IR sounder small satellite for polar orbit weather measurements

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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 m³, 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 CO₂ in 15 μm band for temperature profile calculation

  ➢ Measurement of CO₂ 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
Wavelength band selection

• Temperature sounding
  – MWIR CO₂ band
  – 4.179 – 4.235 μm, spectral sampling of 0.35 nm (0.2 cm⁻¹)

• Humidity sounding
  – MWIR H₂O band
  – 5.1 – 5.448 μm, spectral sampling of 0.42 nm (0.16 cm⁻¹)
Telescope and spectrometer

• Telescope
  – f/2, 2.5 mm aperture
  – 100° 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
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°
  – 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

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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 m²
- 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