Status of Cross-Track Infrared Sounder (CrIS) Pre–launch Calibration

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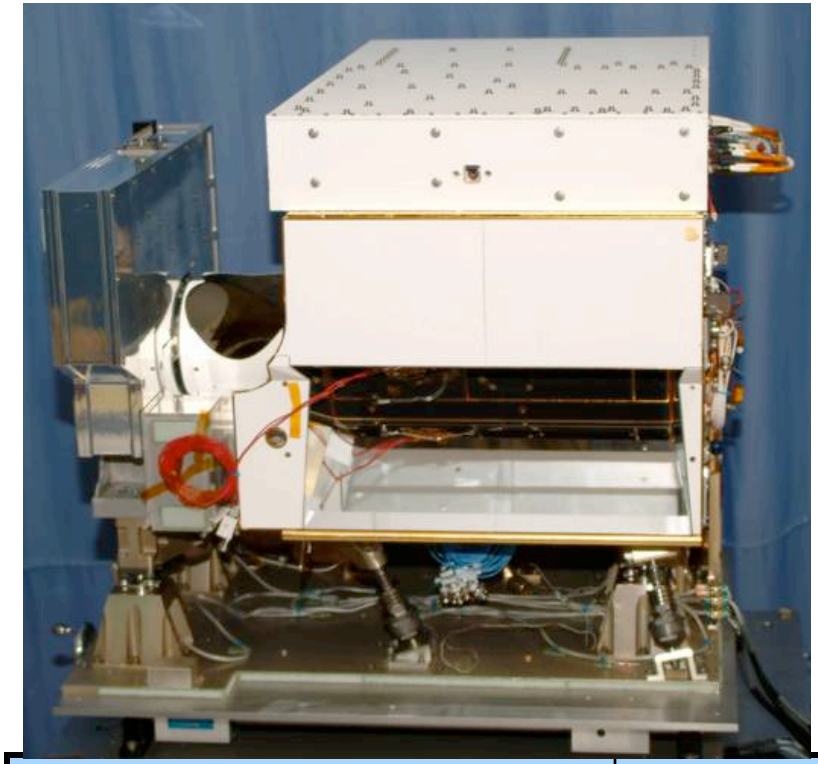
Objectives

- Describe status of evaluation of CrIS TVAC suite of measurements, including radiometric noise, linearity and spectral calibration data

- Provide overview of current efforts to achieve accurate characterization transfer of External Calibration Target (ECT) to the instrument Internal Calibration Target (ICT).

CrIS Sensor Overview



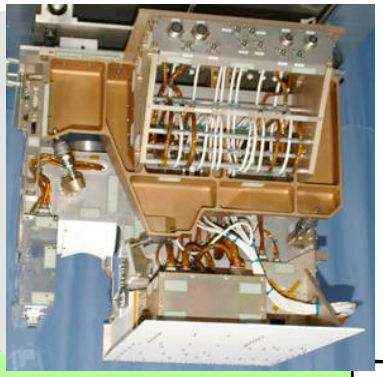
	Spec
Mass, kg	165
Average Power, Allocation W	106/117
Average Data Rate, Mbps	1.5

- The Cross-track Infrared Sounder (CrIS) is a Key Sensor for NPP and NPOESS
  - Fourier Transform Spectrometer providing high resolution IR spectra:
  - Fields of Regard with 3 x 3 FOVs
  - Photovoltaic Detectors in all 3 bands
  - 4-Stage Passive Detector Cooler
  - 14 km nadir FOV spatial resolution
  - 2200 km swath width
  - On-board internal calibration target
- Supplier: ITT Industries
- Key subcontractors:
  - **ABB Bomem**: Interferometer, ICT, SDR Algorithm
  - **DRS**: Detectors
  - **AER**: EDR Algorithm

Band	Wavelength Range (cm-1)	(μm)	Sampling (cm-1)	No. Chan.
SWIR	2155-2550	4.64-3.92	2.5	159
MWIR	1210-1750	8.26-5.71	1.25	433
LWIR	650-1095	15.38-9.14	0.625	713

CrIS Sensor Overview

- CrIS
- ATMS



***RDR** = Raw Data Record*
***SDR** = Sensor Data Record*
***EDR** = Environmental Data Record*

RDRs

CrIS Swath 2200km

ATMS Swath 2500km

3x3 Array of CrIS FOVs (Each at 14-km Diameter)

