TIRCIS: THERMAL INFRARED HYPERSPECTRAL IMAGING USING AN INTERFEROMETRIC IMAGING APPROACH

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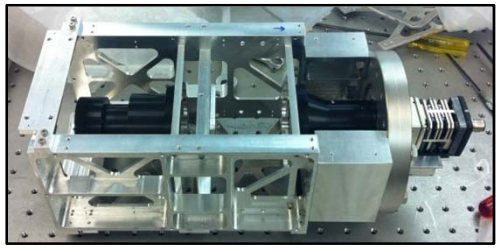
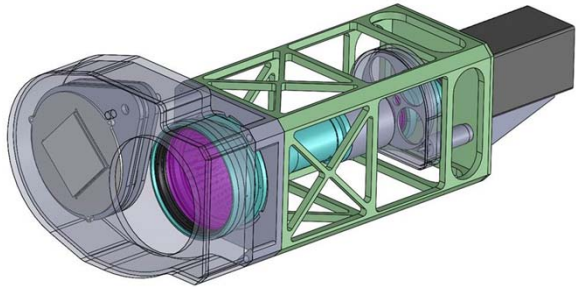
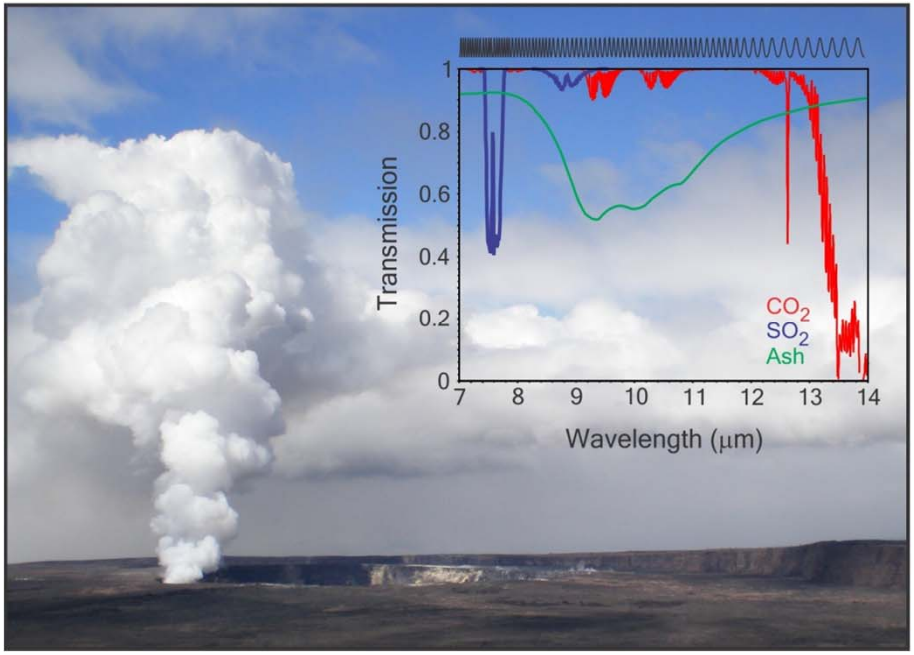
MĀNOA

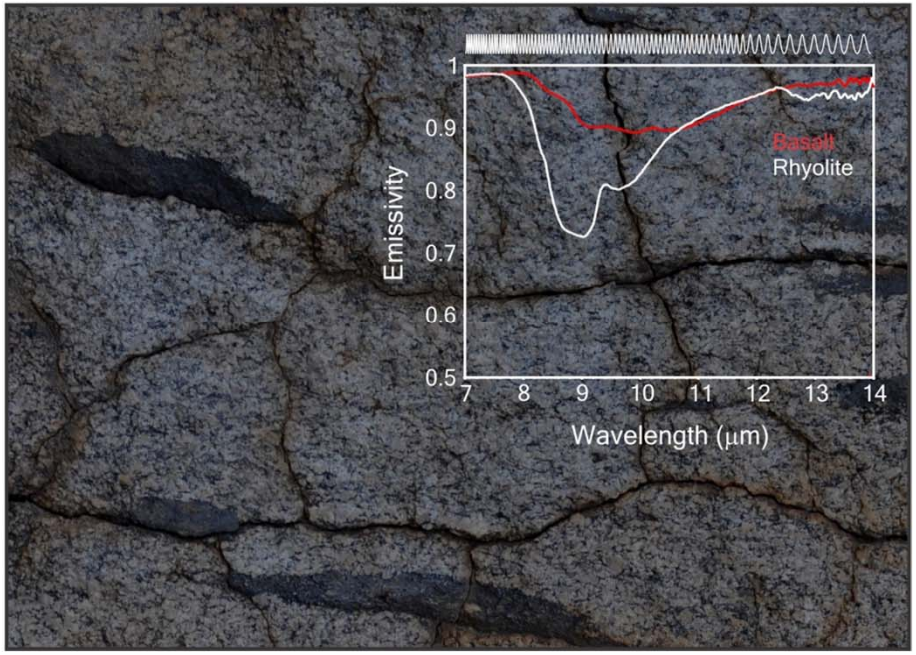
OVERVIEW

- Many targets of interest have distinctive absorption and emission spectra in the long-wave thermal infrared (~8-14 μm)
- Imaging interferometry has potential for characterizing these targets at high spectral resolution, with high signal-to-noise
- IIP project funded in 2014 to produce a compact instrument for this purpose, specifically aimed at small/microsatellite platforms









