NOAA EON-IR CubeSat Study for Operational Infrared Soundings

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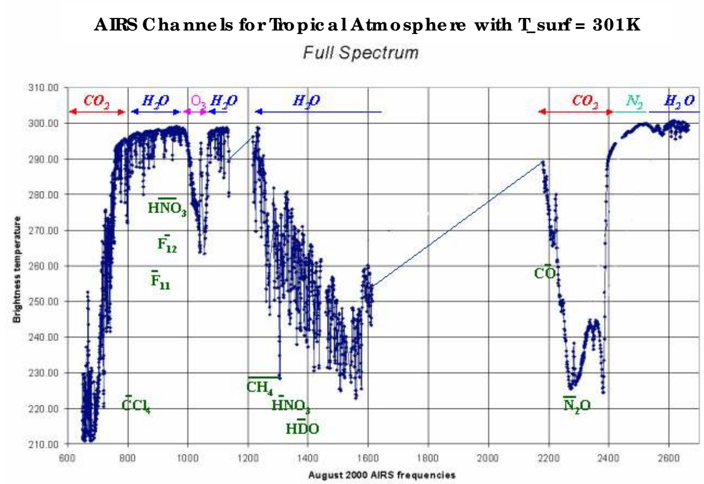
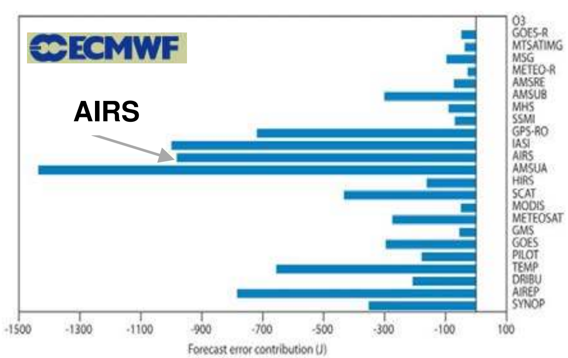
IR Sounders Support Weather Forecasting and Climate Science



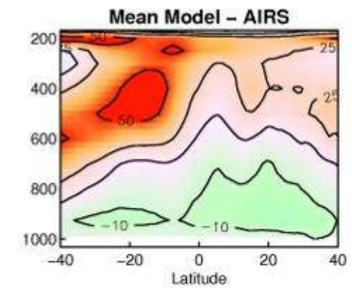
JPL/GSFC

NOAA
NESDIS/NCEP

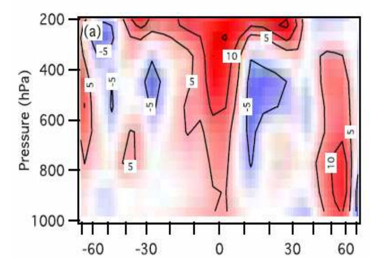
JCSD



Water Vapor Climatology
(Pierce, Scripps, 2006)



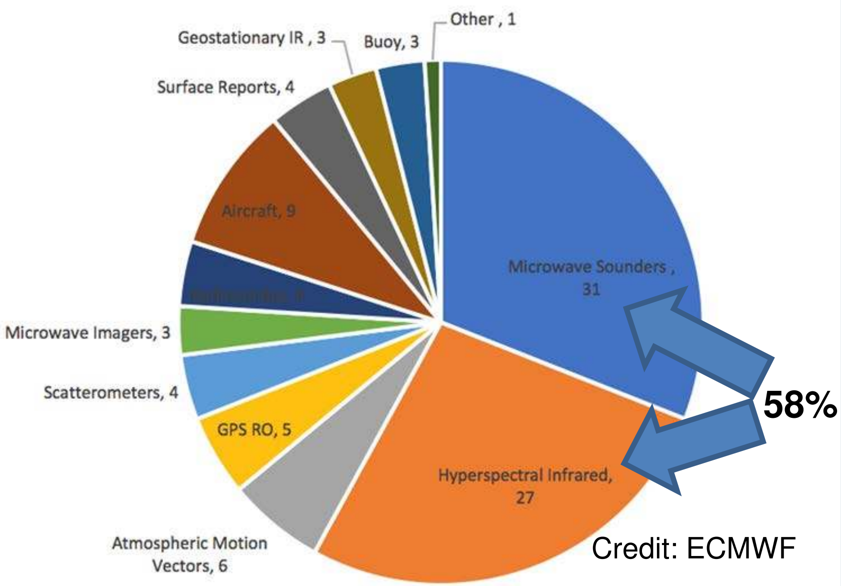
Water Vapor Feedback
(Dessler, Texas A&M, 2008)



