



# MICROWAVE REMOTE-SENSING PROJECT UPDATE

David Walker  
Electromagnetics Division  
NIST, Boulder, CO

Presentation to GSICS Microwave Sub-Group, 6 January 2016

# Contributors

- Technical Staff—NIST FTPs
  - Kevin Coakley, Statistical Engineering Div.
  - Joshua Gordon, RF Electronics Div.
  - Mike Janezic, RF Electronics Div.
  - David Novotny, RF Electronics Div.
  - Jolene Splett, Statistical Engineering Div.
- Technical Staff—NIST Associates
  - Dazhen Gu, RA at CU-CET, ECEE Dept.
  - Derek Houtz, Ph.D. graduate PREP, CU Aerospace Dept.
  - Jim Randa, NIST Retiree
  - Jack Surek, NIST contractor
  - Chunyue Cheng, Guest Researcher, BIRMM (Beijing)

# Collaborators (partial list)

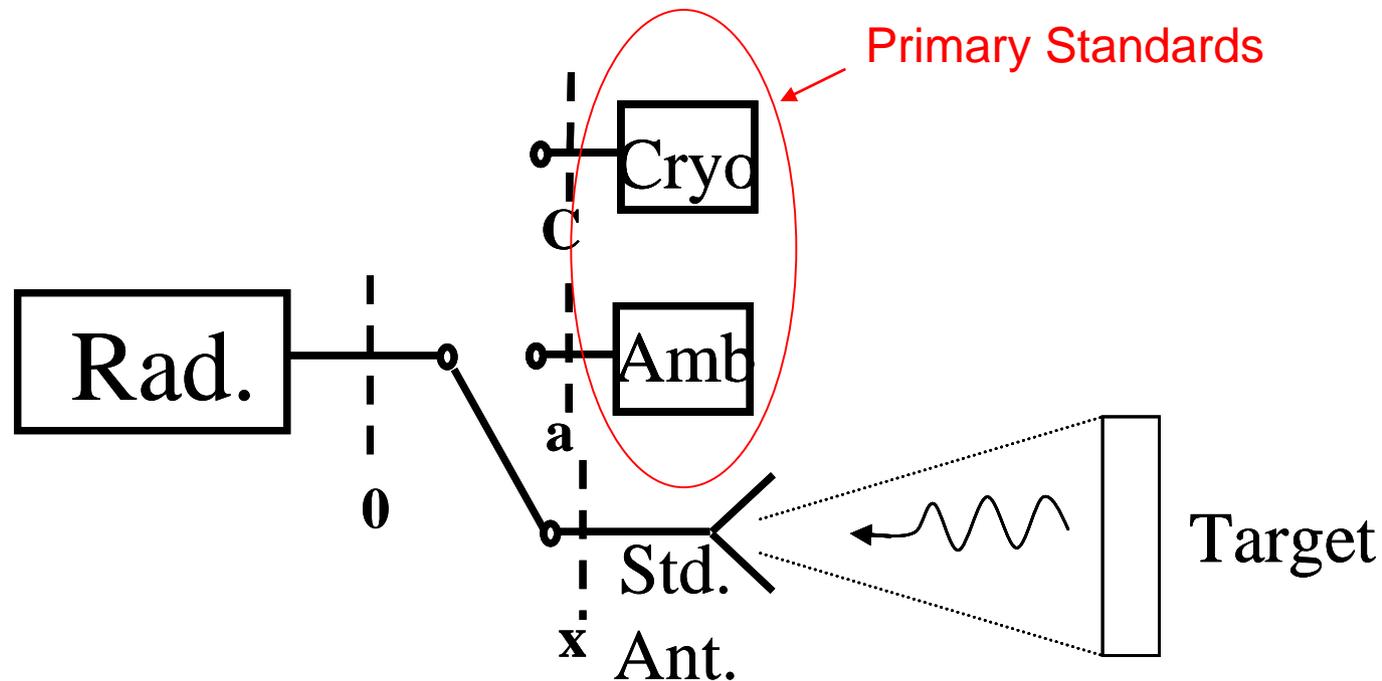
- Bill Blackwell/Vince Leslie, MIT-LL
- David Draper, Ball Aerospace (Boulder, CO)
- Prof. Bill Emery, CU Aerospace Dept.
- Prof. Al Gasiewski, CU-CET Director, ECEE Dept.
- Ed Kim, NASA GSFC
- Paul Racette, GSFC
- Richard Wylde, Thomas Keating Ltd (UK)
- Axel Murk, Univ. Bern (CH)

# OUTLINE

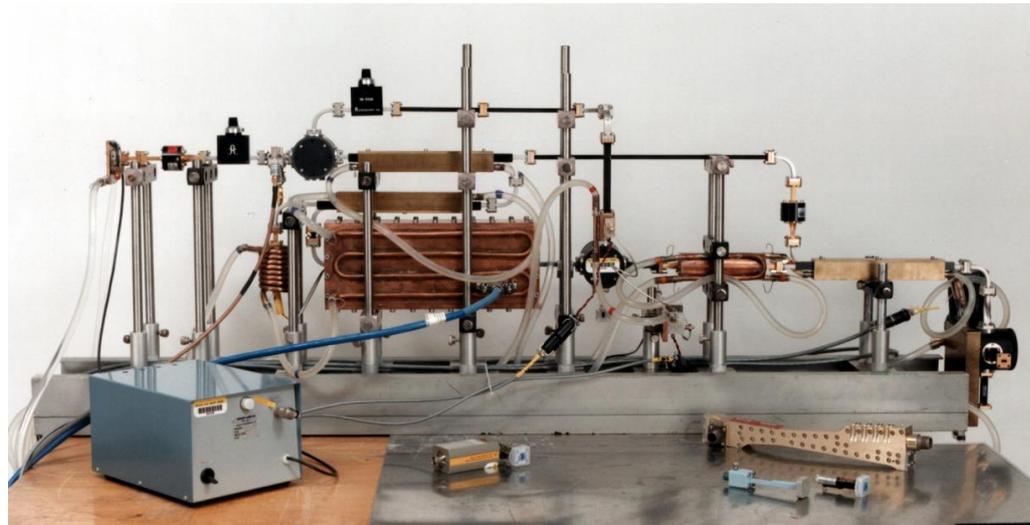
- Current research topics:
  - Brightness-temperature (T<sub>b</sub>) standards
    - Standard radiometer
    - Standard target
  - Robotic antenna range (CROMMA facility)
  - Advanced radiometer calibration methods
  - WR-10 (75 to 110 GHz) radiometer
  - Ocean salinity standards
- Summary & plans

