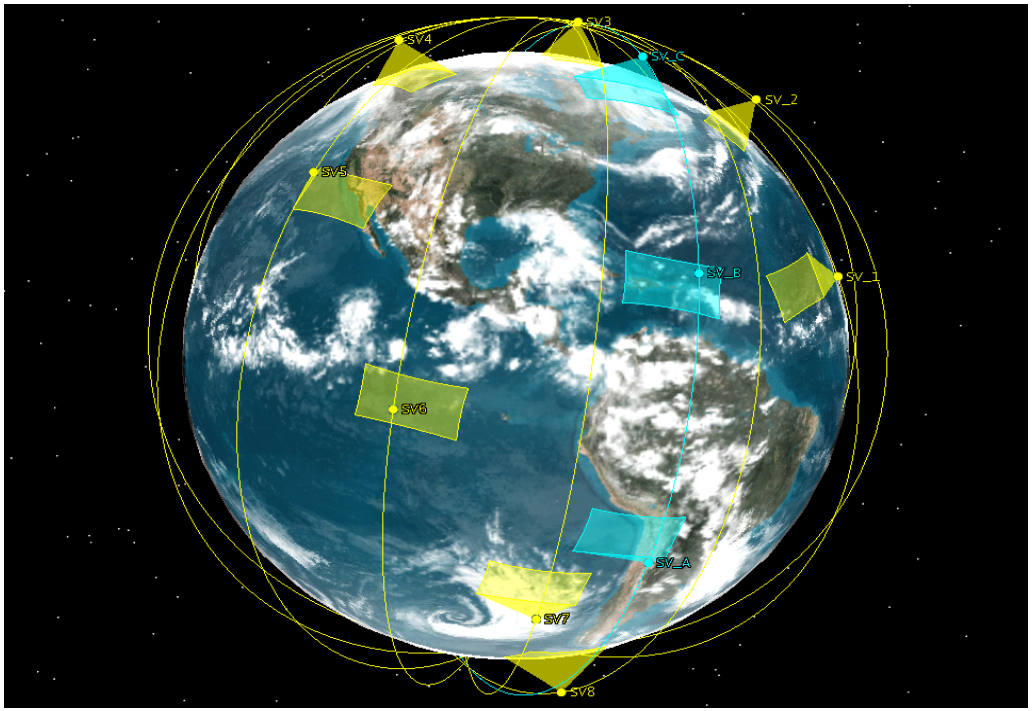
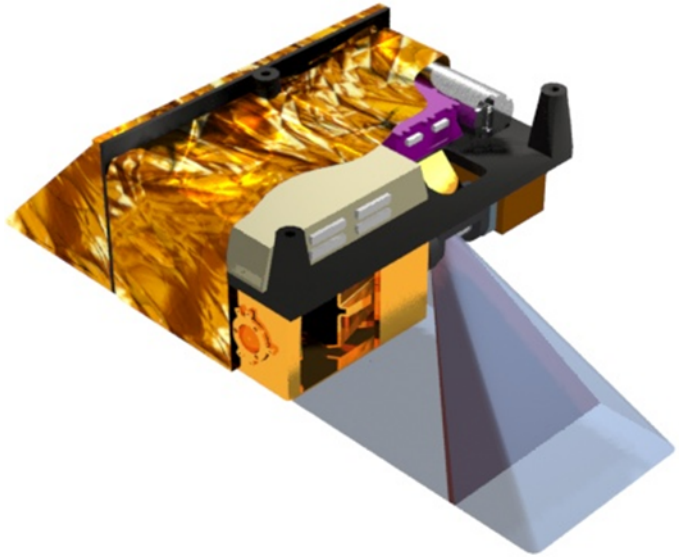
BAE SYSTEMS

MISTiC™ Winds

An Affordable System of Systems Approach for the Observation of Atmospheric Dynamics





