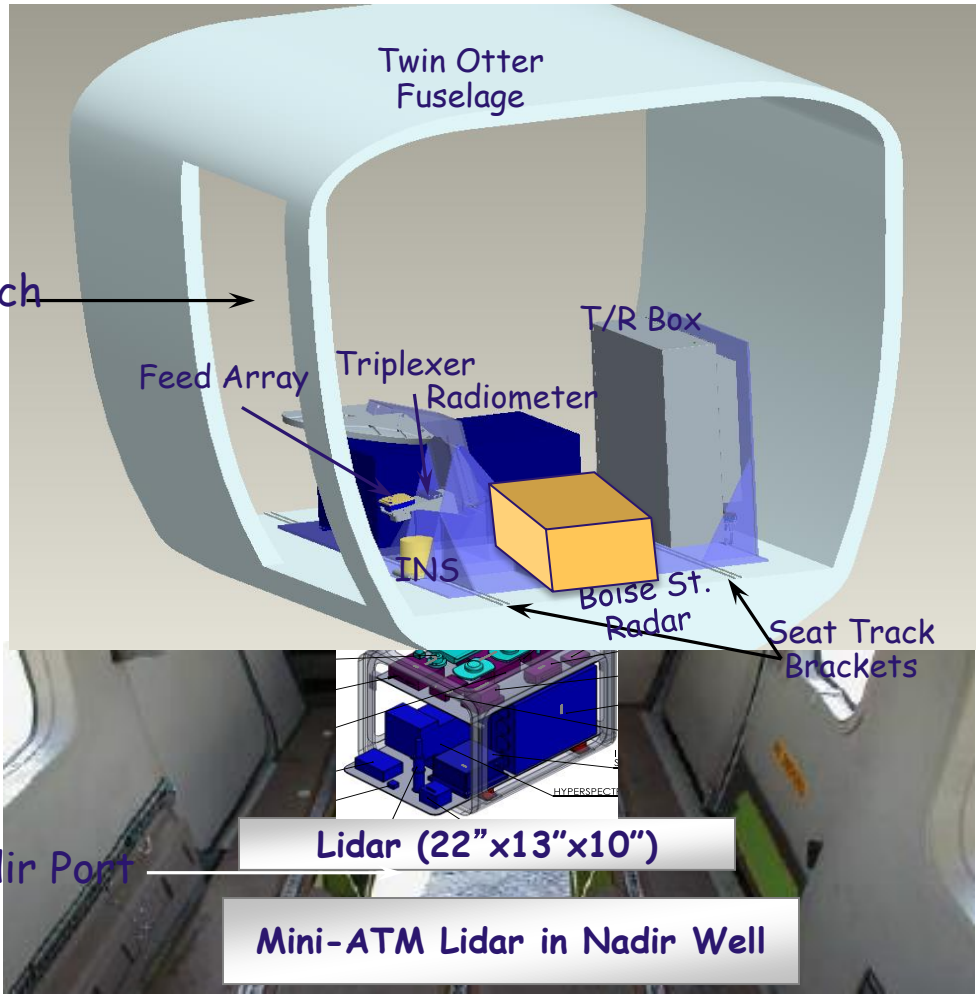
Grand Mesa Snow Measurement
February 2015

Science Experiment I:
Aircraft Procurement and Mechanical Integration

Twin Otter – DC6



Approx. Position in Fuselage



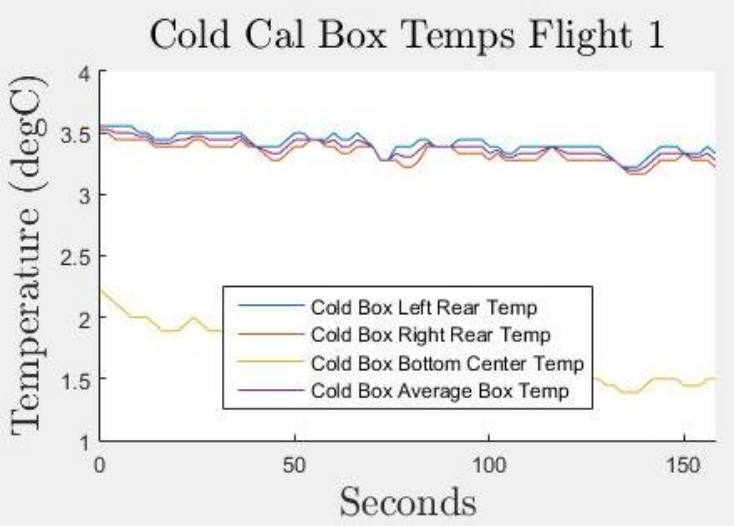
Science Experiment I: Aircraft Measurements