# Radiometric Target Measurement

--Use existing NIST radiometer linked to primary noise standards (SI Traceable):



Waveguide 6-port reflectometer  
with heterodyne receiver



Waveguide banded radiometers



Primary Noise Standards

# Achievable Uncertainty with Standard Radiometer (only)

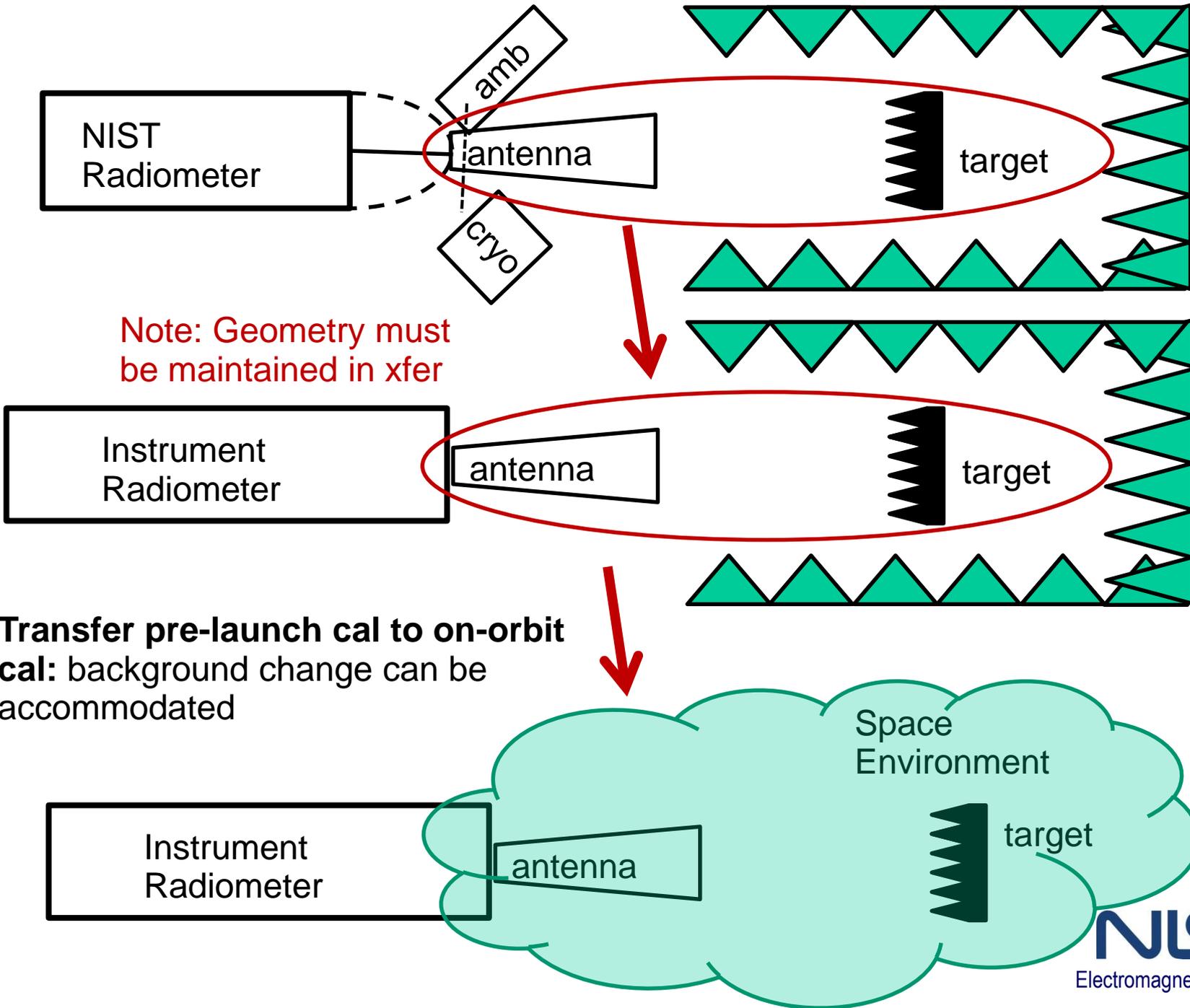
Goal is to reach the accuracy requirements for climate change study—data for 18 to 26.5 GHz

	NIST radiometer	Troposphere	Stratosphere	Precipitation	Water vapor	Sea surface temp
<i>u</i>	~ 0.7-1.0 K	0.5 K	1 K	1 K	1.25 K	0.03 K

Ref: “Stability and accuracy requirements for satellite remote sensing instrumentation for global climate monitoring,” ISPRS 2004.