TIRCIS

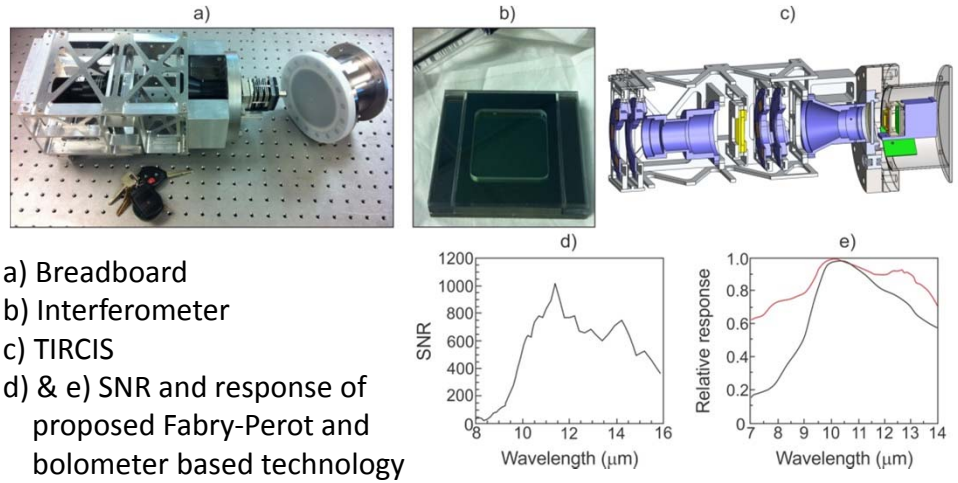
PI: Robert Wright, University of Hawaii at Manoa

Objective

Develop a prototype of a hyperspectral thermal infrared imager for Earth surface remote sensing from a small satellite platform

Performance goals are a instrument that would yield 120 m data from an altitude of ~500 km, in 40 spectral bands between 8-14 microns, with peak SNR of 1000:1

Technologies include uncooled microbolometers and a Fabry-Perot interferometer, in an instrument with one moving part, a mass of <10 kg, and a peak power requirement of <10 W



a) Breadboard
b) Interferometer
c) TIRCIS
d) & e) SNR and response of proposed Fabry-Perot and bolometer based technology

Approach:

i) Modify an existing breadboard to produce a proto-type with mechanical/optical characteristics consistent with operations from LEO

ii) House non-space-hardened components in a small pressure vessel

iv) Integrated software solution for instrument control and on-instrument data reduction using a Gumstix cluster

Key Milestones

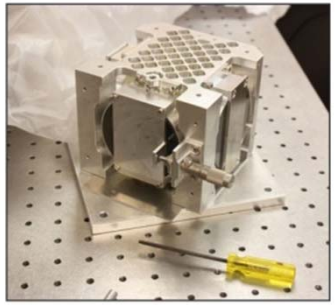
• Optical and mechanical design	10/14
• Fabrication and acceptance testing of custom microbolometer array	04/15
• Fabrication of proto-type	10/15
• Spectral and radiometric characterization	04/16
• Data collection from a light aircraft	10/16
• Proto-type validation in simulated space environment (TVAC; vibration)	04/17

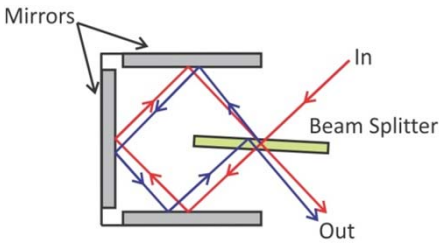
CoIs: P. Lucey, Sarah Crites Univ. Hawaiil. Brandywine Photonics, New England Optical Systems, LumaSense

