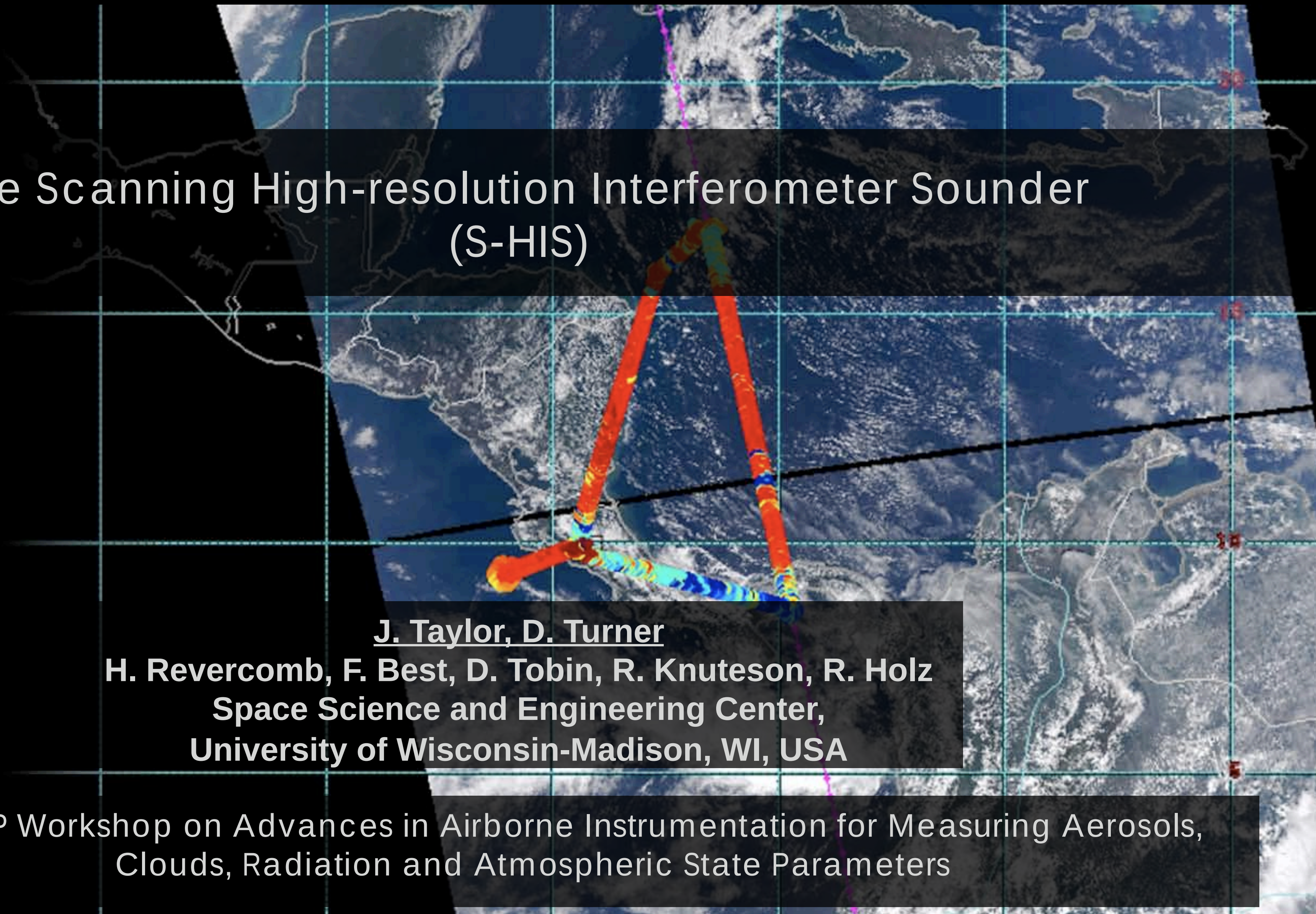
The Scanning High-resolution Interferometer Sounder (S-HIS)



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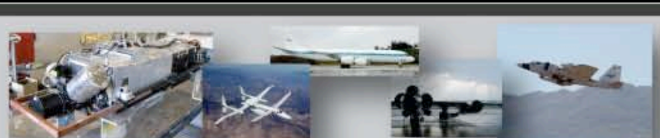
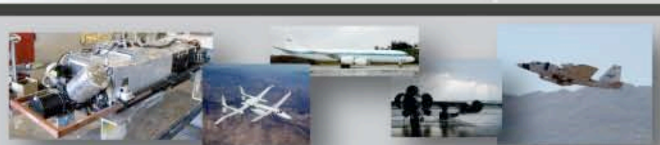
ARM AVP Workshop on Advances in Airborne Instrumentation for Measuring Aerosols, Clouds, Radiation and Atmospheric State Parameters



1. Introduction and Instrument Overview
2. Flight Experience and Operating Environment
3. Instrument Performance
4. ARM Applicable Science/Products
5. Low Cost, High Return Instrument Upgrade Paths



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Introduction

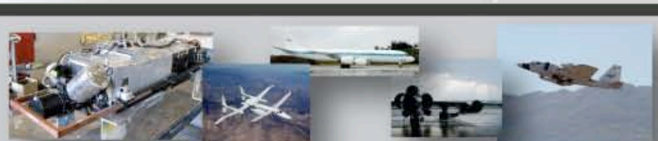
- The Scanning High-resolution Interferometer Sounder (S-HIS) is an advanced version of the High-resolution Interferometer Sounder (HIS) NASA ER-2 instrument.

- Michelson interferometer (customized Bomem DA-5).

- The S-HIS was developed between 1996 and 1998 at the University of Wisconsin (UW) Space Science and Engineering Center (SSEC) with the combined support of the US DOE, NASA, and the NPOESS Integrated Program Office.

- Its design and calibration techniques have matured from experience with the HIS and with the ground based Atmospheric Emitted Radiance Interferometer (AERI) instruments developed for the DOE Atmospheric Radiation Measurement (ARM) program.

- From 1998 to present, the S-HIS has been involved in 23 field experiments on multiple airborne platforms, each with significantly different instrument operating environments. Independent of airborne platform, the S-HIS has provided hyperspectral infrared radiance measurements with high absolute accuracy and low noise.



Introduction [cont.]

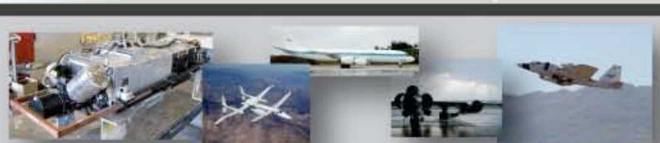
- The S-HIS is extremely well characterized and understood, carefully maintained, and <u>accurately calibrated, with direct traceability to NIST standards</u>.

- The S-HIS performance has been proven on multiple airborne platforms, each with significantly different instrument operating environments.

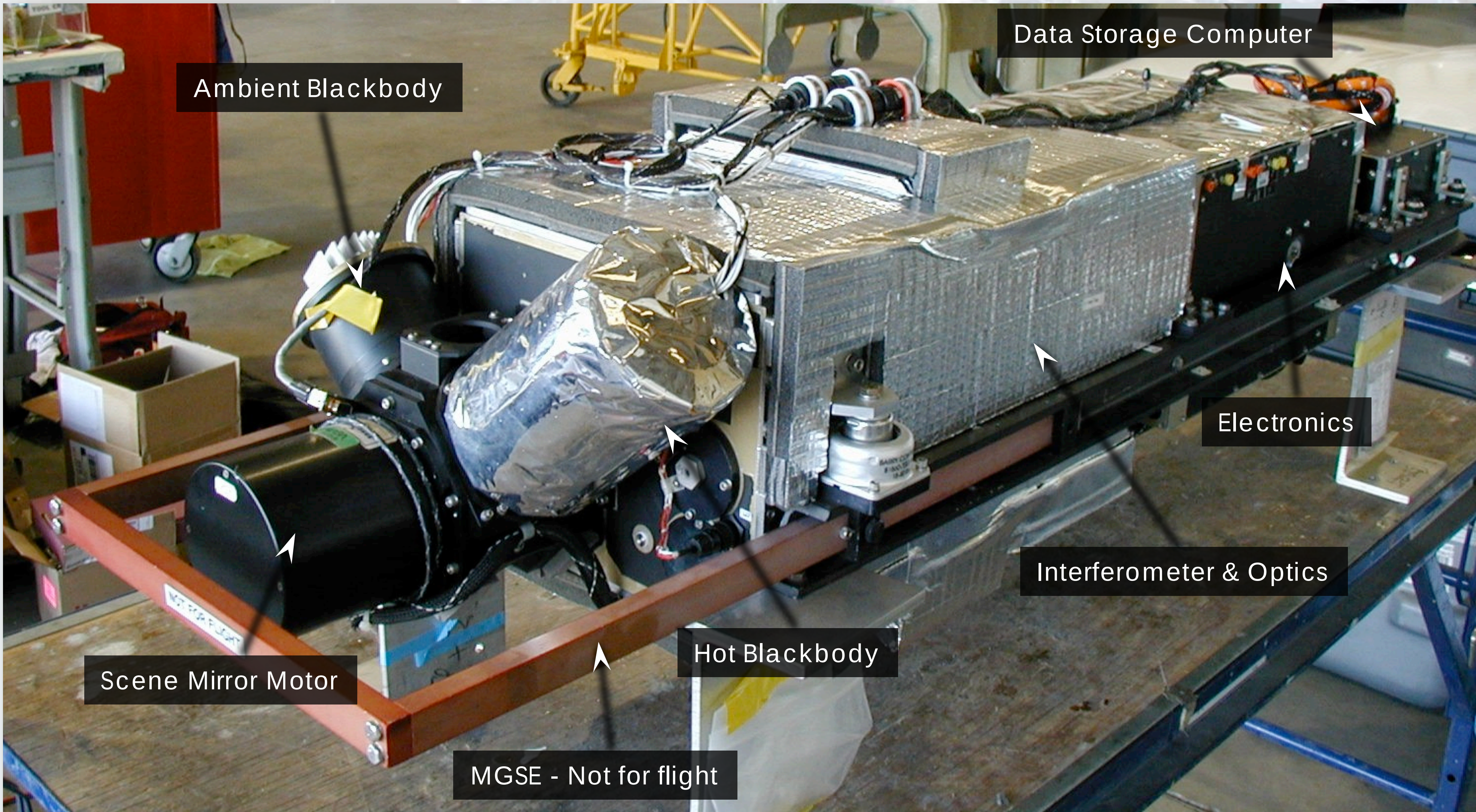
- The S-HIS was initially designed to fly on an unmanned aircraft vehicle (UAV) with limited payload capacity. This drove it to be small, light weight, and modular, with low power consumption.

