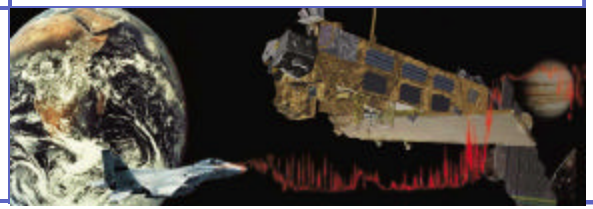
Remote Sensing Team

NASTER System Definition Proposal



Overview

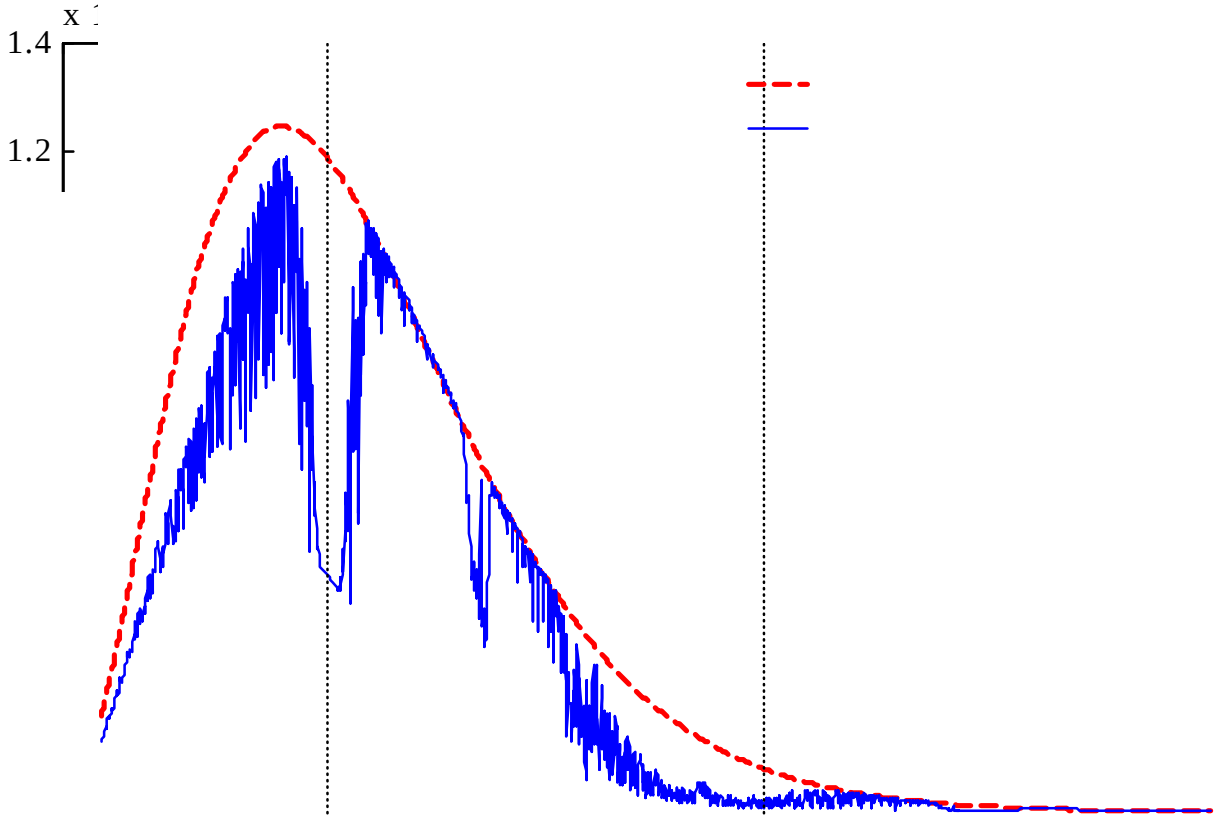
- Review and comment the mid-IR requirements
- Presentation of ABB's current platform technology
- Proposed approach for mid-IR NASTER
- Proposed approach for initial NASTER
- Discussion

Review of Requirements

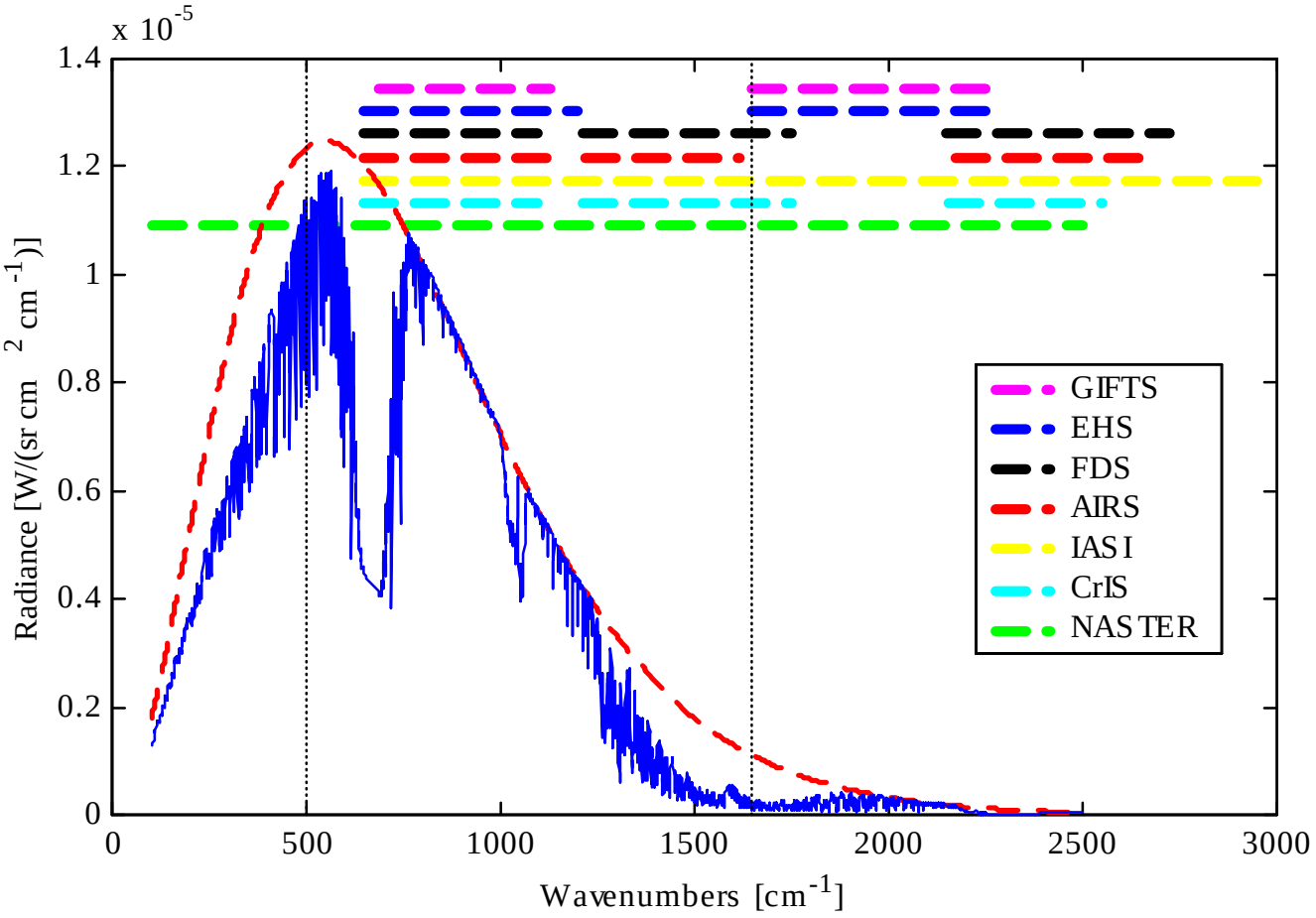
- The first NASTER Strawman requires wide coverage and high spectral resolution
- A modular concept has been developed to address as much as possible the entire specification
- Mid-IR NASTER Strawman requirements are less constraining on the spectral coverage and resolution
- Modules of the initial concept have been used to address this new specification
- We review the Mid-IR requirement first

Mid-IR Requirement Review

- Spectral Limits (SL): 665 - 2860 cm^{-1} (3.5 - 15 microns)
  - We suggest to split the range in 2 bands at 1750 cm^{-1} (5.7 microns)



