IR sounder small satellite for polar orbit weather measurements

Sara Lampen, Sonny Yi, Jared Lang, Caleb Lampen, Adam Vore, David Warren, Eric Herman
The Aerospace Corporation

John J. Pereira
National Oceanic and Atmospheric Administration (NOAA)

Small Satellite Conference
13 August 2015
sara.lampen@aero.org

Current polar orbit weather satellites

- Current hyperspectral IR satellites measure from SWIR – LWIR to fulfill weather and climate monitoring missions
  - *AIRS, CrIS, IASI*
  - *Size: ~1 m^3, Weight: 150 – 240 kg, Power: 120 – 210 W*

- Requirement to measure LWIR results in large aperture optical systems, increasing SWaP of systems

- Key driver of LWIR requirement is measurement of CO_2 in 15 µm band for temperature profile calculation

  ➢ Measurement of CO_2 exclusively in MWIR 4 µm band removes LWIR requirement and enables compact instrument

Compact hyperspectral IR satellite concept

- Mission: Focus on measurements necessary for weather prediction
  - *Temperature and humidity sounding*
  - *High spectral resolution for improved sounding of troposphere*

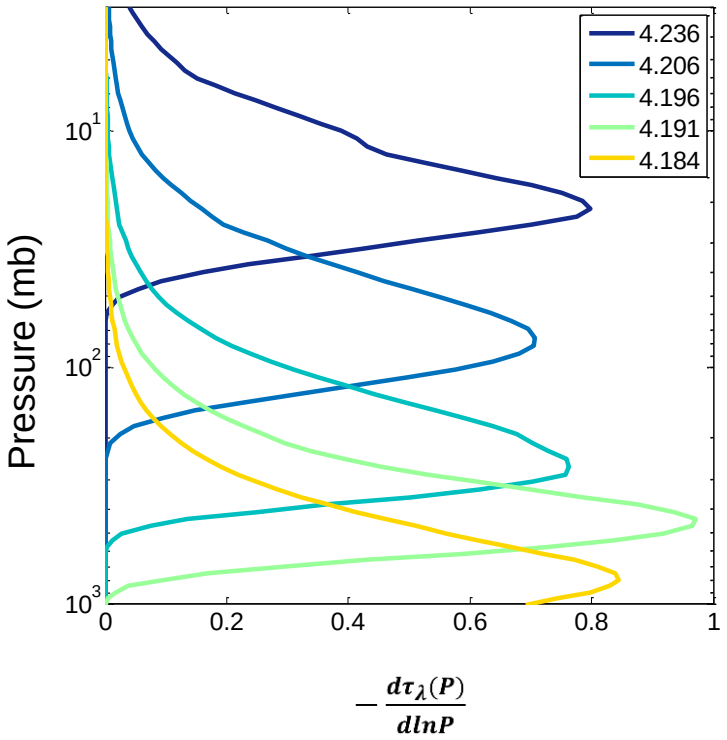
- Size: Small-sat compatible
  - *Aperture size reduced by measuring only in MWIR*
  - *Digital, large-area focal planes used to achieve high spectral resolution while maintaining necessary signal*

Sounding of atmosphere

- Radiance received at top of atmosphere proportional to transmittance of atmosphere as a function of pressure and wavelength
  - *Different wavelengths probe different layers of the atmosphere*
  - *Narrower the spectral bandwidth of individual channels, the narrower the layer of atmosphere*