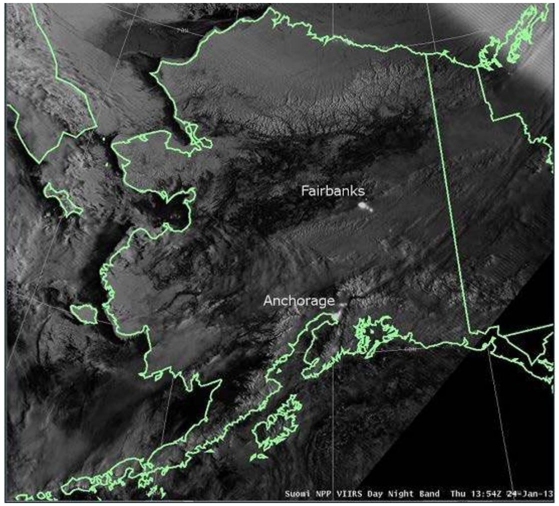
Key Polar Satellite Data

Microwave and infrared atmospheric sounders on polar orbiting satellites have a large positive impact on reducing numerical weather prediction forecast error

Observation Type and % Impact to Reducing Forecast Errors



Credit: ECMWF



Imagery from polar orbiting satellites provides enhanced coverage in high-latitudes where geosynchronous satellite coverage is diminished

Why SmallSats?

- Current environmental satellites are expensive
  - No ability for spares in LEO orbit
  - Long development cycle
  - Failure means lack of data availability
- SmallSats could be the future for some observations
  - Lower cost alternatives
    - Use commercially available parts
    - Less weight means low launch costs
    - Can afford to have a spare for Gap Mitigation
  - Much shorter development time
  - Commercial launch availability
  - Loss of a single spacecraft does not result in the loss of all instruments
- Better capability for partnering opportunities ~ DoD and NASA

Incorporating SmallSats into future architecture plans

Strategy for SmallSat Integration

FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025

Microwave Sounding

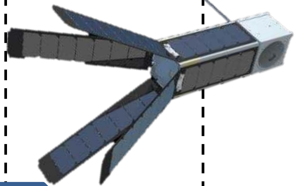
Study/Select

Risk Reduction

Development

LRD

Validation



Potential Enabling Technology: NOAA's EON-MW concept is based on NASA funded MIT/LL CubeSat based microwave sounder technology demonstrations MiRaTA and MicroMAS-2/TROPICS (pictured).

Infrared (IR) Sounding

Potential Enabling Technology: NASA investment in CubeSat based mid-wave IR sounders for the JPL CubSat Infrared Atmospheric Sounder (CIRAS) mission (Pictured)

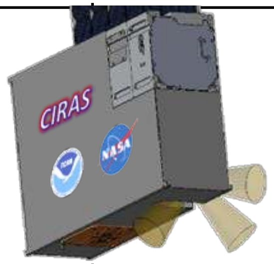
Study/Select

Risk Reduction

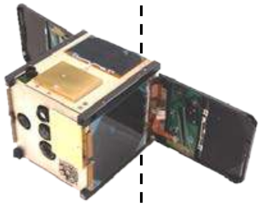
Development

LRD

Validation



Visible / IR Imaging



Potential Enabling Technology: Department of Defense investment in low-light CubeSat based imagers such as AeroCube-4 (pictured)

Study/Select

Risk Reduction

Development

LRD

Validation

Challenges for CubeSat IR sounder

- Temperature control is among the highest challenges, along with a larger aperture size required for longer wavelengths.
- IR sensors are extremely sensitive to noise due to thermal emission of the optics and Johnson noise in the detectors, especially in the LWIR, and require a significant amount of cooling.
- Other technology risk areas include Focal Plane Array (FPA) technologies, miniature reliable cryo-coolers, compact optics, and IR Immersion grating spectrometers.