Science Experiment: Grand Mesa Colorado

Pre-Flight Calibration Before Each Flight

- Hot target (kept outside, temp ~17Cº - 19Cº)
- Cold target (kept outside, temp ~2Cº - 3.5Cº)
- Hot and cold targets were cycled onto the calibration structure
- Zenith (Cold Sky)
- 45º (Cold Sky)

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




Cold Sky Cal @ Zenith


Cold Sky Cal @ 45º


Cold/Hot Target Cal


WISM Payload @ Twin Otter Door

Science Experiment I: Aircraft Measurements

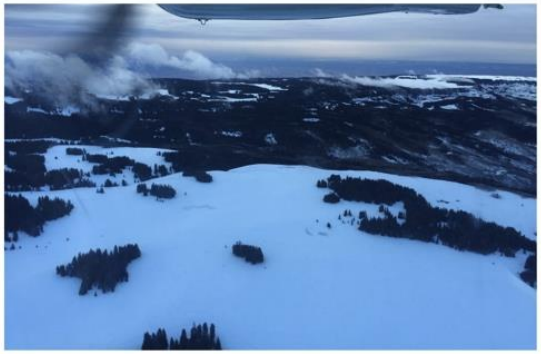
Science Experiment: Grand Mesa Colorado

4 Flights

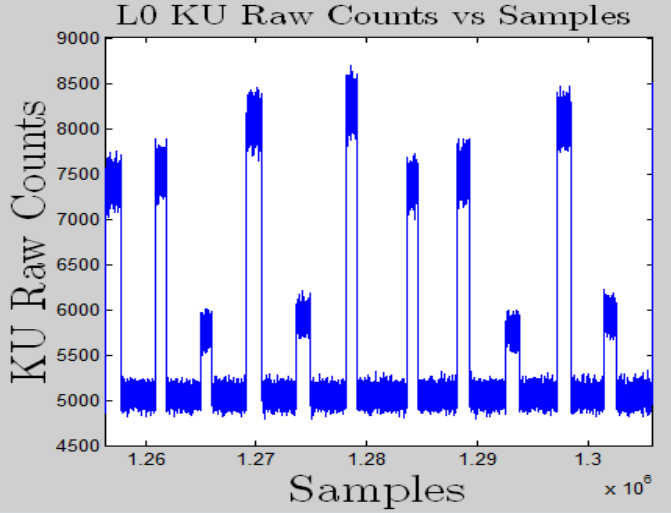
- 2/21/2015 Mesa
- 2/22/2015 GJT Airport (Lidar/Radar) Cal
- 2/24/2014 Mesa morning & Mesa afternoon

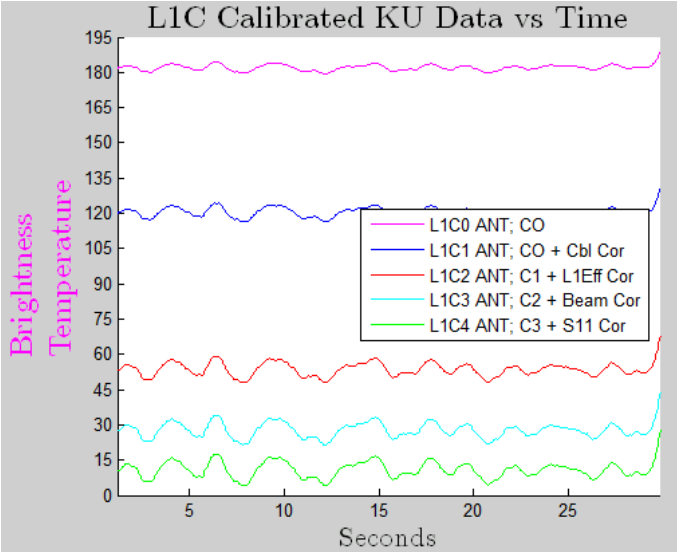
Ground Truth Site Visit with HP Marshall, PhD and Kelly Elder, PhD