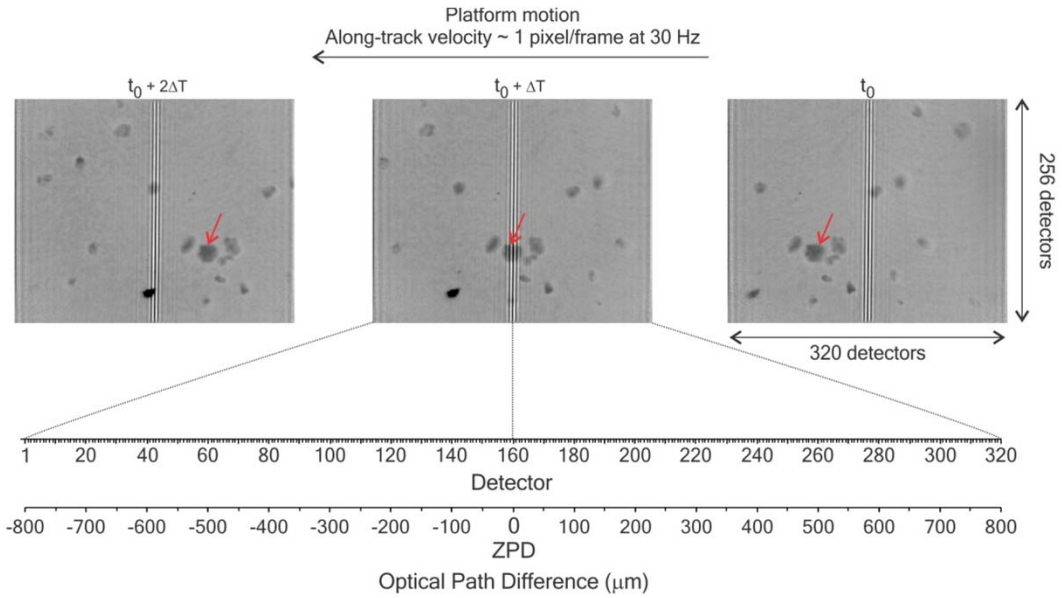
TRL_{in} = 4

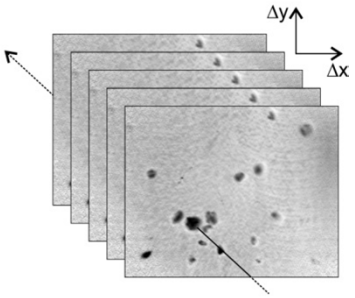
ESTO Earth Science Technology Office

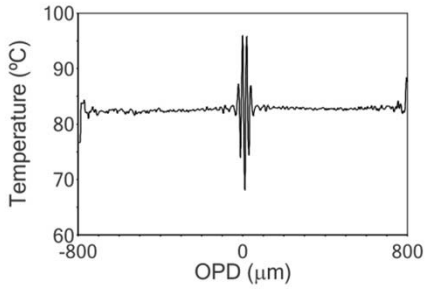
SPECTRAL IMAGING USING AN INTERFEROMETER

