# NASTER Workshop

## S-HIS Lessons Learned

NASA LaRC

July 10 & 11, 2003

# S-HIS Overview

# UW Scanning HIS: 1998-Present

## (HIS: High-resolution Interferometer Sounder, 1985-1998)

### Characteristics

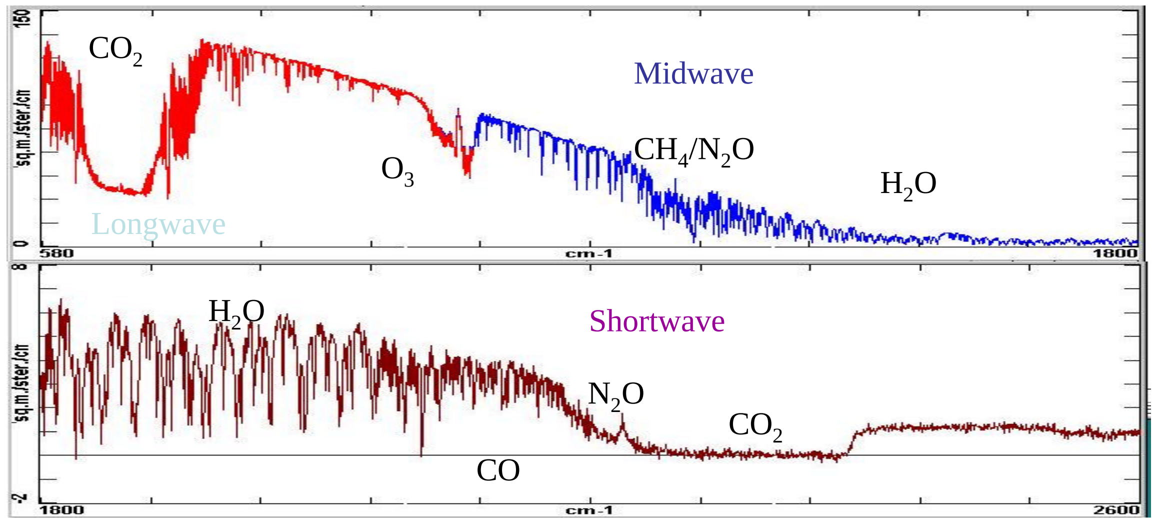
**Spectral Coverage:** 3-17 microns

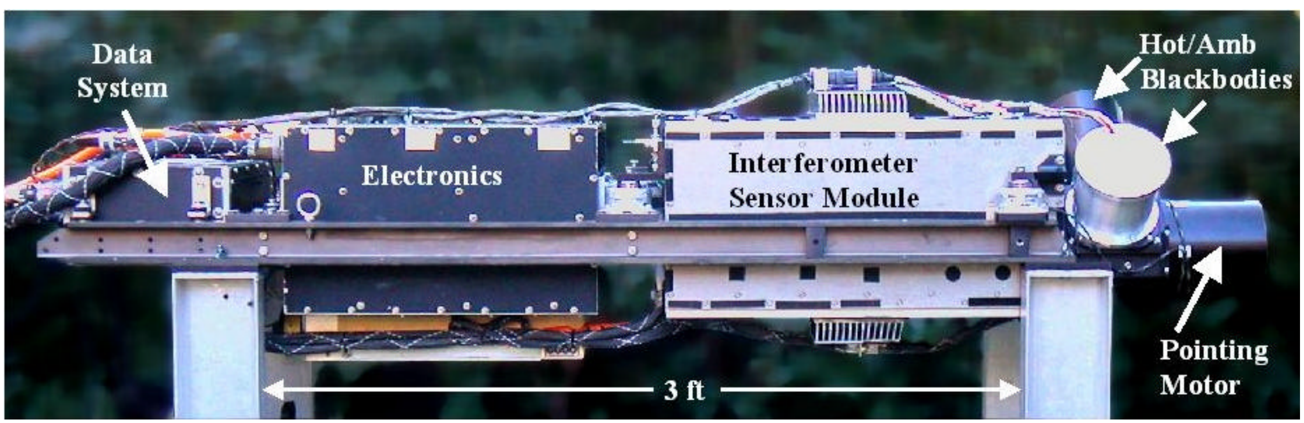
**Spectral Resolution:** 0.5 $cm^{-1}$

**Resolving power:** 1000-6000

**Footprint Diam:** 1.5 km @ 15 km

**Cross-Track Scan:** Programmable including uplooking zenith view

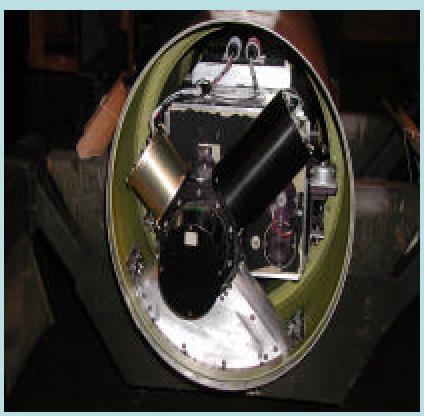


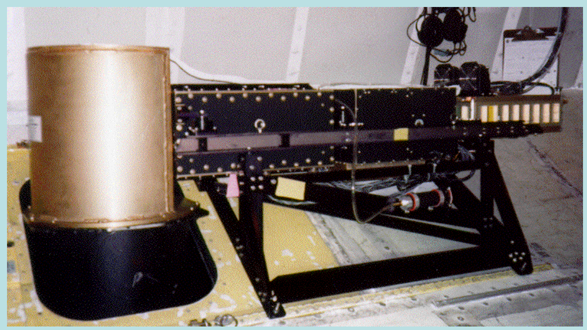



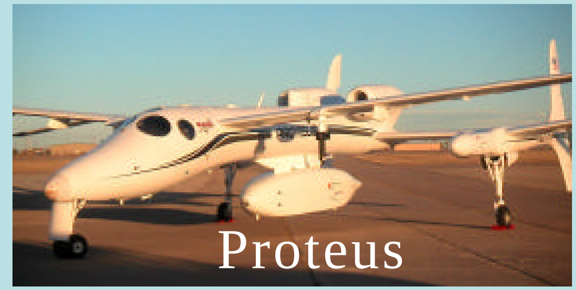

### Applications:

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

# S-HIS Platforms




Uplooking & Cross-track

# Worked Well on S-HIS Consider for NASTER

# Worked Well-Consider for NASTER

- Extensive Housekeeping System
- Tilt Measurement and Correction
- Unpressurized Interferometer
- Flexible Control System
- Robust and upgradeable Data Storage Capability
- Uplook View
- Split Cycle Stirling Cooler
- Detector Aperture Sharing