- Measurements assimilated into numerical weather models

Atmospheric weighting functions

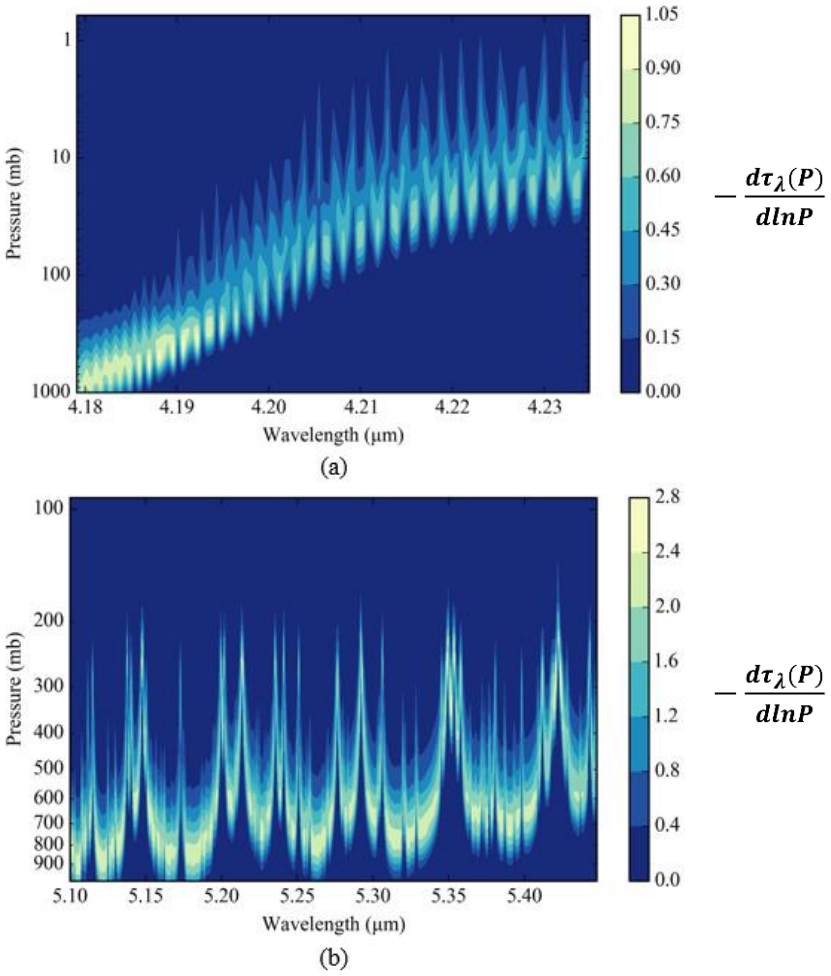


AEROSPACE

Wavelength band selection

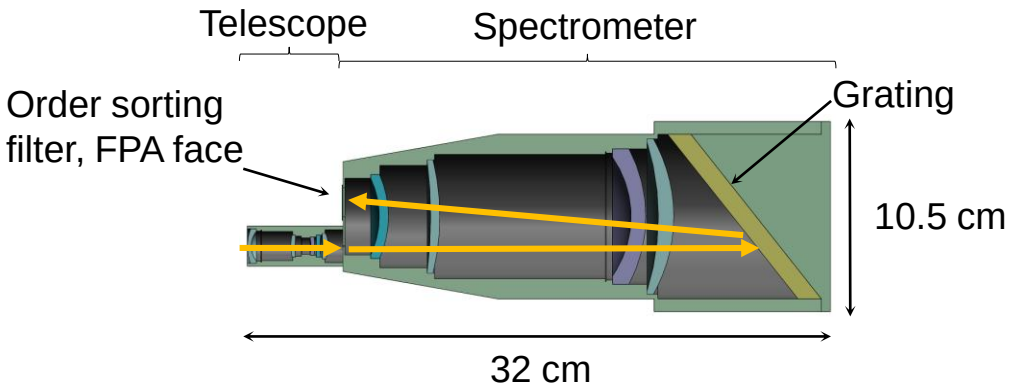
- Temperature sounding
  - *MWIR CO_2 band*
  - *4.179 – 4.235 μm, spectral sampling of 0.35 nm (0.2 cm^{-1})*
- Humidity sounding
  - *MWIR H_2O band*
  - *5.1 – 5.448 μm, spectral sampling of 0.42 nm (0.16 cm^{-1})*