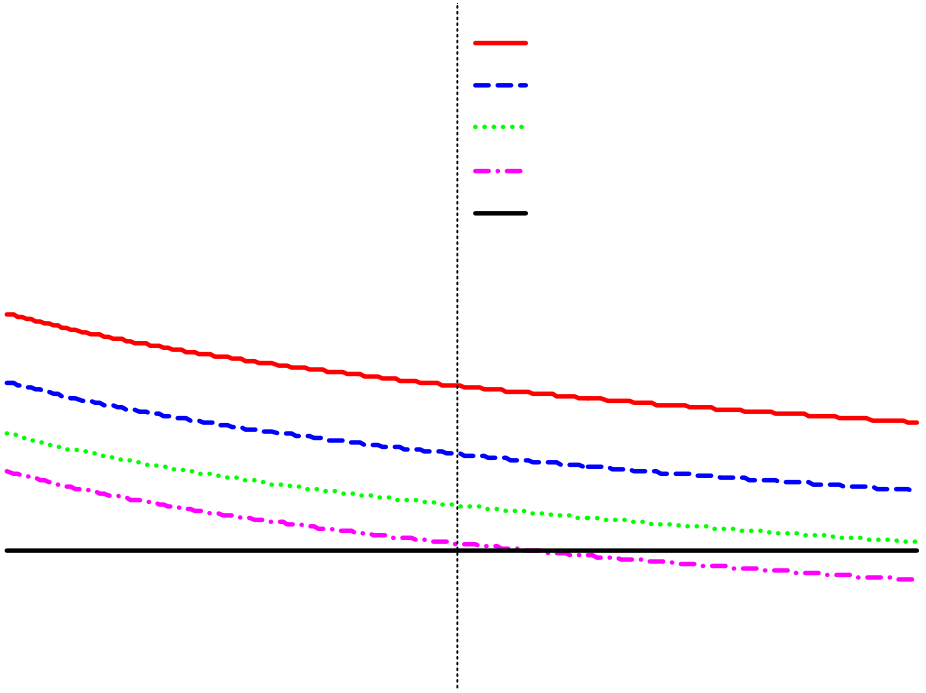
Spectral Coverage



- NASTER seems to be an Application test-bed for HES
- NASTER does not seem to be a Hardware test-bed for HES

Mid-IR Requirement Review

- Spectral Resolution (SR): Selectable from 0.25 - 1.25 cm^{-1}
  - Resolution limits maximum divergence inside interferometer
  - Off-axis pixels result in more constraining limitations
  - We suggest 0.25 cm^{-1} for the mid-wave and 0.5 cm^{-1} for the short - wave and use off-axis IFOV's with an inverse telescope (0.5)



Circular, on-axis

Mid-IR Requirement Review

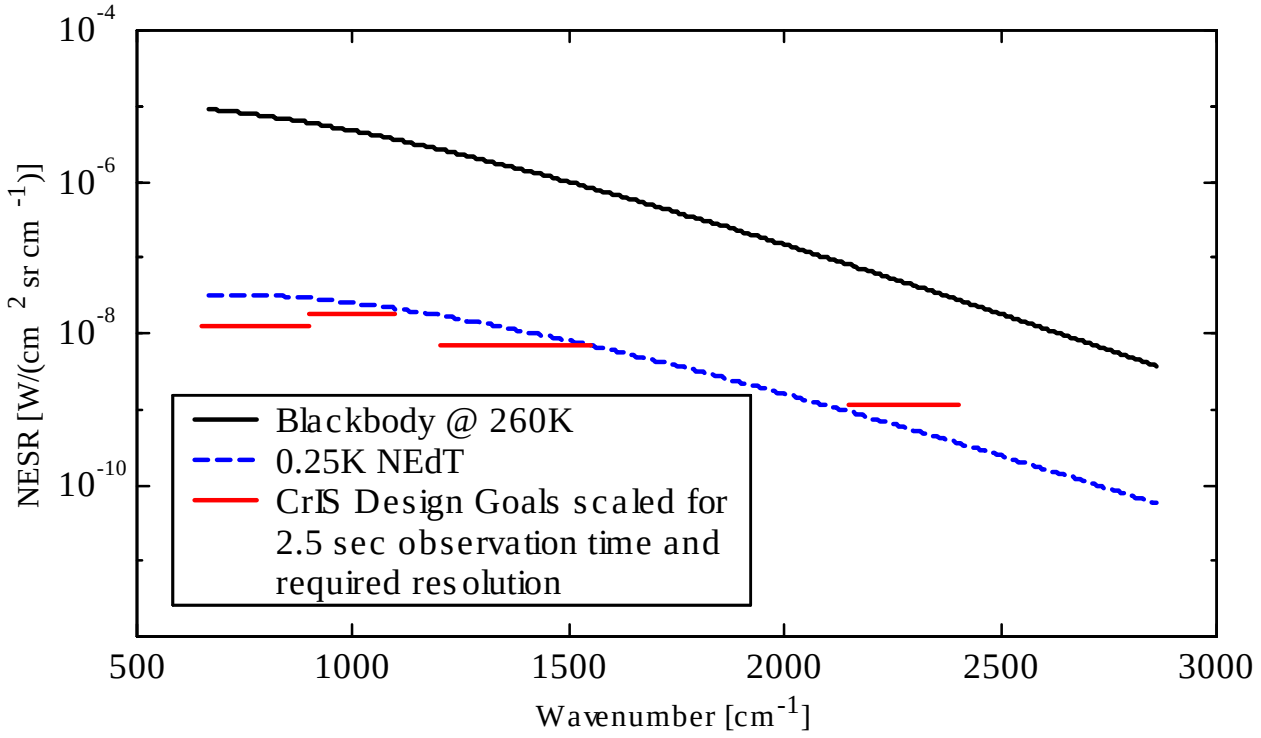
- Ground Resolution (GR): Contiguous at ≤ 500 meters from 20 km flight altitude within single FOR
  - Defines IFOV of 25 mrad
  - We suggest 250 meters ground resolution (12.5 mrad IFOV)
- Field of Regard (FOR): ≤ 2 km from 20 km flight altitude
  - Requirement suggests a 4x4 detector array
  - We suggest an 8x8 detector array to cover the 100 mrad square FOR

Mid-IR Requirement Review

- Along-track Scan Coverage (ATSC): ≤ 2 km FOR contiguity at 20 km for an aircraft speed of 400 kts
  - Speed and IFOV defines observation time of 10 seconds
  - Motion compensation and 10 seconds observation time provide contiguous along-track coverage
- Cross-track Scan Coverage (CTSC): Selectable from 2 to 20 km, depending on spectral resolution, from 20 km flight altitude for an aircraft speed of 400 kts
  - Defines a minimum observation time of 1 second

Mid-IR Requirement Review

- Noise Equivalent delta Temperature (NEdT): Spectrally random brightness temperature ≤ 0.25 K @ 0.25 cm^{-1} spectral resolution within the spectral range of 4.5 to 14 microns scene temperature of ≤ 260 K



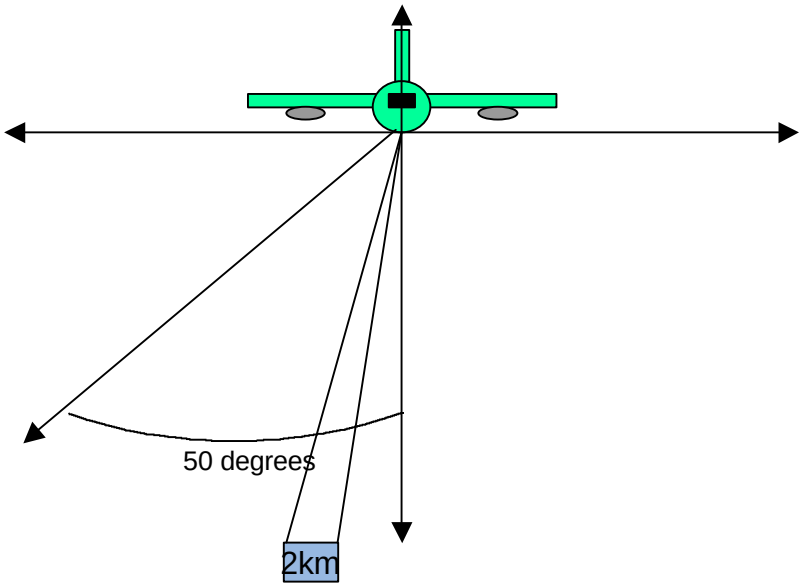
Required performances are similar to Design Goals for CrIS

Mid-IR Requirement Review

- Absolute Error (AE): Absolute brightness temperature error ≤ 0.5 K within the spectral range of 4.5 to 14 microns scene temperature within the 200 - 300 K range
  - Main contributors are radiance uncertainty of calibration targets and non-linearity of detector response
- Calibration Sources (AE): Warm Blackbody, Ambient Blackbody, Zenith Sky view

Mid-IR Requirement Review

- Scan Angle Coverage (SAC): Selectable over a range from zenith (180°) to Horizontal (at either + or - 90°) to any combination of a set of viewing angle steps which together provide contiguous coverage over a range from ±50 degrees about Nadir (0°)
  - Defines the scene selection continuous pointing range of ±50 degrees plus 5 discrete pointing position
  - Requires scanning without FOV rotation



Mid-IR Requirement Review

- Lifetime: ≥ 10 years through parts replacement over time
  - Build the system with standard parts used in commercial standard products
  - Requires a single contractor responsible for the system
    - Contractor must have access to standard spare parts
- Design type: Modular to allow for detector, spatial and spectral resolution, and data system upgrades as technology matures throughout the lifetime of the NASTER
  - Use flexible electronics (digitally controlled interferometer)
  - Provide good transmission over a broad spectral range for the interferometer
  - Provide sufficient resolution capability