Current coverage: 12 to 65 GHz; soon to include 75 to 110 GHz band (WR-10)

# Transfer NIST $T_b$ cal to instrument radiometer



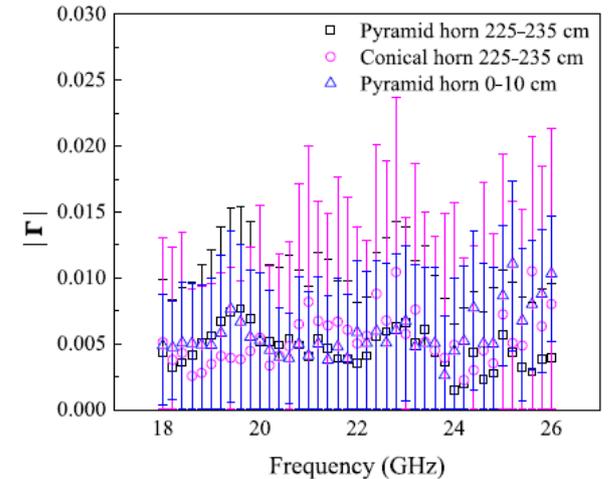
# Black Body Targets--Current Design

Constrained volume and mass for space and aircraft calibration

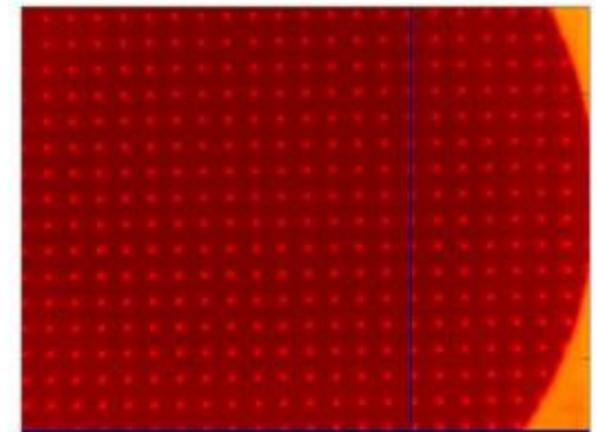
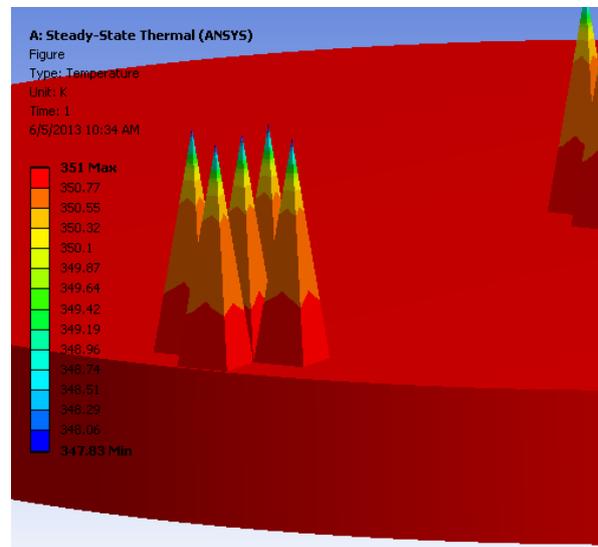
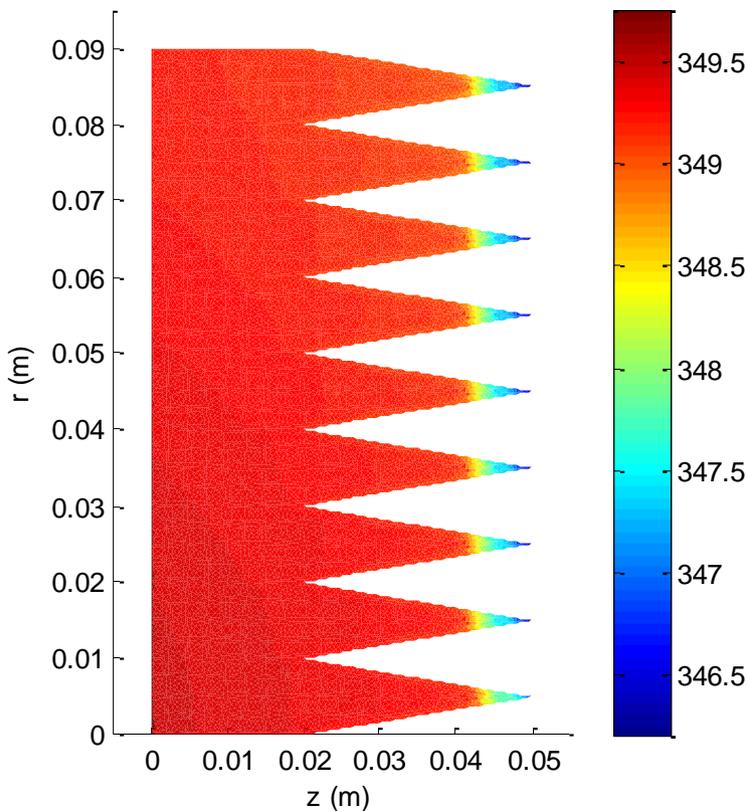
large temperature gradients

Up to 0.6 K mean offset from recorded temp

Narrow optimal operating frequency range due to periodic pyramid structure



Gu, Dazhen. "Reflectivity Study of Microwave Blackbody Targets" Trans. on Geoscience and Remote Sensing, vol. 49, No. 9, Sept. 2011.



Cox, A.E. et al. "Initial Results from the Infrared Calibration and Infrared Imaging of a Microwave Calibration Target" Int. Geoscience and Remote Sensing Symposium, Denver 2006.