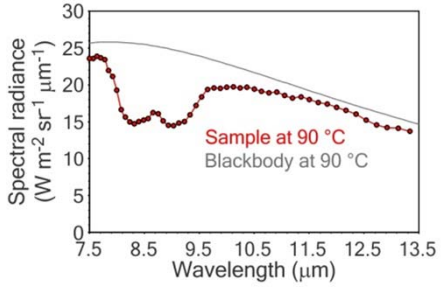


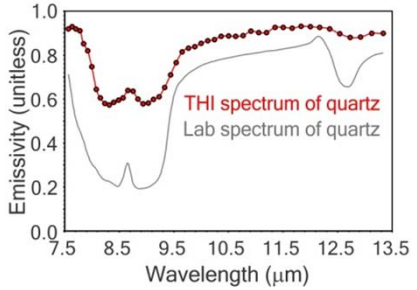




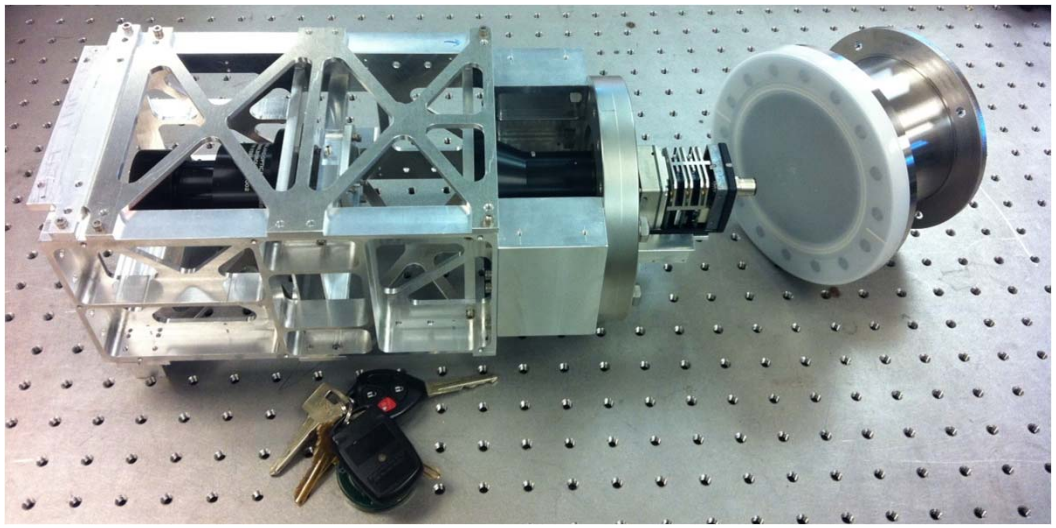




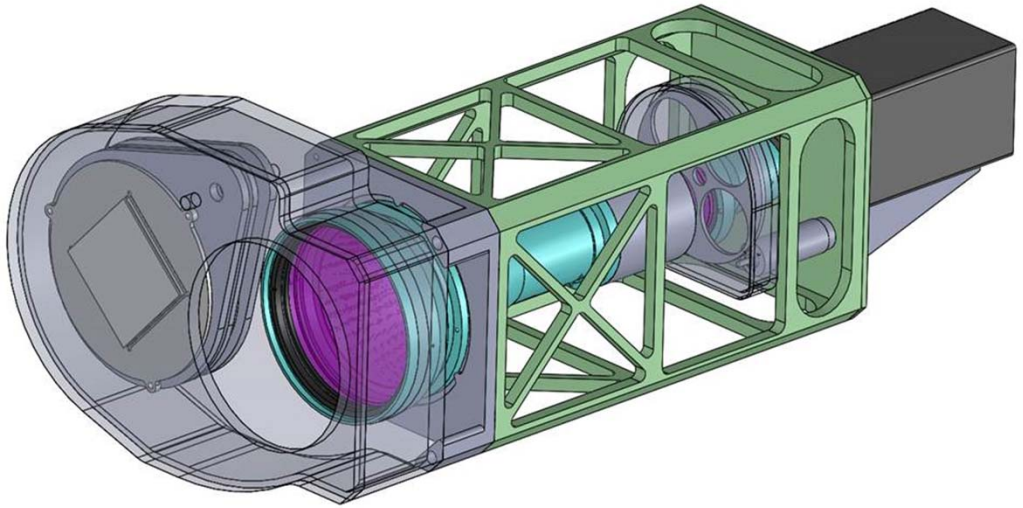




THERMAL INFRARED COMPACT IMAGING SPECTROMETER



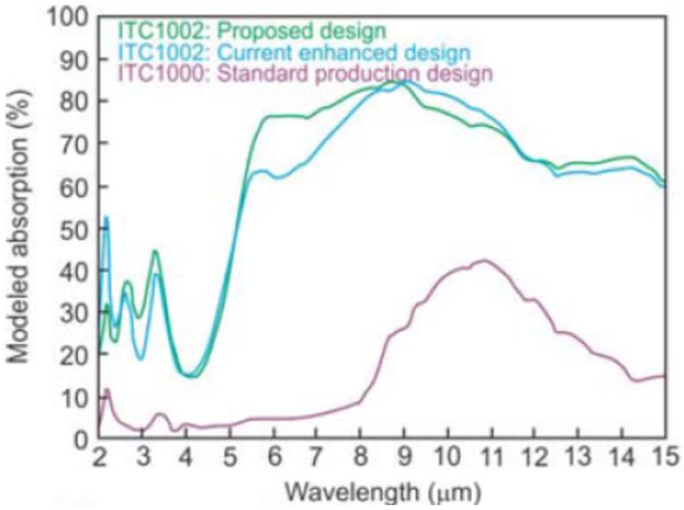
- Uncooled microbolometer
- Fabry-Perot interferometer
- Refractive lenses
- Calibration system

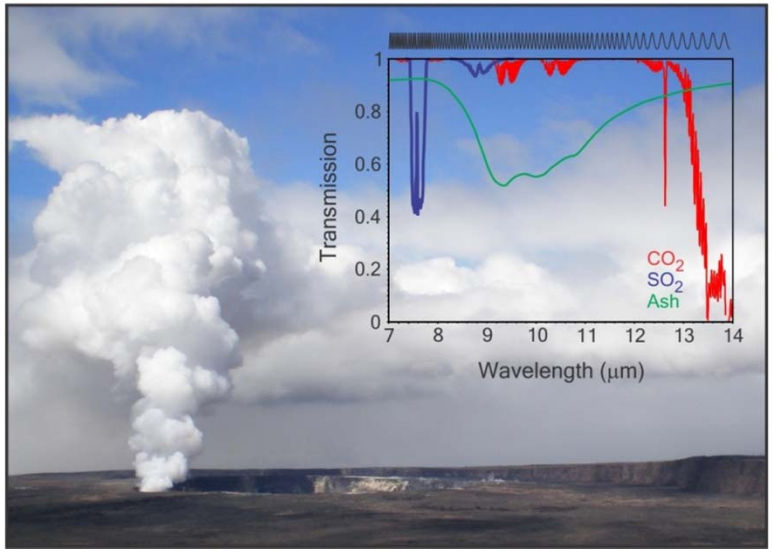


Volume = 66 cm × 35 cm × 25 cm
Mass = 7 kg

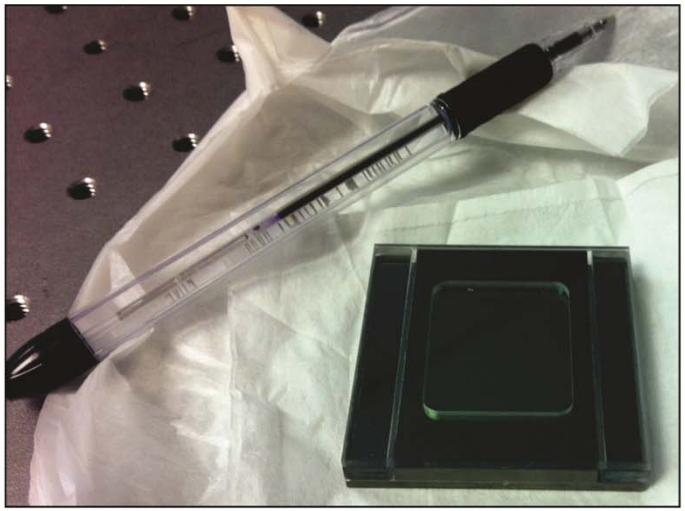
UNCOOLED MICROBOLOMETER

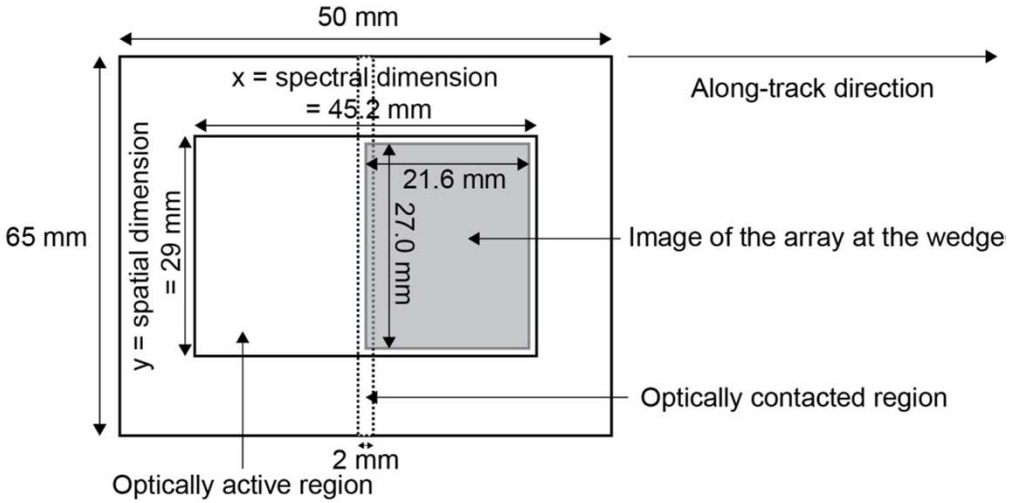
- LumaSense MC320
- 320 × 256 × 37.5 μm, VOx
- 16 bit, 60 Hz, NEΔT = 0.06 °C at 30 °C
- 7 W (typical)
- 0-50 °C operating
- 83 mm × 81 mm × 178 mm