# Worked Well-Consider for NASTER

- Small Size, Mass, and Power with Modularity
- Electronic Static Tilt Adjustment
- Base Instrument Power on 28 VDC
- Michelson Drive linear bearing based drive
- Dynamic Alignment Stiffening and Damping
- ABB tightly coupled to ambient temperature

# Extensive & Flexible Housekeeping System

- 128 samples are collected every 1/2 second
- There are 72 different engineering parameters that can be assigned in any combination to the 128 samples
- The following have proven to be very useful
  - Temperatures to monitor blackbodies and the thermal performance (structure, electronics, critical components)
  - Detector temp. and cooler current to monitor cooler health
  - DA Motor Voltages, ZPD Magnitudes, Laser Intensity

# Tilt Measurement & Correction

- Implementation of an interferometer mirror Tilt Monitoring System has allowed S-HIS to measure vibration induced tilt.
- S-HIS showed that tilts can be measured and corrected for in ground processing
- For NASTER tilt artifacts could be removed during flight (correction built into hardware), or during post-flight ground processing.
- Tilt measurements can be used for vibration diagnostics

# Unpressurized Interferometer

- The S-HIS Interferometer is unpressurized. It exhausts pressure on ascent through a 0.5 psig relief valve. During descent incoming air is passed through desiccators.
- Benefits of this system include:
  - No pump-down required on ground
  - Easier to eliminate detectable quantities of $H_20$
  - Less structural mass
- This system is useful for any box

# Flexible Control System

- The S-HIS had programmable settings for key operational parameters
  - Scene mirror angles and number of interferometer scans at each scene
  - Blackbody temperatures
  - Housekeeping parameters
  - Fault Protection System

# Robust and Upgradeable Data Storage Capability

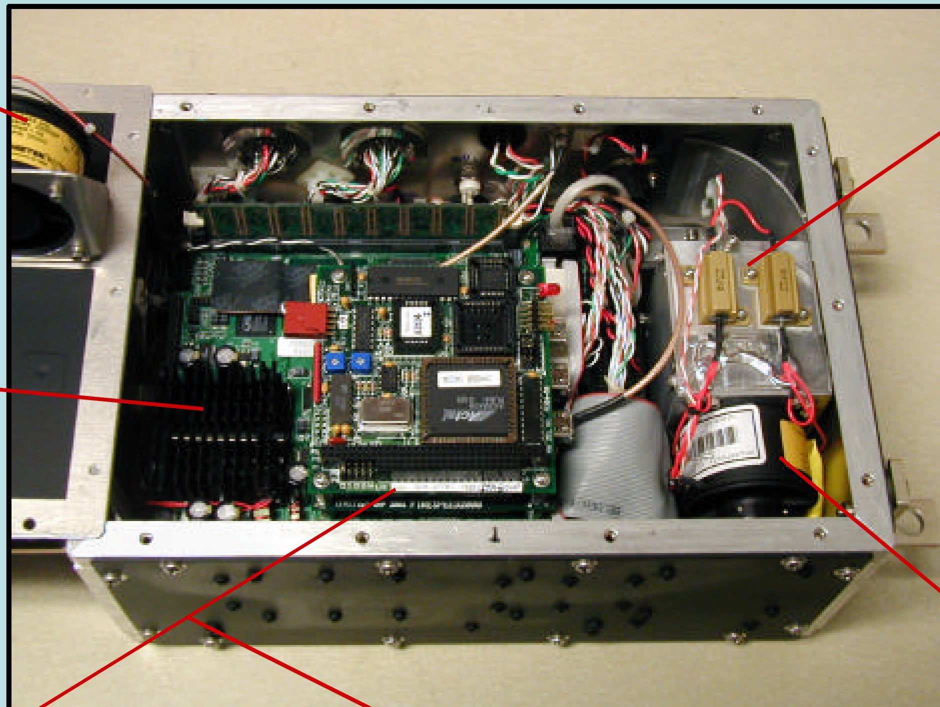
- The original S-HIS data storage computer was a hardened laptop enclosed in a pressurized enclosure. This system was heavy and needed additional vibration isolation to operate.
- A new data storage computer was developed that uses a Solid State Drive (SSD). This system requires no pressurization and was demonstrated on both the ER-2 and Proteus platforms

# S-HIS Data Storage Computer

CPU Chip
Cooling Fan

Heated
Heat Sink

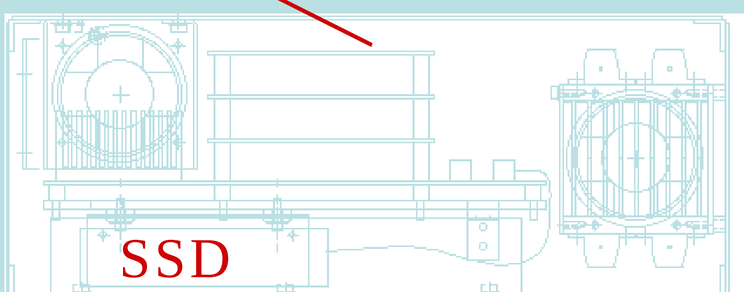
CPU with
Heat Sink



[Solid State
Drive on
Bottom Side]

Air Mixing Fan
Coupled to
Flow-through
Heated Heat Sink

Main Board
With I/O
Modules




Storage volume is easily expanded

# Data Storage Computer Specifications

- Versalogic VSBC-8 single board PC/104+, 5V
- Celeron 566MHz low-power, 128MB RAM
- 4 ATA, 2 RS-232, 2 RS-232/422/485, 2 USB
- ECP Parallel Port
- 100MBit Ethernet
- 8-Channel single-ended ADC
- IRIG-B PC/104 time sync
- 3-port FireWire/IEEE1394 PC/104+ board
- Analog video/audio digitizer PC/104+ board
- 8.7GByte BitMicro Solid State Disk