- 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

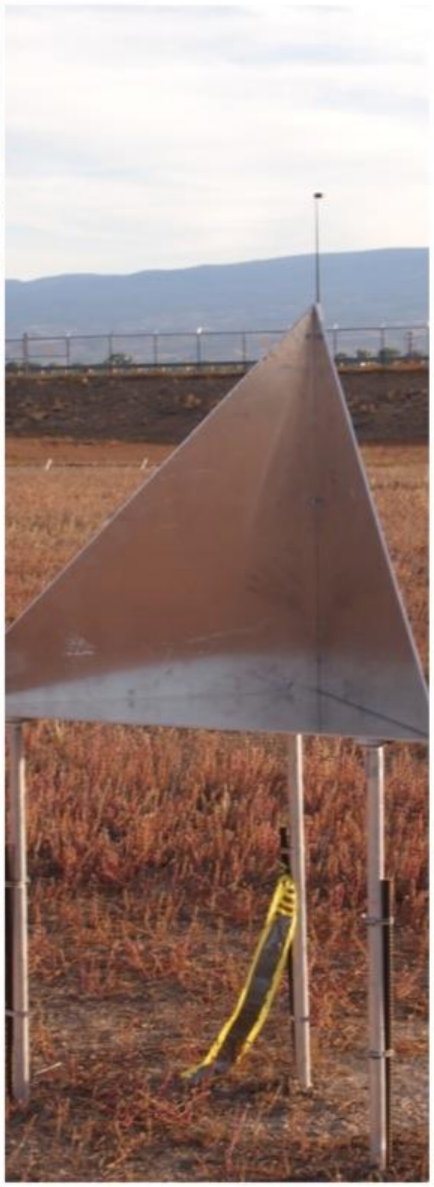
Enhanced Design

- 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

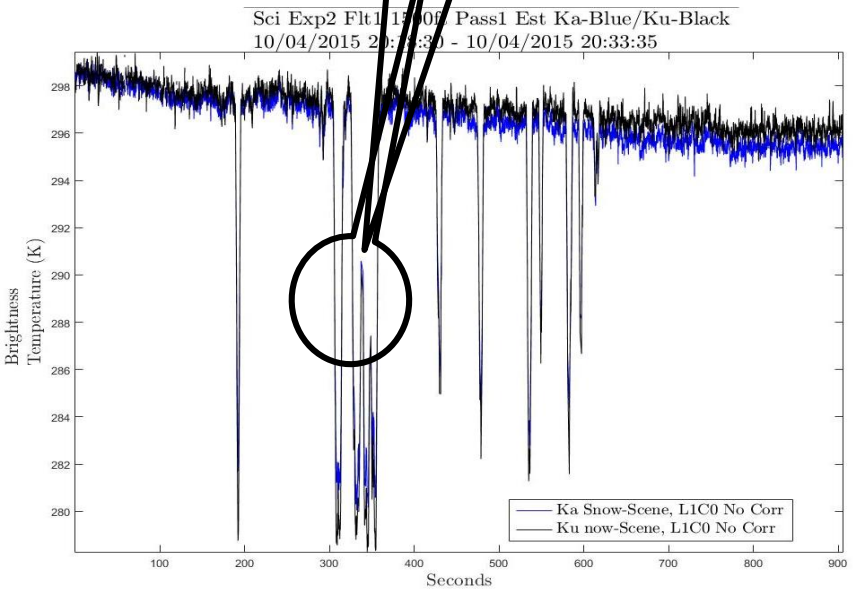
Science Experiment II

Grand Mesa Snow Free Measurement October 2015

Science Experiment II: Pre-Flight



Science Experiment II: Flight



Science Experiment II:
Flight Measurement Summary

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

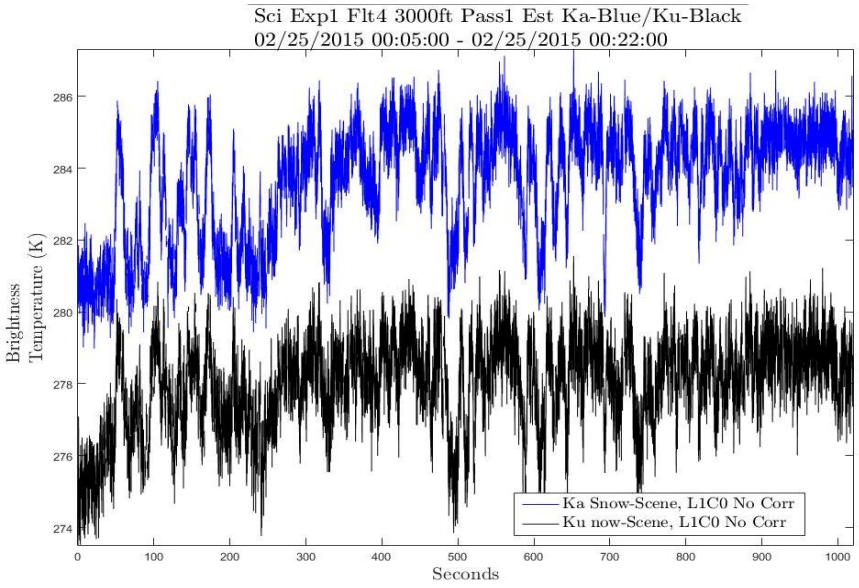
Validated Data
Unsure: Data received but not processed
No Usable Data

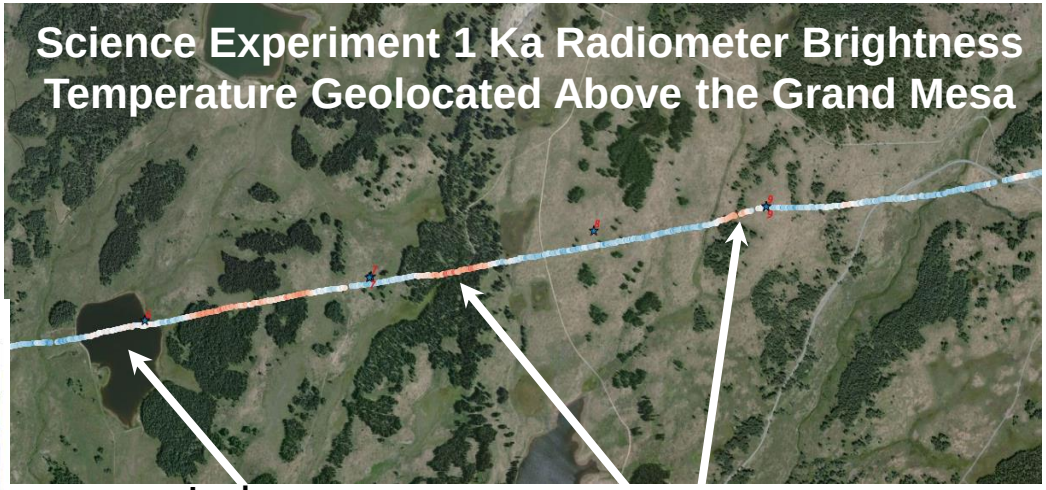
Current Status and Path Forward

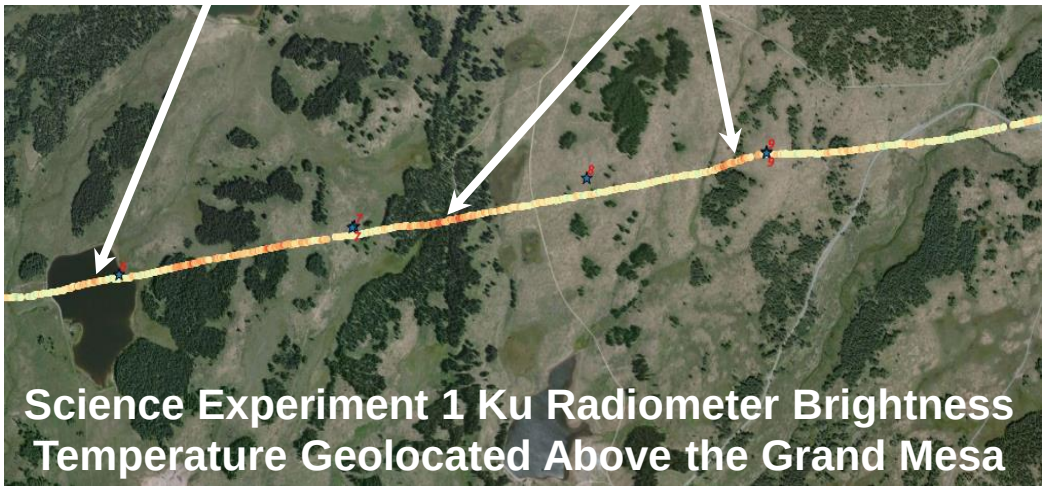
Current Status:
Science Experiment I Data Post Processing and Analysis