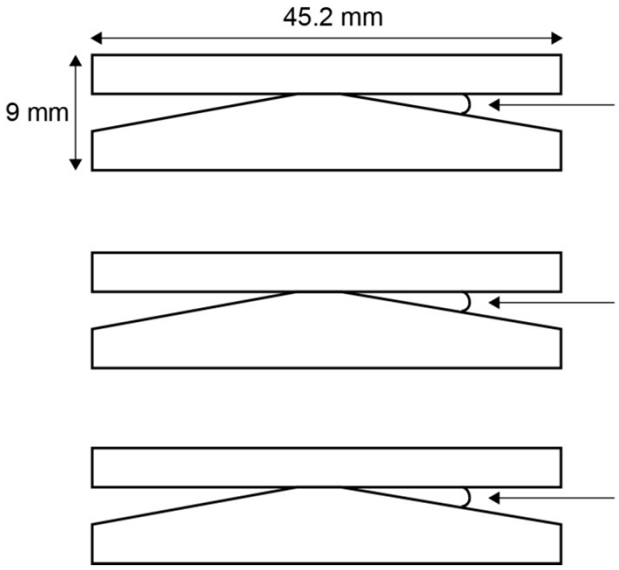




FABRY-PEROT INTERFEROMETER (GE)



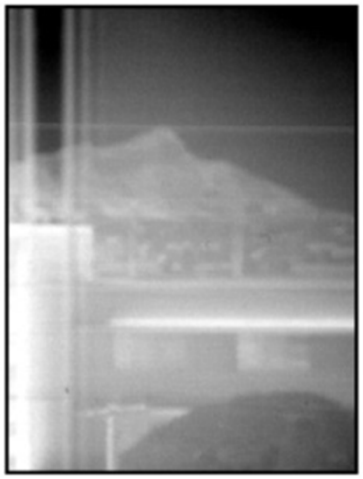




5 mrad = 44 cm^{-1} = low spectral resolution
~ 0.4 μm ~15 channels between 8 and 14 μm

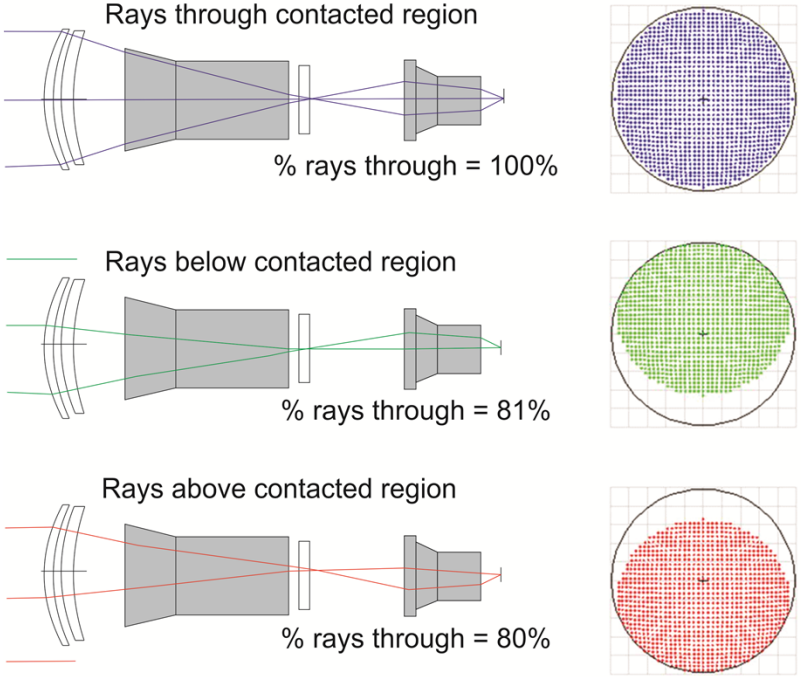
15 mrad = 8.7 cm^{-1} = optimum spectral resolution
~ 0.09 μm ~ 60 channels between 8 and 14 μm