Central or Regional Ground Stations

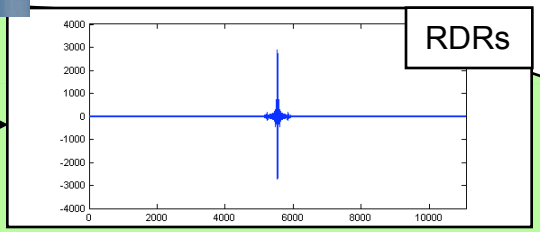
Decode Spacecraft Data

Co-located ATMS SDRs

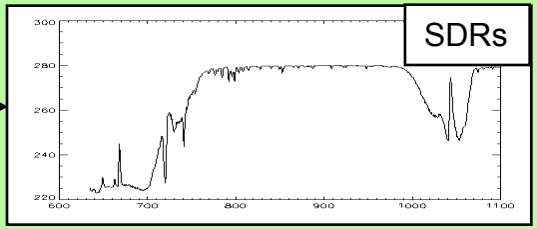
SDR Algorithms

EDR Algorithms

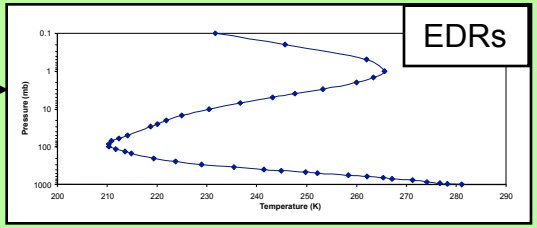
RDRs



SDRs



EDRs



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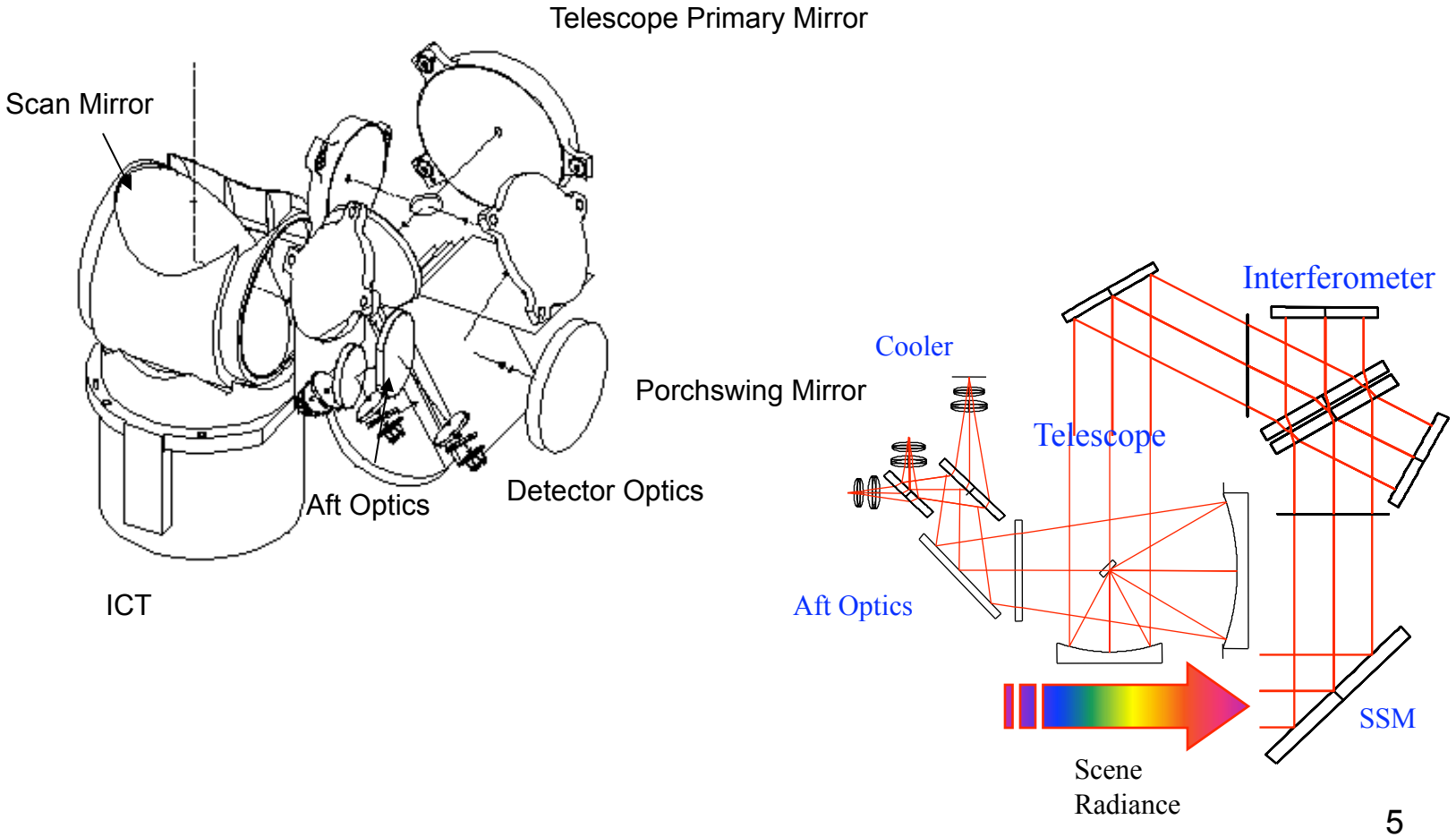
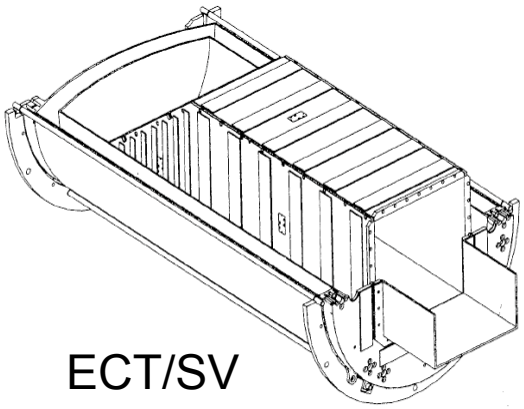
CrIS Sensor: Optical Schematic Showing Key Components for Onboard Calibration