MISTiC™ Winds

- Provides High Spatial/Temporal Resolution Temperature and Humidity Soundings of the Troposphere
  - Atmospheric State and Motion
- Enabled by:
  - LEO Constellation Approach
  - Micro-Sat-Compatible Instrument
  - Low-Cost Micro-Sat Launch

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Science Team: H. H. Aumann JPL, J. Susskind NASA GSFC

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MISTiC™ Winds-An Affordable System of Systems Approach for the Observation of Atmospheric Dynamics

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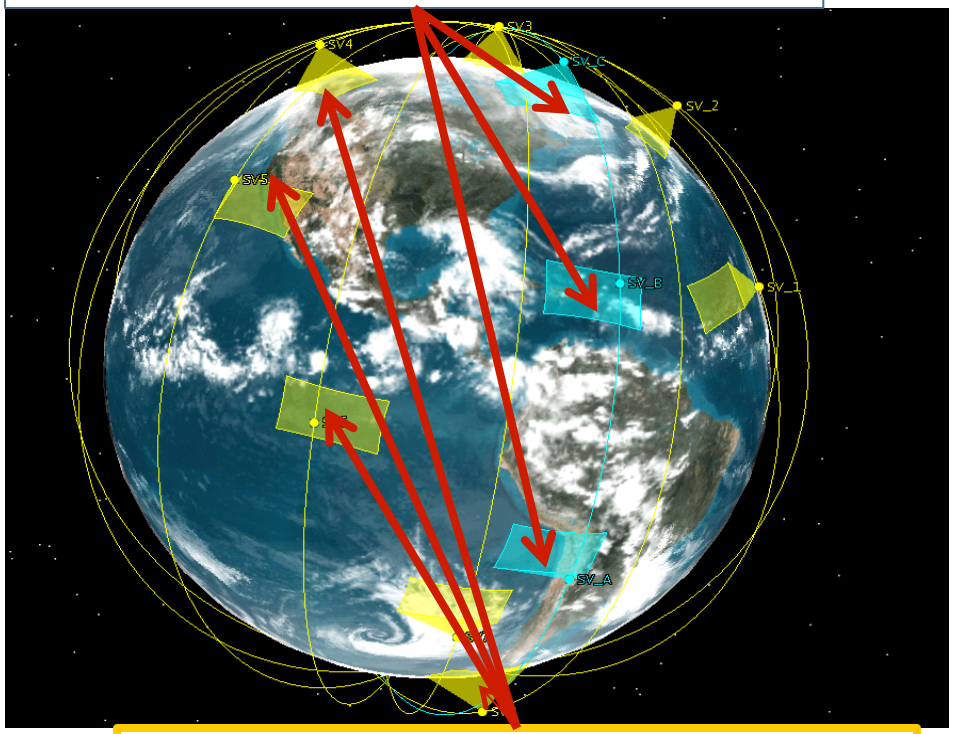
- MISTiC™ Winds Temperature and Humidity Sounding Constellation Options.
  1. Frequent-Sounding Constellation
     - e.g. 90 min refresh-globally.
  2. Wind-Vector Formations
     - e.g. 4 3-Satellite Formations for Cloud-Drift and Water Vapor Motion-Vector Winds
       - 3-Hr Refresh for 3D Winds *and* Atmospheric Soundings

Miniature Spectrometers Operated in Constellations Offer Lower Cost /Lower Risk Approach than GEO for Frequent-Refresh IR Soundings & 3-D Winds

A Motion-Vector Winds Formation



90 min Refresh of IR Soundings Provided by Spectrometers in 8 Orbital Planes (gold)