Mid-IR Requirement Review

- Operational Requirements: Command Uplink/Data Downlink via over-the-horizon communications
- Aircraft Compatibility: ER-2 (20 km), Proteus (17 km), Global Hawk (20 km), and, if feasible, the new SCI space plane “Spaceship 1” (55 km)
  - Low pressure not seen as a problem with components used

Overview

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ABB's Current Platform Technology

- Current platform technology consists of cube-corner based interferometers
  - Provides low-cost, reliable, products 24/7 unattended operation
  - 4-port, **2-port**, and double-pass
  - Based on wishbone scan arm
  - Permanently aligned
- Flat mirror DA interferometers not used in commercial products
  - Porchswing scanning mechanism only supported for space qualified projects
  - Flat mirror interferometers are optically efficient for large imaging

ABB's Current Platform Technology

- New BMXS electronics
  - Digital scan servo control
    - Programmable scan profile
  - Flexible IR sampling based on high density fringe sampling
    - Constant clock sampling with phase detection
    - Variable OPD sampling
  - Ethernet, LVDS, 10/100 base
  - Embedded Linux
  - May support dynamic alignment

ABB's Current Platform Software

- FTSW100 software suite includes
  - Run time module
    - Continuous spectrometer operation
    - Continuous housekeeping logging and diagnostics using multiple I/O
      - CAN Bus and CAN Open
    - Control of measurement cycles
  - Configuration tools
  - Spectroscopy module
    - Radiometric functions
    - Chemometric functions
  - Database management
    - Propriatary SPC type files
    - Data can be exported to industry standard XML type

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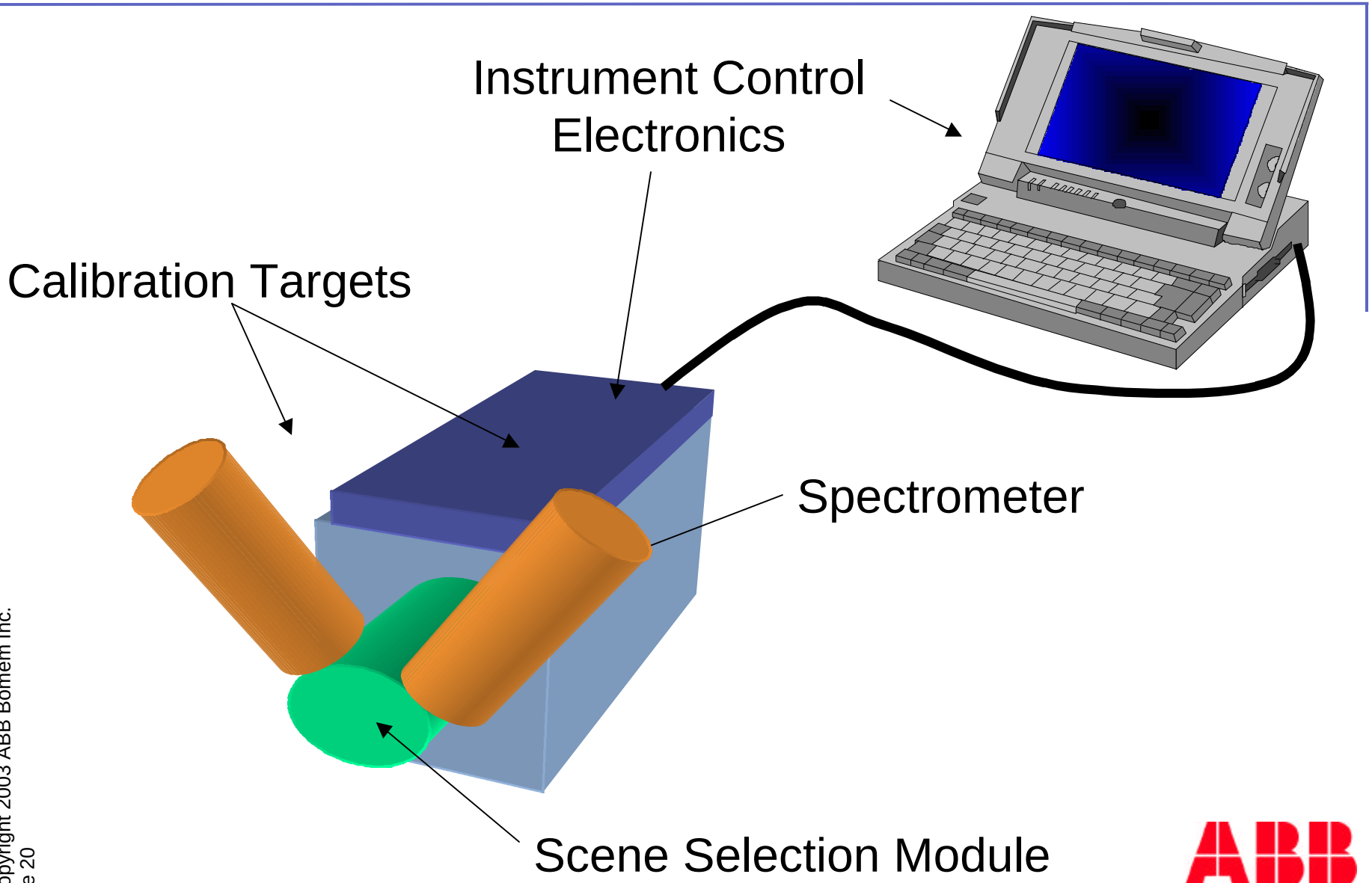
Proposed Approach for Mid IR NASTER

- 2 Spectral Bands with band separation optics at 1750 cm^{-1}
- 2 imaging, fiber coupled, detector modules
- New COTS control electronics with Ethernet link
- Digitally controlled spectrometer
- Double pendulum, cube-corner, interferometer with good efficiency from 300 to 2860 cm^{-1}
- Selectable resolution with 0.075 cm^{-1} as minimum spectral sampling
- ILS compatible with spectral sampling of 0.25 cm^{-1} from 665 to 1750 cm^{-1}, and 0.5 cm^{-1} from 1750 to 2860 cm^{-1}
- 250 meters IFOV at 20 km altitude
- 10 seconds per interferometer sweep for 2 km swath
- 34 mm ∅ entrance pupil. f/1 optics at detector
- 8x8 FOR with contiguous coverage along-track
- Motion compensation pointing mirror
- 2 on-board calibration targets (Ambient and Hot)

Proposed Approach for Mid IR NASTER



Modules Description

Instrument Integration & Support

Scene Selection Module

- Telescope
- Pointing mirror with motion compensation
- Control electronics

Spectrometer

- Interferometer with control electronics
- Output optics
- Detectors and readout electronics

Calibration Targets

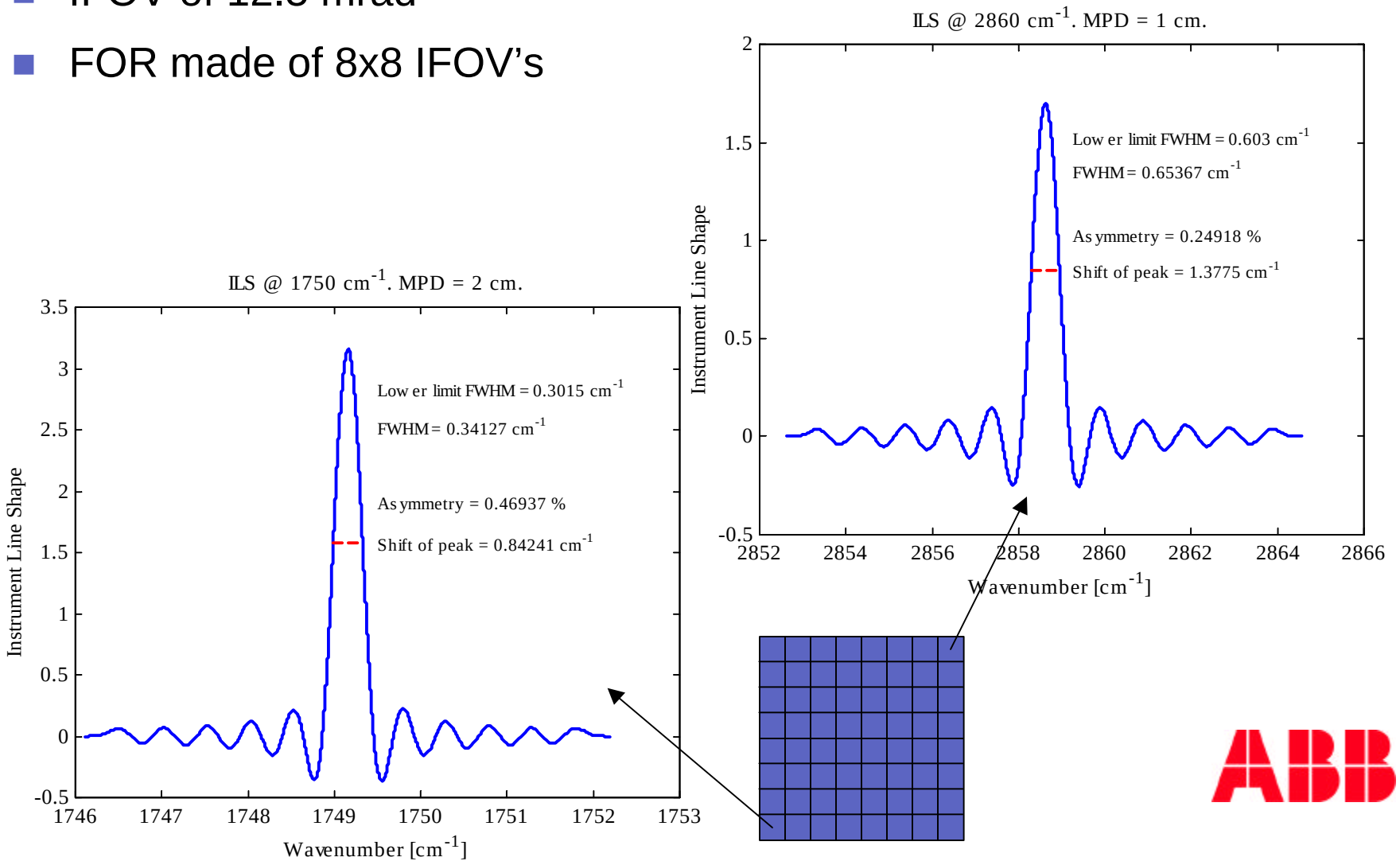
- 1 ambient (passive) cavity
- 1 hot (active) cavity
- Temperature controller