Targets for CrIS Calibration

- CrIS Internal Calibration Target ICT: Key Features
  - Enhanced Martin Black diffuse anodized coating
  - Relatively deep cavity
  - 4 NIST-traceable 4-wire PRTs (2 per side)
  - Passive thermal design allows ICT temperature to float with instrument; when combined with nearly isothermal instrument surroundings and SDR environmental model, radiometric errors due to non-ideal emissivity are small
  - Proven space heritage (MOPITT)
- CrIS External Calibration Target ECT: Key Features
  - Wedge cavity multiple bounce specular cavity with emissivity>0.995 provided by ABB/Bomem
  - Estimated ECT temperature uncertainty 69 mK, based on capsule-type standard PRT (Rosemount model 162D)
  - Calibration over temperature range 200-310 K against Secondary Standard PRT
- CrIS Spaceview Target SV: Most Key Features same as ECT
- Gas Cell Measurements
  - Hot temperature blackbody measurements of gas cells filled with CO2 (LWIR), CH4 (MWIR) and HBr (SWIR)

ICT



ECT/SV Schematic

TVAC Calibration Critical for CrIS SDR Algorithm

- TVAC measurements used to derive and tune coefficients in the SDR algorithm
- Raw Data Records (RDR) contain engineering data packets populated pre-launch with required coefficients for full spectral/ radiometric calibration
- Calibration coefficients transmitted to ground together with CrIS interferogram telemetry data, including interferogram identifiers and quality control data
- Some tuning of TVAC calibration coefficients anticipated on orbit

CrIS TVAC Testing Comprehensive

- All CrIS system level TVAC testing has been performed including
  - Cooler, cold start, survival heaters
  - EMI
  - Vibration
  - Dynamic interaction
  - Thermal cycling and balance
  - FOV Slit and Spot Scan
  - Radiometric calibration at 3 different instrument temperature regimes
  - Spectral measurements (Gas Cell) at 3 different instrument temperature regimes (e.g. Mission Nominal, Protoqual Low and Protoqual High)
  - Scan scenario (multiple orbits)

- TVAC testing continues with EDU3 ICT
  - TVAC tests showed lower than expected FM1 ICT effective emissivity
  - Original FM1 ICT emissivity degrades radiometric performance
  - Preliminary testing shows EDU3 ICT emissivity performance near specification levels
  - TVAC radiometric regression testing for EDU3 ICT in progress

CrIS Pre-launch Test Phases

- System Integration
- Bench Level Testing
- EMI Testing
- Vibration
- Post Vibe/Bench Testing
- Thermal Vacuum Testing (see following chart)
- Post Environmental Bench
- Thermal Vacuum Regression Testing (in progress)
- Post TVAC Workmanship-level Vibration and Magnetic Moment Testing