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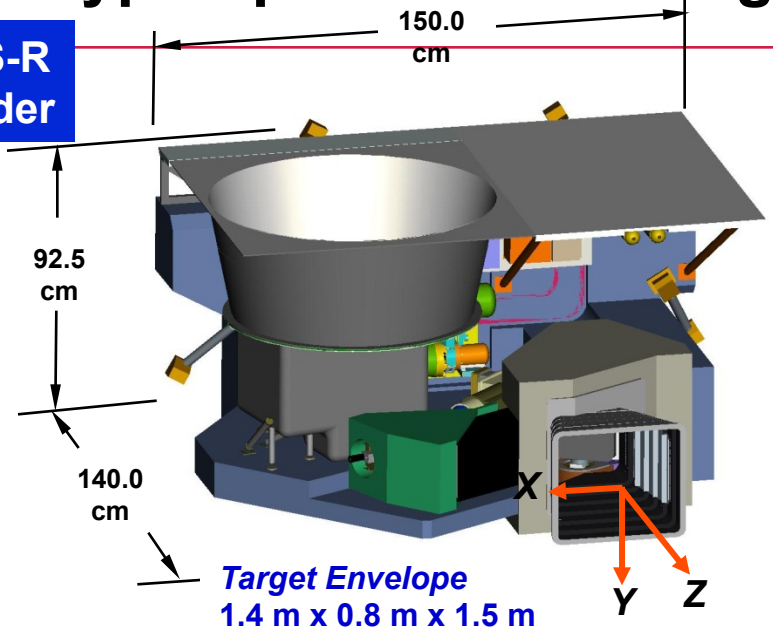
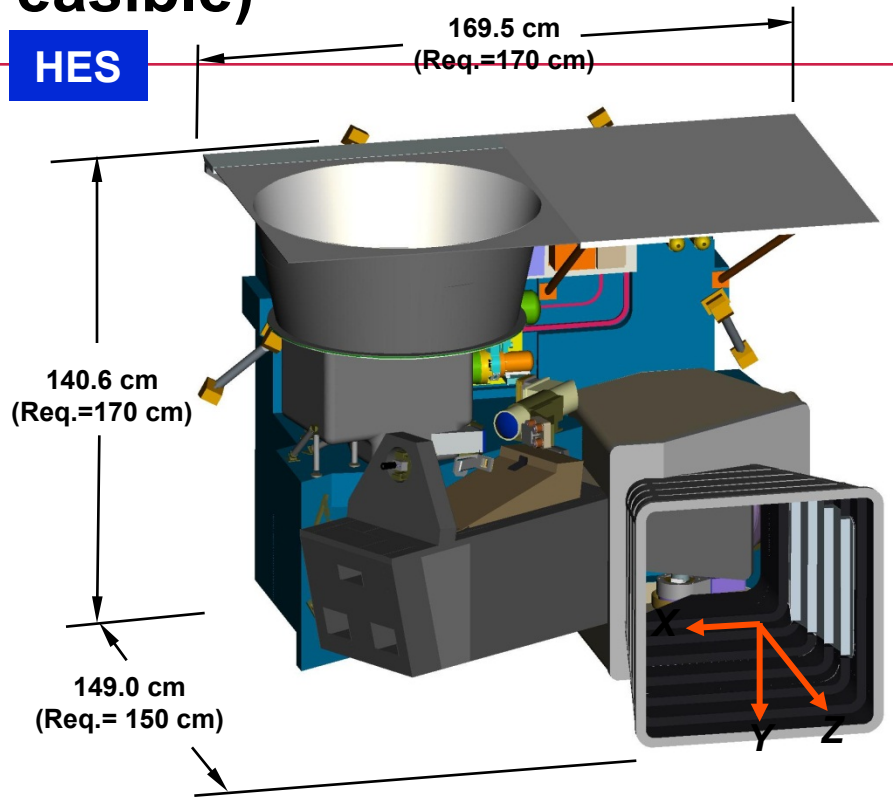
GOES-R Sounder (HES) after Formulation Phase (Geo Hyperspectral Sounding Feasible)