# Data Storage Software

- Embedded Linux, 2.4 kernel
  - Bootstrap from FAT filesystem to RAMdisk
  - Journaled filesystem (ReiserFS) for data
- GNU development environment
- RS-232 + EPP Parallel link to control DSP
- RS-232 / IRIG-B link to aircraft
- Streams of “RSH” raw data
  - Sequence of blocks of packets
  - Half hour per RSH file (<=200MB)

# Uplook View

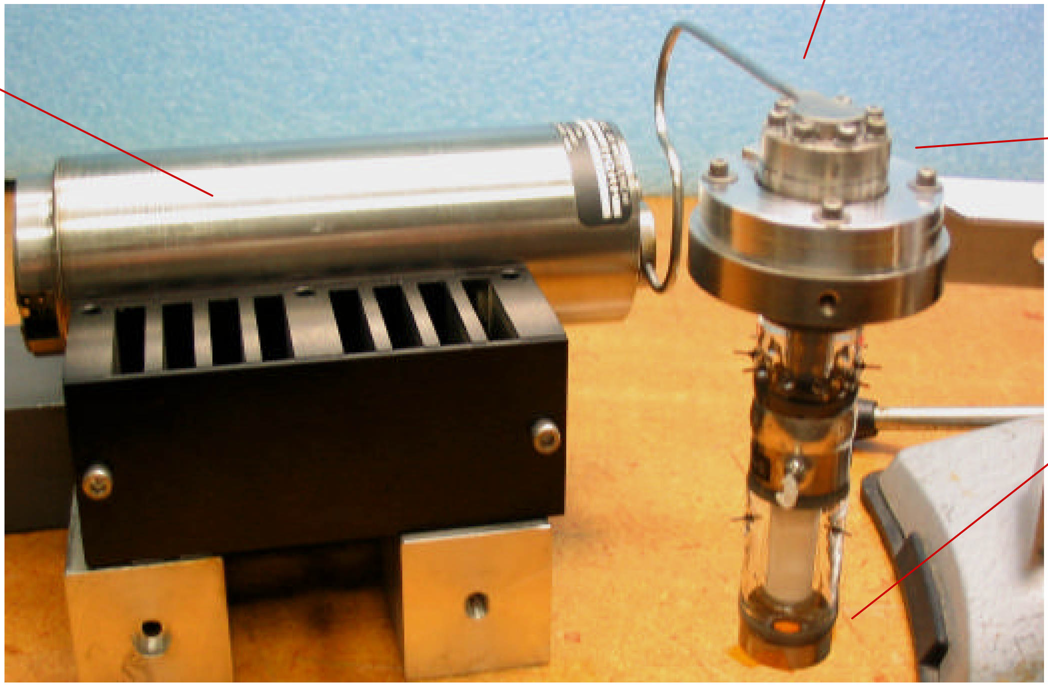
- Provides a good check on calibration
- Useful for providing constraint on
  - Upper level water vapor
  - Cloud emissivity

# Split Cycle Stirling Cooler

- Allows vibration isolation
- Simplifies cooler replacement

Compliant Transfer Tube Allows mechanical decoupling

Compressor



Cooler Exander

Detector

# Detector Aperture Sharing

- Provided very compact optical design (at expense of performance hit)
- Only one cooler required for four bands

# Small Size, Mass, & Power, Along With Modularity

- Small Size, Mass, & Power, Along with Modularity provides:
  - easier intigration to multiple platforms
  - greater opportunity to fly with other instruments on a given platform

# Electronic Static Tilt Adjustment

- Allows DA mirror to have a static offset
- In S-HIS this reduces the susceptibility to magnitude tilt errors

# Base Instrument Power on 28 VDC

- S-HIS Started out using both 28 VDC and 400 Hz power
- In going to the Proteus the 400 Hz requirement was eliminated.
- This is beneficial because:
  - Eliminates bulky ground support power supply
  - Some platforms will not have 400 Hz avalilable

# Michelson Drive
# Linear Bearing-based Drive

- As-delivered Bomem flexure-based drive gave large vibration induced tilt.
- New linear bearing based drive is considerably stiffer.
- New drive uses voice coil actuator and original Bomem tachometer and drive electronics