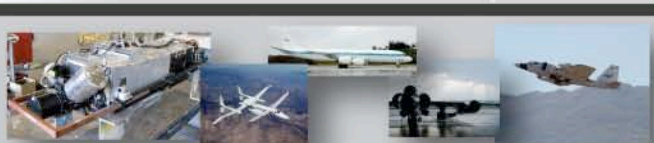
- Its relatively small size, modular design, and low power requirements facilitate integration into multiple airborne platforms, and provide compatibility with ever changing instrument payload configurations.

- These characteristics make the S-HIS both an important and flexible validation tool that is currently being used by both NASA and NPOESS.



UW-SSEC S-HIS (1998 - present)
Instrument Description: Overview





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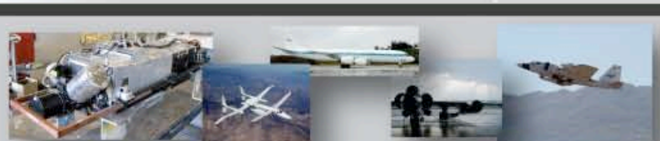
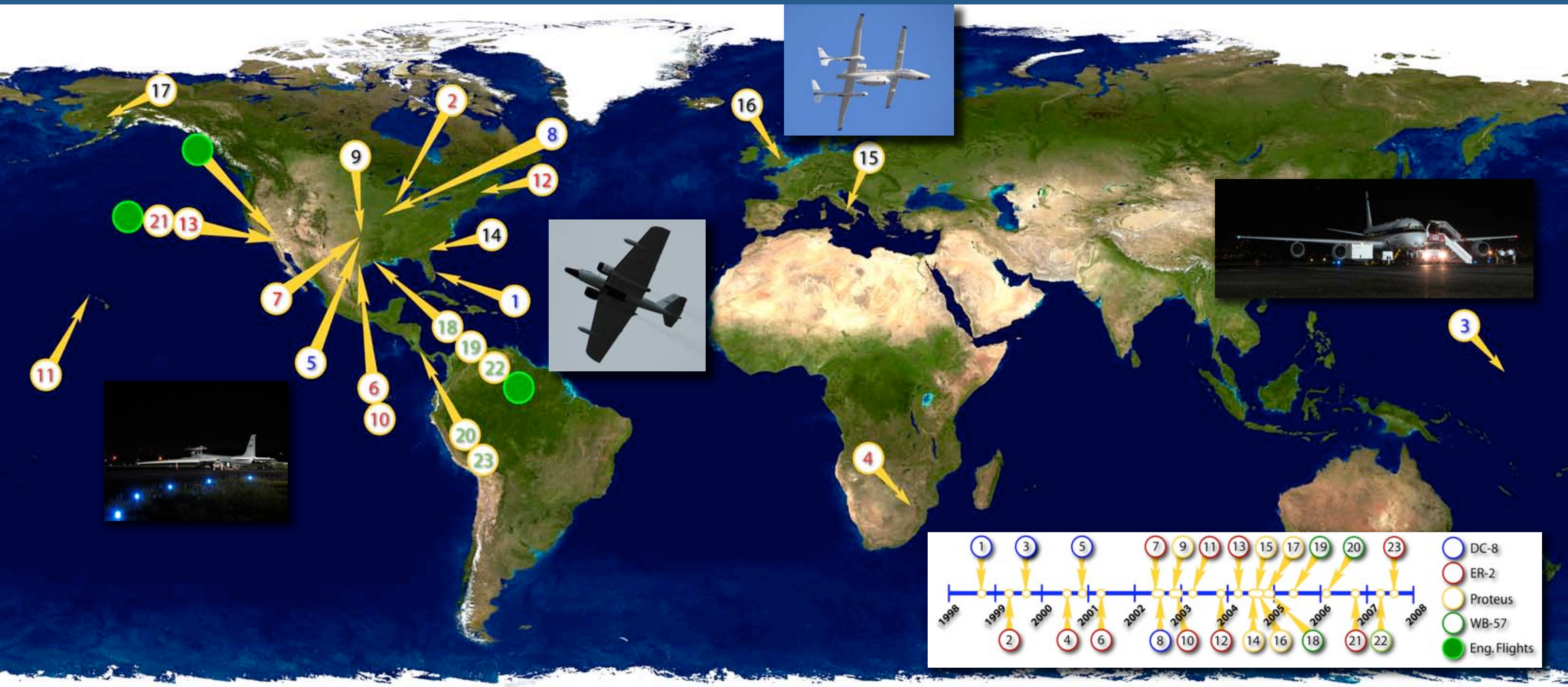
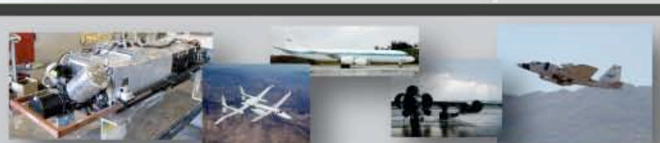


Flight Experience and Operating Environment



- From 1998 to present, the S-HIS has been involved in 23 field experiments on the NASA DC-8, NASA ER-2, Scaled Composites Proteus, and the NASA WB-57
- Key 2007 Activities: NIST TXR, JAIVEx 2007, TC4-2007
- During JAIVEx the NASA WB-57 completed 10 science flights totaling roughly 50 science flight hours, with the S-HIS collecting science data for approximately 49 of these 50 science flight hours (~98%), with no loss of at-altitude data (only data losses were during ascent/descent)
- During TC4 the NASA ER-2 completed 11 science flights totaling roughly 66 science flight hours, with the S-HIS collecting science data for roughly 64.9 of these 66 science flight hours (~98.25%), with no loss of at-altitude data (only data losses were during ascent/descent)



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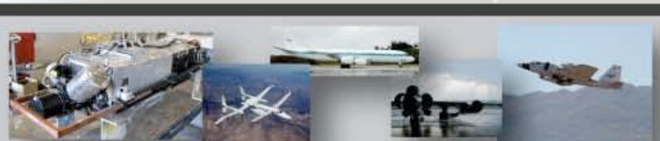
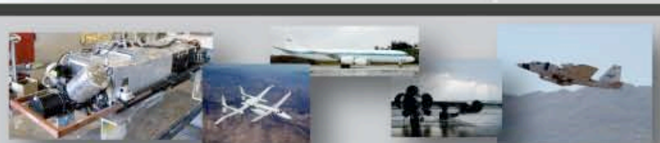


Instrument Performance: Radiometric Calibration

- Achieving high absolute accuracy has been a major objective of the S-HIS program at the UW-SSEC.
- The blackbody reference sources for the S-HIS are high emissivity cavities (normal emissivity ≈ 0.999) carefully designed, fabricated, and characterized at the UW-SSEC
- NIST traceability (Direct via NIST TXR for full flight thermal conditions)
- Formal 3 sigma (i.e. not to exceed) absolute uncertainties for temperature and cavity emissivity of 0.10 K and 0.001 [Best et al; 1997, 2003], respectively.
- For $T_B \geq$ 220K the resulting absolute radiometric accuracy is better than 0.3 K (3-sigma) and the reproducibility is better than 0.2 K
    - These are conservative estimates of the uncertainty, with the absolute accuracy representing a not to exceed value.
    - An RSS of the error contributors indicates expected uncertainties that are about half of these values over much of the spectrum, and ground tests with a third blackbody confirm this tighter expectation.