Instrument Control Electronics

- Data management
- Dashboard (user interface)

Mid IR NASTER - Resolution

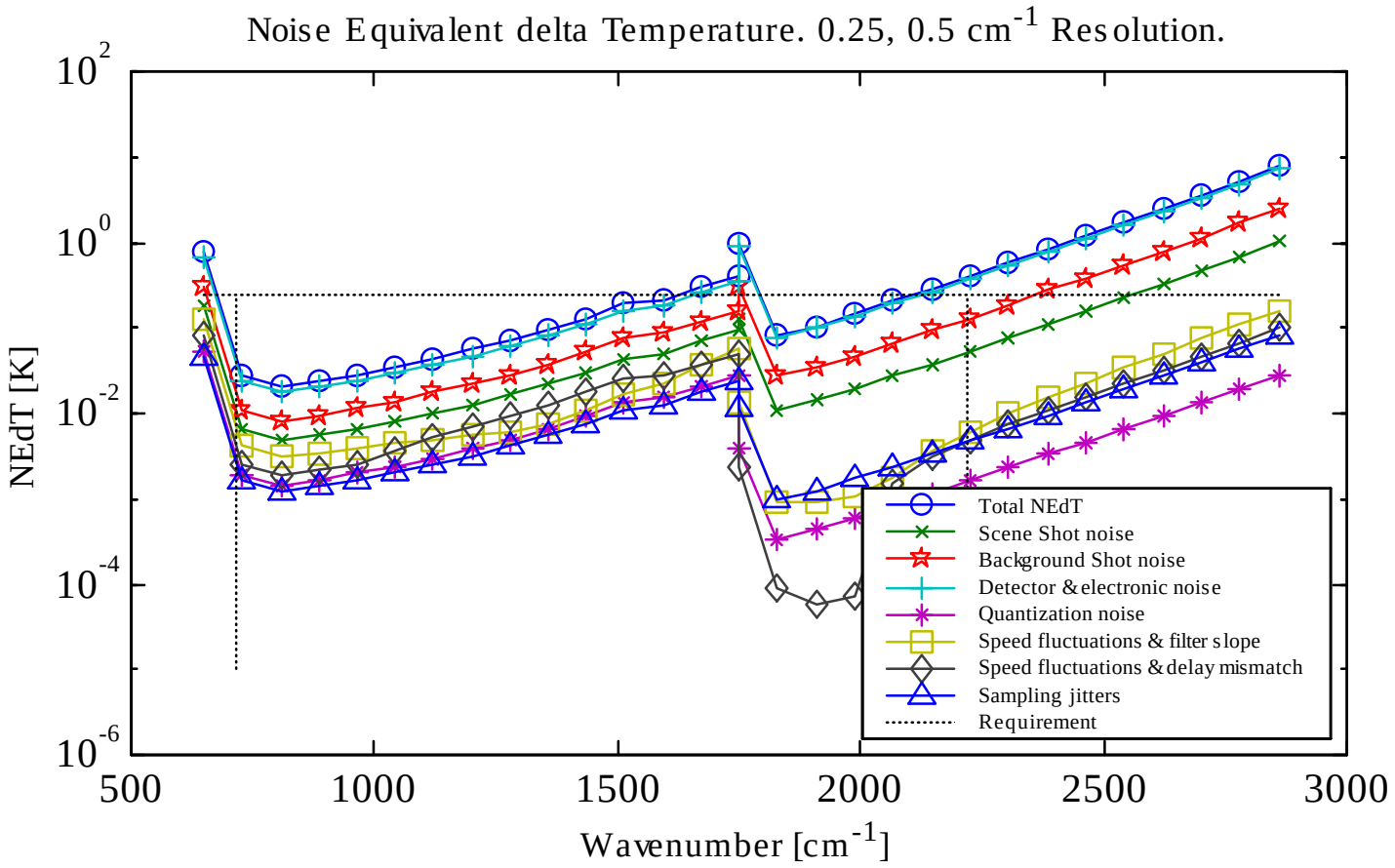
- Inverse telescope to reduce beam divergence inside interferometer
- IFOV of 12.5 mrad
- FOR made of 8x8 IFOV's



Mid IR NASTER - NEdT

- Gold coated mirrors for pointing, telescope, and cube corners
- CsI beamsplitter
- PIR fiber to couple the interferometer to a PC-MCT linear array of 64 elements
- D* of $4x10^{10}$ jones for the LW and $8x10^{10}$ jones for the SW
- LW cut-off at 14.3 microns, SW cut-off at 5.7 microns
- 375 microns pixels (f/1 optics at the detector)
- 10 seconds observation time
- 2x2 pixel aggregation for 500 meters ground resolution
- Instrument temperature at 25°C
- SW is the middle portion of the full interferogram