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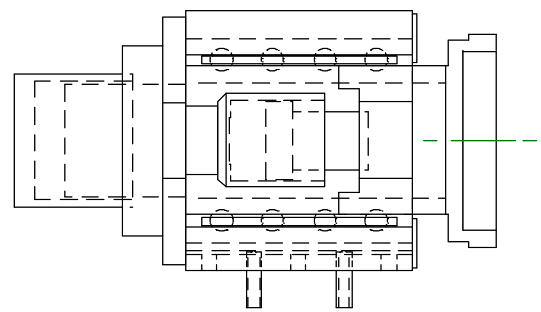
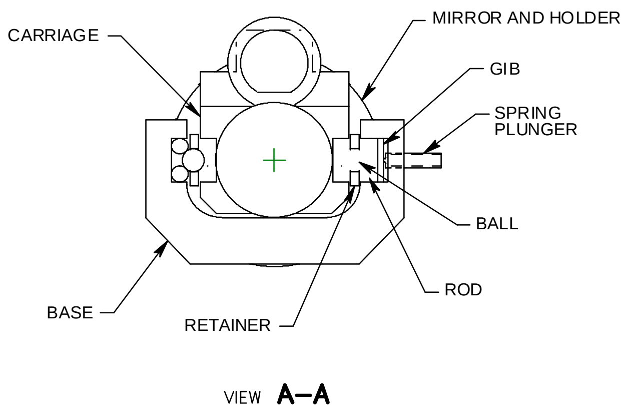
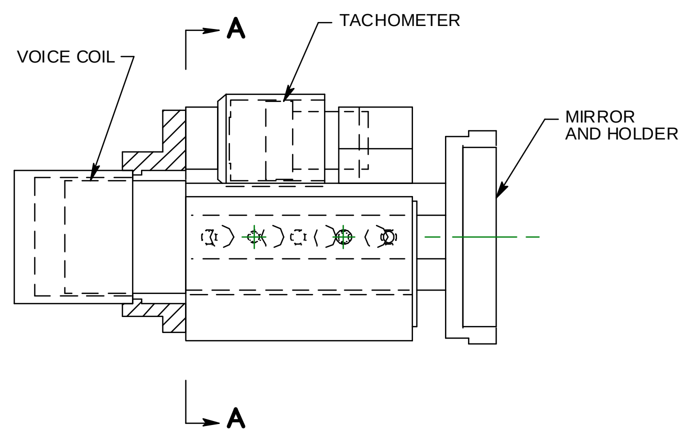
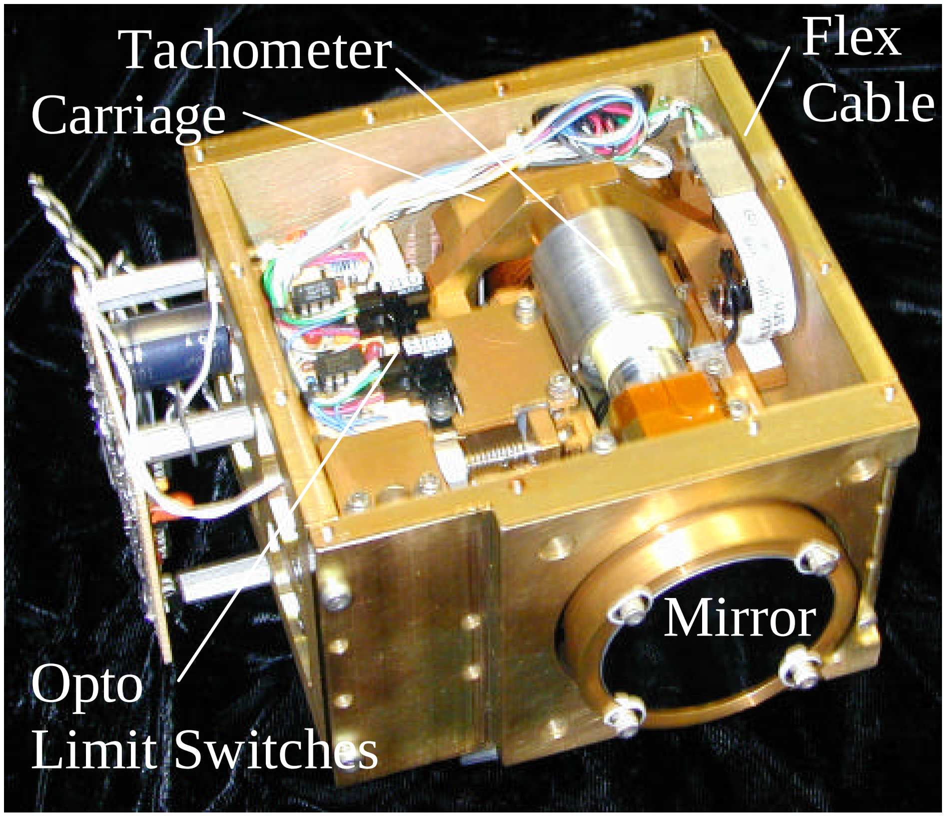
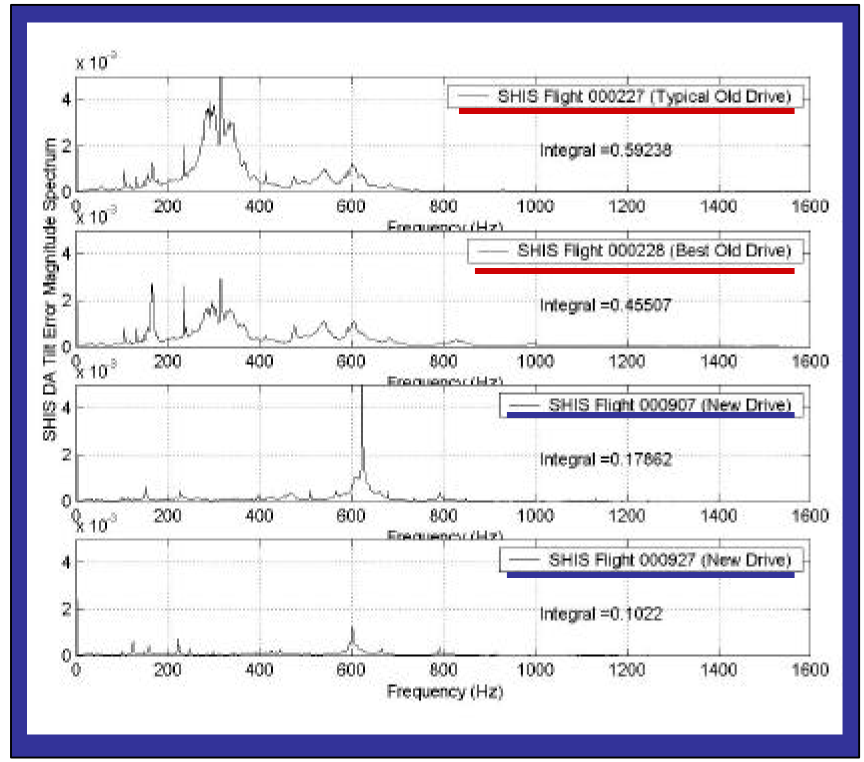




# S-HIS Linear Bearing Based Michelson Drive




Comparison of Tilt Spectra measured during flight form the **old** and **new** Michelson Drive assemblies as measured by the S-HIS laser based dynamic Alignment system. The new drive eliminates significant tilt dynamic amplitude Below 600 Hz. In addition, the overall tilt magnitude is lower by almost a factor 6 with the new drive.