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



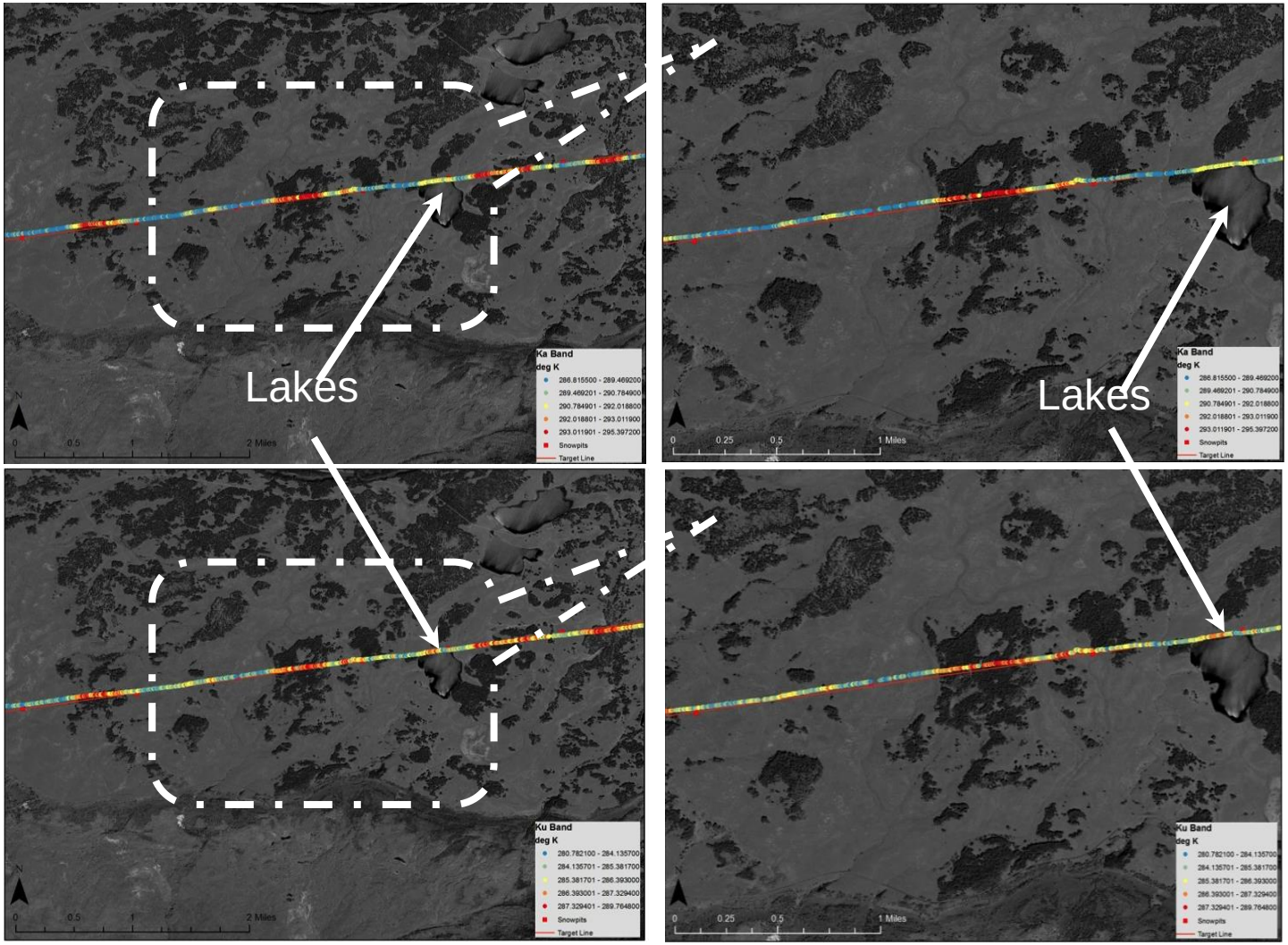




Current Status:
Science Experiment I Data Post Processing and Analysis

