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

- 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

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 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

**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

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

- SWIR Coverage at NEAT and Δν Sufficient for CO₂ 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. N₂O
- Moisture in Planetary Boundary Layer
- Moisture Profile in Lower and Middle Troposphere
  - WV Motion Vector Winds
- Clouds
  - Cloud MV Winds
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
  - $\leq 0.1K$ 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)

### MISTiC™ Key Instrument Performance Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Spectral Frequency</td>
<td>1750 cm⁻¹</td>
<td>5.72 µm</td>
</tr>
<tr>
<td>Maximum Spectral Frequency</td>
<td>2450 cm⁻¹</td>
<td>4.082 µm</td>
</tr>
<tr>
<td>Spectral Sampling</td>
<td>~ 2:1</td>
<td>&lt; 590 spectral samples</td>
</tr>
<tr>
<td>Spectral Resolution @ minimum</td>
<td>&gt; 700 :1</td>
<td>( \nu / \delta \nu ) ((comparable to CrIS-Apodized))</td>
</tr>
<tr>
<td>Spectral Calibration Knowledge</td>
<td>1/100,000</td>
<td>( \delta \lambda / \lambda )</td>
</tr>
<tr>
<td>Angular Sampling</td>
<td>1.6 m (cross-dispersed)</td>
<td>1.38 km (@ Nadir)</td>
</tr>
<tr>
<td>Orbital Altitude and Orbit</td>
<td>705.3 km</td>
<td>Polar/Sun-Synchronous</td>
</tr>
<tr>
<td>Angular Range (cross-track)</td>
<td>1570 radians</td>
<td>90 Degrees—Same as AIRS @ Nadir</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>&lt; 3.0 km (geometric mean)</td>
<td>@ Nadir</td>
</tr>
<tr>
<td>Radiometric Sensitivity</td>
<td>&lt; 200 mK (max)</td>
<td>(≤ 150 mK @ 2380 cm⁻¹)</td>
</tr>
<tr>
<td>Radiometric Accuracy</td>
<td>&lt; 1%</td>
<td>@ 300K Scene Background</td>
</tr>
</tbody>
</table>

### 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 Demonstrated 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)
  - 3.0 km @ Nadir
  - Reduced Spectral Range Enables Major SWAP Reduction

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*BAE SYSTEMS*

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

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Power</th>
<th>Size (cm)</th>
<th>Mass (kg)</th>
<th># of Levels*</th>
<th>** State Measured</th>
<th>Orbit and # Platforms</th>
</tr>
</thead>
<tbody>
<tr>
<td>MISTiC™</td>
<td>&lt;60 W***</td>
<td>20x34x35***</td>
<td>15</td>
<td>~10</td>
<td>YES</td>
<td>LEO (12)</td>
</tr>
<tr>
<td>HES</td>
<td>550 W</td>
<td>170x170x150</td>
<td>315</td>
<td>~10</td>
<td>YES</td>
<td>GEO (6)</td>
</tr>
<tr>
<td>Hybrid Wind LIDAR (est)</td>
<td>750 W</td>
<td>150x150x100</td>
<td>400</td>
<td>10-15</td>
<td>NO</td>
<td>LEO (4)</td>
</tr>
</tbody>
</table>

* Number of wind levels in the troposphere  
** Atmospheric State Measurement (Vertical & Spatial Temperature and Moisture Fields etc)  
***Updated (based on small satellite provider discussions

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

~50 kg µ-Satellite & Payload

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