GOES-R Sounder



HES



GOES-R Sounder Characteristics
- Mass: 169 kg
- Power: 223 W
- Data Rate: 1.8 Mbps
- CONUS Sounding Coverage Rate:
  - CONUS/hr @ 10 km GSD (Can Provide 2x CONUS/Hr also)
- Disk Sounding Coverage Rate:
  - 62 Deg. Disk/hr @ 20 km GSD
- Meso-scale Demonstration @ 5 km

Shared Characteristics
- Spectral Coverage:
  - 4.165-5.92 μm (1689-2400 cm^{-1})
  - 9.65-14.7 μm (680-1036 cm^{-1})
- Spectral Resolution: $\lambda/\delta\lambda$>1000
- NEΔT: 0.2K
- Spectral Stability: <0.01 $\delta\lambda$

HES Characteristics
- Mass: 214 kg
- Power: 326 W
- Data Rate: 7.3 Mbps
- SW/M Coverage Rate:
  - CONUS/hr @ 5 km GSD
- Disk Sounding Coverage Rate:
  - 62 Deg. Disk/hr @ 10 km GSD

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GOES-R Advanced Baseline Imager, AIRS, and CrIS

- Size of Geo-Stationary Imagers/ Sounders Driven by Orbit Radius
- Size of IR Sounders Driven by # of Channels and LWIR Band Cooling

MISTiC™ Instrument Would be Much Smaller than AIRS

- Artist's Rendering Depicts a MISTiC™ Instrument, for Comparison to AIRS
- Instrument Concept Design in-Progress
  - Baseline envelope consistent with hosting on a 50 kg ESPA-Class Microsatellite
  - "Objective" Envelope consistent with 27U Cubesat Envelope
- Small instrument size depicted continues to appear feasible

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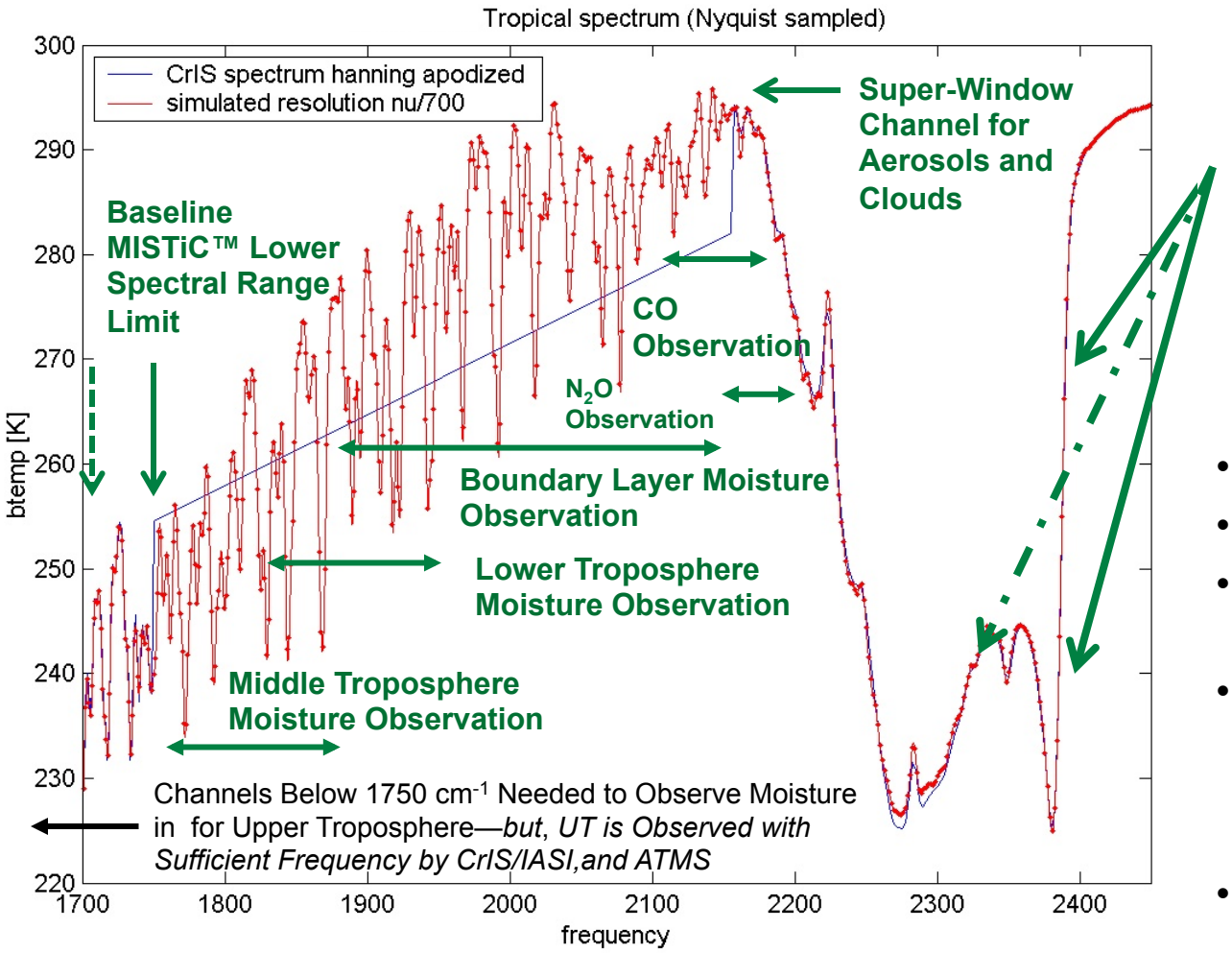
For MISTiC™, we Select ~ 600 Spectral Channels in the Mid IR-*Sufficient to Sound the Dynamic Portion of the Atmosphere*