19 mrad = 6.5 cm^{-1} = near-Nyquist
~ 0.065 μm ~90 channels between 8 and 14 μm

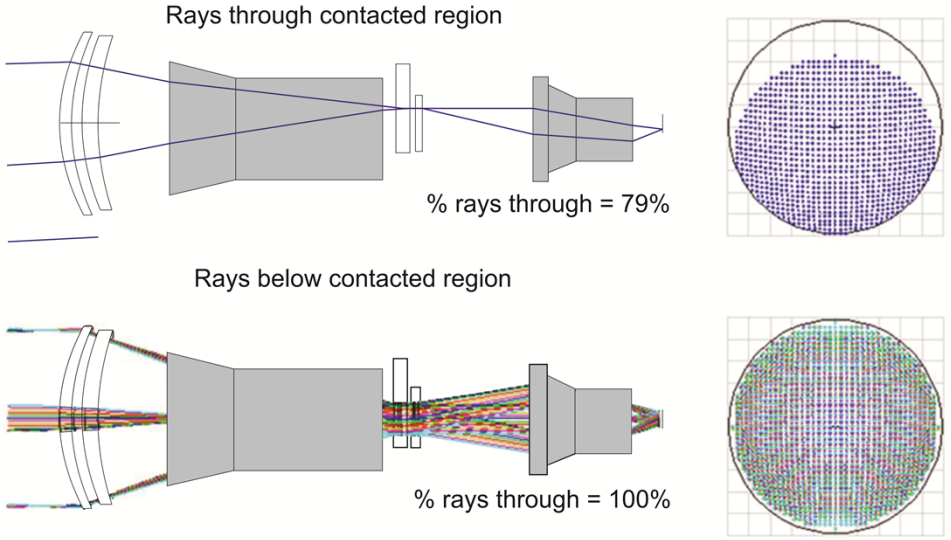


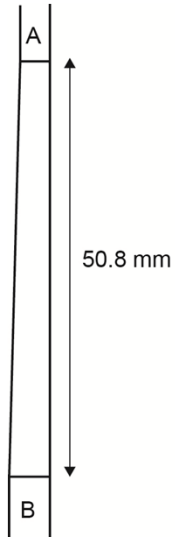
COMPENSATING PRISM

Etalon centered on optical axis,
no compensating prism



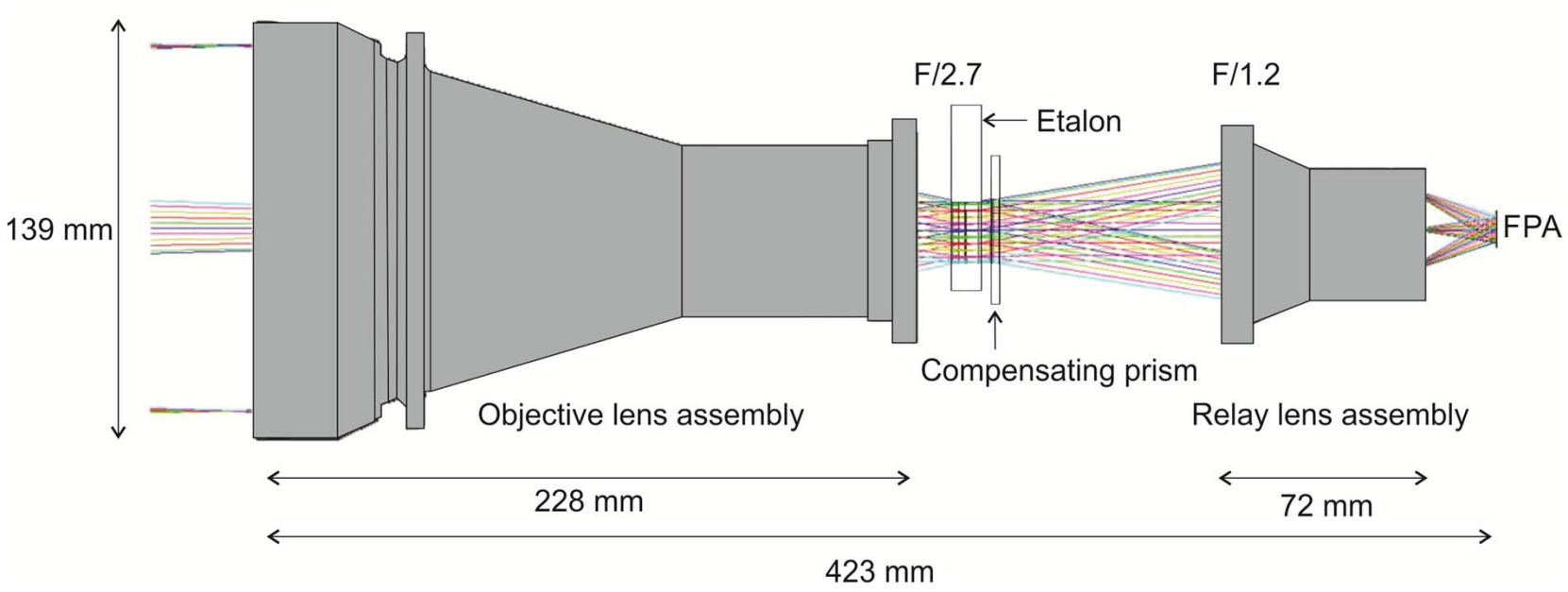
Etalon offset from optical axis,
with compensating prism





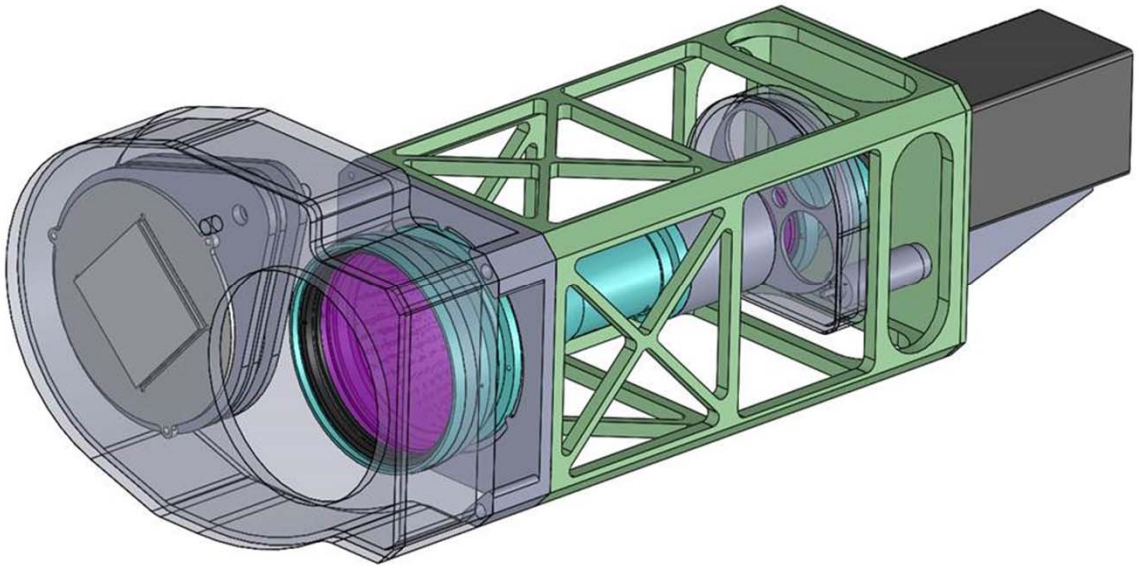
Low (A/B, in mm)	= 2.873/3.127
High	= 2.619/3.381
Nyquist	= 2.517/3.483