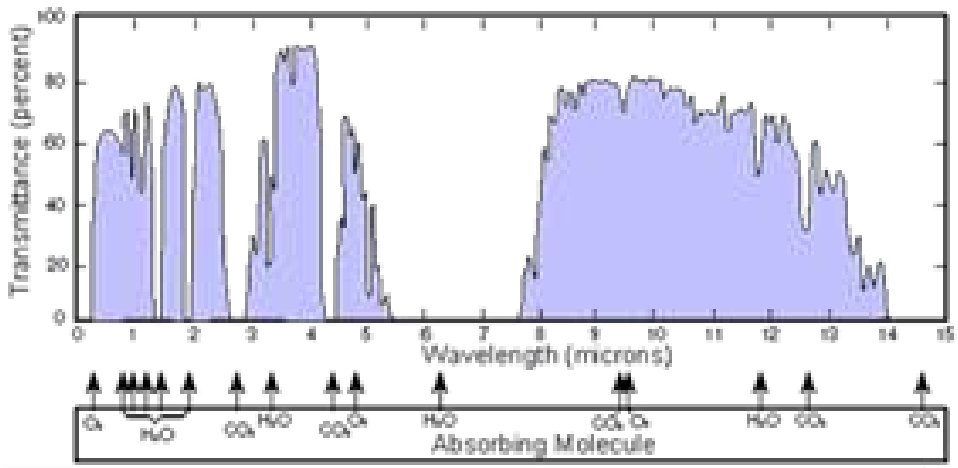


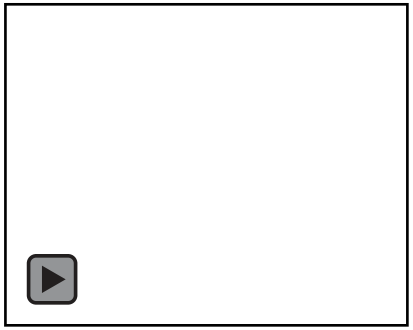
Figure 1: Electromagnetic Spectrum Transmission in the Infrared Wavelength

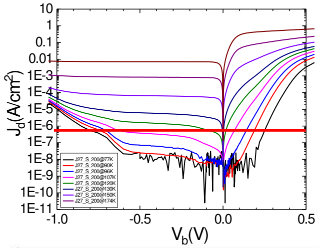
2015 Study

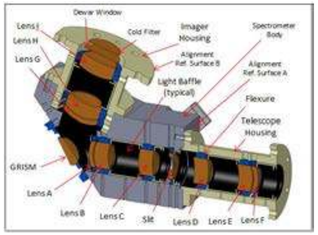
- NESDIS and JPL began studying the optimal performance of a CubeSat based infrared sounder in comparison to CrIS performance.
- TRL assessment of all mission components and subsystems
- Recognizing the difficulty with the thermal and power requirements of LWIR sounding, the study focused on design of the MWIR only in a 6U CubeSat.
- The study addressed the optical, mechanical, thermal, detector and electronic requirements from such a system.
- The EON-IR (MWIR-Only) instrument that resulted employed passive cooling for the spectrometer and a micro pulse tube cryocooler for cooling the detector.
- After completion of this first study, the ESTO funded CIRAS project began the design phase.
- Immediately it was found that the fully functional design arrived at during the NOAA study was not affordable for the CIRAS and a few changes were made including adding a second cryocooler for the spectrometer since passive cooling was more complex, and replacing the pulse tube cryocooler with a commercial less expensive and less reliable cooler.