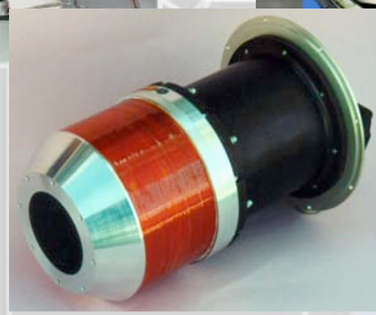
SSEC Spectrometer, Blackbody Heritage & Ties to NIST

Ground-based

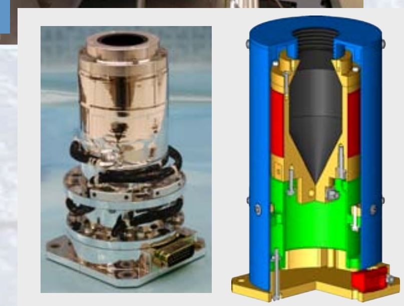
High-altitude Aircraft

Spaceflight

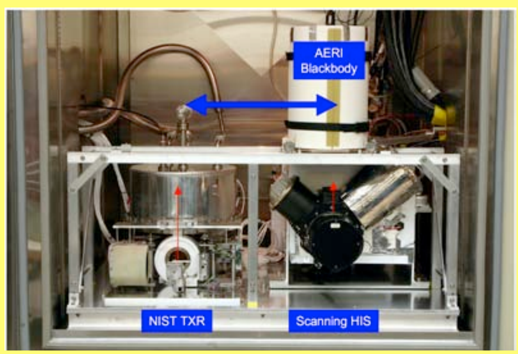
NIST Waterbath Blackbody



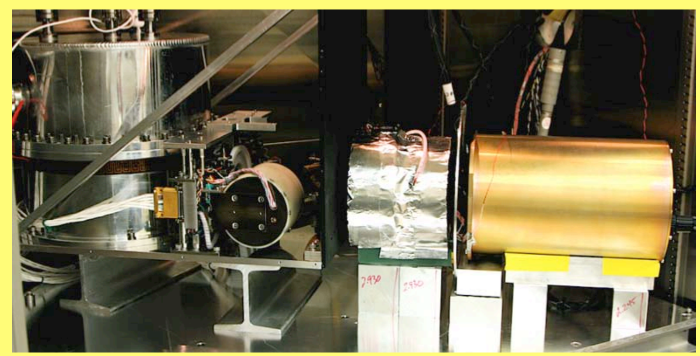
NIST TXR



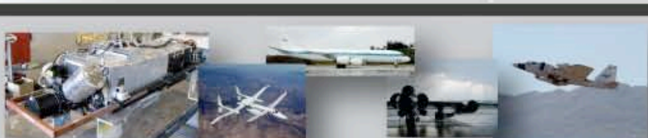
< 0.065 K error (293 to 333 K)



< 0.06 K error (220 to 333 K)



ε > 0.9994 (within estimated uncertainty)



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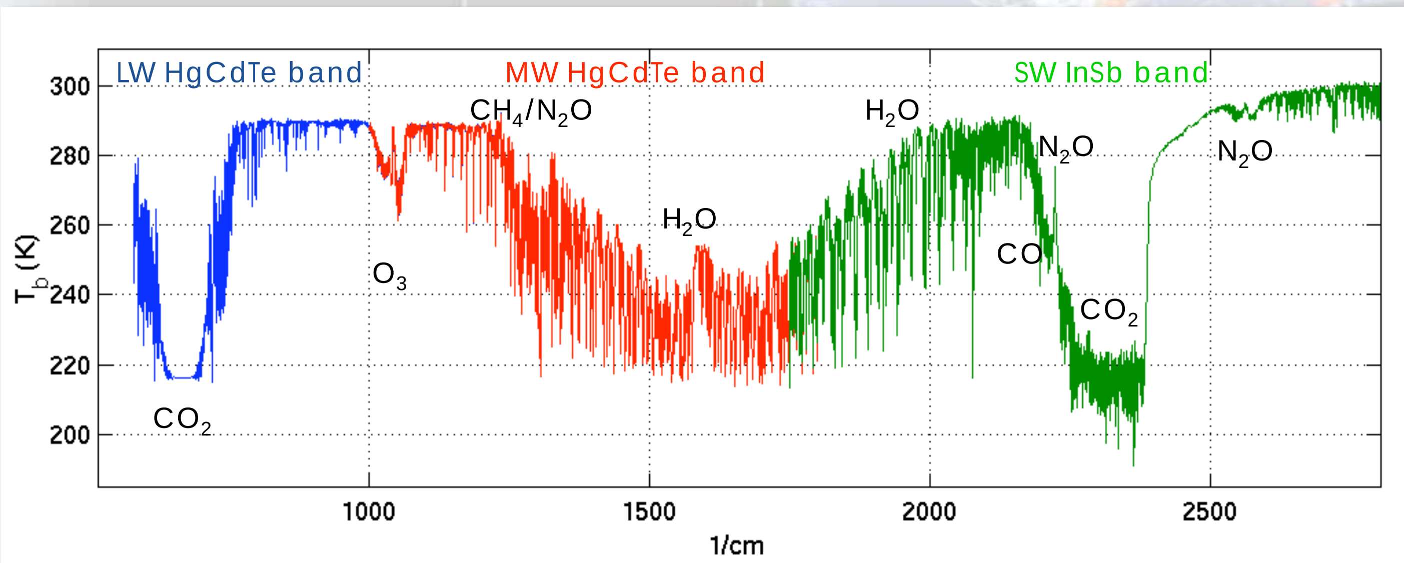
Information Content in S-HIS Spectra

Characteristics

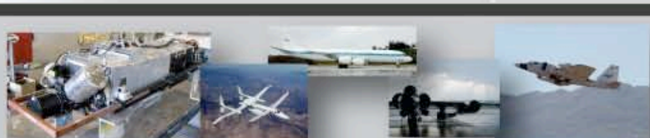
Interferometer Type: Voice coil DA plane mirror (Custom / modified Bomem DA-5)
Resolving Power: 1000 - 6000
IFOV: 100 mrad (2 km @ 20 km, nadir)
Field Mirror Scan: Programmable
RMS Noise (per spot): < 0.25K at 260K

Spectral Coverage: 580 - 3000 cm^{-1}
LW: 580 - 1200 cm^{-1}
MW: 1000 - 1820 cm^{-1}
SW: 1750 - 3000 cm^{-1}
Spectral Resolution: 0.5 cm^{-1}