OPTICAL LAYOUT



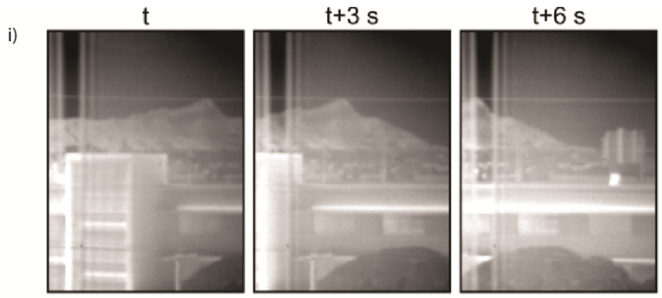
Assumptions: 55 kg microsatellite for ~3 year mission at 480 km altitude
to give 120 m GSD (0.25 mrad IFOV)

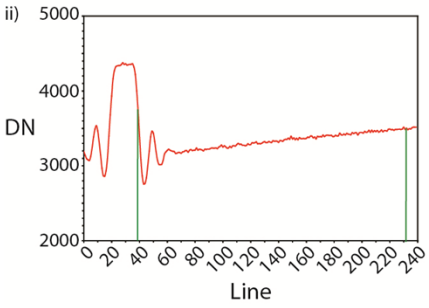
RADIOMETRIC CALIBRATION

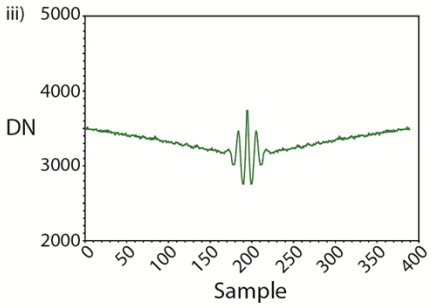


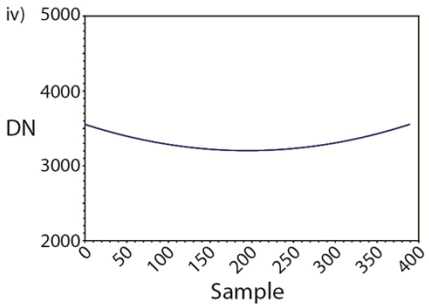
- Two calibration sources (cold, ambient, hot; 0-50 °C)