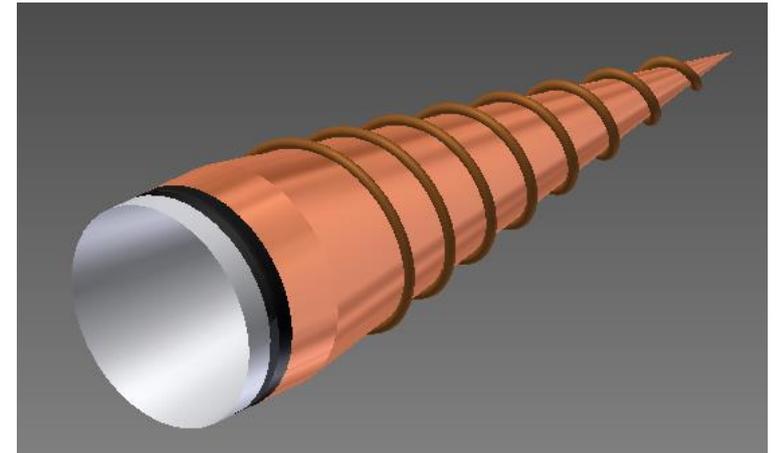
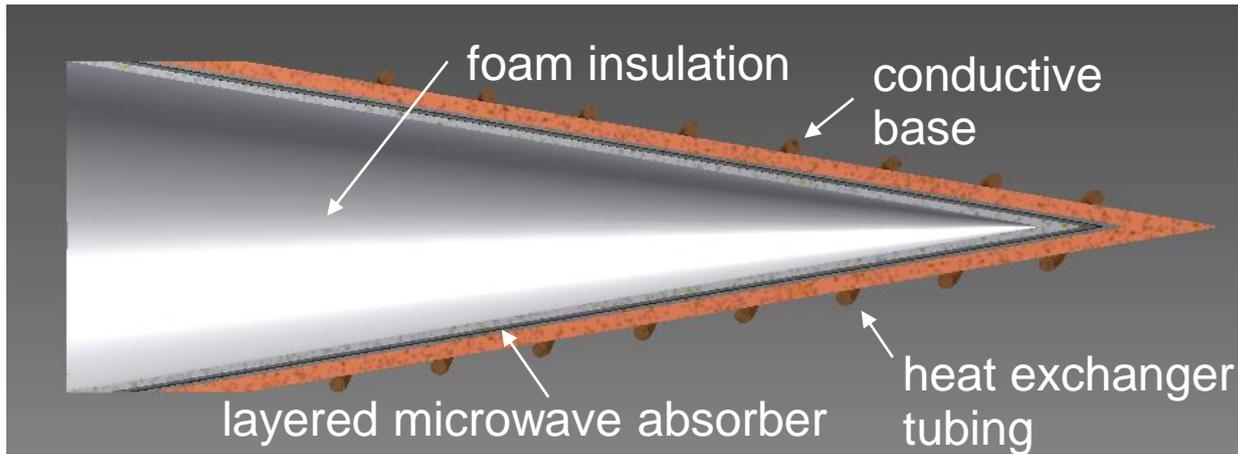
# NIST BB Standard Target Design

Single open conical structure

Uniform emissivity  $\approx 1$  over broad microwave frequency spectrum (10-200 GHz)

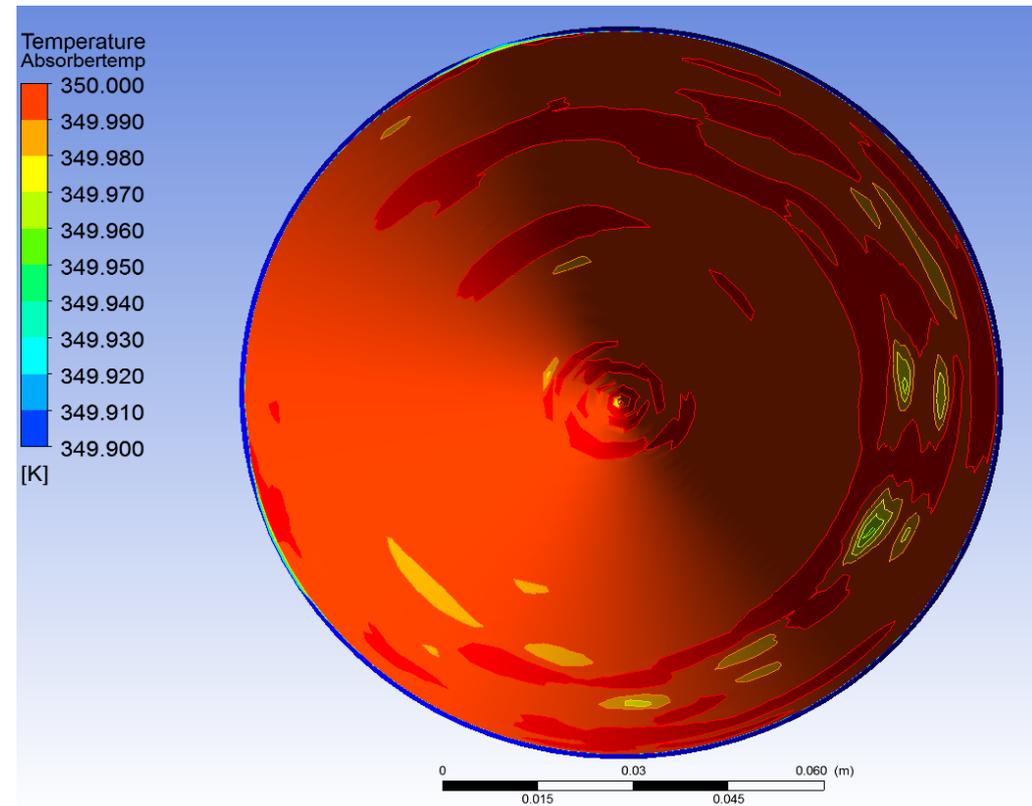
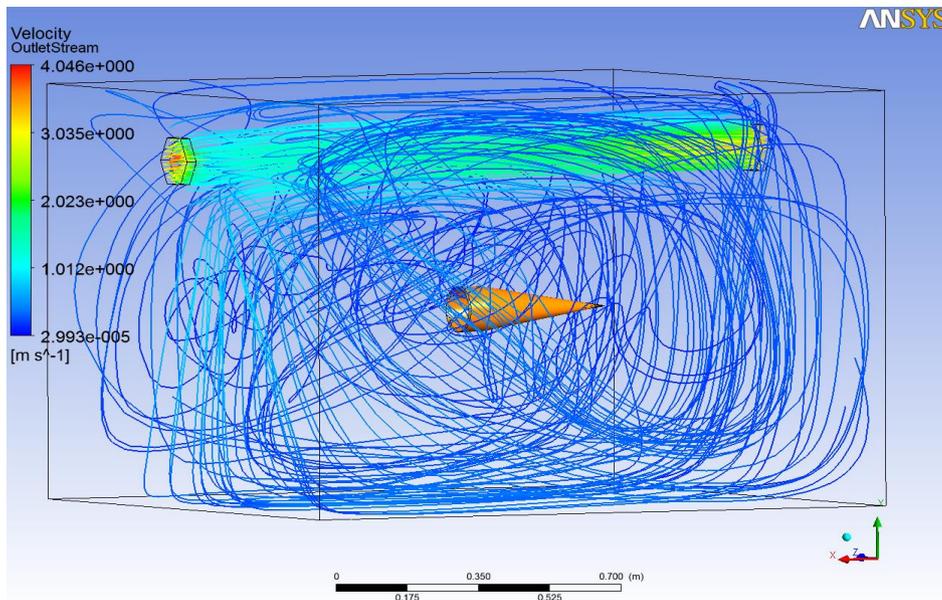
Minimal temperature gradients