# Dynamic Alignment Stiffening and Damping

- The as-delivered Bomem Dynamic Alignment Mechanism was modified to eliminate or significantly reduce effects of mechanical resonances within the range of rejected frequencies.
- Changes include:
  - Voicecoil mounting was changed from the mirror support plate to the cover plate
  - Mirror support plate and cover were stiffened
  - Damping was added to the mirror support plate, and cover
  - Damping was also added between the voicecoil and the cover plate
- DA Changes allowed servo gain to be raised significantly
- DA must be tuned for the platform

# Modified Dynamic Alignment System

Voice coil coupling changed from mirror plate to cover

Added Damping

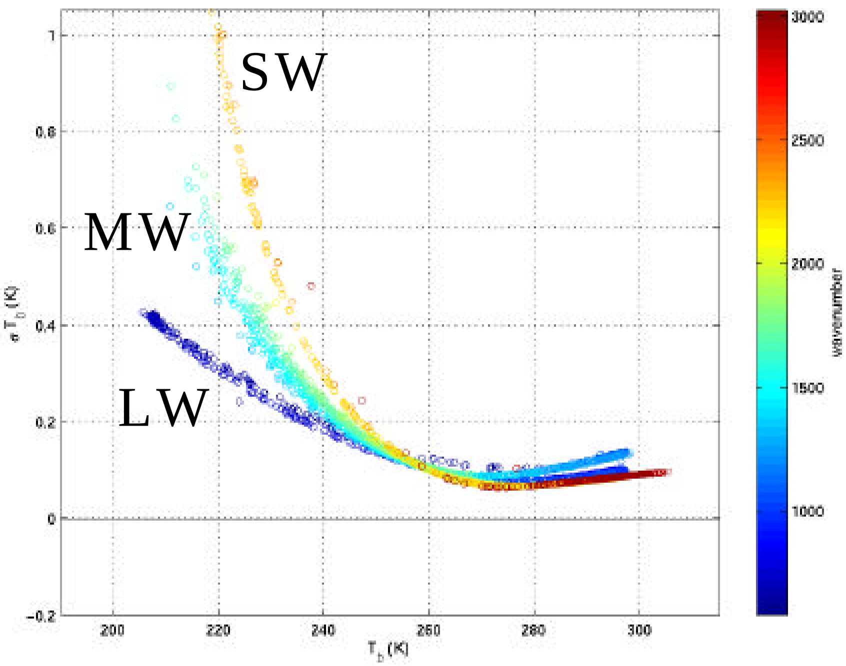
Added Stiffening

# ABB Tightly Coupled to Ambient Temperature

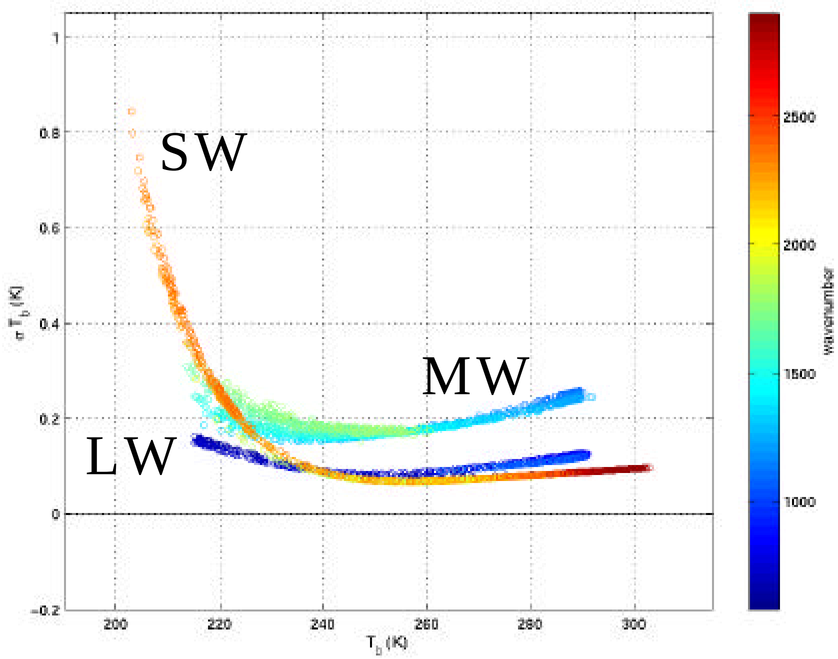
- Radiometric accuracy was improved by better coupling the ABB to the ambient temperature during flight
- The ABB on S-HIS was originally configured to be moderately coupled to the front-end support structure. This allowed the ABB to get cold but provided enough thermal insulation to allow heating during descent to protect BB.
- The “moderate” thermal coupling did not allow the BB to track ambient temperature adequately
- The solution was full thermal isolation from the front-end structure and direct coupling to the ambient air (cooling fins coupled to cavity with a fan)

# Scanning-HIS Radiometric Calibration Budget for 11/21 case

$T_{ABB}$ = 260K, $T_{HBB}$ = 310K




$T_{ABB}$ = 227K, $T_{HBB}$ = 310K



# ABB Implementation that Povides Coupling to Pod Ambient Air via Fan

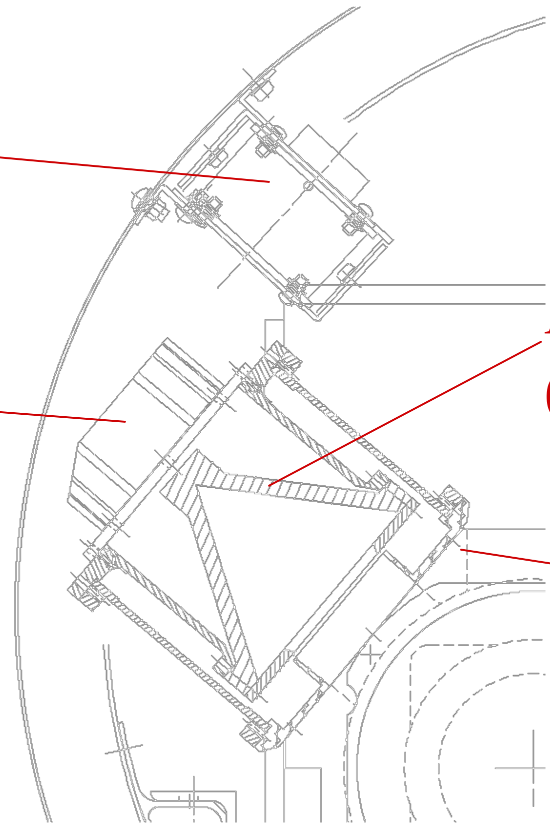



ABB Cavity closely tracks the Pod Ambient Air Temperature

# Software Design

# S-HIS Flight Control Software

- TI DSP C40 Controller Processor
  - Performs real-time ingest sequencing
  - Custom DSP assembly software
  - Downloads data to Storage Computer
  - **High reliability, not as flexible as desired**
- TI DSP C40 Science Processor
  - Filtering and decimation of raw interferograms
  - **Negligible remaining margins for additional functions**