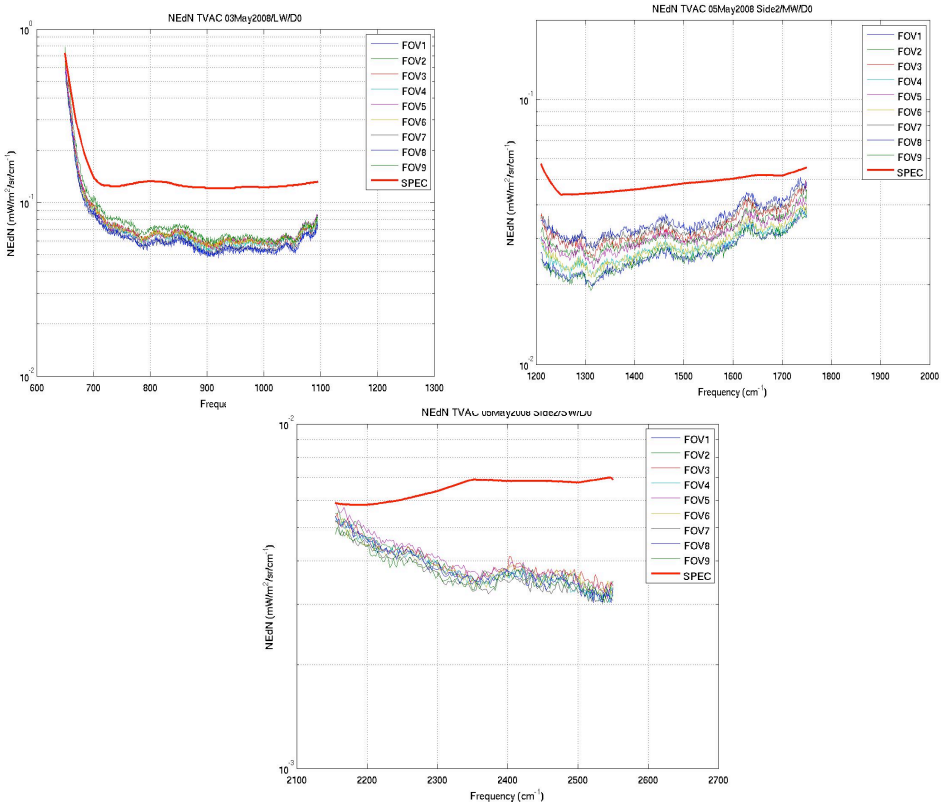
Summary of TVAC Data Analyses Performed

- NEdN Trending
- Spectral overlay and comparisons with line-by-line models
- Non-linearity
- Short and long term repeatability
- Target effective emissivity retrievals
- Spatial registration/spot size and center positions
- Scan scenario
- Dynamic Interaction effects

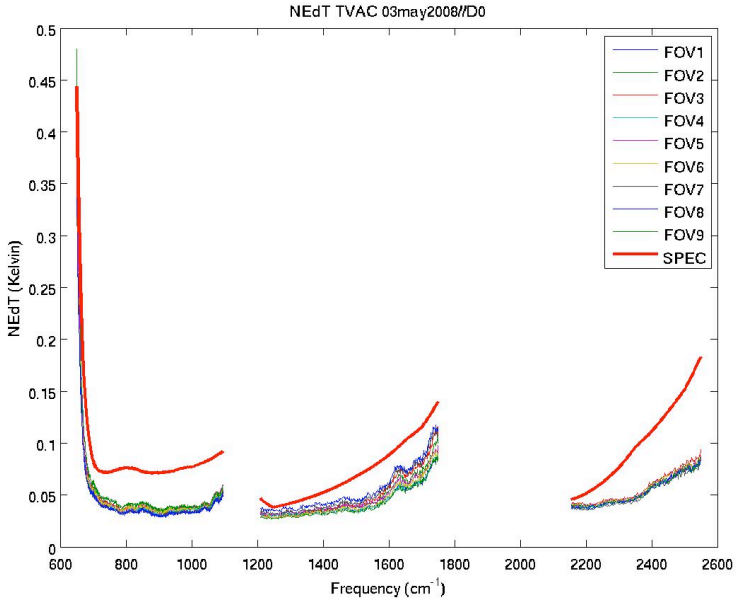
CrIS SDR Analysis Teams

- Several groups contribute to the CrIS pre-launch calibration, including verification of SDR algorithm:
  - ITT (Instrument Vendor)
  - Government Specialists
    - UWisc SSEC
    - MIT
    - SDL
  - NGST
- Teams collaborate in data analyses, trouble-shooting, correction techniques; generally reach consensus on paths forward through bench and TVAC testing
- Results of several key analyses presented at CALCON conference (See papers by D. Tobin, M. Esplin, L. Strow, R. Glumb, J. Predina et al.)