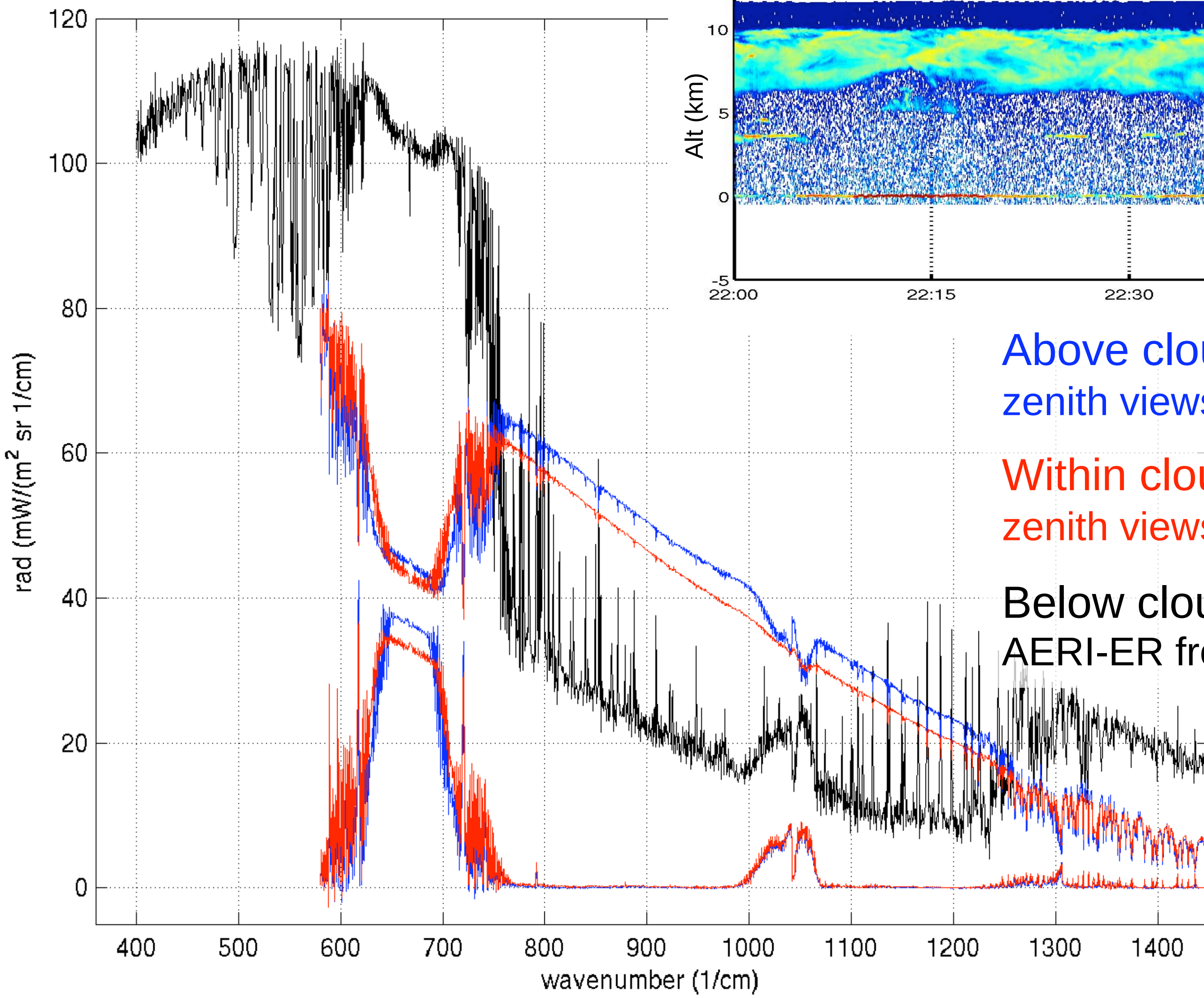


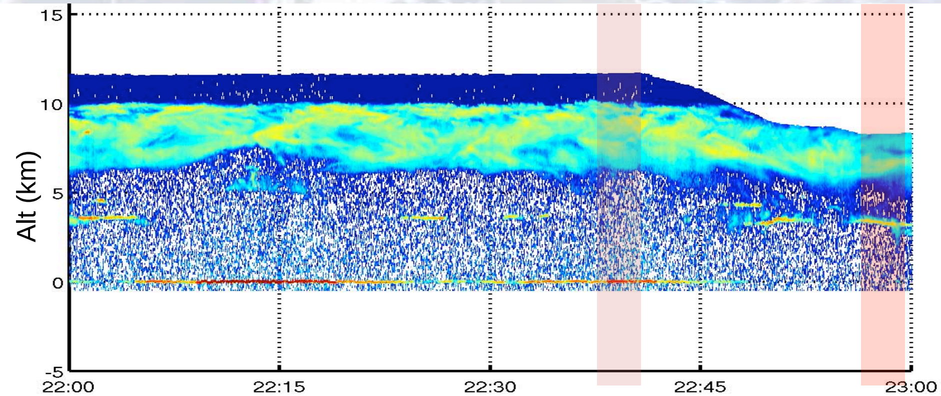
Applications

- Radiances for Radiative Transfer
- Temp & Water Vapor Retrievals
- Cloud Radiative Prop.
- Surface Emissivity & T
- Trace Gas Retrievals
- Calibration Validation



Spectral Radiance Data (Zenith and Nadir)

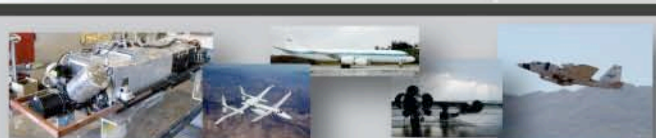




Above cloud (S-HIS nadir and zenith views from 22:35 to 22:40)

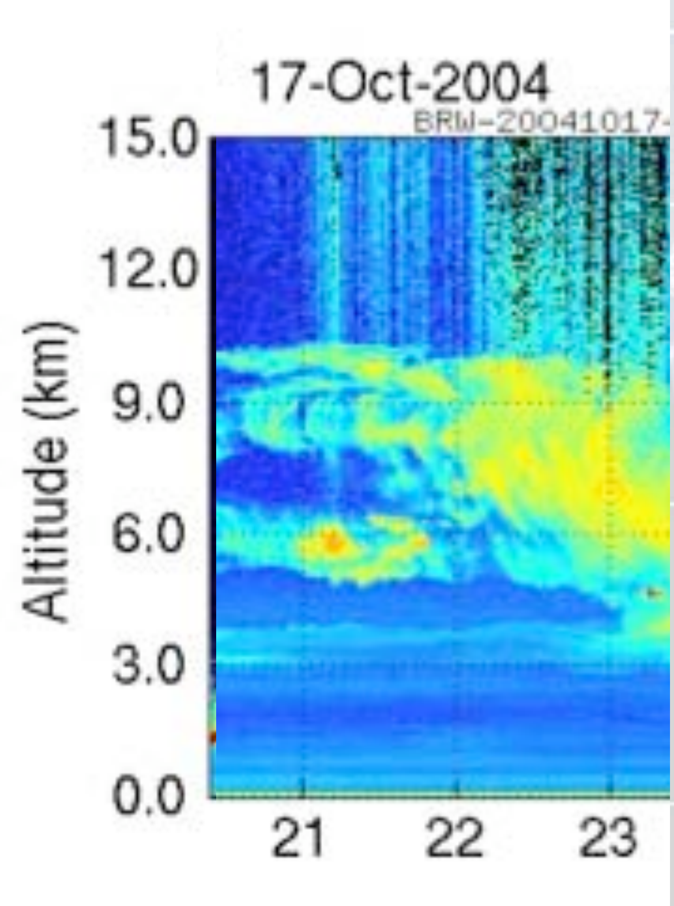
Within cloud (S-HIS nadir and zenith views from 22:55 to 23:00)

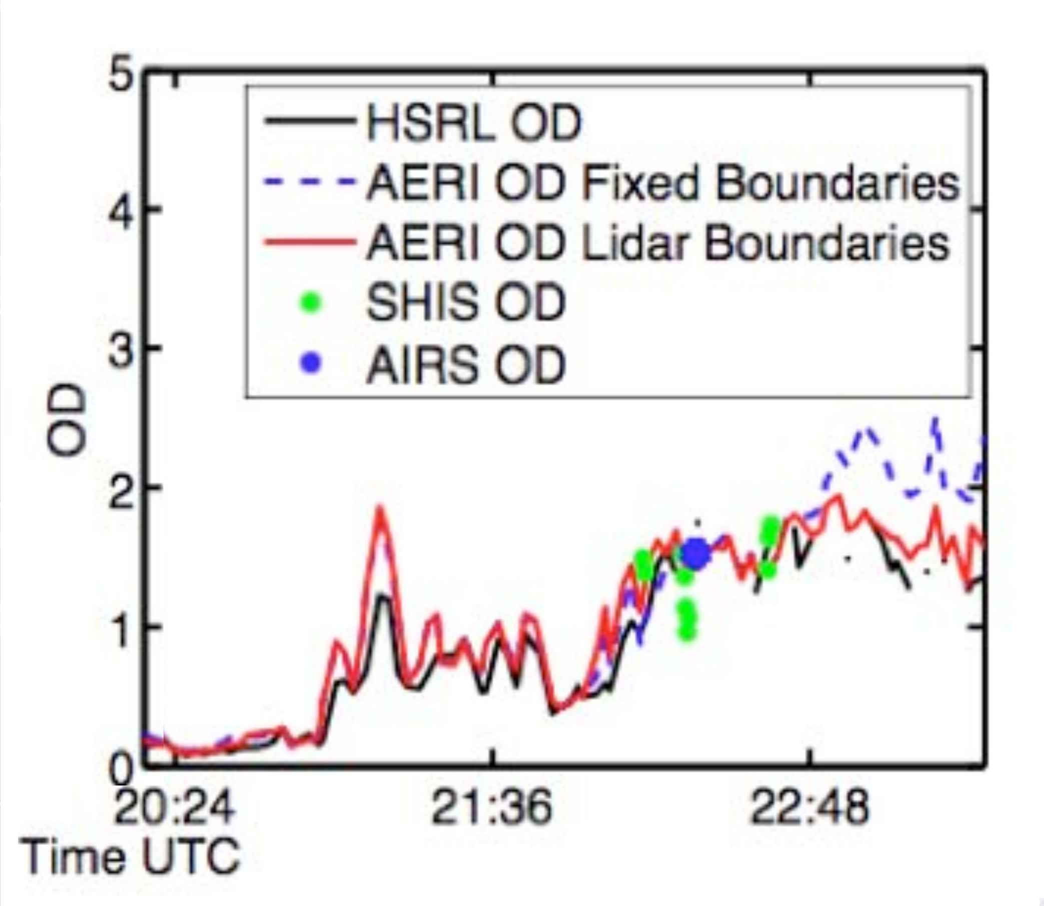
Below cloud (ground based AERI-ER from 22:35 to 23:00)