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

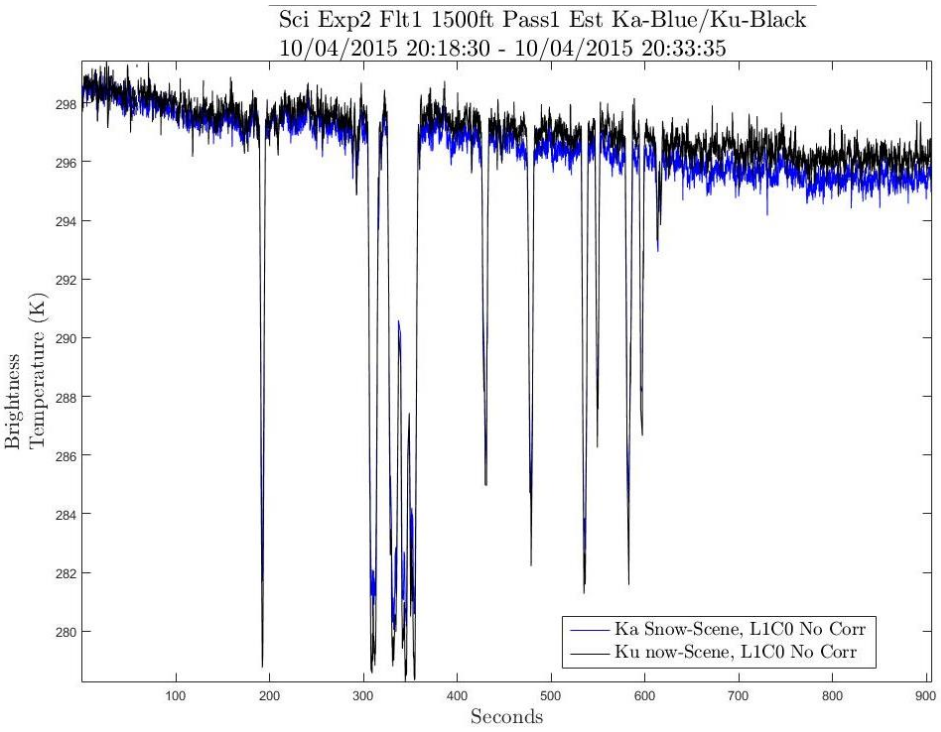
T_B of Lakes vs Canopy Demonstrate the Desired Trend Over the Grand Mesa