Instrument Noise Is Excellent



NEdN – Mission Nominal Plateau TVAC



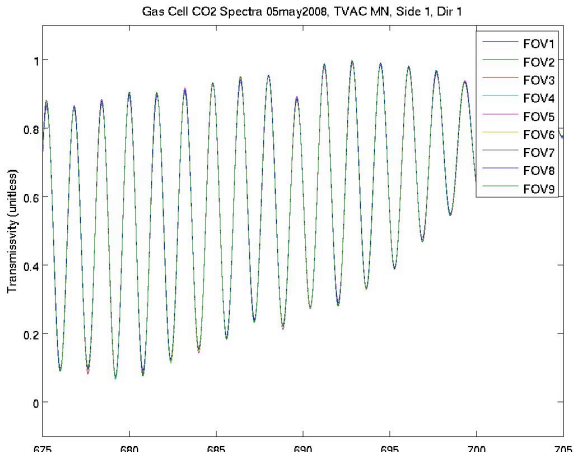
NEdT – Mission Nominal Plateau

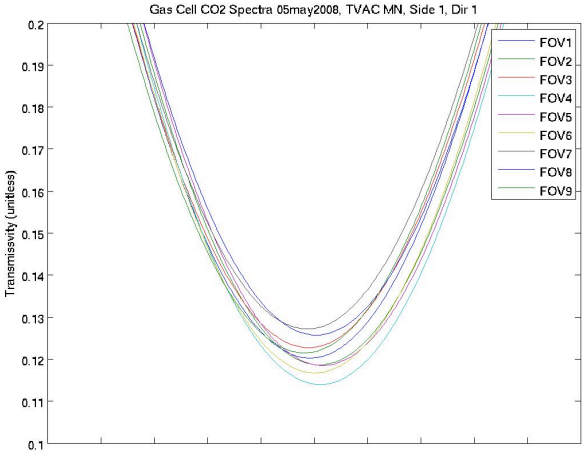
NEdN with considerable margin relative to performance specification; shows some correlation of noise from FOV to FOV

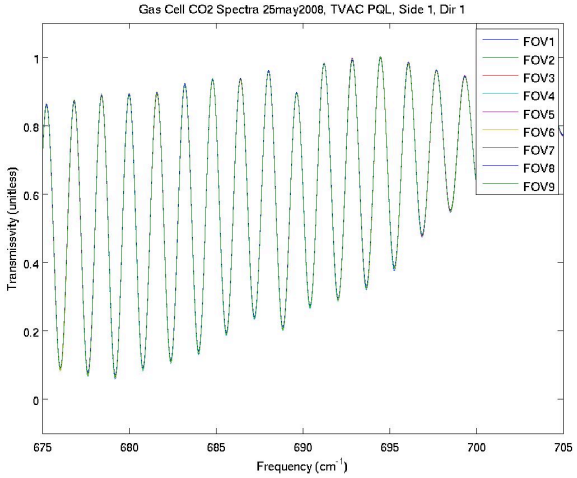
Instrument Line Shape

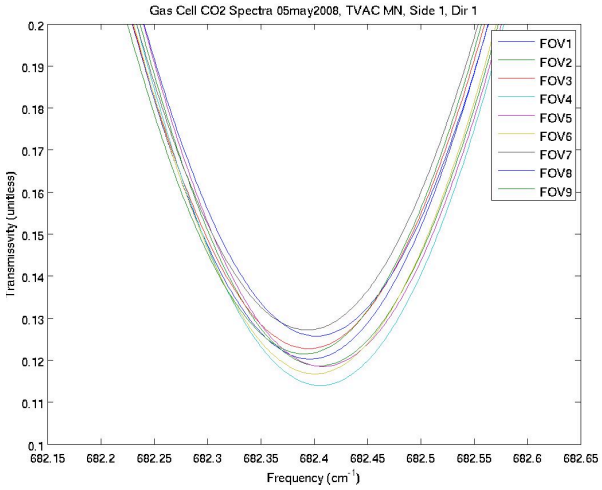
CrIS Spectral Overlay (9 FOVs) LWIR CO2 Transmissivity

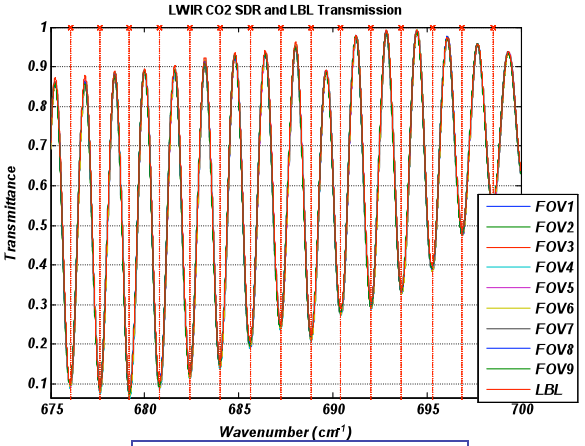
MN











Data vs. line-by-line spectral calculation by ITT

PQL

CO_2 Spectral Region

Expanded view at 682 cm^{-1}

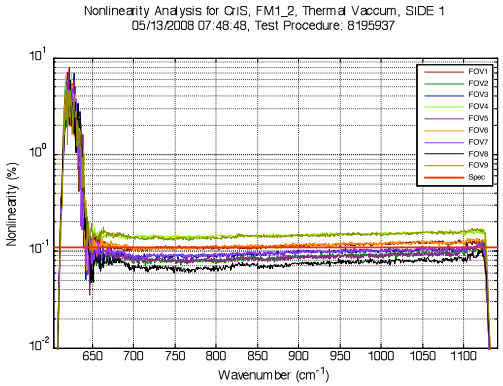
FM1 meets FWHM spec allocation with margin (better than 5 ppm)
ILS correction results in less than 0.2% peak to peak residual error