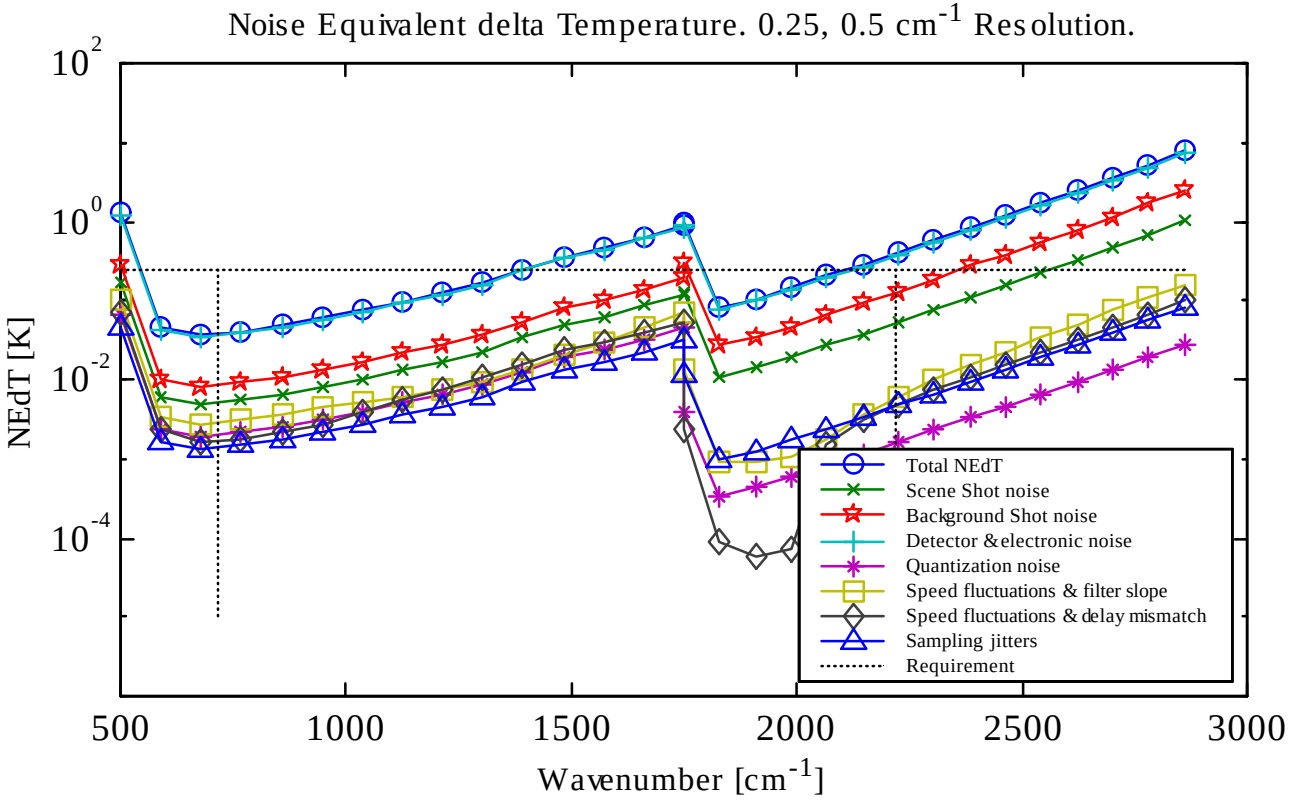
Mid IR NASTER - NEdT



- Detector noise limited
- Second contributor is shot noise from self-emission

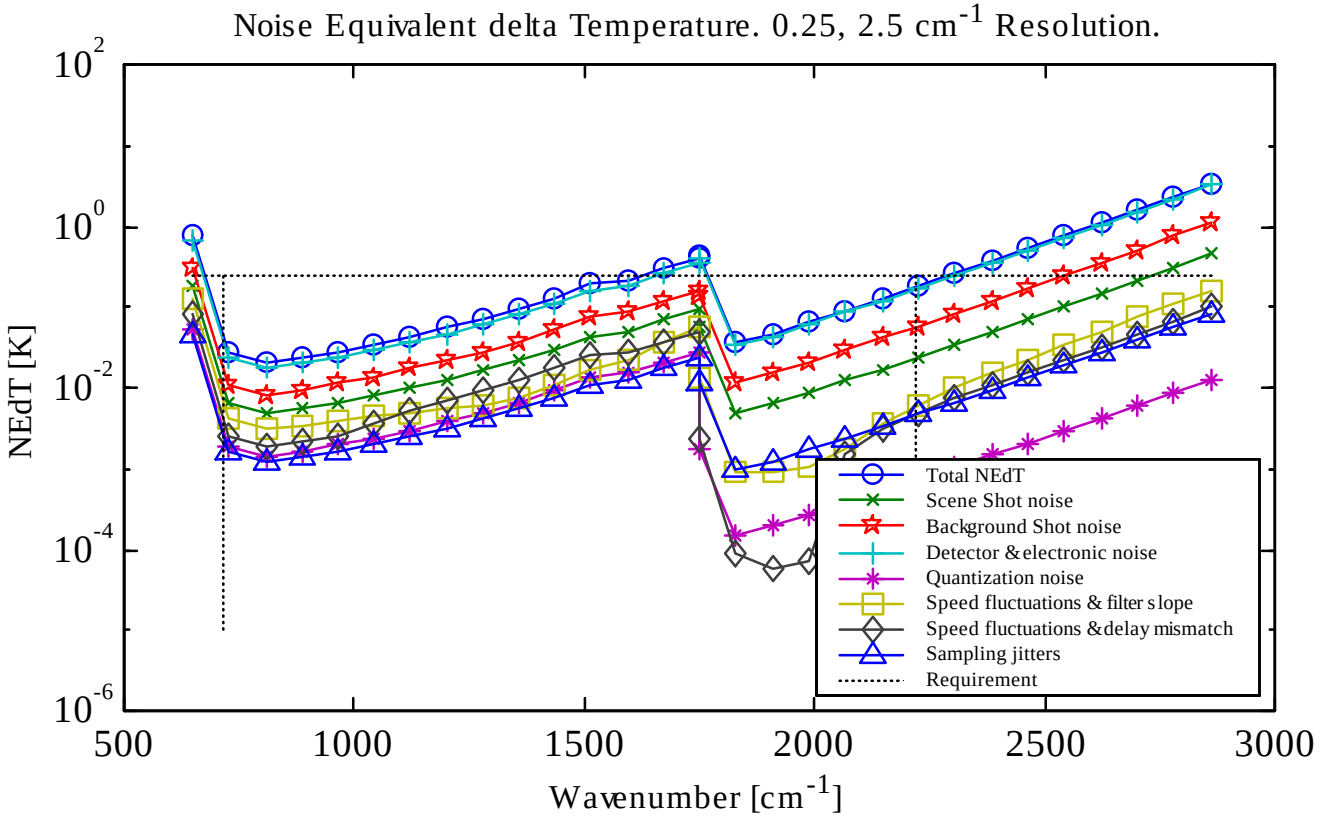
Mid IR NASTER - NEdT

- LW cut-off at 18.2 microns to get the entire CO_2 absorption bands
- D* of $2x10^{10}$ jones for the LW
- Loss of performances in the water vapour bands from 1450 to 1750 cm^{-1}



Mid IR NASTER - NEdT

- Decrease the resolution to 2.5 cm^{-1} in the SW to meet requirement at 4.5 microns



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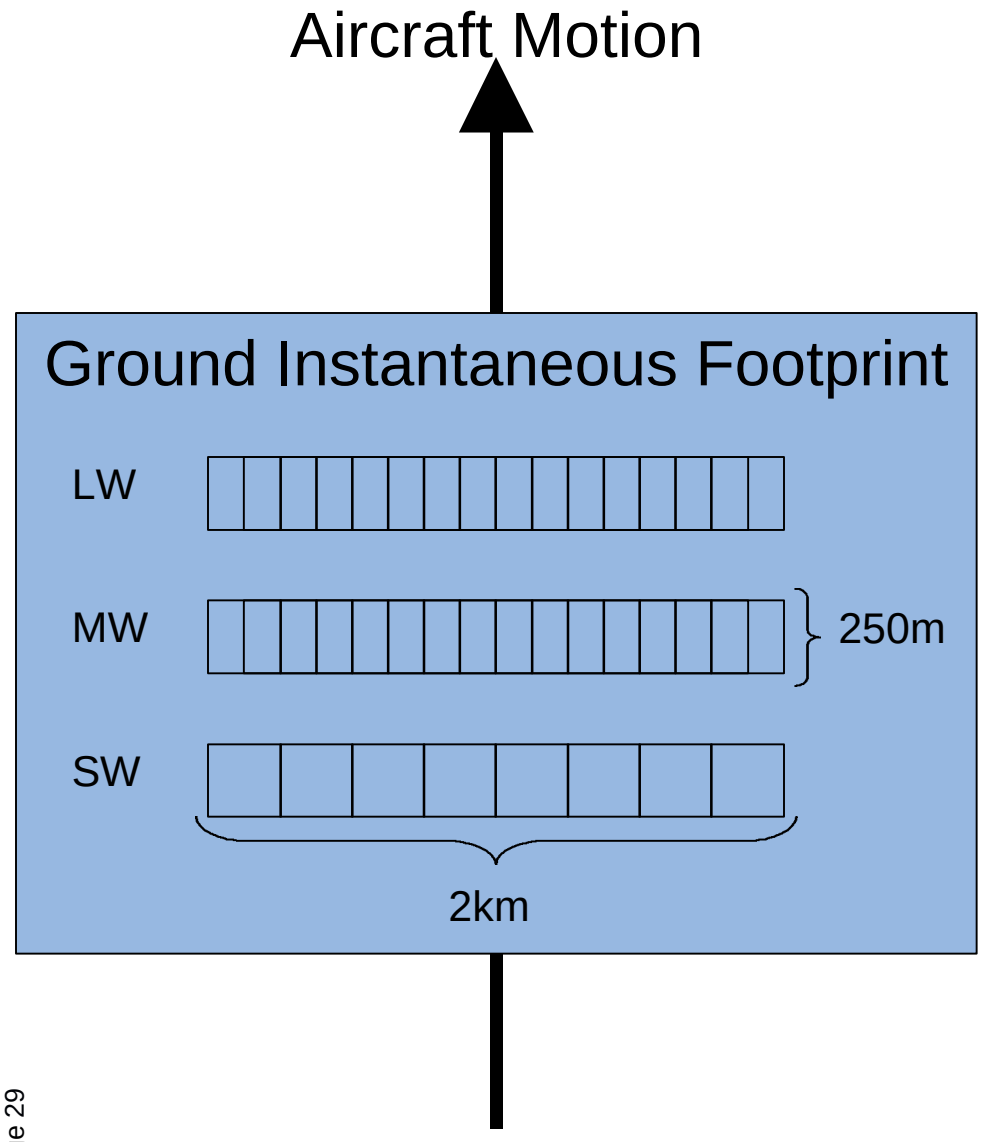
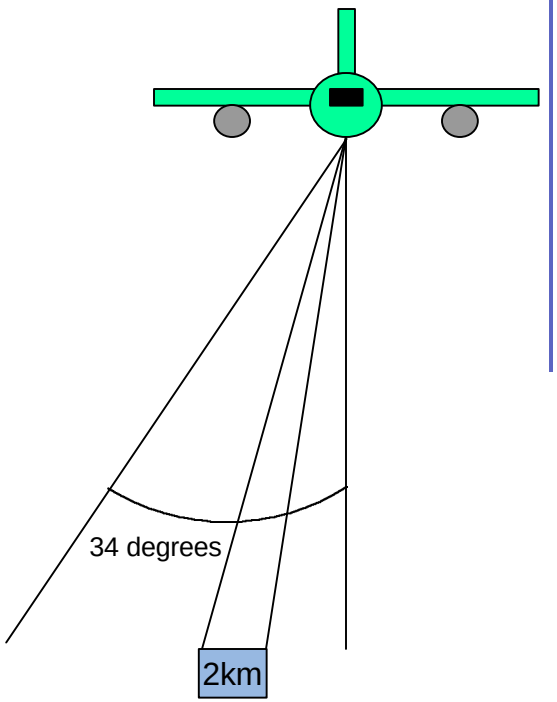
Proposed Approach for Initial NASTER