- SWIR Coverage at NEΔT and $\Delta\nu$ Sufficient for CO_2 R-Branch Temperature Sounding of Surface to Upper Troposphere
  - Sharper vertical resolution using Wings
  - Spectral Resolution > 700:1 is Sufficient
- Mid-Trop. CO
- Mid-Trop. N_2O
- Moisture in Planetary Boundary Layer
- Moisture Profile in Lower and Middle Troposphere
  - WV Motion Vector Winds
- Clouds
  - Cloud MV Winds

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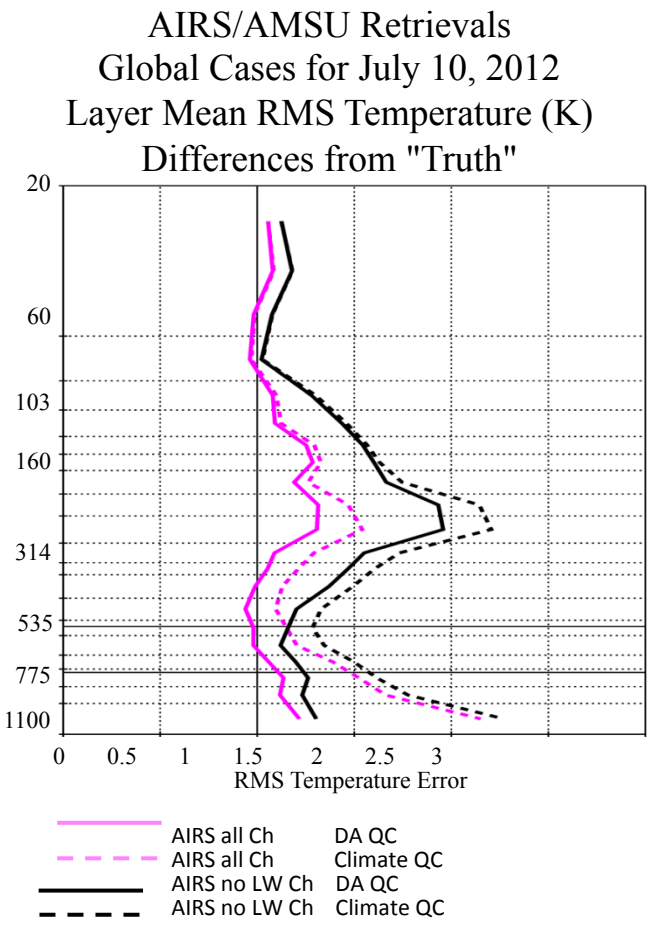
Vertical Temperature Profile Retrieval with SWIR/MWIR Sounder Comparable to AIRS & CrIS in Lower Troposphere