Atmospheric weighting functions



Telescope and spectrometer

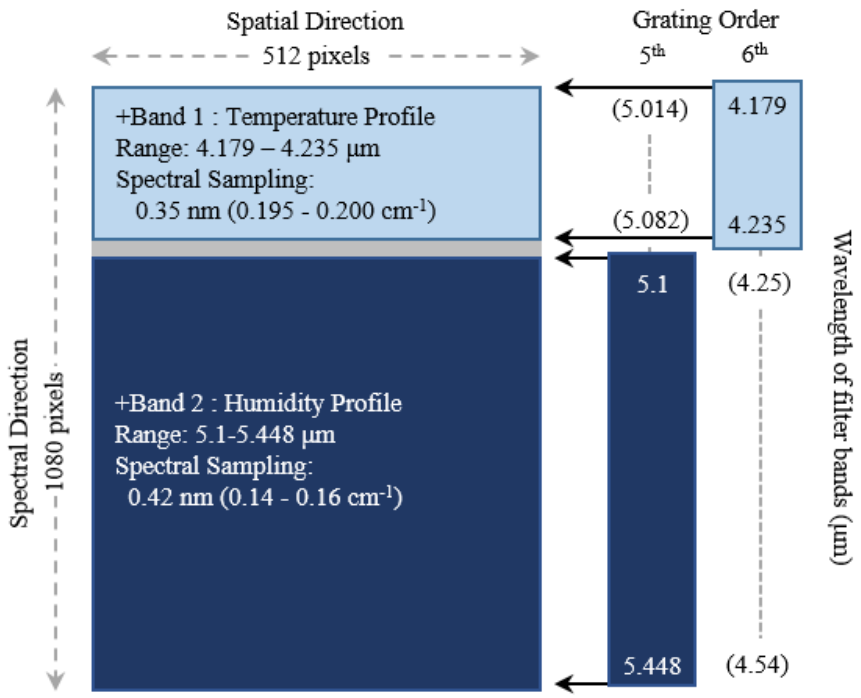
- Telescope
  - *f/2, 2.5 mm aperture*
  - *100^{o} field of view*
- Spectrometer
  - *Refractive, Littrow spectrometer*
  - *Low-order echelle dispersion grating*



- Size: 32 x 10.5 cm, Weight: ~ 3 kg

Order sorting filter

- Butcher block filter sorts overlapping orders from grating
- 5th and 6th grating orders used for humidity and temperature measurements
- Design trades spectral coverage, spectral resolution, and grating efficiency

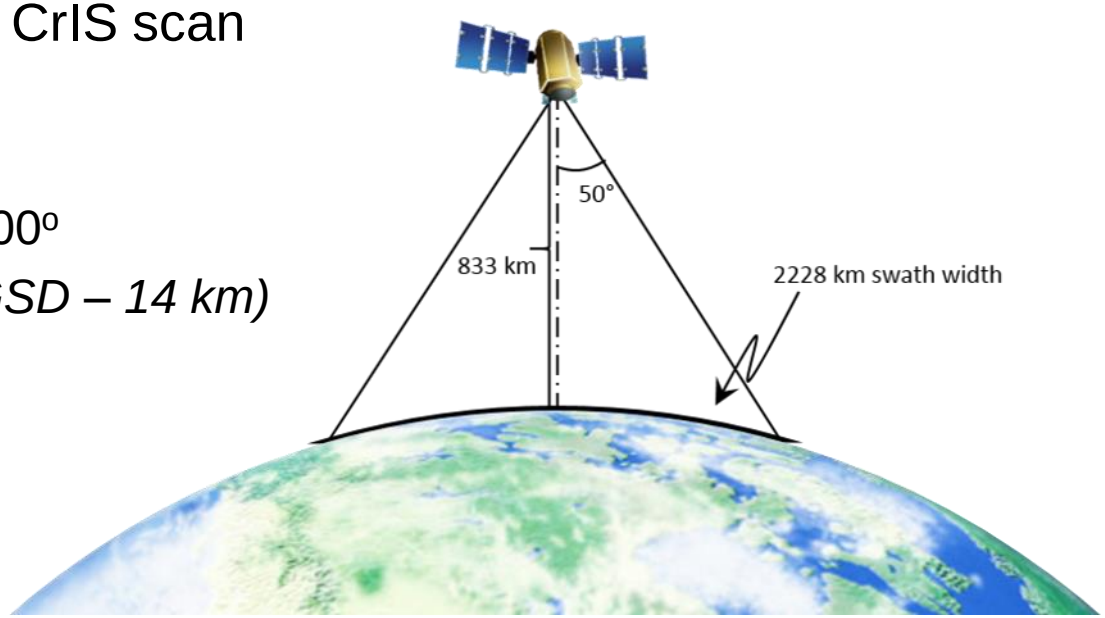


AEROSPACE

LEO IR Sounder scan geometry

- Uses single pushbroom sounder
  - *Collects data using spacecraft motion*
  - *No scanning parts*

- Designed to meet or exceed CrIS scan geometry
  - *Swath width – 2228 km*
    - Telescope field of view - 100^{o}
  - *GSD – 3 km at nadir (CrIS GSD – 14 km)*



Spacecraft design assumptions

- ESPA ring launch (size limit: 96 x 61 x 71 cm)
- Full spacecraft less than 100 kg
- Sun-synchronous orbit with deorbit mechanism
- Class C/D mission with minimum 2 year life