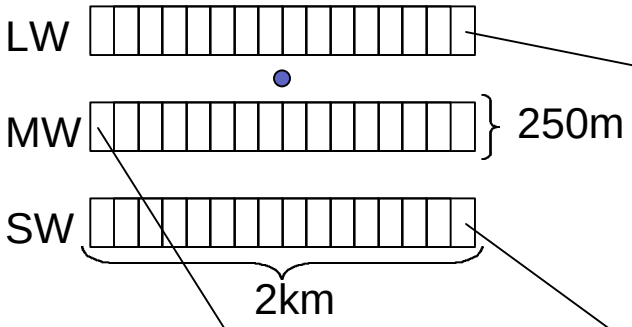
- 3 Spectral Bands (300 to 500 cm^{-1}, 500 to 1650 cm^{-1}, and 1650 to 2550 cm^{-1})
- 3 detectors in 1 Stirling cooler (no band separation optics)
- New COTS control electronics with Ethernet link
- Digitally controlled spectrometer
- Selectable resolution with 0.075 cm^{-1} as minimum spectral sampling
- ILS compatible with spectral sampling of 0.075 cm^{-1} in the LW, 0.25 cm^{-1} in the MW, and 2.5 cm^{-1} in the SW
- 250 meters IFOV
- 1.25 second per interferometer sweep
- 34 mm ∅ entrance pupil. f/1 optics at detector
- 1x8 FOR with contiguous coverage along-track
- +/- 34 degrees cross track scans with motion compensation
- 2 on-board calibration targets (Ambient and Hot)