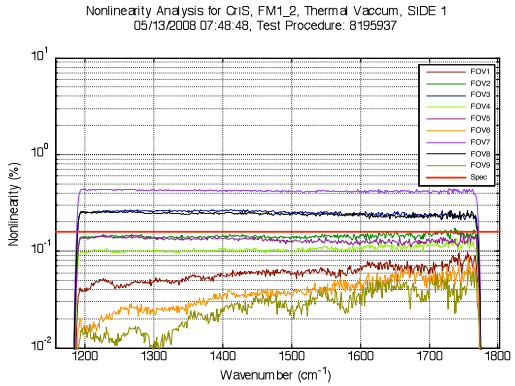
Instrument Non-linearity

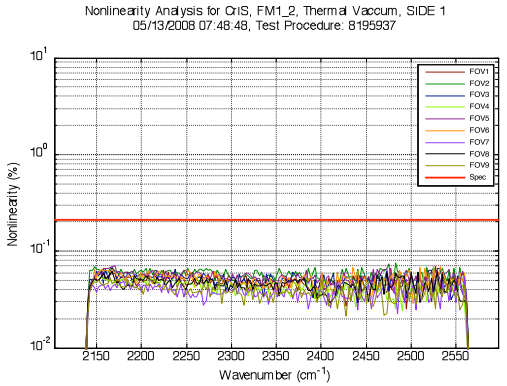
Non-linearity highest in MWIR (~0.5%); smallest in SWIR; significant variation from detector to detector, but stable

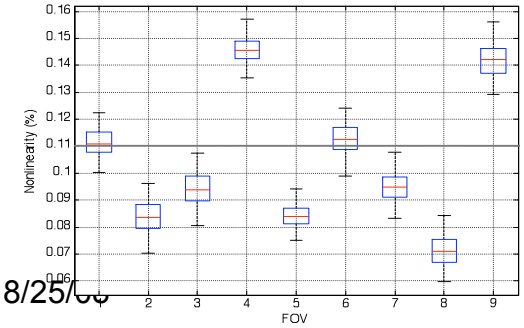
Non-linearity repeatable effect that can be effectively minimized by corrections in SDR algorithm

Studies indicate corrections can be made to within very small radiance errors (0.1%) over most of the instrument Earth scene measurement range