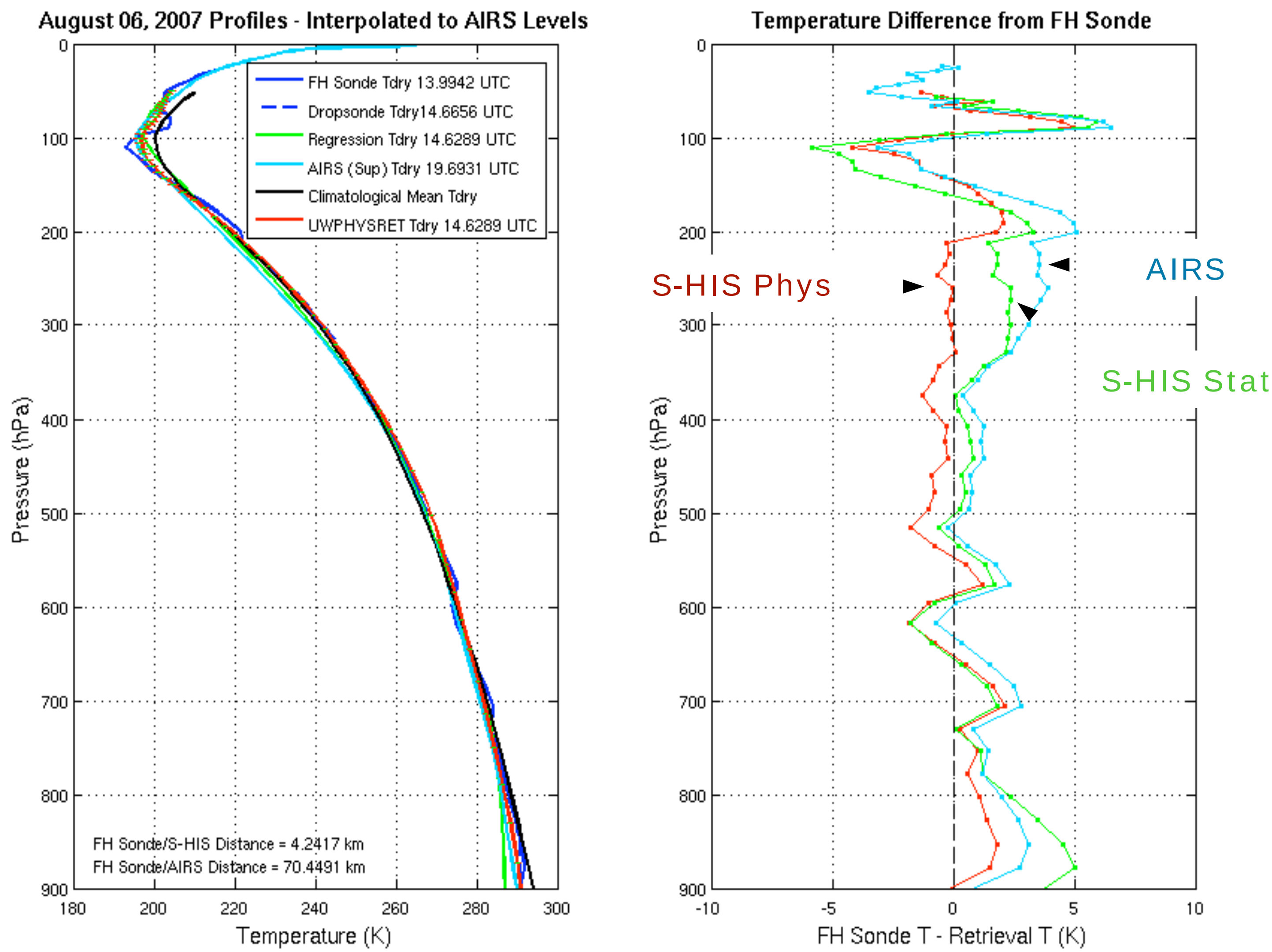
Cloud Optical Depth Retrievals

ARM M-PACE, Barrow, AK

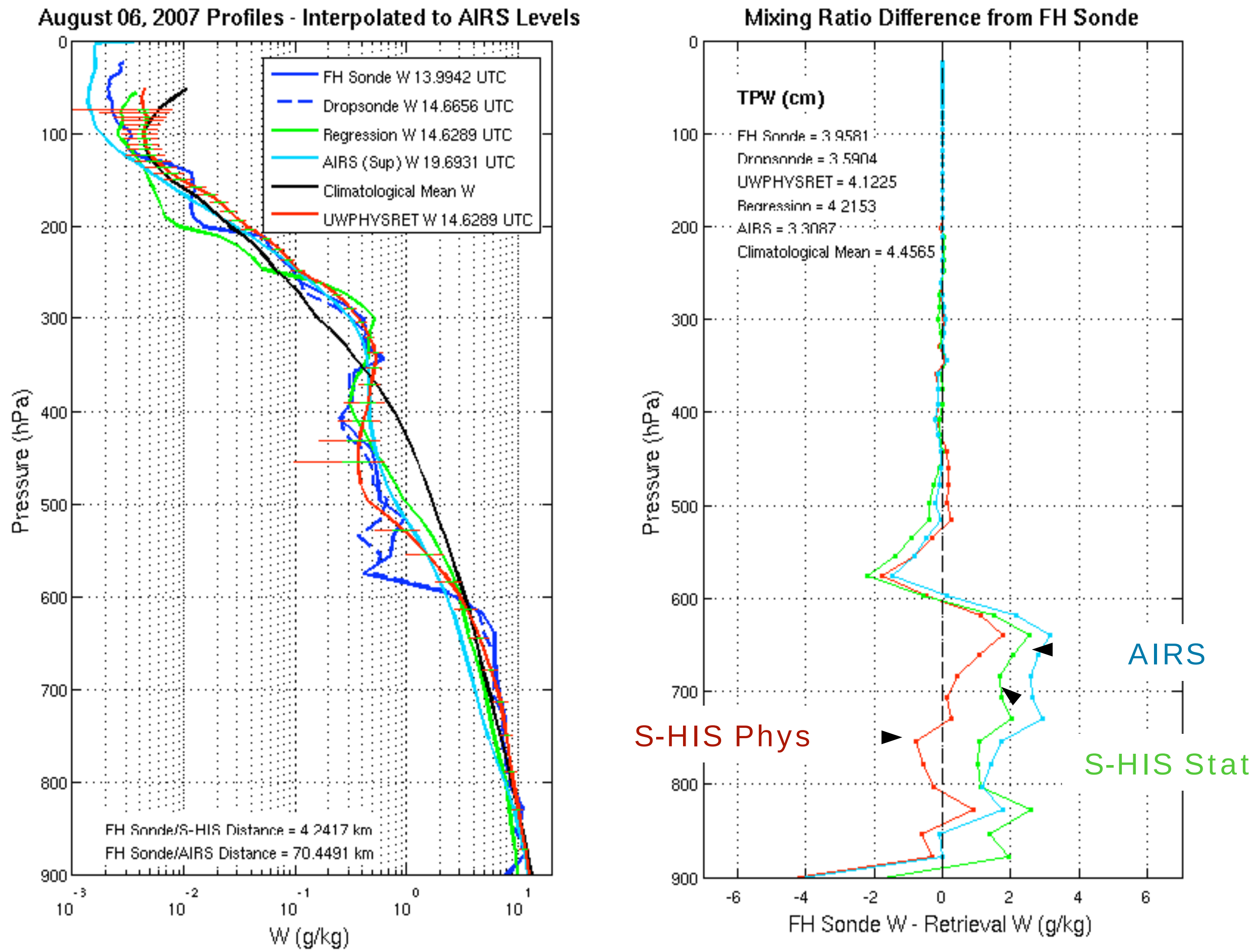


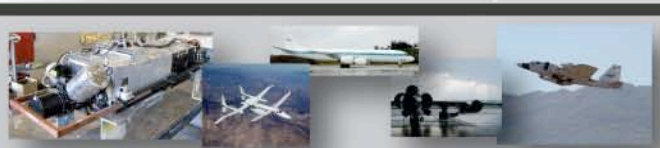


Retrieved Temperature Profiles



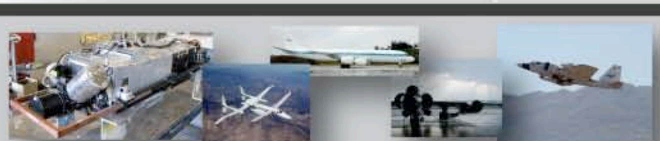
Retrieved Humidity Profiles





Extended Range Spectral Coverage

- Current detector/dewar is a ‘3-color’ system with a spectral range of 580cm^{-1} – 3000 cm^{-1}
- Two other detector/dewar systems delivered during instrument development
- One of these systems is a ‘4-color’ system with a spectral range of ~450cm^{-1} – 3000 cm^{-1} and vendor provided performance specifications that indicate slightly reduced performance in the MW, and equivalent LW and SW performance (compared to current detector configuration)
- End to end instrument testing, characterization with this ‘4-color’ detector-dewar system has never been completed
- Would require optical alignment, performance testing, and bias optimization
- If performance in LW/MW/SW is acceptable, would provide ELW coverage similar to AERI-ER



Infrared Imager Module

- S-HIS FOV: 100 mrad, 2km, from 20km altitude
- Uncooled Infrared Imager module
  - FOR co-registered with S-HIS FOV
  - high spatial resolution coverage (10m from 20km altitude)
  - Spectral coverage options:
    - Broad IR coverage (8 – 14 μm), or
    - 1 or more window channel bands (~1μm – 1.5μm FWHM)
  - Leverage S-HIS instrument resources to minimize imager module cost; ie. Onboard computer, calibration reference blackbodies, scene mirror, instrument structure and enclosures, aircraft nav-data interface, GPS, IMU etc.
- Would provide non-uniform scene information, cloud coverage, surface emissivity variation

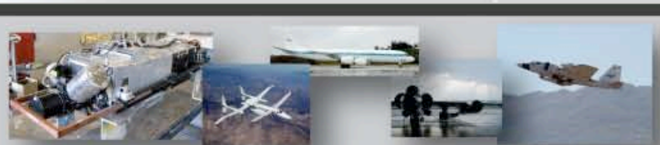
Summary

- From 1998 to present, the S-HIS has been involved in 23 field experiments on multiple airborne platforms, each with significantly different instrument operating environments. Independent of airborne platform, the S-HIS has provided hyperspectral infrared radiance measurements with high absolute accuracy and low noise.