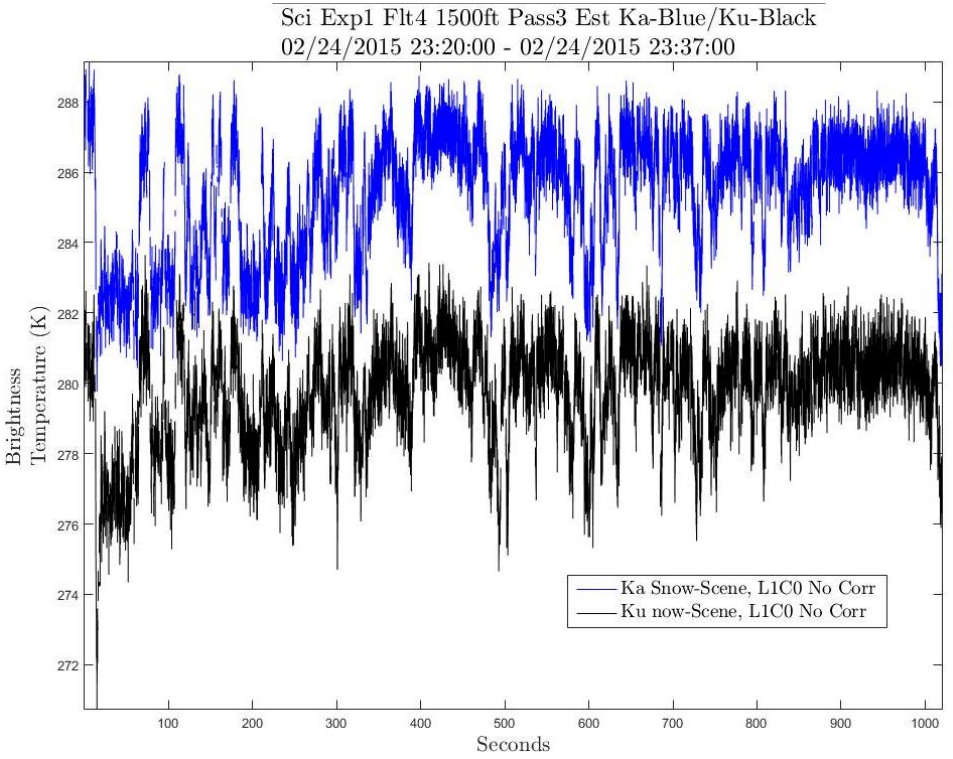


Current Status:
Science Experiment II Data Post Processing and Analysis

SE1 vs SE 2 @1500Ft Eastbound: Data Analysis

Calibration with No Correction

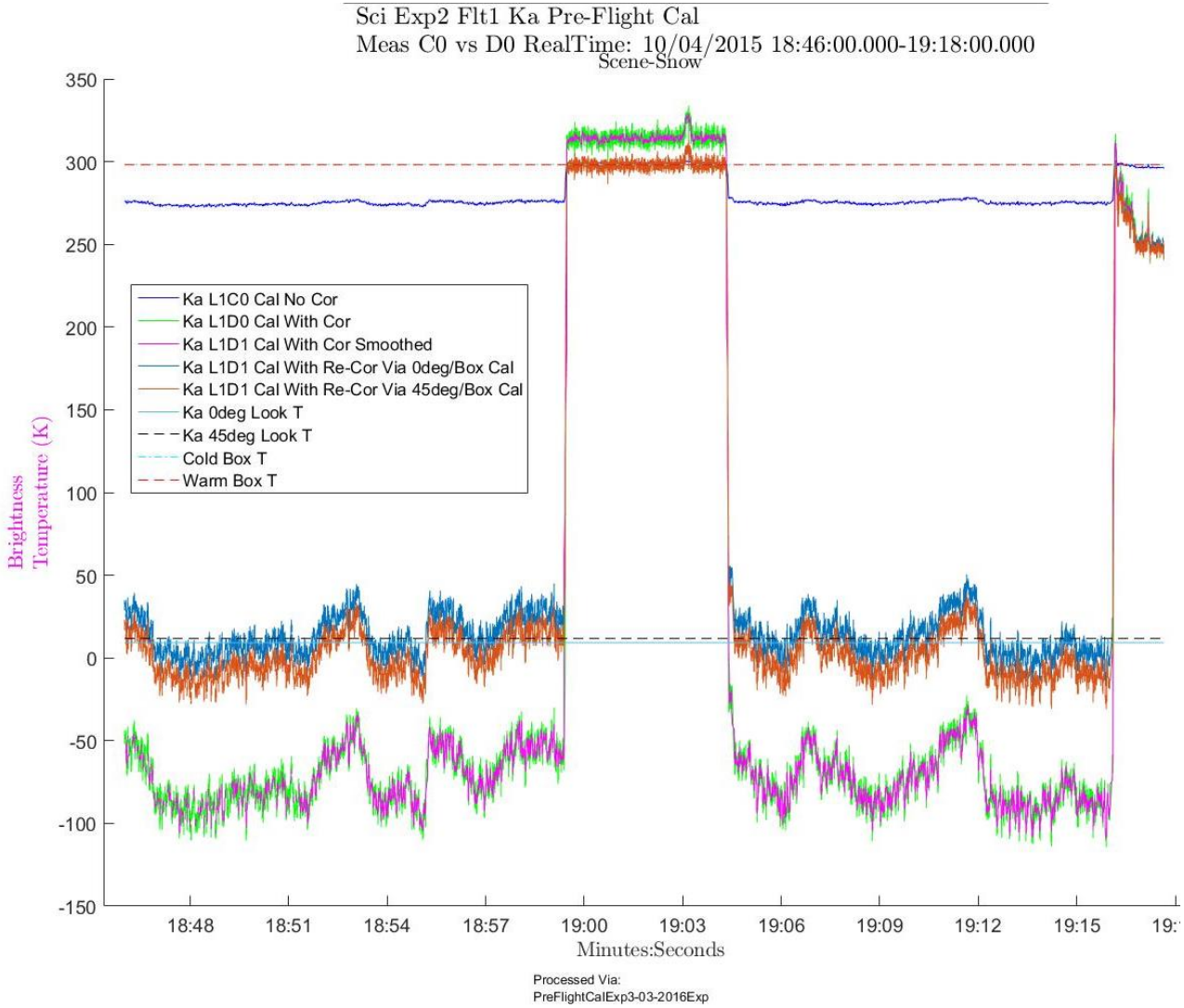




Current Status: Calibration Correction

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