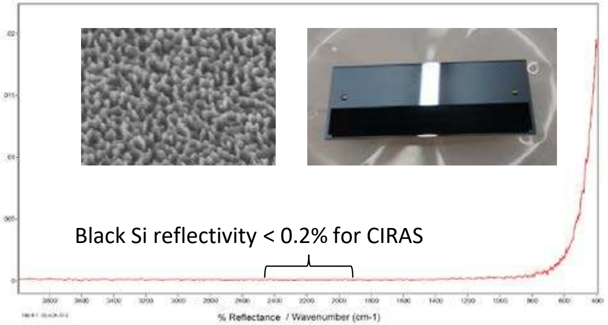
CIRAS Key Technologies Development Status

- **HOT-BIRD Detectors (TRL 6)**
  - The new High Operating Temperature Barrier Infrared Detector (HOT-BIRD) detector materials developed at JPL provide superior uniformity and operability, higher operating temperature, and low 1/f noise.
  - Detector/ROIC (Sensor Chip Assembly, SCA) complete. SCA's under test.
- **MWIR Grating Spectrometer (MGS) (TRL 5)**
  - All refractive grating spectrometer with a 16 degree Field of View. Covers 4.08-5.13 µm and 625 channels. MGS design complete. Build by Ball Aerospace with immersion grating and slit by JPL.
  - MGS in final design and parts procurement phase at Ball. Slit in design, procuring immersion grating substrate.
- **Black Silicon IR Blackbody (TRL 5)**
  - A cryo-etched silicon surface that exhibits less than 0.2% reflectance across a broad spectral band. Developed at JPL
  - CIRAS Black Si Slit and Blackbody currently in the design phase.
- **All technologies will be advanced to TRL 7 at the end of the spaceflight mission**







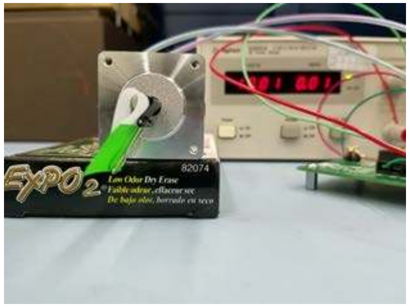


EON-IR 2016/2017 Statement of Work

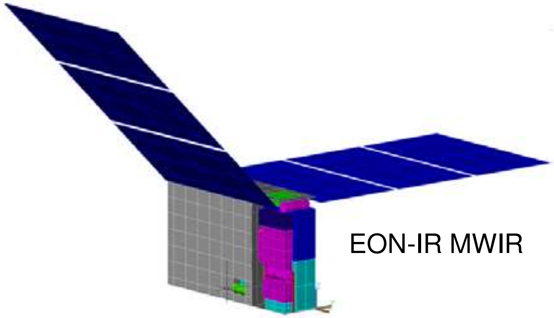
1. Improve the design of EON-IR to increase reliability commensurate with a mission of two years in length or longer. This task will examine the reliability and mission assurance of the EON-IR and its subsystems, primarily electronic, including the spacecraft.
2. Examine the ability to provide full swath scanning. This task will explore the ability to scan the EON-IR to achieve full swath as currently obtained from the operational sounders. Model the scanning mechanism and impacts on the sensor collection as well as the dwell times.
3. Improve the EON-IR thermal/mechanical design. Model designs for an FPA mount and cold shield/filter for EON-IR with sufficient fidelity to estimate total photon flux at the detector for accurate predictions of noise performance, and estimate total thermal load at the detector cryocooler cold finger. Provide a better estimate of the amount of heat needed to dissipate by the cryocoolers and radiators.
4. Identify drivers and limitations to expand the EON-IR pathfinder channel capability to CrIS sensor capabilities. The objective is to determine if there are viable options to expand EON-IR beyond the Mid-wavelength Infrared (MWIR) to include Long-wavelength Infrared (LWIR). This task should look at thermal impacts as well and also possible increase in CubeSat size to accommodate additional capability