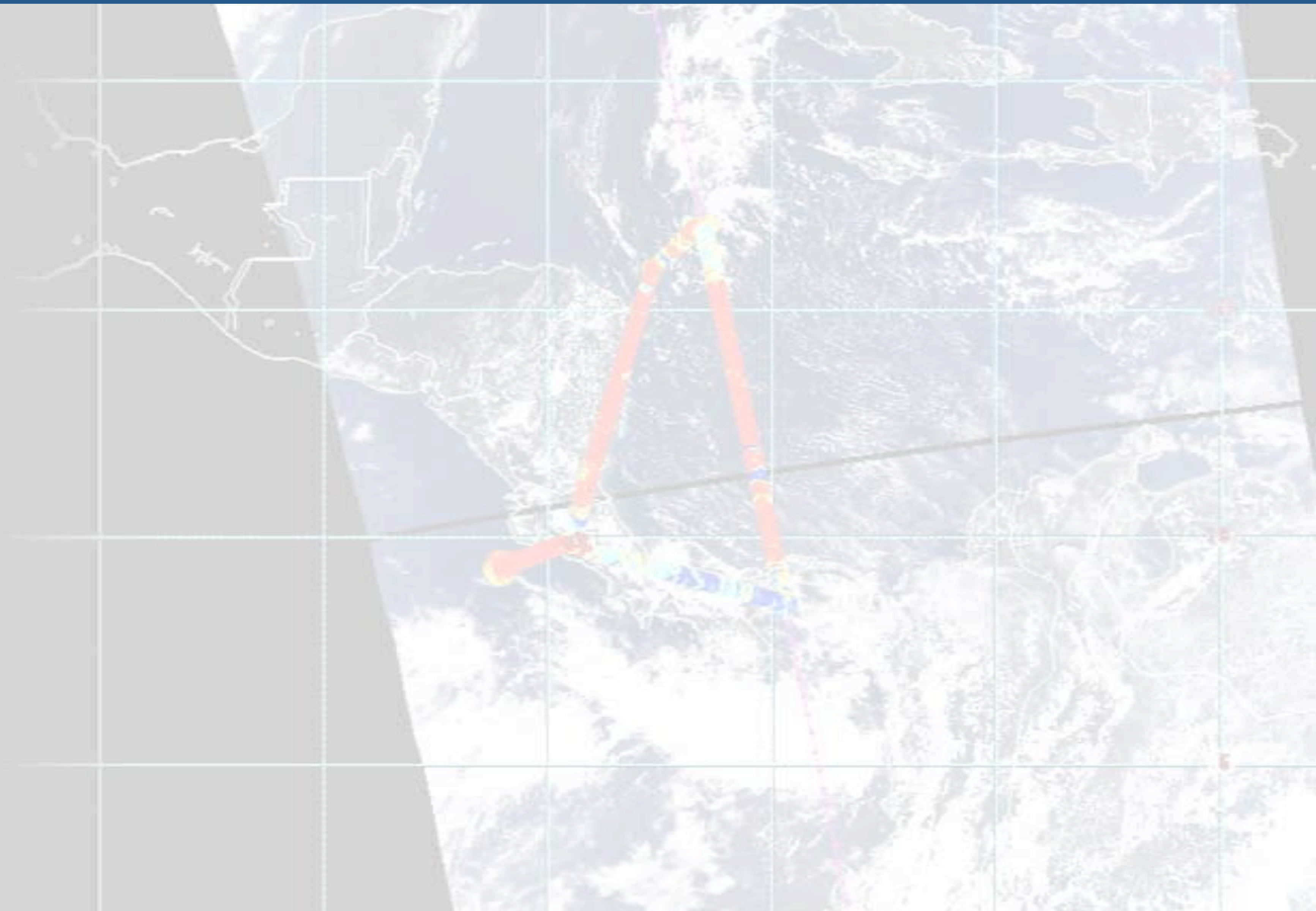
- Its relatively small size, modular design, and low power requirements facilitate integration into multiple airborne platforms, and provide compatibility with ever changing instrument payload configurations.

- The S-HIS is extremely well characterized and understood, carefully maintained, and accurately calibrated, with direct traceability to NIST standards.

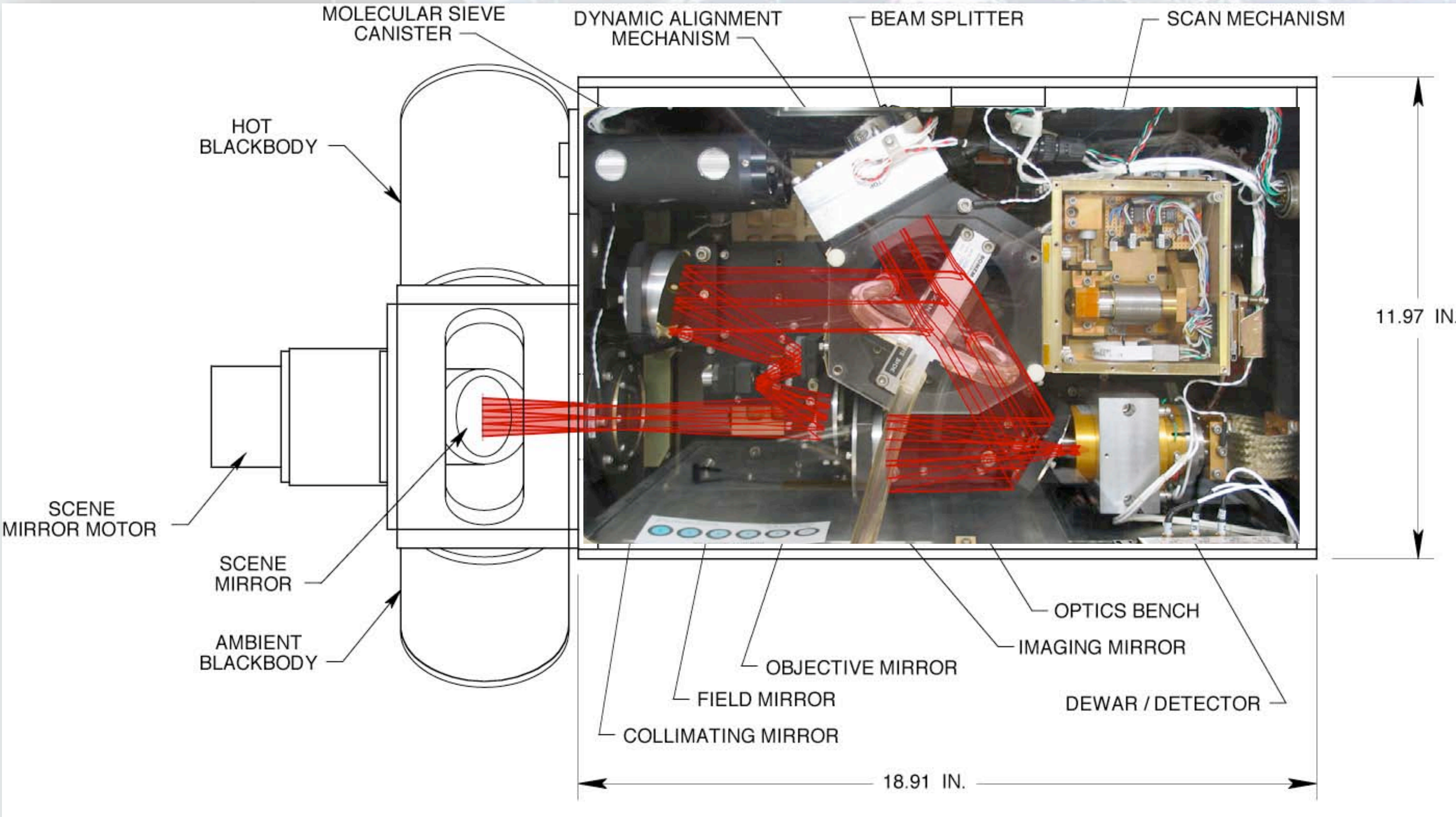
- S-HIS data are used for a wide array of scientific studies, and the scientific utility can be even further enhanced with some relatively inexpensive upgrades



Backup Slides

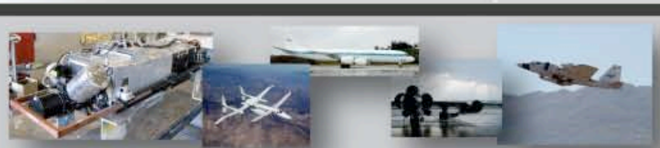


Instrument Description:
Interferometer Module



Flight Experience and Operating Environment

- The optical, electrical, and mechanical interfaces are usually well defined and may be accommodated with specific design modifications and/or features
- The operational environment is often not well defined, and depends not only on the aircraft, but also on mount location within the payload, and aircraft navigation (altitude, velocity, pitch, roll, flight profile, etc)
- The Pressure, Vibration, and Thermal Environment have the largest potential impact on instrument operation and vary greatly from aircraft to aircraft
- Independent of airborne platform, the S-HIS has provided hyperspectral infrared radiance measurements with high absolute accuracy and low noise.