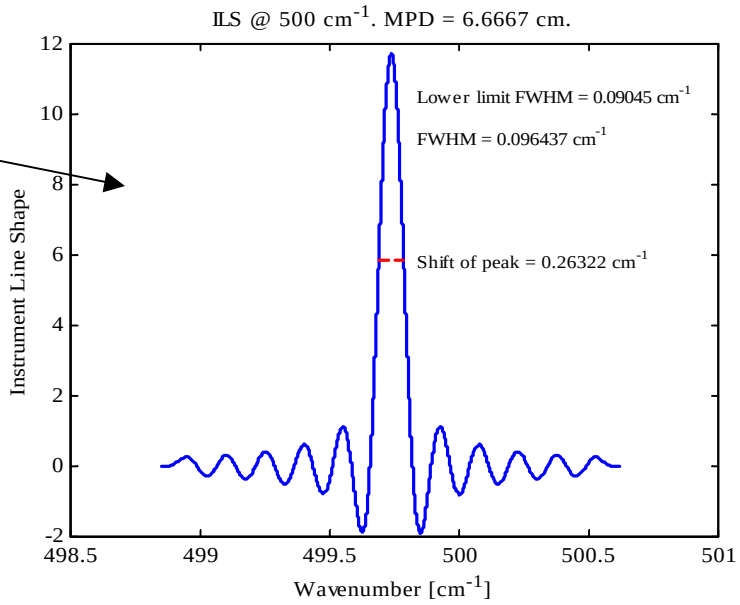
Proposed Approach for Initial NASTER

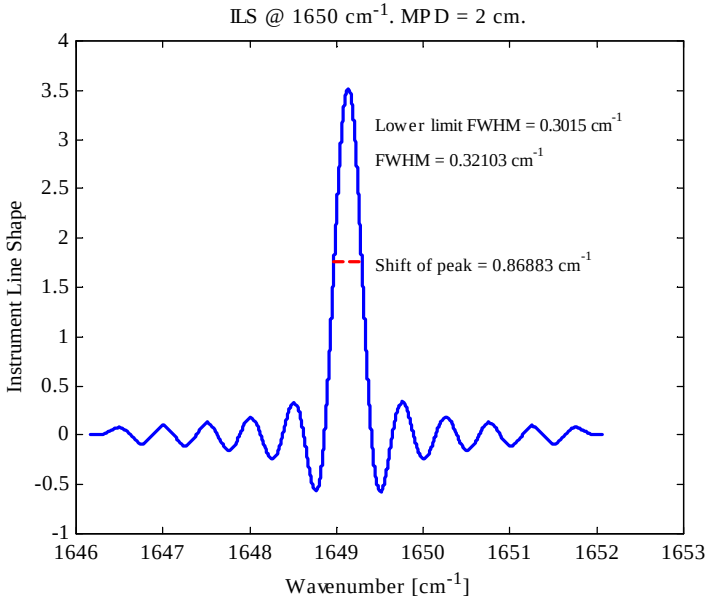


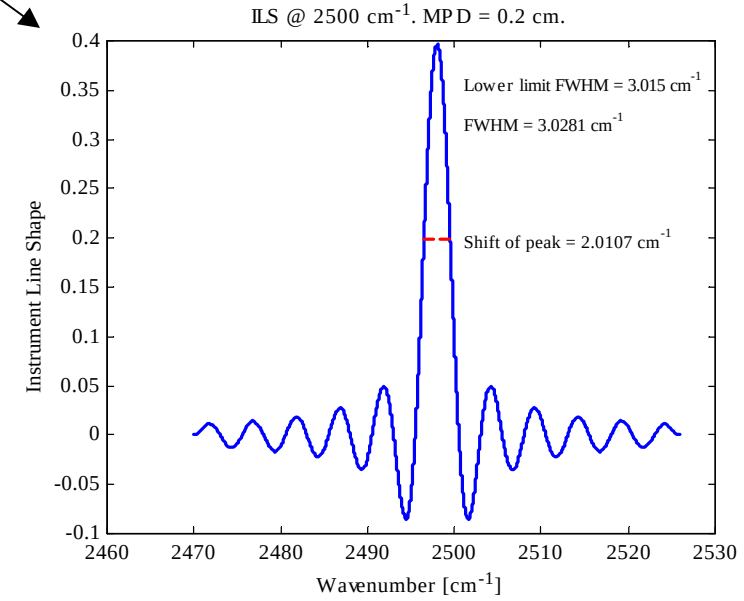


Resolution

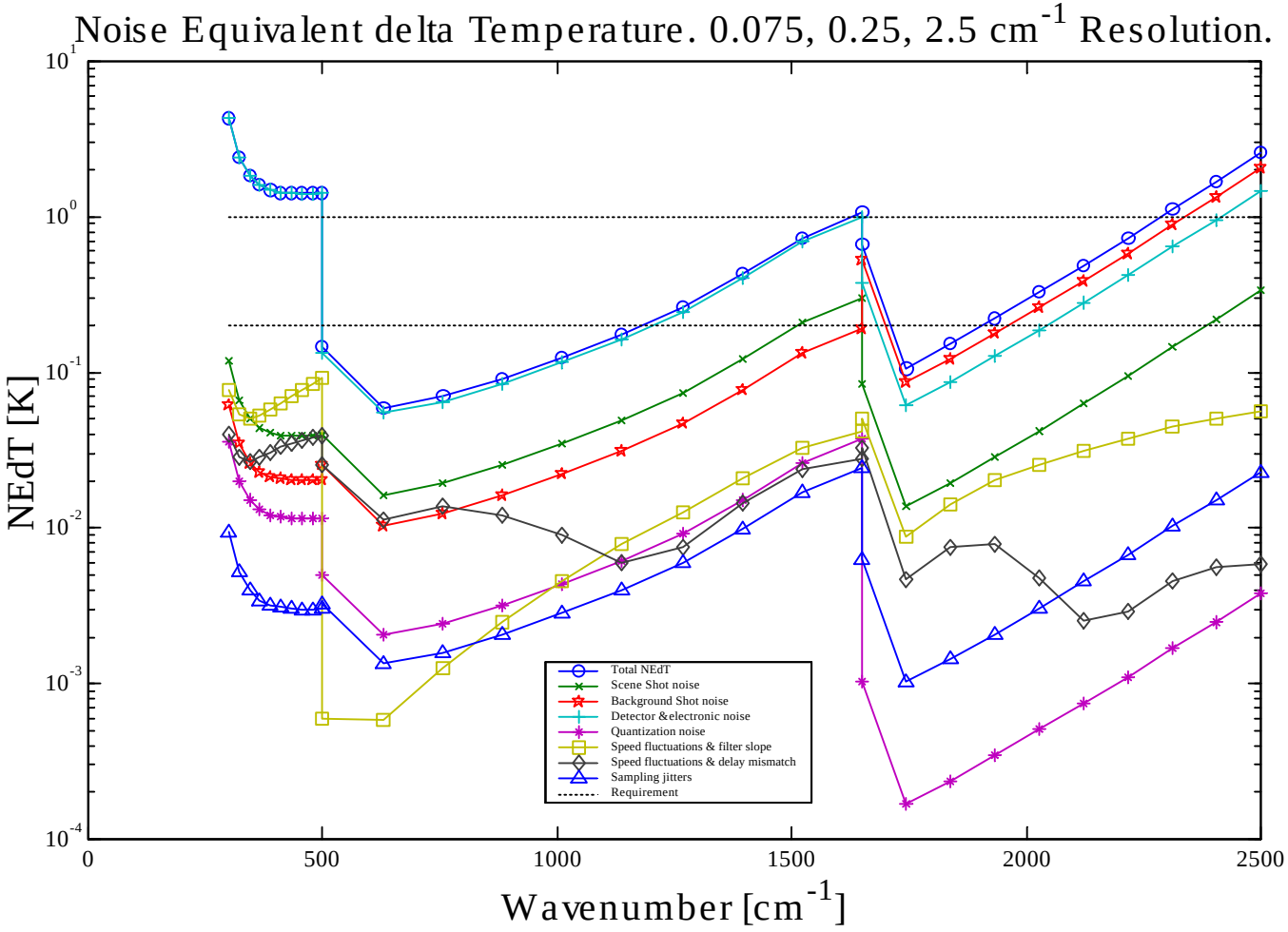






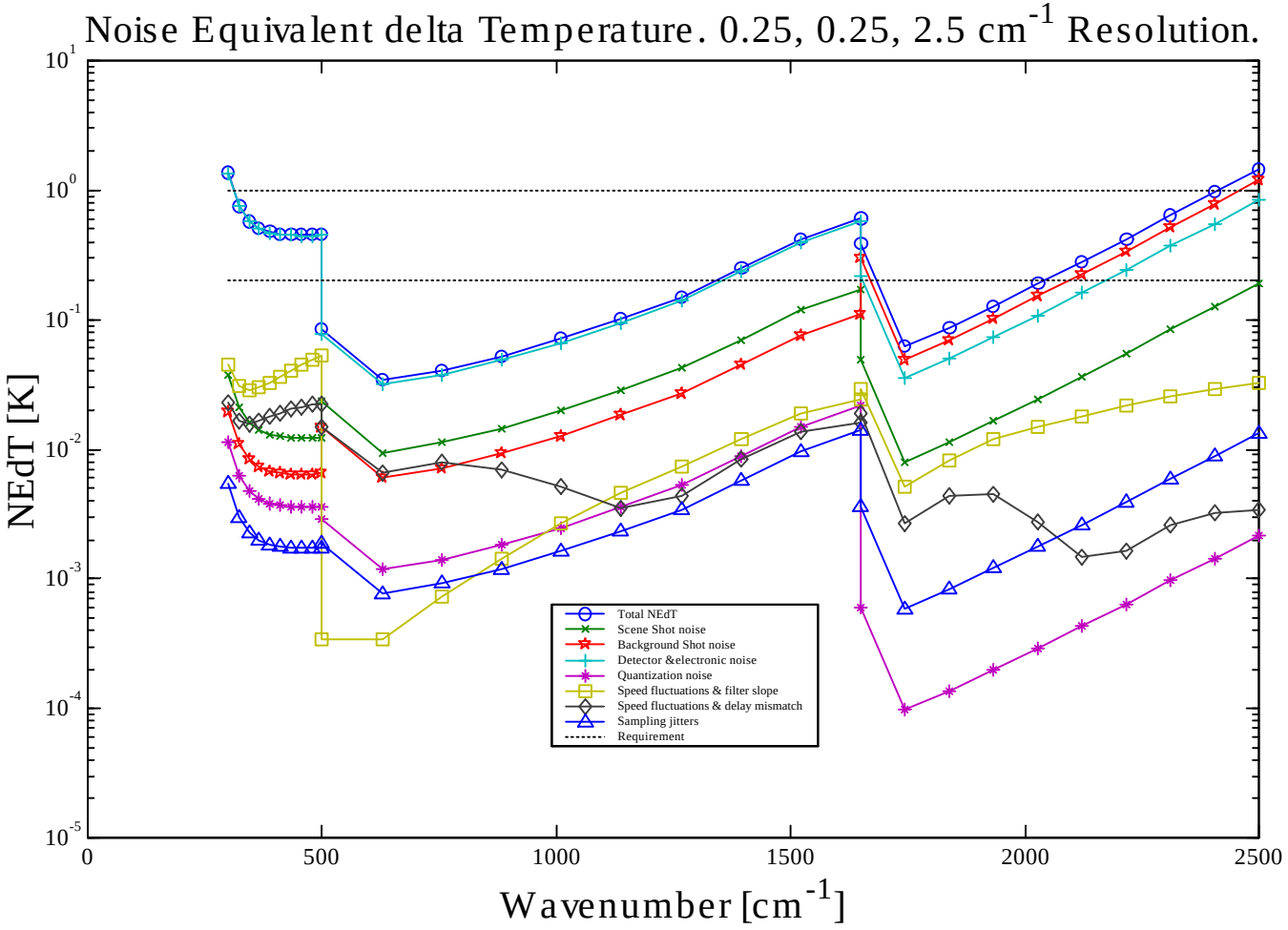


Proposed Approach for Initial NASTER



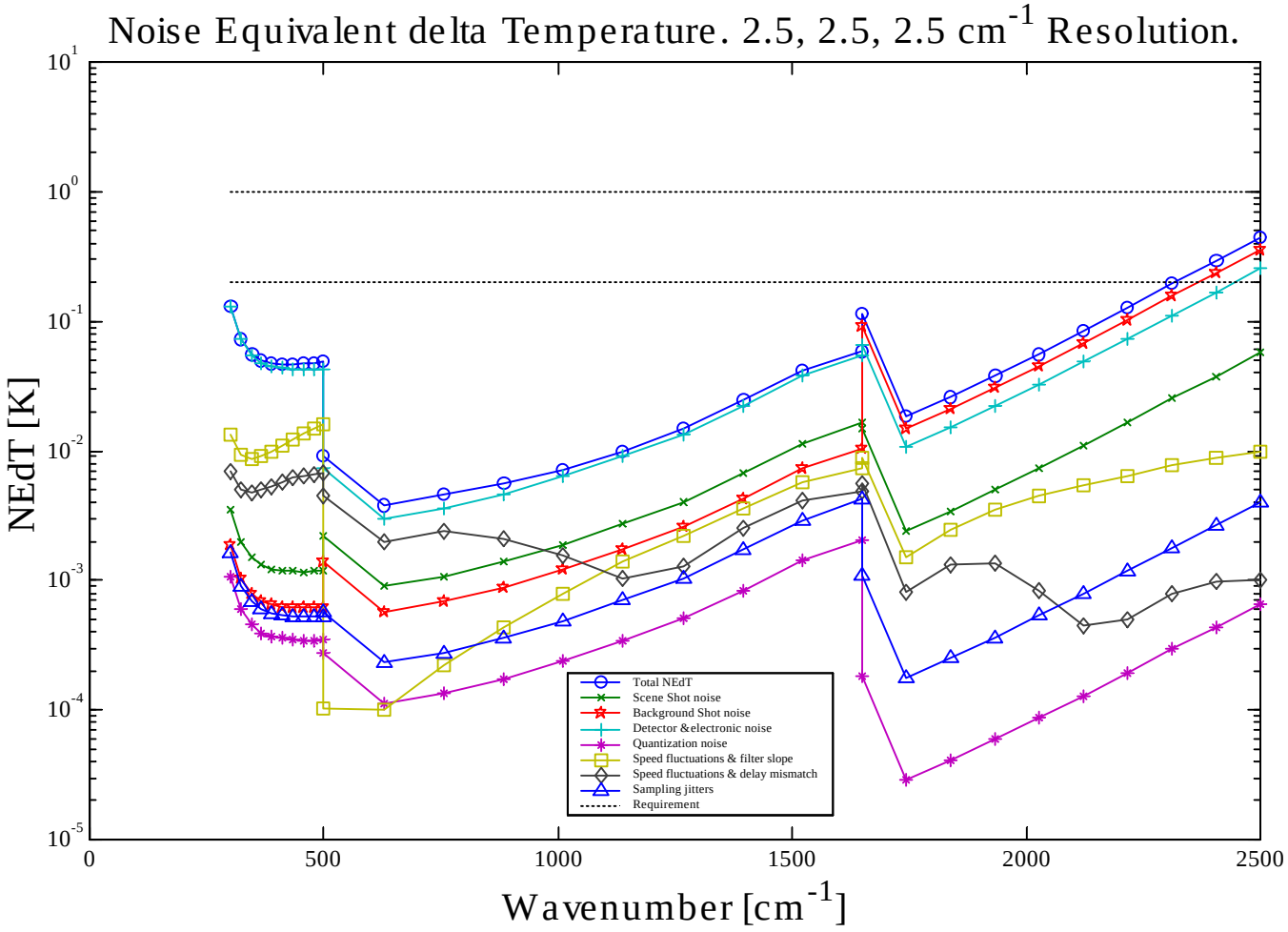
- D* = 4×10^{9} (LW), 4×10^{10} (MW), and 1×10^{11} (SW) jones
- MW and SW are middle portions of full resolution interferogram
- 1 sweep, IFOV's aggregation to 500 meters square