IR Sounder spacecraft design

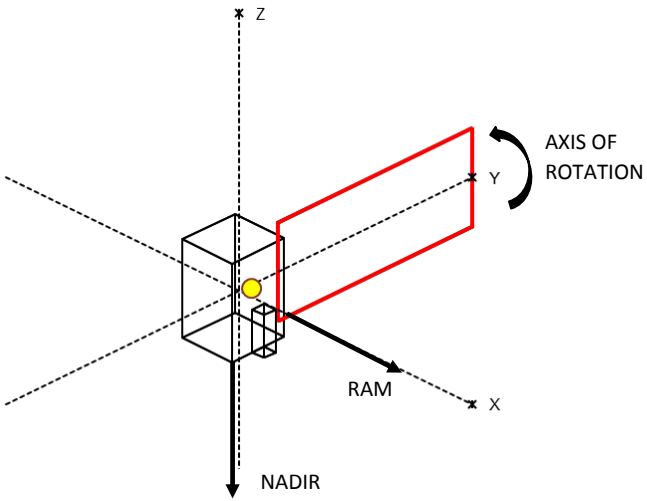


Illustration of spacecraft

	CBE Mass (kg)	Cont. (kg)	Mass Total (kg)
Spacecraft Total	71.5	15.4	86.9
Payload Total	10.0	3.0	13.0
Bus Total	61.5	12.4	73.9

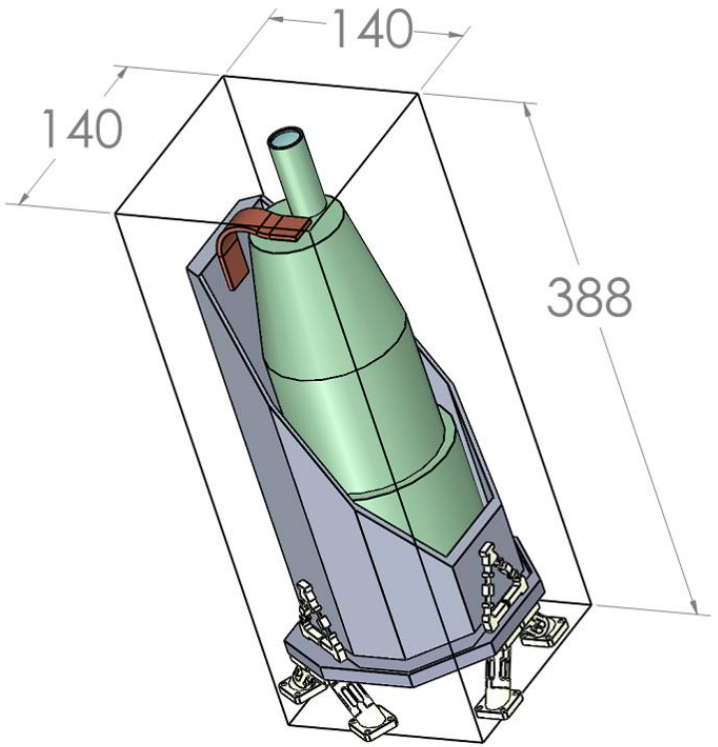
	CBE Power (W)	Cont. (W)	Power Total (W)
Spacecraft Total	218.9	50.5	269.4
Payload Total	150	45	195
Bus Total	68.9	5.5	74.4

Thermal control design

- Single-stage mechanical cryocooler to cool FPA and spectrometer to 90 and 120 K
- Trade studies- Dual cryocoolers, radiator placement, cryoradiator, design sink temperature
- Thermal control system
  - *Detector and optical assembly enclosed by radiation shield*
  - *Low conductance structural mounts to limit parasitic heat leaks*
  - *Dual flexible conductive link between sensor and cold tip*
  - *Tactical cryocooler (Thales or Sunpower) with space-qualified electronics (Iris Technologies)*
  - *Radiator area – 0.55 m^2*
- Total cooler power < 120 W

Conclusions -
Compact MWIR sounder feasible on small-satellite

- Analysis shows can perform temperature and humidity sounding in MWIR
- Telescope and spectrometer designed for compact sensor
  - *Size: 32 x 10.5 cm, Weight: ~ 3 kg*
- Thermal and spacecraft studies show feasibility for small-sat



Dimensions in mm