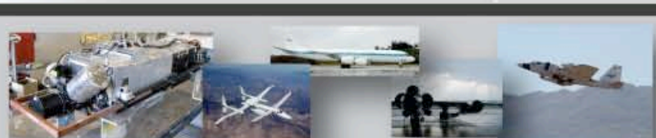


Instrument Performance: Radiometric Noise

- S-HIS noise levels are sufficiently low to allow cloud and surface properties to be derived from each <u>individual</u> field of view. Temperature and water vapor profiling can be performed on individual field of views after taking advantage of Principal Component Analysis to reduce noise levels [Antonelli et al, JGR, 2004].

- Individual fields of view can be averaged to further reduce the noise for analysis of larger field features (ie. Calibration validation of satellite -based instruments)

- An operational tilt correction algorithm has been developed and can be used to minimize vibration induced Interferometric noise, further improving instrument noise performance, independent of airborne platform.

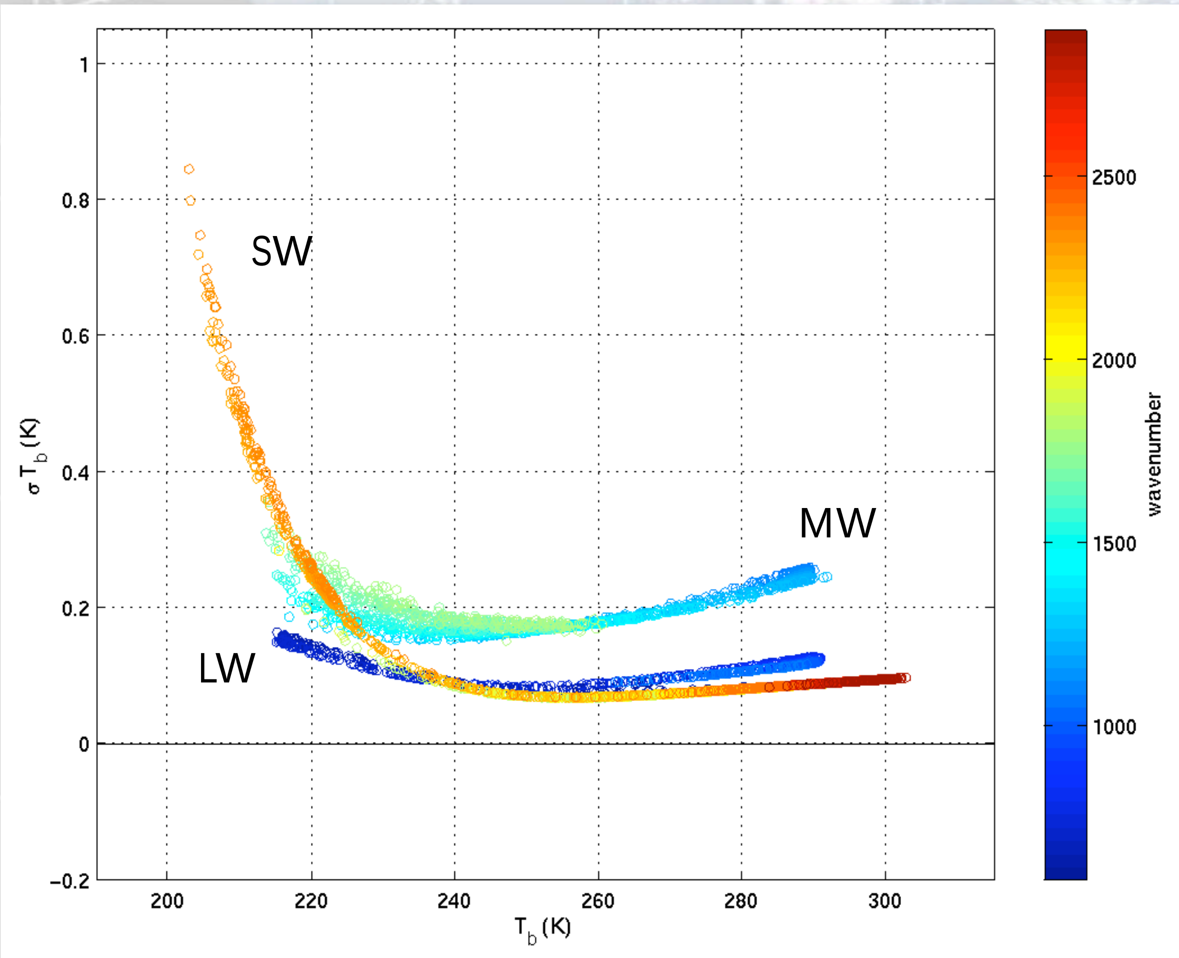


Instrument Performance: Radiometric Calibration [cont.]

S-HIS Radiometric Calibration Budgets

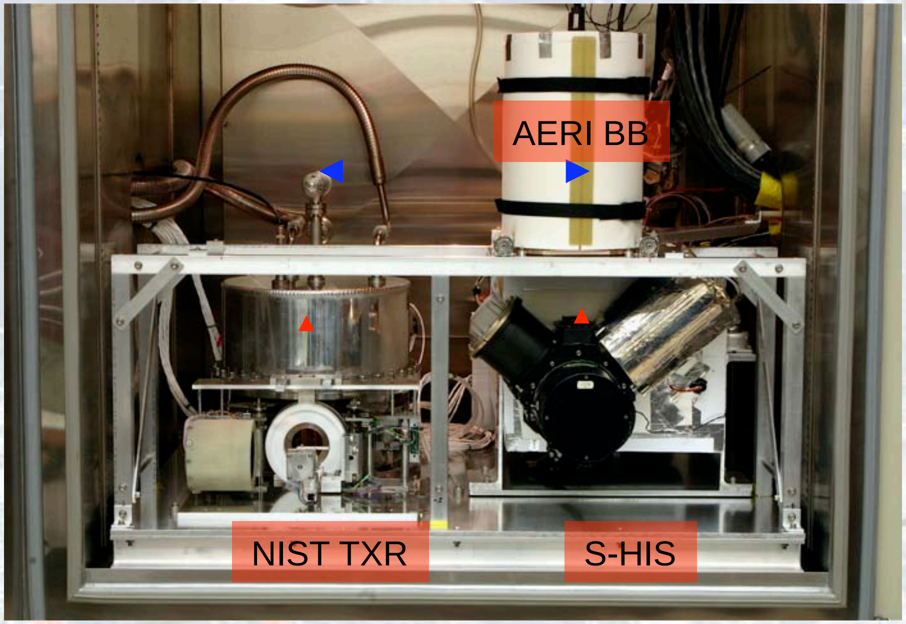
**3-sigma Uncertainties, similar to Best, et al., CALCON 2003 for AERI

T_{ABB}= 227K, T_{HBB}= 310K, 11/16/02 Proteus

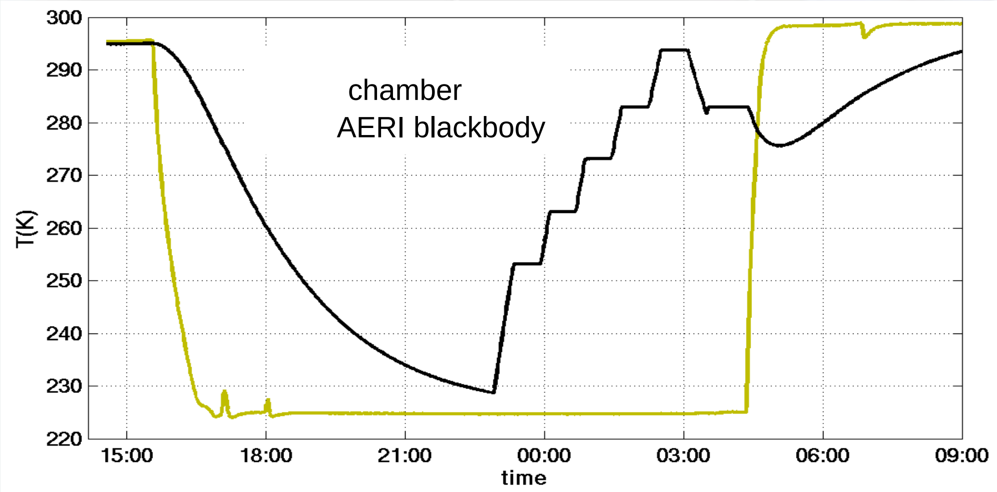


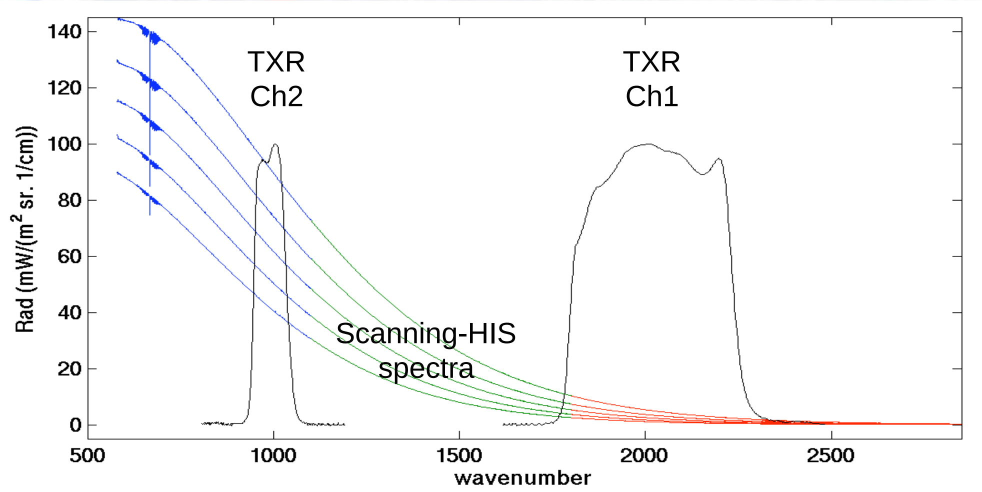
Instrument Performance: Radiometric Calibration [cont.]