# Recommend for NASTER

- QNX, VxWorks, RTMS or Linux/RTLinux
- Streaming data model
  - Sequence of groups of packets
  - Real-time monitoring over network socket
  - Break into ~200MByte files
  - Download data from instrument over network
- Strict decoupling of data collection from both data storage and interpretation logic
- Journaled filesystem for data, RAMdisk for OS
- Use GNU / Open Source tools for longevity

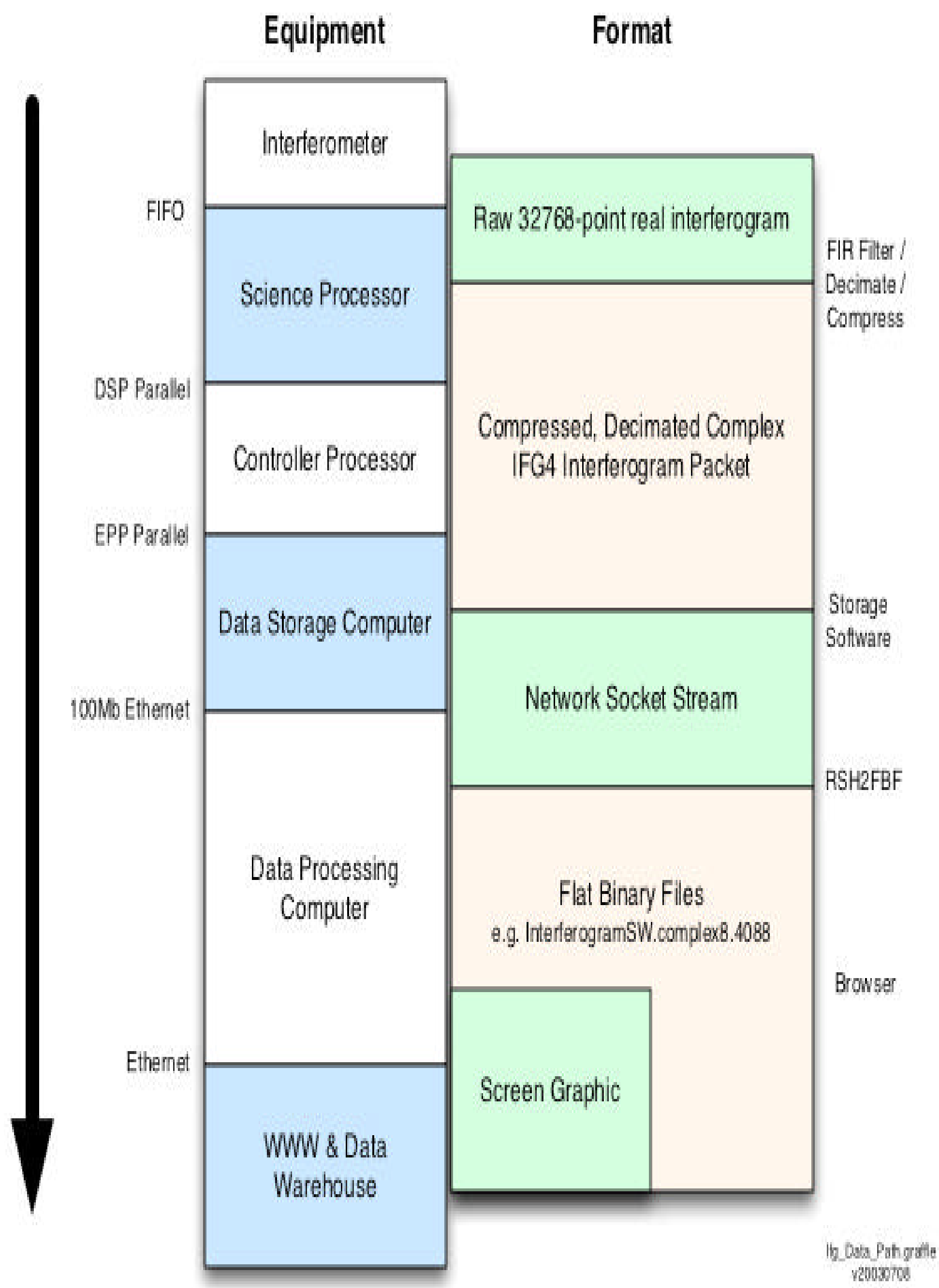
# Remote Capabilities: Configuration

- Select new blackbody set-points
- Mirror sequence reprogramming
- Load instrument test software into RAM
- Load flight software into flash

# Remote Capabilities: Operations

- Full instrument telemetry stream
  - Science GUI
  - Engineering GUI
- Descent-mode toggle
- Generate instrument status summary onboard
  - Low-bandwidth text block for downlink
- Check data stream integrity
- Reset mirror sequencing
- Change output file

# S-HIS Example Interferogram Data Path



# Additional Things to Consider for NASTER

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- Velocity Monitoring
- 3rd Blackbody
- Visible Imaging System
- IR Imaging System