Operating temperature range: 80 K to 350 K



# Std Target--Thermal Modeling

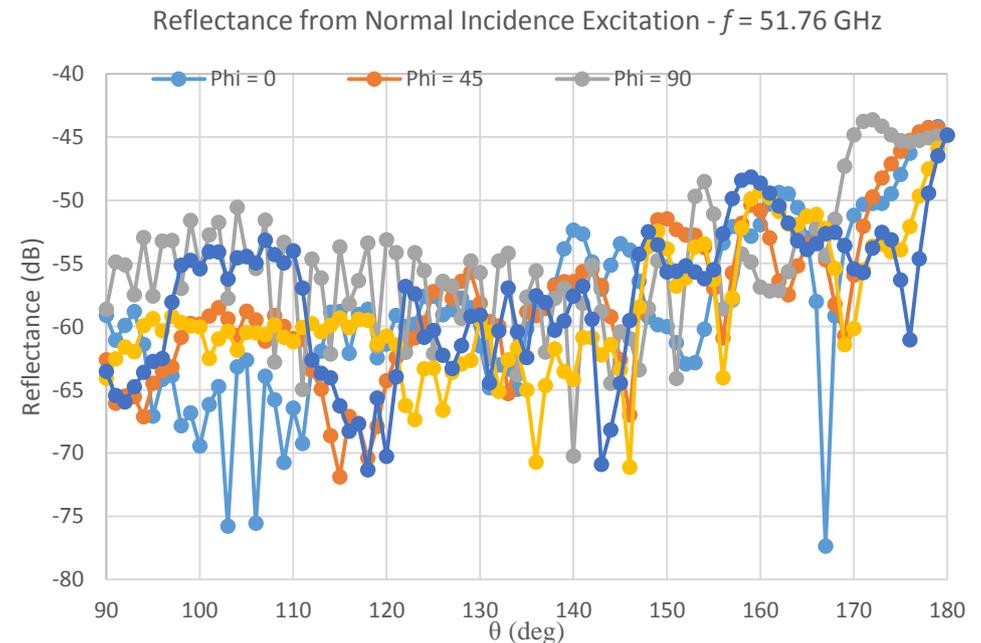
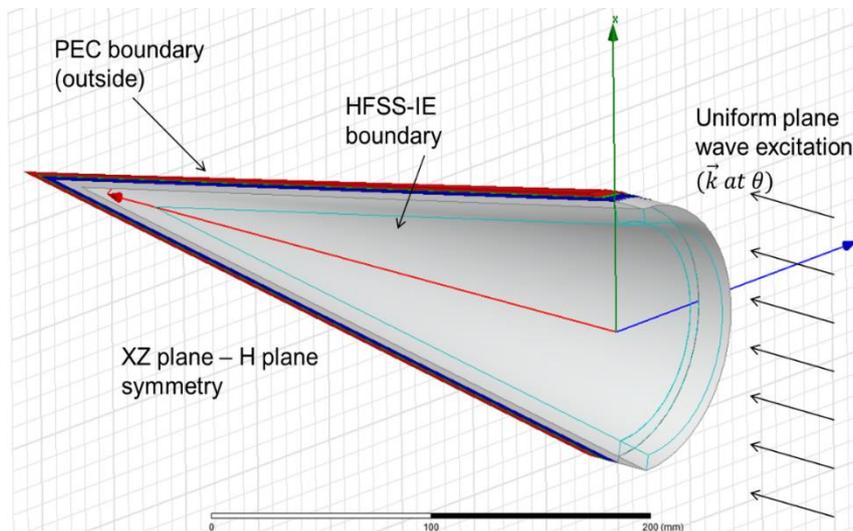
- Physical T of BB design simulated with CFD software
- TVAC as well as ambient environment
  - Thin polyethylene foam insulating layer necessary even in vacuum



simulated streamlines in anechoic chamber (left) and resulting temperature contour with 3 mm insulation layer (right)