Proposed Approach for Initial NASTER



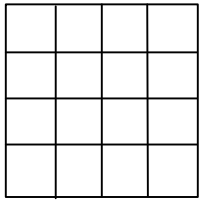
- 3 sweeps, IFOV's aggregation to 500 meters square

Proposed Approach for Initial NASTER



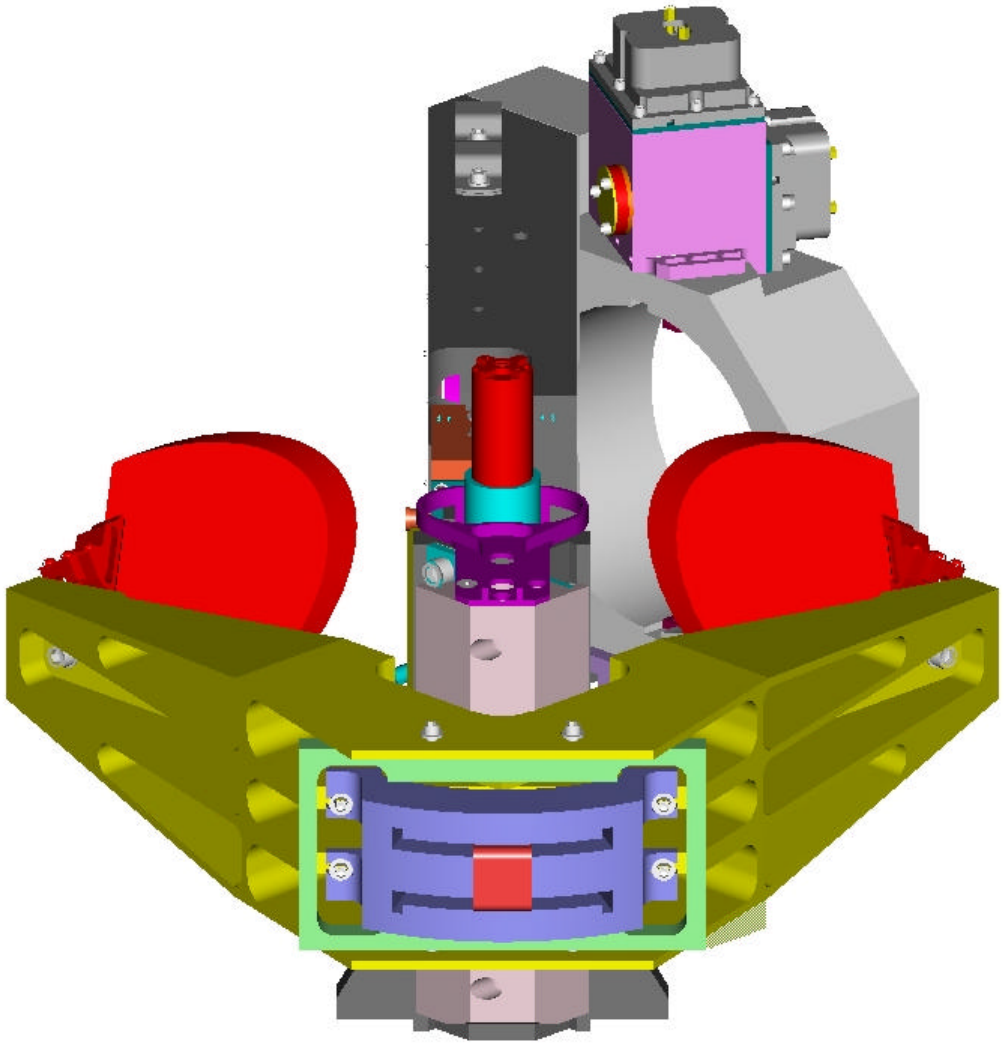
- 33 sweeps, IFOV's aggregation to 500 meters square

Summary for Initial NASTER

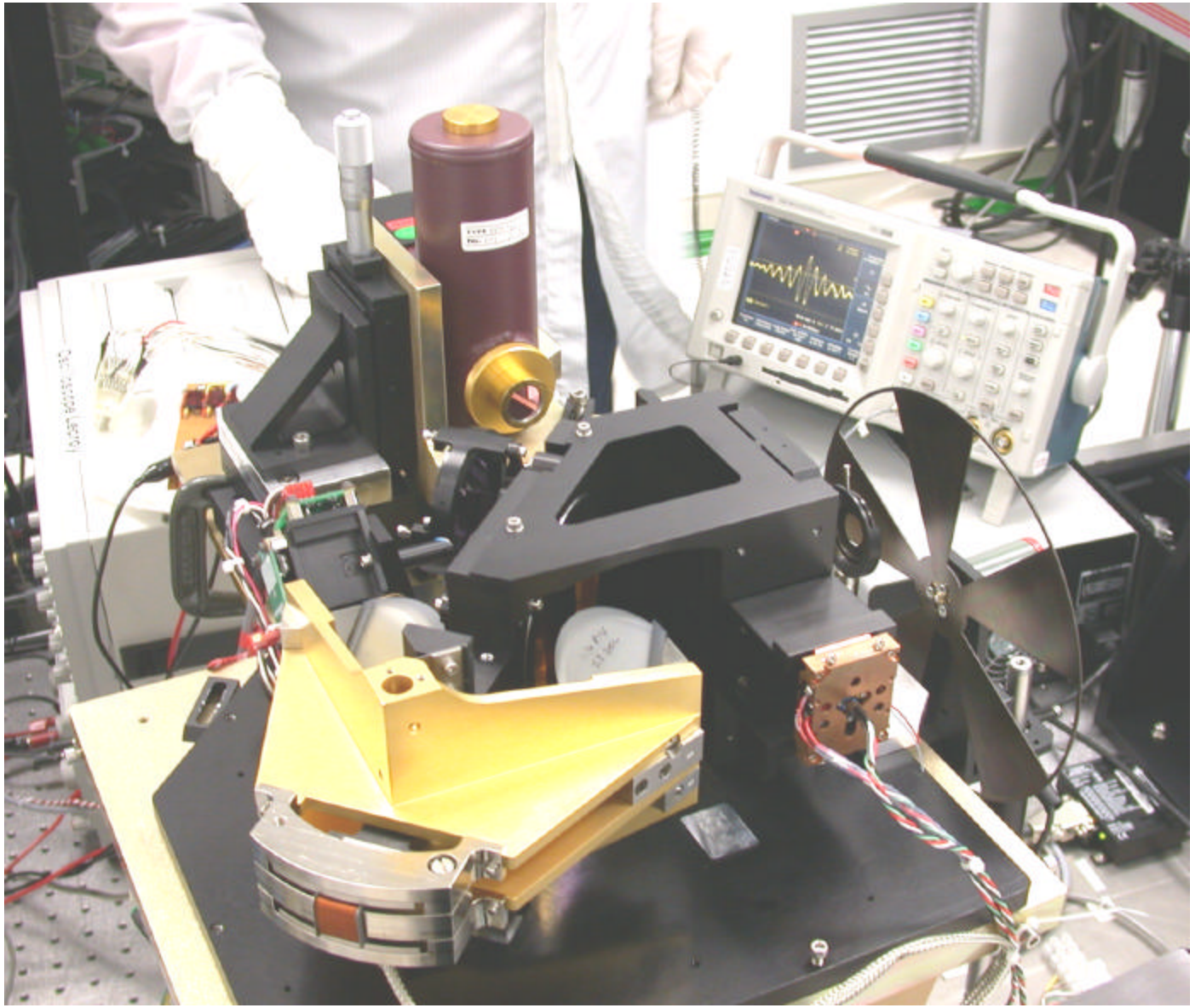
	Desired	***Proposed***
Range	100 – 2500 cm^{-1}	300 – 2500 cm^{-1}
Resolution	0.025 cm^{-1}	0.075 cm^{-1} < 500 cm^{-1} 0.25 cm^{-1} < 1650 cm^{-1} 2.5 cm^{-1} < 2500 cm^{-1}
Ground resolution	500 m x 500 m	250 m x 250 m
FOR	 2 km	 2km aggregate to 4x1
Observation time	10 sec	1.25 sec
Cross-track	2 – 20 km	2 – 20 km (0.825 cm^{-1})
NedT (260 K)	0.2 – 1 K	1.2 K < 500 cm^{-1} 0.05 – 1 K < 1650 cm^{-1} 0.7 – 2.5 K < 2500 cm^{-1}

Proposed Approach for Initial NASTER

- MR type (AERI) interferometers with higher resolution and larger aperture considered in other airborne and space programs



SOFIS FTS On-board GCOM-A1



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ABB