# Back-up

# SSEC Scanning HIS on 1st ARM-UAV Mission with Proteus, October 2002


**S-HIS** scans cross-track downward & looks upward

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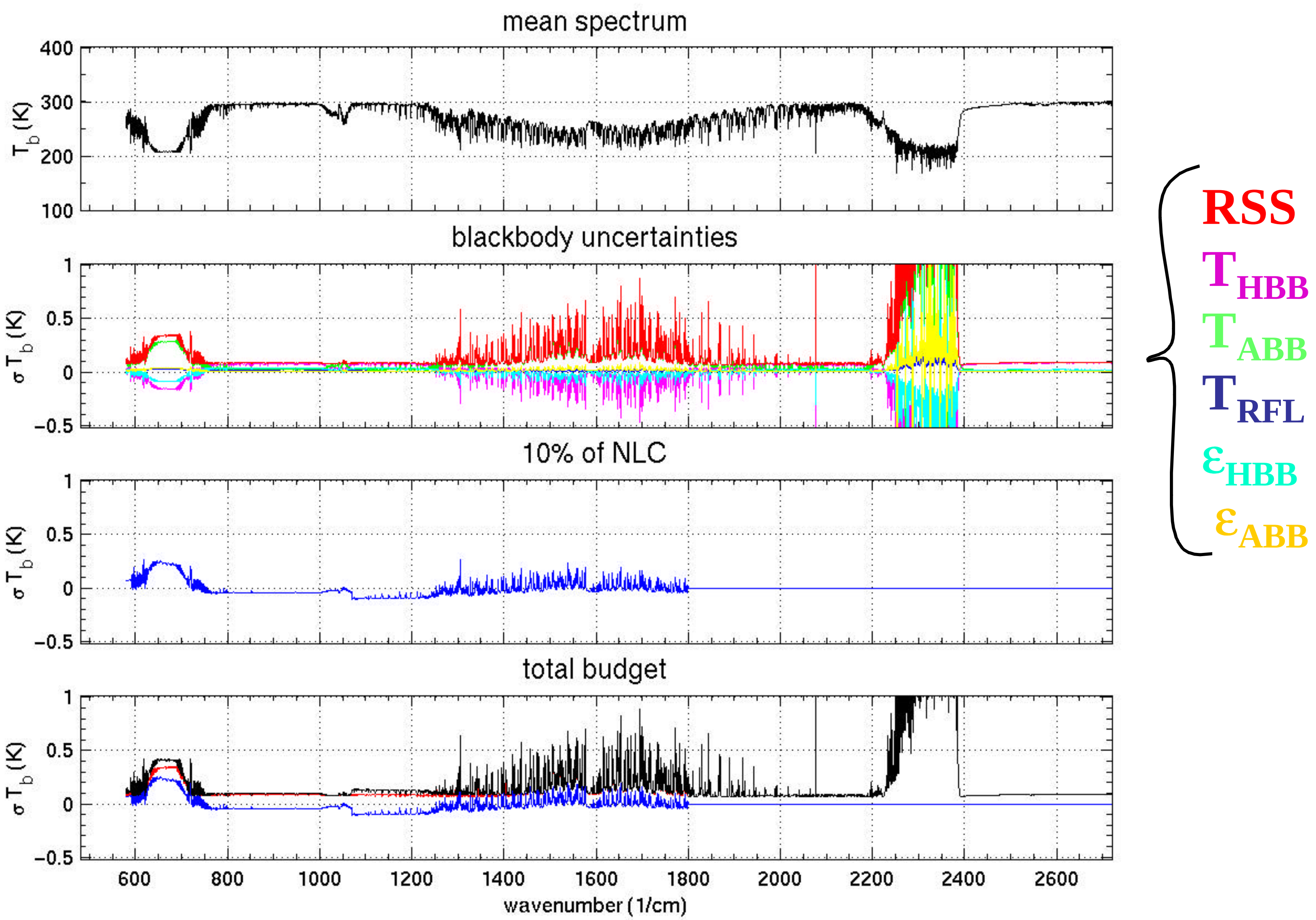

# Calibration Errors at 1600 $cm^{-1}$

| **Input Parameters** | | | **Uncertainties** | | |
|---|---|---|---|---|---|
| wn | **1600** | Wavenumber, [cm-1] | | | |
| Thbb | **310** | Temp. of Hot Blackbody, [K] | $^2$Thbb | **0.1** | [K] |
| Tcbb | **260** | Temp. of Cold Blackbody, [K] | $^2$Tcbb | **0.1** | [K] |
| Tstr | **240** | Temp. of Structure Reflecting into BB's, [K] | $^2$Tstr | **5** | [K] |
| Ehbb | **0.999** | Emissivity of HBB, [-] | $^2$Ehbb | **0.001** | [-] |
| Ecbb | **0.999** | Emissivity of CBB, [-] | $^2$Ehbb | **0.001** | [-] |

# Calibration Errors at 1600 $cm^{-1}$

| Input Parameters | | | Uncertainties | | |
|---|---|---|---|---|---|
| wn | **1600** | Wavenumber, [cm-1] | | | |
| Thbb | **310** | Temp. of Hot Blackbody, [K] | $^{2}$Thbb | **0.1** | [K] |
| Tcbb | **227** | Temp. of Cold Blackbody, [K] | $^{2}$Tcbb | **0.1** | [K] |
| Tstr | **240** | Temp. of Structure Reflecting into BB's, [K] | $^{2}$Tstr | **5** | [K] |
| Ehbb | **0.999** | Emissivity of HBB, [-] | $^{2}$Ehbb | **0.001** | [-] |
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# Impact of Various ABB Temperatures