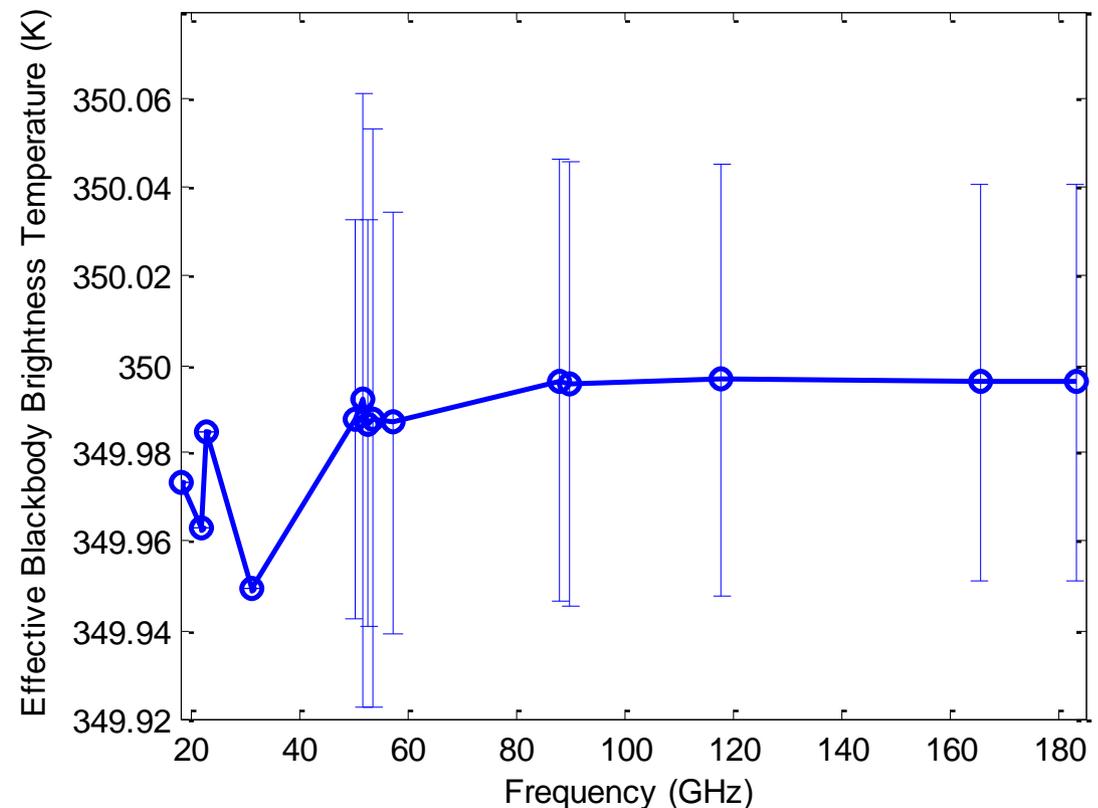
# Electromagnetic Modeling

- Optimized absorber layer solution input to full wave finite element electromagnetic solver (HFSS\*)
- Emissivity derived from reflectance distribution
  - ~1 hour/frequency point running on 16-processor 130 GB RAM HPC



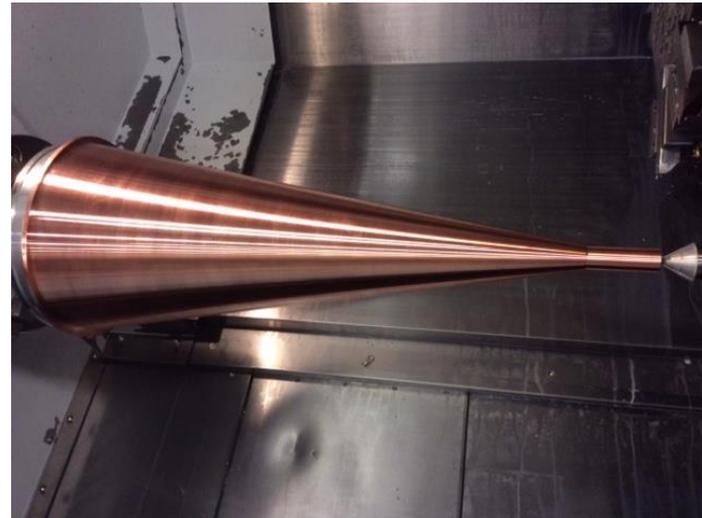
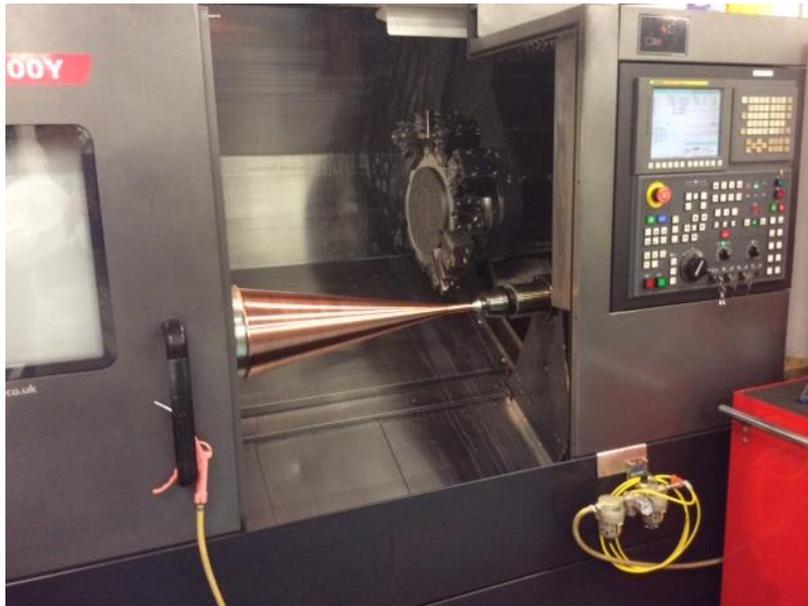
# $T_B$ and Uncertainty Calculation

- Calculate effective brightness temperature from physical temperature, electromagnetic blackbody reflectivity, and antenna pattern simulations
- 350 K set temperature
- U calculation by Monte Carlo simulation including:
  - Mat'l parameter U
  - EM simulation convergence error
  - CFD simulation error
- **Total u = ~0.05 K**
  - **U (k=2) = ~ 0.1 K**