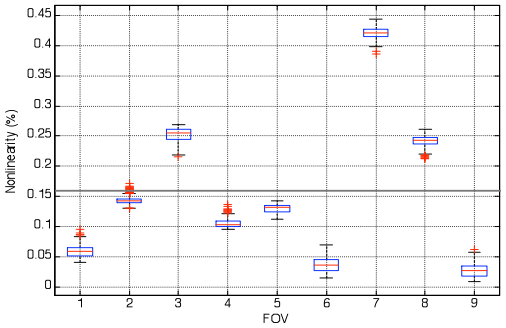




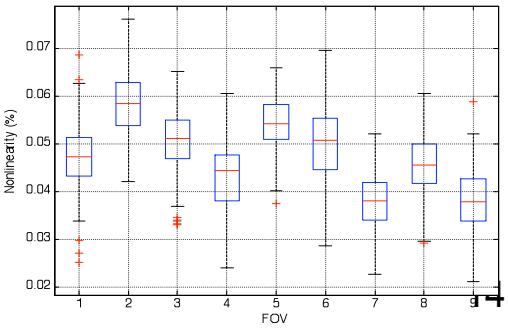




LWIR



MWIR

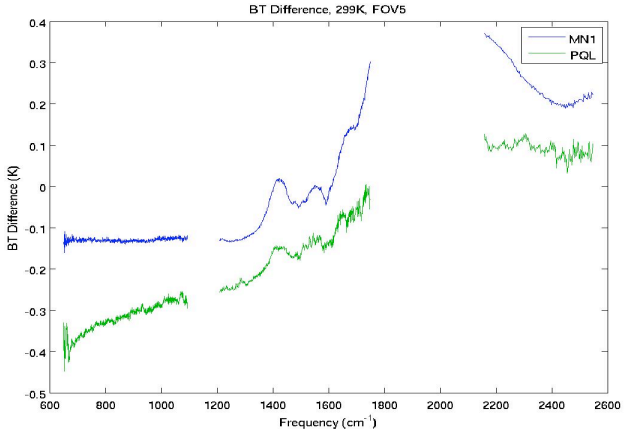


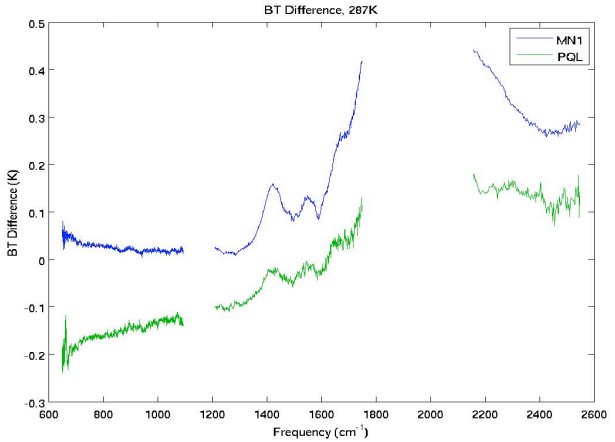
SWIR

Radiometric Accuracy (1 of 3)

- Three primary sources of radiometric calibration error
  - Non-linearity
  - ICT radiance error
  - ECT/ICT temperature bias errors

- FM1 TVAC measurements show evidence of wavelength dependent calibration bias error
  - Direct measurement of FM1 ICT radiance using ECT as reference results in lower than expected ICT radiance observed in MWIR and SWIR bands
  - Magnitude of error varies with scene temperature, instrument temperature and FOV
  - Radiance error as large as 1-2% due to combination of non-linearity, ICT emissivity anomaly and ECT temperature offset



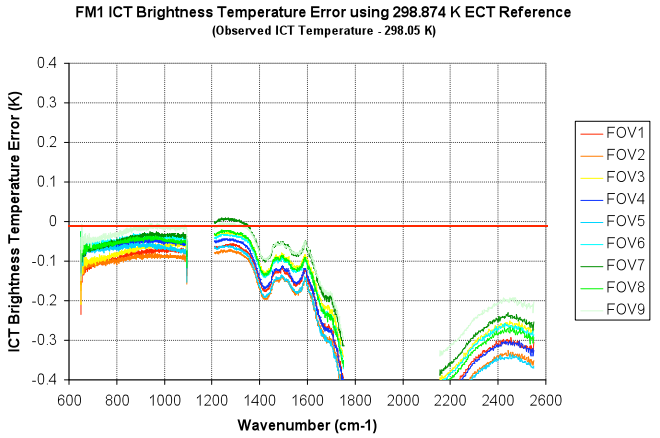


Temperature difference between measured scene brightness temperatures and in situ ECT reference temperature at two different instrument temperatures for FM1 ICT

Radiometric Accuracy (2 of 3)

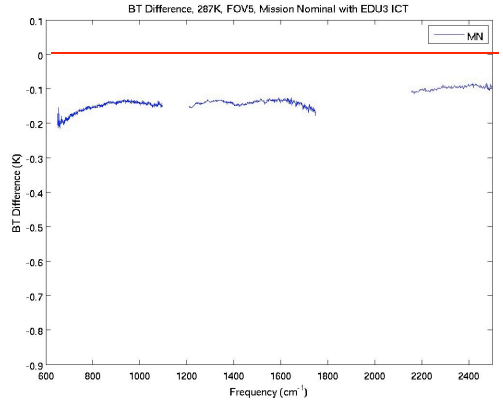
- EDU3 ICT TVAC measurements show significantly less wavelength dependent calibration error - note flatness of curves
- Temperature difference relative to external calibration target is reduced
- Plots show ECT PRT reference temperature minus retrieved ICT brightness temperature