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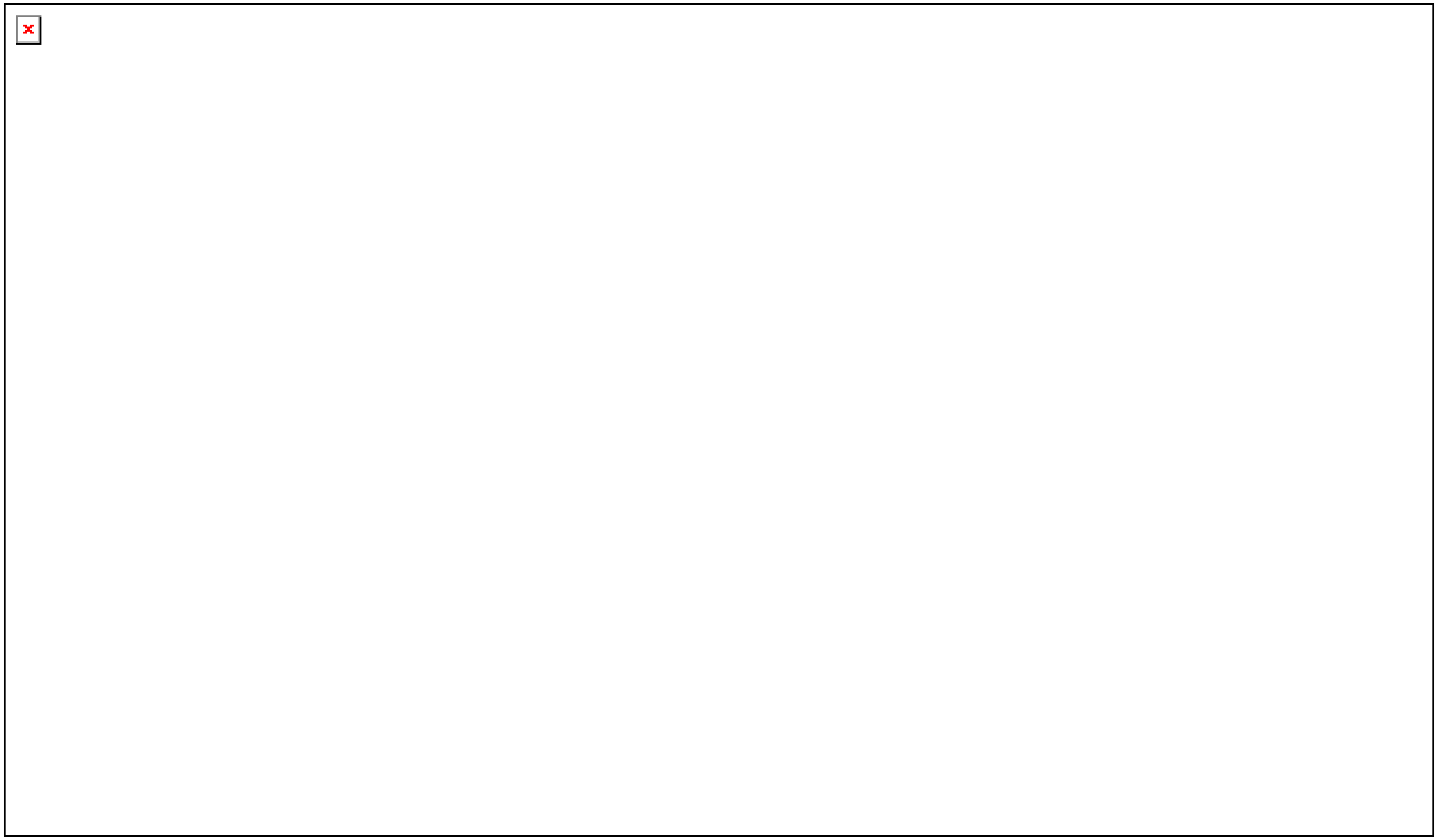

Important to have ABB well coupled to Ambient Temperature

# Scanning-HIS Radiometric Calibration Budget for 11/21 case

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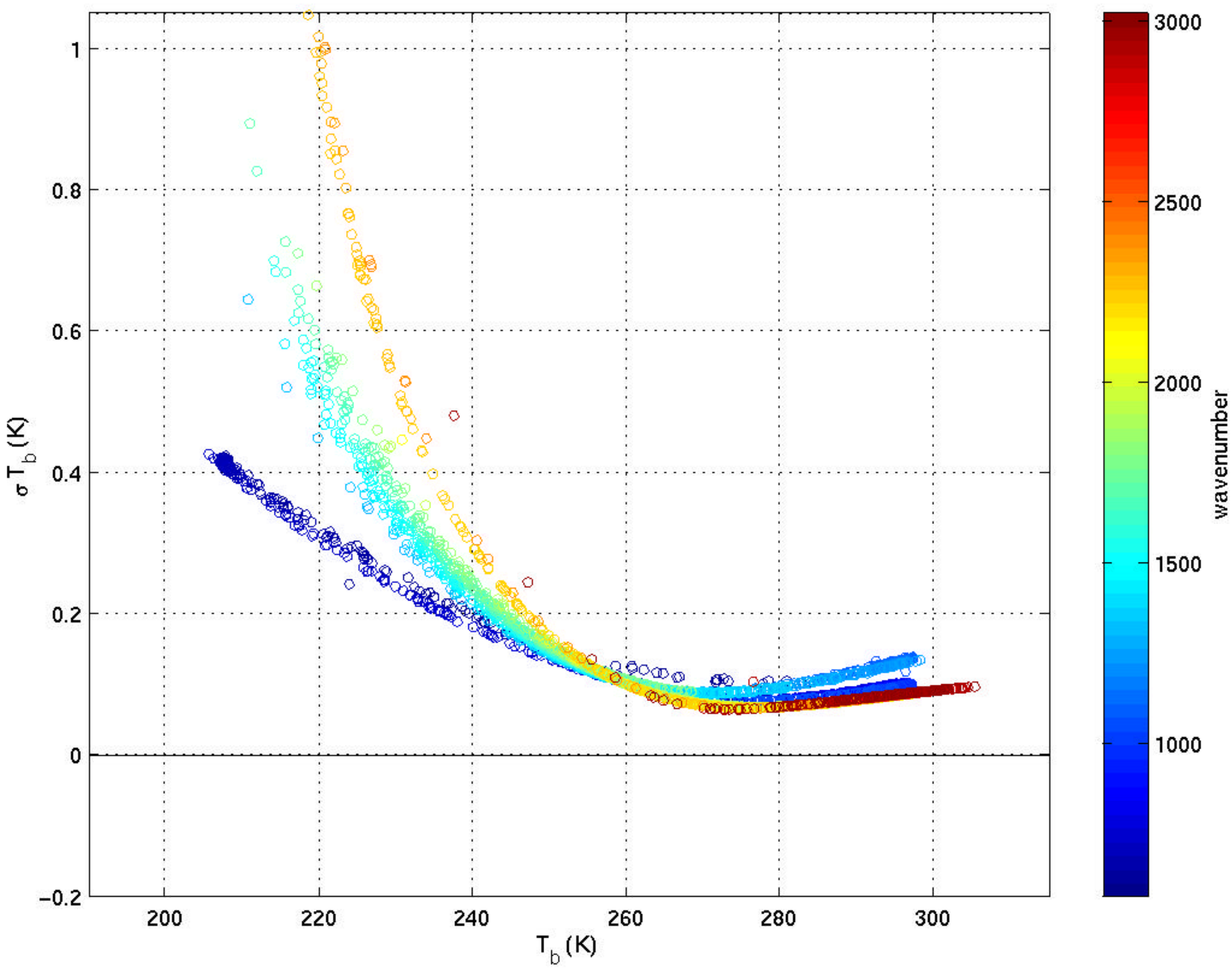

# Scanning-HIS Radiometric Calibration Budget for 11/16 case

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