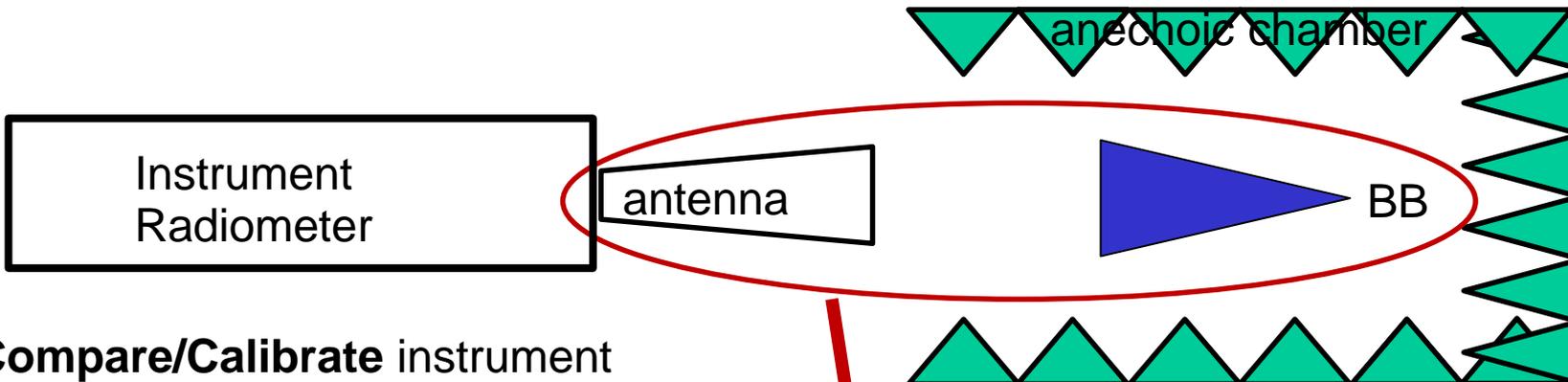


# BB Standard Target—Status

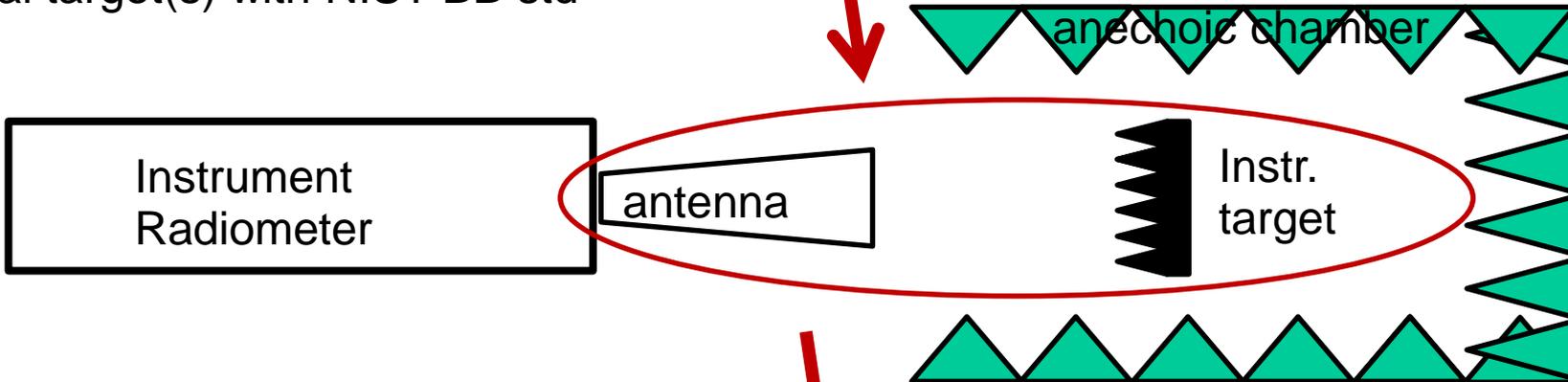
- Design finalized FY15 with  $\epsilon$  and  $u(T)$  goals met
- Contract let to Thomas Keating, Ltd.
  - 2 targets: 23 cm and 13 cm apertures, to match ATMS requirements
  - Absorber test samples being measured to confirm model-fabrication compatibility
  - Target fabrication will include absorber “witness samples” to verify EM performance
  - Estimated completion: September 2016



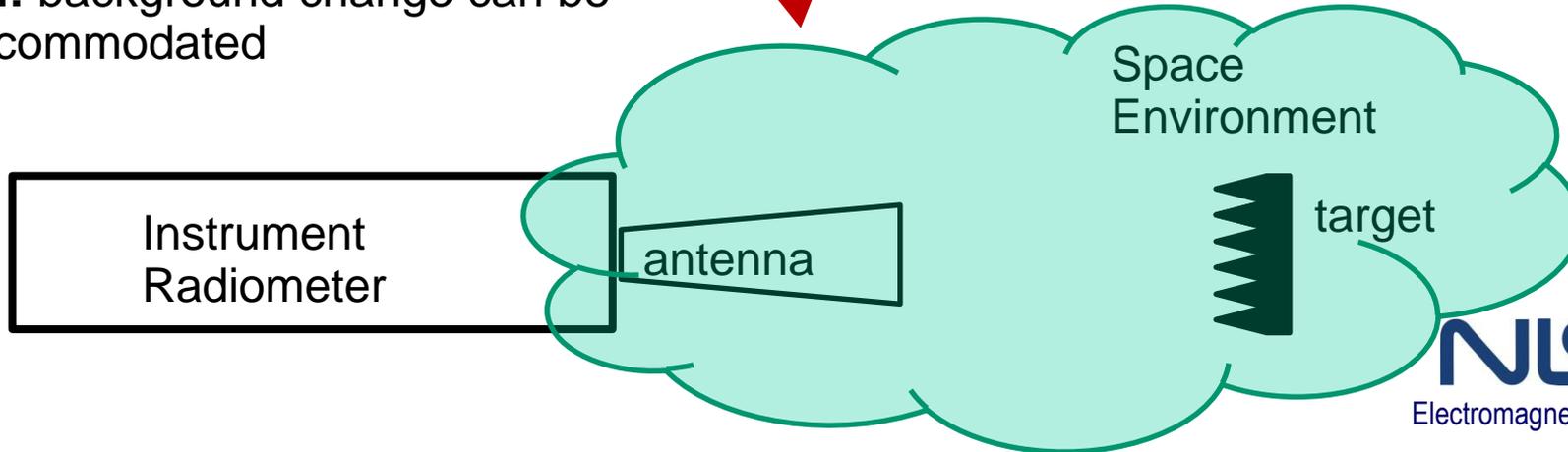
# Transfer NIST BB $T_b$ std to instrument radiometer