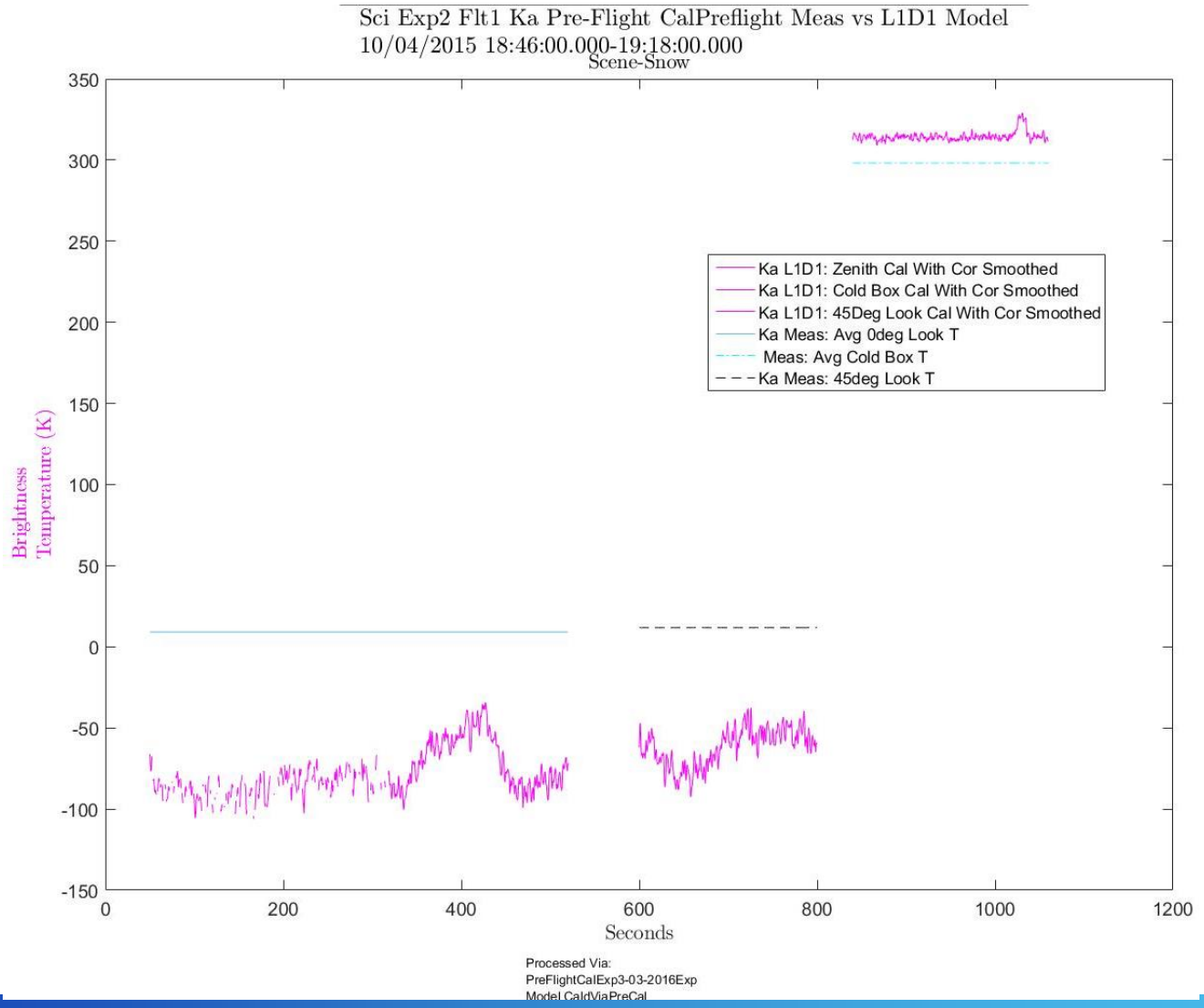
Radiometer data before (blue) and after (pink/green) the model is applied



Current Status:
Model Optimization to Correct the Calibration

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

Optimization Setup



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