- Vertical Temperature Profile Retrieval Accuracy for Two Different Quality Control Thresholds are Shown
  - Using All AIRS Channels—red curves
  - Using SWIR/MWIR-Only –black curves
- Modest Additional Error Experienced when using only SWIR/MWIR Channels
  - ≤ 0.1K Added Error in Lower Troposphere
  - NOTE-AIRS Version 6 Algorithm Primarily uses SWIR-MWIR Channels for Sounding, using LWIR Channels only for Cloud-Clearing
- Additional Benefit from MISTiC™ Express- *fine spatial resolution* (~ 3 km @ nadir)
  - Yield of Cloud-Clear Observations much higher for MISTiC™ than for CrIS, IASI, and AIRS
  - Increased Cloud Contrast in Partly Cloudy Scenes



(from Joel Susskind NASA GSFC)

MISTiC™ Winds Level 1 Instrument Performance Characteristics and Level-2 Sounding Data Quality (updated)

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MISTiC™ Key Instrument Performance Characteristics		
Characteristic	Value	Comments
Minimum Spectral Frequency	1750 cm^{-1}	5.72 μm
Maximum Spectral Frequency	2450 cm^{-1}	4.082 μm
Spectral Sampling	~ 2:1	<590 spectral samples
Spectral Resolution @ minimum	>700 :1	$\nu/\delta\nu$ ((comparable to CrIS-Apodized)
Spectral Calibration Knowledge	1/100,000	$\delta\lambda/\lambda$
Angular Sampling	1.6 mr (cross-dispersed)	1.38 km (@ Nadir)
Orbital Altitude and Orbit	705.3 km	Polar/Sun-Synchronous
Angular Range (cross-track)	1570 radians	90 Degrees—Same as AIRS
Spatial Resolution	<3.0 km (geometric mean)	@ Nadir
Radiometric Sensitivity	<200 mK (max)	(<150 mK @ 2380 cm^{-1})
Radiometric Accuracy	<1%	@ 300K Scene Background
Key Sounding Data Product Characteristics,		
Vertical Resolution—Temperature	~ 1 km	In Lower Troposphere
Layer Accuracy	~ 1.25 K	In Lower Troposphere
Vertical Resolution—Humidity	~ 2 km	In Lower Troposphere
Layer Accuracy—Humidity	~ 15 %	In Lower Troposphere

- MISTiC™ Data Quality Requirements Similar to those Demonstra-ted by NASA's Successful AIRS Instrument
  - Spectral Resolution
  - Spectral Calibration Stability
  - Radiometric Sensitivity/Accuracy
- Spatial Resolution Notably Finer than AIRS Resolution (13 km @Nadir for AIRS)
  - 3.0km @ Nadir
- Reduced Spectral Range Enables Major SWAP Reduction

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Comparative System of Systems Estimates for Instruments for Tropospheric Wind Profile Measurement

Instrument	Power	Size (cm)	Mass (kg)	# of Levels*	** State Measured	Orbit and # Platforms
MISTiC™	<60 W***	20x34x35***	15	~10	YES	LEO (12)
HES	550 W	170x170x 150	315	~10	YES	GEO (6)
Hybrid Wind LIDAR (est)	750 W	150x150x 100	400	10-15	NO	LEO (4)