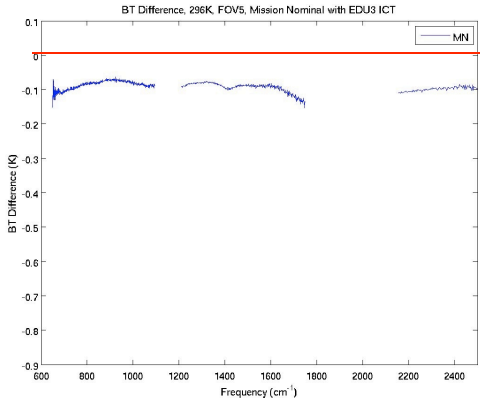
ITT EDU3 ICT Results – all FOVs



ITT FM1 ICT Results – all FOVs

NGST EDU3 ICT Results FOV5 @287 K

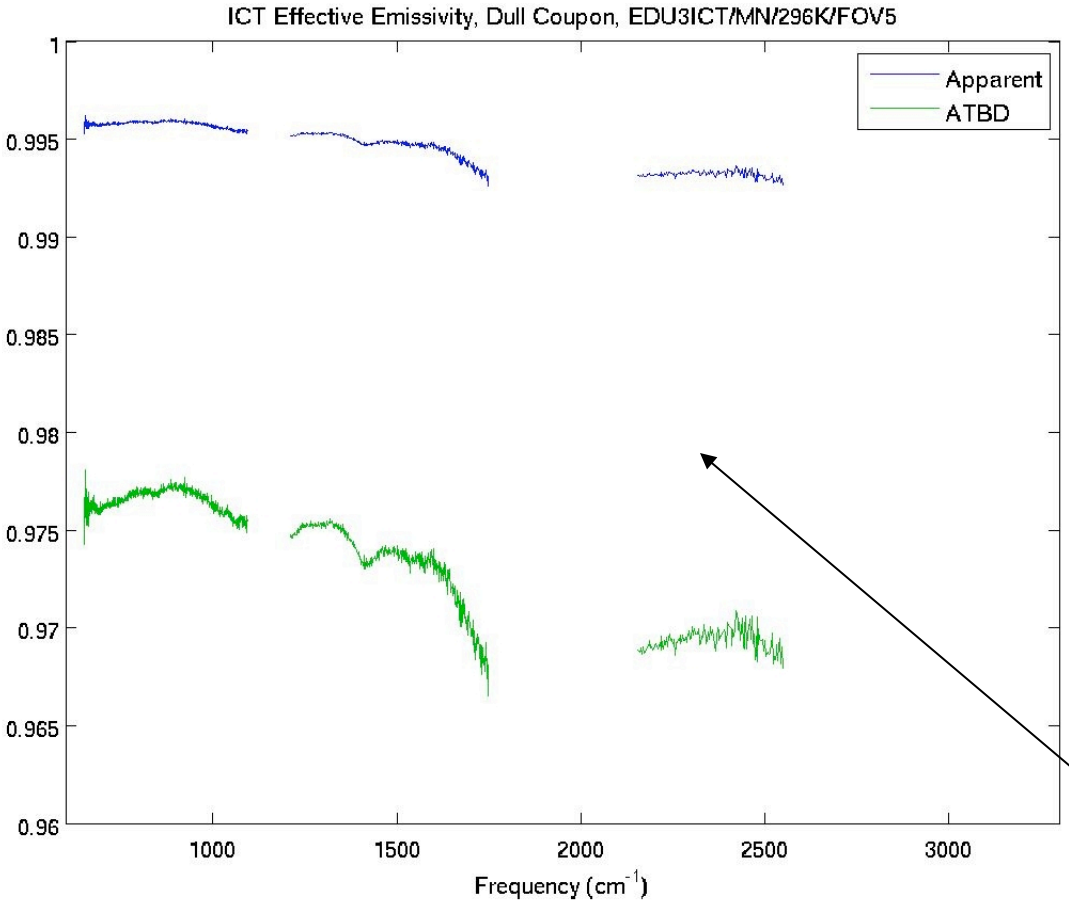




NGST EDU3 ICT Results FOV5 @296 K

Radiometric Accuracy (3 of 3)

- Preliminary retrieved EDU3 ICT effective emissivity close to expected values based on NIST measurements of coating coupon B 'dull' Enhanced Martin Black



Apparent = Retrieved effective emissivity without modeling radiance reflected by external environment surrounding ICT

ATBD = Retrieved effective emissivity including radiance reflected by external environment surrounding ICT, adapted from Algorithm Theoretical Basis Document

Recent test results from ITT using transfer radiometer show effective emissivity 0.98 at ~2500 cm^{-1}

FM1 Calibration Work

- Calibration of ECT/ICT PRTs performed
  - ECT thermal equilibrium soak in vacuum chamber; all ECT PRTs calibrated to NIST ITS-90 temperature scale using highly characterized reference probes
  - 9 temperature point (230 – K) re-calibration of EDU3 ICT PRTs by ABB (NIST traceable)
- ITT TSSR relative radiance measurements of EDU3 surface emissivity performed
- TVAC radiometric regression testing of EDU3 ICT in progress – includes stepped linearity tests, NEdN, scan scenario, ICT environmental model
- ITT TSSR relative radiance measurements of FM1 ICT cavities for root cause emissivity failure pending

Summary

- High degree of instrument fidelity
  - Better than expected noise performance
  - High spectral accuracy

- Non-linearity correction methodology in work;
  - Worst case non-linearity about 0.5%
  - SDR algorithm updates planned (non-linearity correctable to ~0.1%)

- Absolute ICT radiometric accuracy determination in progress
  - TVAC regression testing with EDU3 ICT replacement unit
    With focus on ICT emissivity model and linearity tests
  - PRT re-calibration traceable to NIST