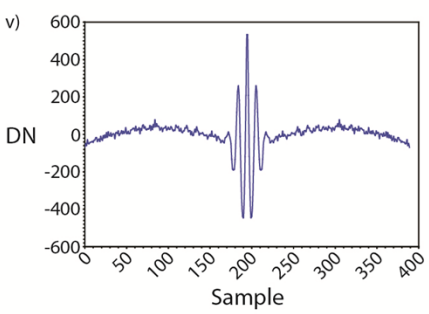
DATA PROCESSING

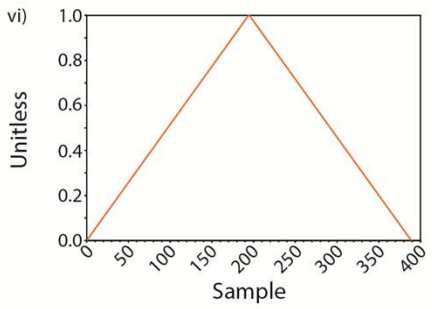


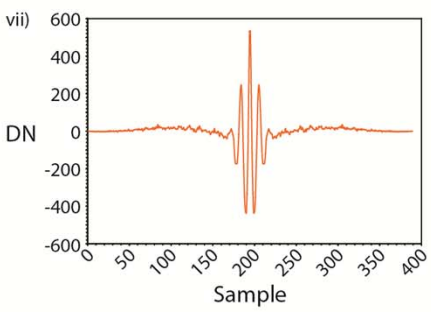


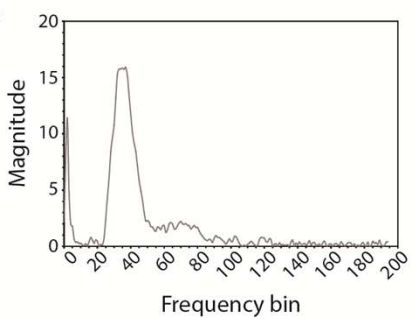




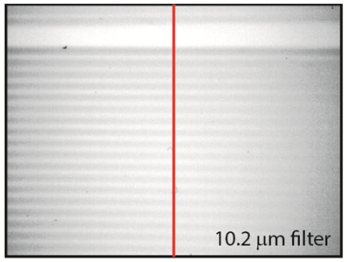


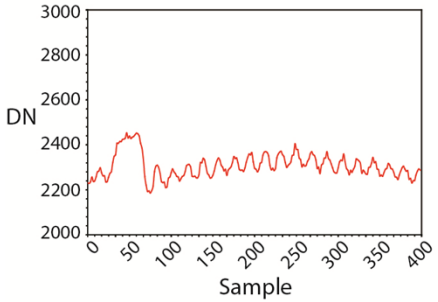


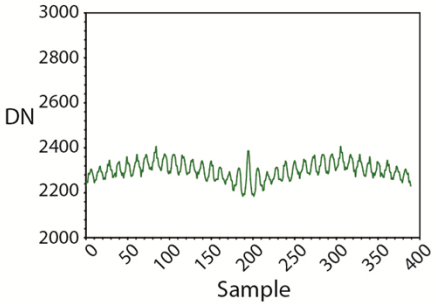


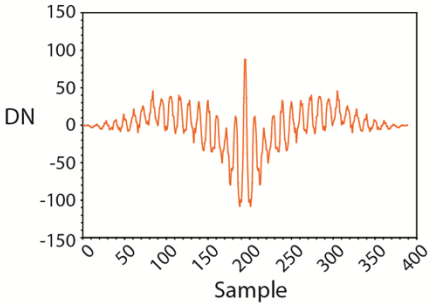


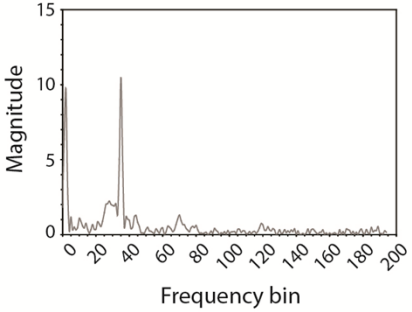
WAVELENGTH CALIBRATION

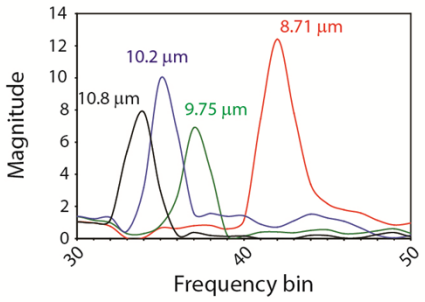


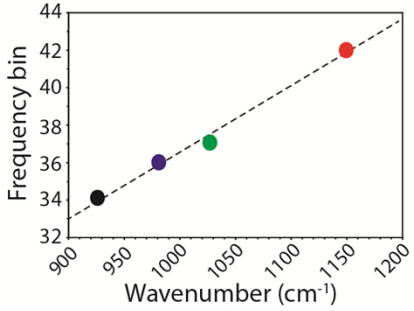




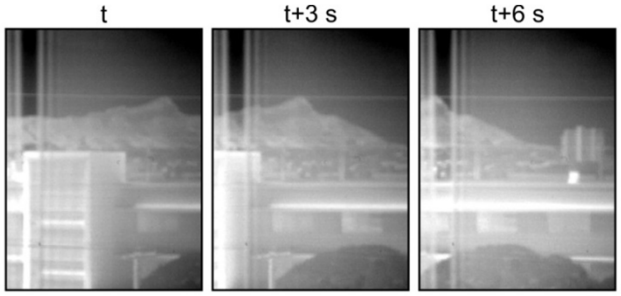


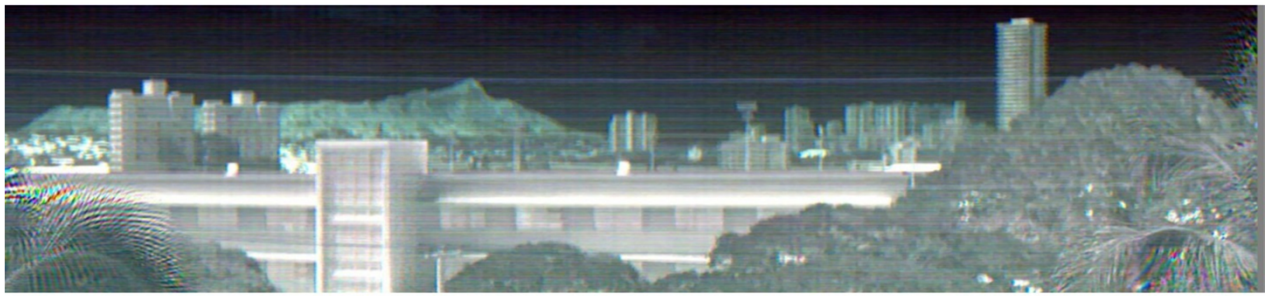


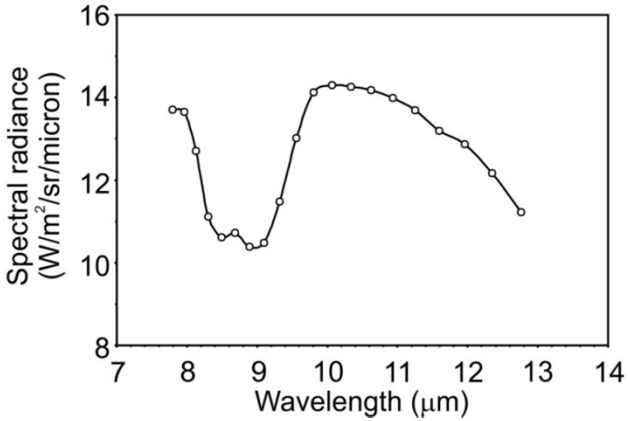




EXAMPLE OF SOME DATA







SUMMARY

- Imaging interferometry can provide high spatial, high spectral, and high temporal resolution image data for quantifying the chemical composition of targets
- TIRCIS will provide ~50 spectral measurements in the 8-14 μm window
- Status: optical design finalized; mechanical design being finalized “as we speak”; data reduction software prototyped