EON-IR 2016/17 Study Results

- The study was to benefit from the InVEST CIRAS program and identify the additional risks associated with the requirements of an EON-IR system.
- Task 1: Mission Reliability Improvement
  - Major portions of the EON-IR concept have low risk due to the commonality with CIRAS, however, further definition of EON-IR revealed several life limiting components which needed further reliability study and would possibly change the TRL of EON-IR.
    - Electronics: Parts identified with SEL sensitivity.
    - Scanning: Commercial scan motor has not undergone life testing.
    - Cryocoolers: Ricor K508N used on CIRAS not best choice for EON-IR. Alternate long-life microcoolers identified
- Task 2. Full Swath Scanning Study
  - Task demonstrated that full swath scanning is achievable with desired scan rates
- Task 3. Improve the MWIR portion of EON-IR Thermal/Mechanical Design
  - Results demonstrated that the heat generated by electronics and active cooling of the optics and detectors can be passively radiated by the 6U CubeSat structure
- Task 4. Expand the EON-IR Channel Capability
  - A Team-X study demonstrated that an LWIR Sounder can be designed to comfortably fit into a 12U CubeSat using a combination of active and passive cooling



EON-IR Scan Control Demo

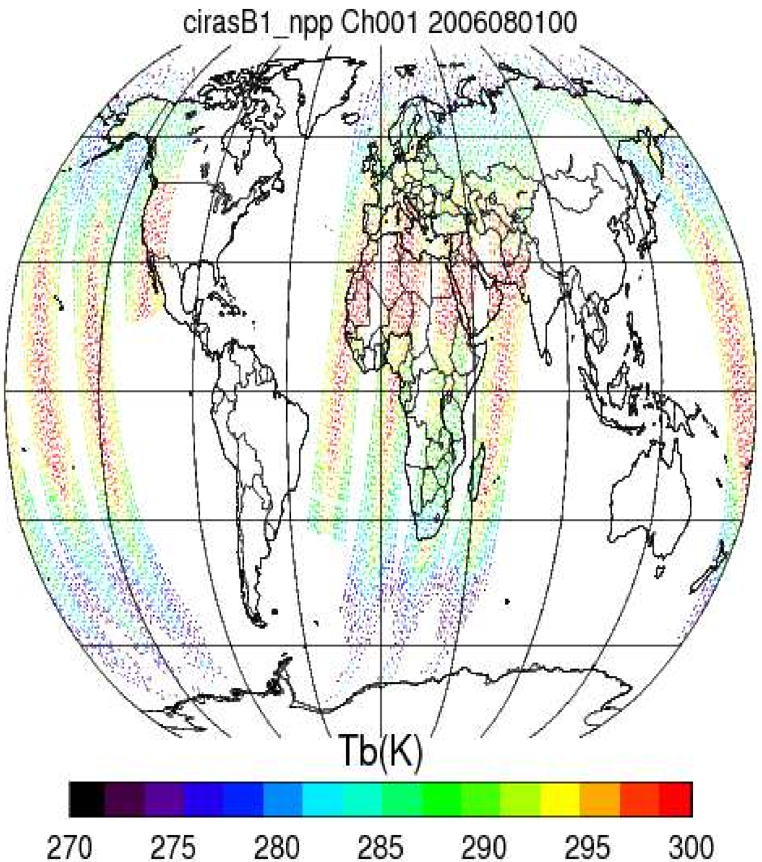


EON-IR MWIR

EON-IR LWIR 12U Concept Layout

EON – Microwave and Infrared Data Impact Studies

- Scope:
  - Determine the quantitative value of MicroMAS-2 and CIRAS in the reduction of forecast error in global and regional numerical weather prediction (NWP) models:
    - Impact of MicroMAS-2 in the absence of ATMS
    - Impact of CIRAS in the absence of CrIS
- Recent Work:
  - Created simulated MicroMAS-2 and CIRAS data CubeSat Sounders for studying impact
  - Created orbit simulator for MicroMAS-2 and CIRAS
- Next Steps:
  - Complete work to quantify and summarize impacts on simulated global NWP models



Simulated CIRAS data using JPSS CrIS

Conclusion

- NOAA, NASA, and JPL are all working together to provide IR sounding technology in a CubeSat
- IR soundings have major impacts on weather forecast models
- MWIR is viable and being demonstrated on a CubeSat format in CIRAS
- LWIR concepts have been developed to fit onto a 12U CubeSat form
- EON-IR expands beyond the technology demonstration to a longer operational mission life