**Compare/Calibrate** instrument cal target(s) with NIST BB std



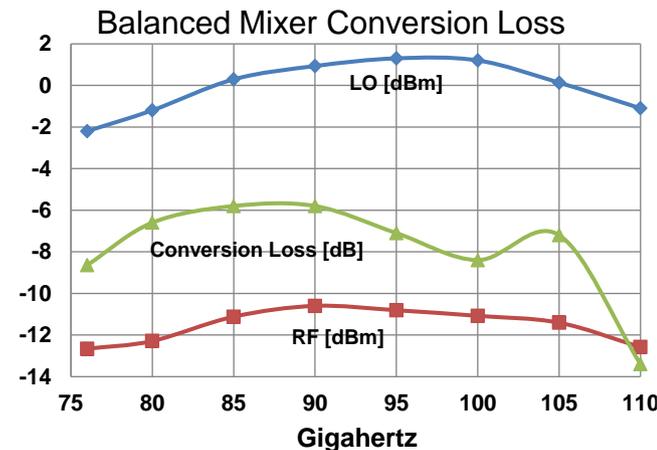
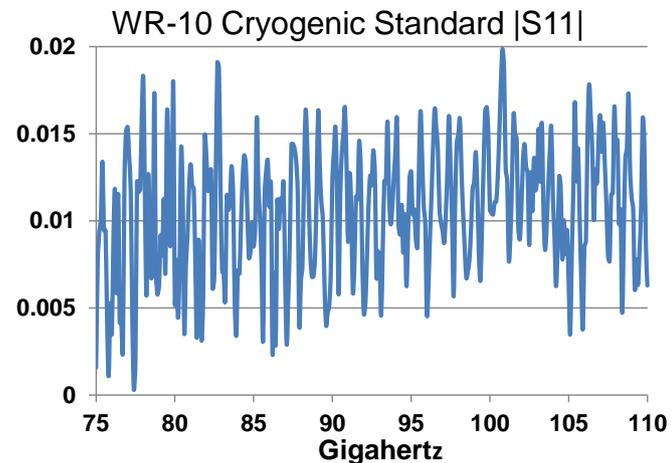
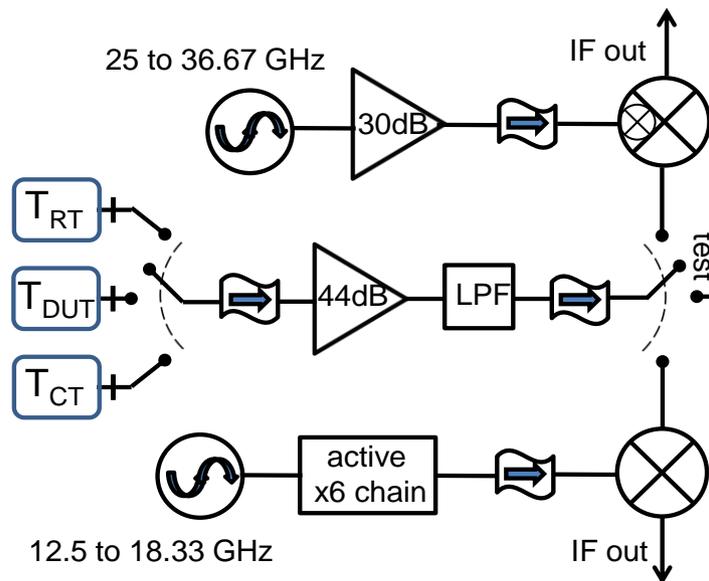
**Transfer pre-launch cal to on-orbit cal:** background change can be accommodated



# WR-10 Radiometer

- WR-10 cryogenic noise standard:
  - W. C. Daywitt, "Design and Error Analysis for the WR10 Thermal Noise Standard," NBS Technical note 1071, Dec. 1983.
- Similar architecture to other NIST noise radiometers, with 2 separate IF chains
- Component evaluation and subassemblies under construction
- Est. completion Dec. 2016

WR-10 Radiometer Circuit schematic



# Summary & Plans

- $T_B$  standard radiometer
- Initial development 18-26.5 GHz band; 12 to 65 GHz now, with 75-110 GHz radiometer in 2017
- **Demonstrate practical cal. transfer to flight instrument**
- **Primary standard target**
  - Significant reduction in uncertainty—U ~ 0.1 K)
  - Provides a means for  $T_b$  transfer & verification
  - Modeling & design completed
  - **Fabricate & test target FY16-17**
- **Ocean salinity**
  - Resonant cavity for L-band under construction
  - Sea water traceable measurements in FY17
- **Robotic antenna range (CROMMA) operational**
  - “Millimeter-Wave Near-Field Measurements Using Coordinated Robotics,” Gordon, J.A.; Novotny, D.R.; Francis, M.H.; Wittmann, R.C.; Butler, M.L.; Curtin, A.E.; Guerrieri, J.R., IEEE Trans. Antennas and Propagation, 2015, Volume: 63, Issue: 12, Pages: 5351 - 5362, DOI: 10.1109/TAP.2015.2496110