* Number of wind levels in the troposphere

** Atmospheric State Measurement (Vertical & Spatial Temperature and Moisture Fields etc)

***Updated (based on small satellite provider discussions

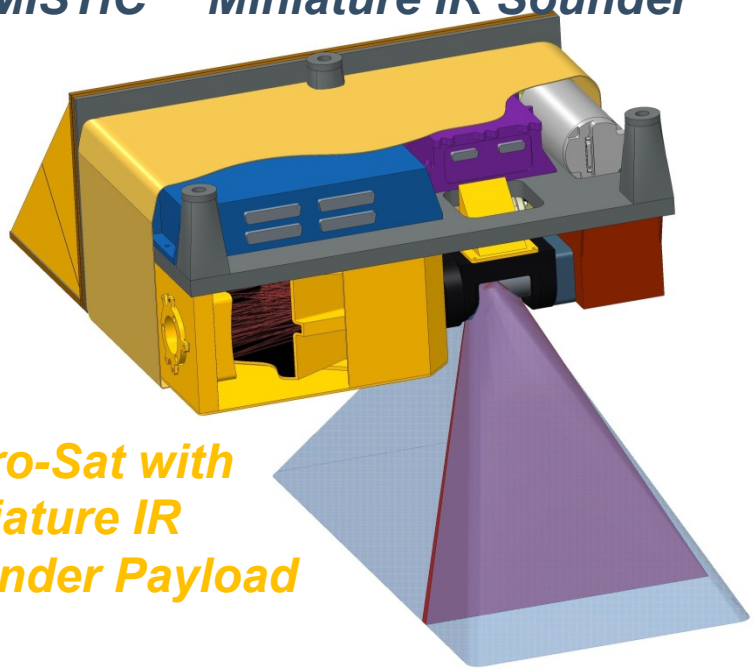
Miniature Spectrometers Operated in Constellations Offer Lower Cost /Lower Risk Approach than GEO for Frequent-Refresh IR Soundings & Winds

BAE SYSTEMS

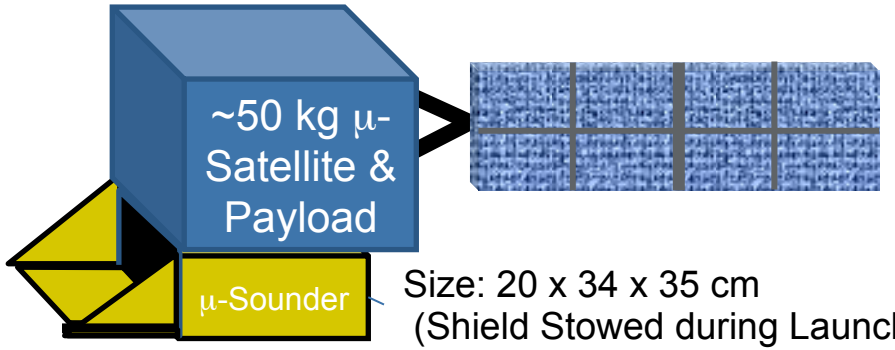
MISTiC™ Winds-A Miniature High Vertical Resolution Infrared Sounder for 3D Winds and Frequent IR Soundings

- Miniature Spectrometers Enabled by:
  - Optimized Low-Impact Spectral Channel Selection Proven through a Decade of NASA's AIRS Experience
  - Innovative Opto-Mechanical/Thermal Design Minimizes S/C Resources Needed to Cool IR Spectrometer
  - Advanced Large-Format IRFPA, Miniature Cryocooler, and Electronics
- Compact IR Sounder Design, Mature Algorithms and Technologies Enable:
  - Payload Hosting on a Micro-Satellite for a Low-Cost Total IR Sounding Mission
  - ~1 km Vertical & ~3 km Horizontal Resolution (@Nadir) in the Troposphere

MISTiC™ Miniature IR Sounder



Micro-Sat with Miniature IR Sounder Payload



Size: 20 x 34 x 35 cm
(Shield Stowed during Launch)