Perform **periodic end-to-end radiance evaluations** under flight-like conditions with NIST transfer sensors such that satellite validation analyses are traceable to the NIST radiance scale

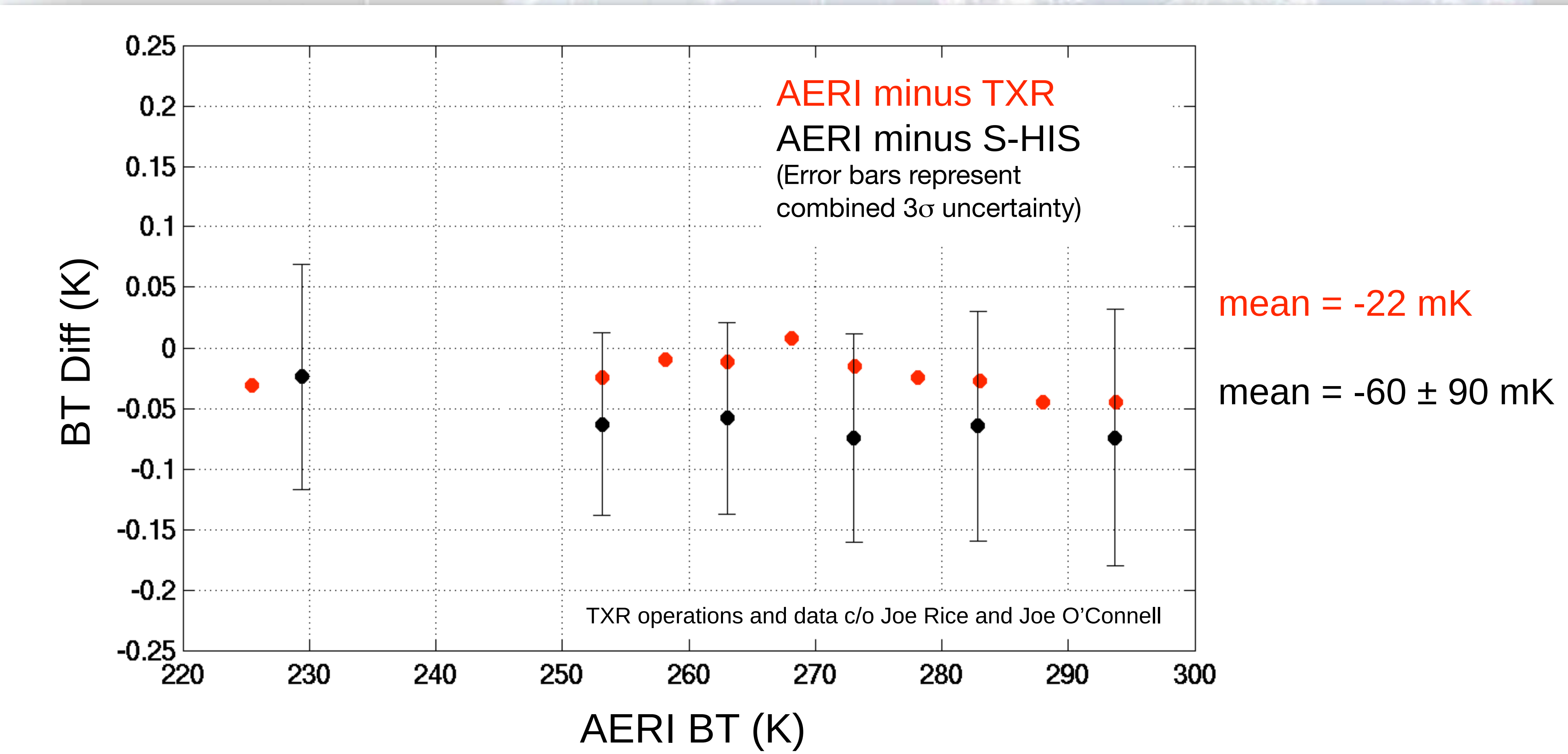


January 2007, testing at UW/SSEC

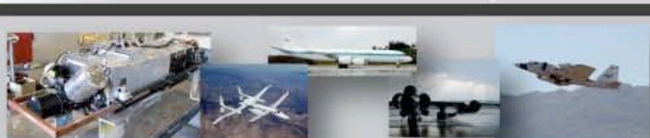




Differences wrt AERI Blackbody predicted radiance:

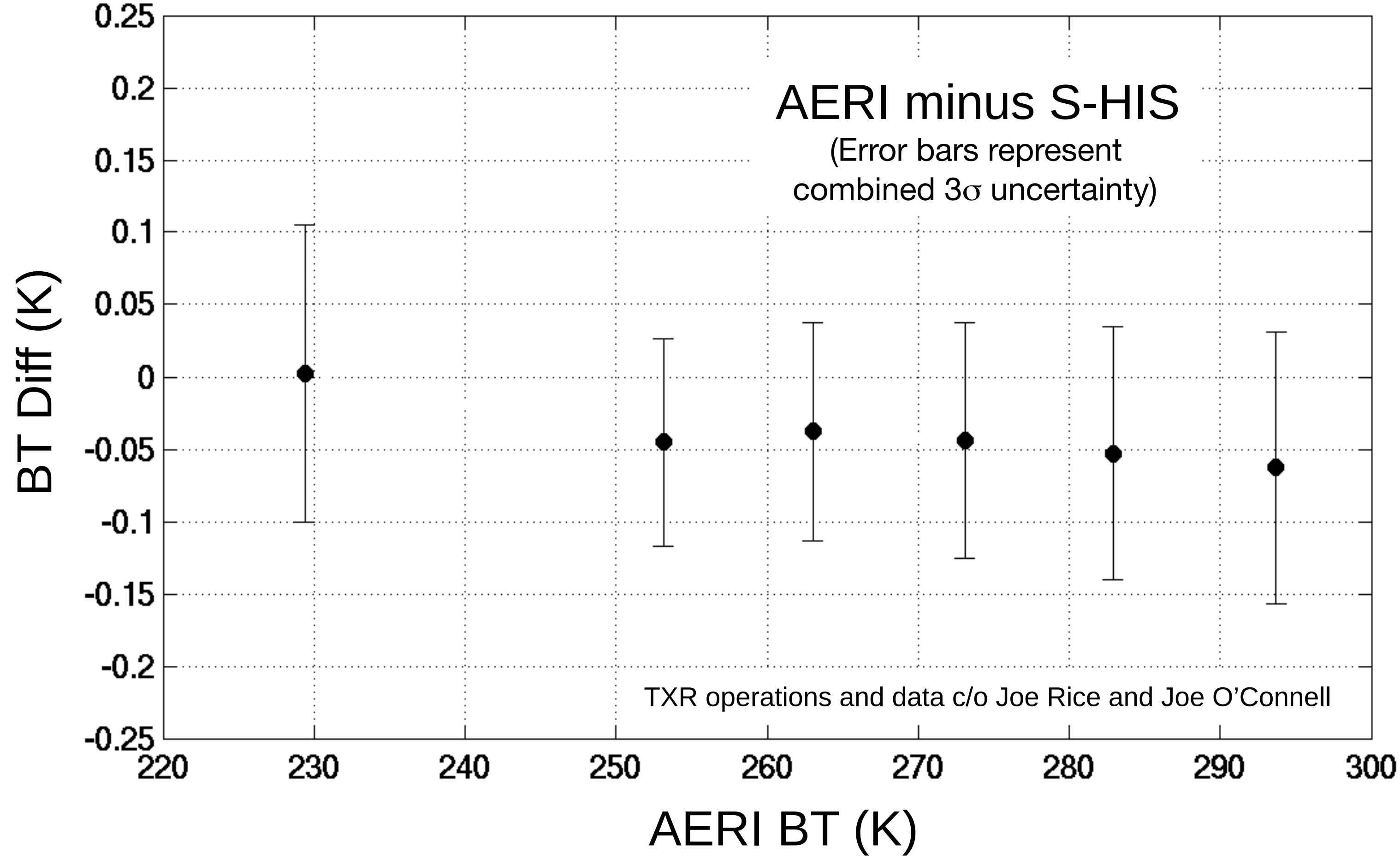


- mean agreement between TXR and S-HIS of ~40 mK, well less than propagated 3-sigma uncertainties



Instrument Performance: Radiometric Calibration [cont.]

Differences wrt AERI Blackbody predicted radiance:



mean = -40±85 mK

- mean agreement between predicted and S-HIS of ~40 mK
- TXR Ch1 analysis requires refinement *at this time*