HyspIRI Thermal Infrared Radiometer (TIR) Instrument Conceptual Design

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<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>BASELINE</th>
<th>SCIENCE REQUIREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Resolution (m)</td>
<td>60</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>Revisit (days)</td>
<td>5</td>
<td>&lt;6</td>
</tr>
<tr>
<td>Noise equivalent delta temperature (K)</td>
<td>&lt; 0.2</td>
<td>&lt; 0.3</td>
</tr>
<tr>
<td>Absolute accuracy (K)</td>
<td>0.5</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Saturation – low temperature bands (K)</td>
<td>500</td>
<td>&gt;400</td>
</tr>
<tr>
<td>Saturation – high temperature band (K)</td>
<td>1200</td>
<td>&gt;1100</td>
</tr>
<tr>
<td>Overpass time (hh:mm)</td>
<td>10:30am</td>
<td>10-3pm</td>
</tr>
<tr>
<td>Nighttime imaging</td>
<td>Yes</td>
<td>Required</td>
</tr>
<tr>
<td>Number of Bands (spectral range: 3 – 12 µm)</td>
<td>8</td>
<td>&gt;= 8</td>
</tr>
<tr>
<td>Coverage</td>
<td>Land and coastal regions, Oceans at 1 km resolution</td>
<td>Land and coastal regions</td>
</tr>
<tr>
<td>Data latency</td>
<td>2 days</td>
<td>&lt; 1 week</td>
</tr>
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Rationale for Whisk vs. Pushbroom Scanning

Science Requirements
- 60 m Resolution
- 5-Day repeat

Instrument Requirements
- ~10,000 pixels cross track
- ~600 km swath
- 51° Cross-track swath

Whiskbroom (Push-Whisk)
- Single telescope with scanning mirror
- Single detector array with 256 pixels per band

Pushbroom
- ~10 detector arrays, each with ~1,000 pixels per band
- ≥3 telescopes

Science Requirements
- 0.5% Radiometric accuracy for 300 K scenes

Instrument Requirements
- Frequent 2-point calibrations (space and blackbody)

Whiskbroom (Push-Whisk)
- Scanning mirror allows easy and frequent 2-point calibrations
- No mapping gaps

Pushbroom
- Calibration mechanism required – must enable multiple telescopes to view space and blackbody
- Gap in mapping during calibration

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Rationale for Mercury Cadmium Telleride (MCT) Detectors

Science / Instrument Requirement
0.2 K resolution for 300 K scene

MCT Detectors
• Quantum efficiency ≥ 70%
• 0.06 K resolution at 60 K (69 W cooler power)

QWIPs
• Quantum efficiency ~3%
• > 0.3 K resolution at 40 K (225 W cooler power)

Uncooled Microbolometers
• Too slow for push-whisk method
• Even with pushbroom, resolution ~0.8 K

Science / Instrument Requirement
8 spectral bands 4-12 µm

QWIPs
• Multiple arrays required to cover all bands

Uncooled Microbolometers
• Not sensitive to 4 µm band

MCT Detectors
• Single band-gap material can cover full spectral range

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TIR Scanning and Data Rate

- 60 m Pixel Footprint at Nadir
- Time-Averaged Science Data Rate 0.020 Gbps
- Assuming 14 bits, 2:1 Compression, 31% Land
- Scan Mirror Rotation Rate 14.2 RPM
- Pixel Dwell Time 32 microseconds
TIR Instrument Concept

Mass and Power (JPL Team X)
- Mass CBE 60 kg
- Power CBE 103 W

Diagram showing:
- Blackbody
- Radiator for Cryocooler and Electronics Heat
- Space View Port
- Cryocooler
- Passive Cooler for 200K Shield

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HyspIRI-TIR telescope concept

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aperture Size</td>
<td>208 mm</td>
</tr>
<tr>
<td>f/#</td>
<td>2.0</td>
</tr>
<tr>
<td>Focal Length</td>
<td>416 mm</td>
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HyspIRI-TIR optics consists of a 3-mirror off axis Cassegrain plus relay optics.

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TIR Focal Plane Concept

- MCT Detector Array – 256 elements cross-sweep
- 1 Bandgap to Cover Full Spectral Range
- ≥ 4 Detector Columns per Spectral Channel to Allow Time Delay and Integration (TDI)

- Butcher-Block Filter Assembly
- Baffles to Prevent Crosstalk Between Spectral Channels

- CMOS Read-Out Integrated Circuit (ROIC)
- 32 Output Signals to Enable Necessary Pixel Read Rate

- 60 K Cold Tip of Cryocooler

- Peak Data Rate = 256 Mpixels/sec (256 detectors cross-sweep, x4 for TDI, x8 spectral bands every 32 µs).
  - 32 analog output lines, each operating at >10 MHz
  - Digitization in off-chip ADCs
  - TDI performed by FPGA after digitization

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• ROICS, Detector Arrays, and Hybrids produced by Teledyne Imaging Systems.
• ROICS have been designed, fabricated, and tested at room temperature.
• ROIC functionality confirmed. Noise at room temperature as predicted.
• 13.2 µm cutoff MCT detector arrays have been fabricated.
• Test detectors show specified performance.
• First hybrids will be assembled and tested in December 2012.
TIR Calculated Performance

Noise-Equivalent Temperature Difference with TDI

Scene Temperature (K)

Noise-Equivalent Temperature Difference (K)

- 3.98 microns
- 7.35 microns
- 8.28 microns
- 8.63 microns
- 9.07 microns
- 10.53 microns
- 11.33 microns
- 12.05 microns
TIR Calculated Performance

Noise-Equivalent Temperature Difference with TDI

- 3.98 microns
- 7.35 microns
- 8.28 microns
- 8.63 microns
- 9.07 microns
- 10.53 microns
- 11.33 microns
- 12.05 microns

Scene Temperature (K): 300 to 1100
Noise-Equivalent Temperature Difference (K): 0 to 1.0

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NGAS HEC (High-Efficiency Cooler) is fully flight qualified with two units currently operating in space (Japanese Advanced Meteorological Imager – JAMI, launched in 2005 and Thermal and Short Wave Infrared Sensor – TANSO, launched in 2009). Thermal Shield at 200 K to Reduce Load on Cryocooler, Passive cooler similar to that flying on the Moon Mineralogy Mapper (M³), Radiator for cryocooler heat.
Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR)

- Funded by NASA Instrument Incubator Program (IIP)
- For demonstration of key HyspIRI TIR technologies – focal plane and scan mirror / encoder
- Assembly will start Spring 2013
- Testing in Fall 2013
- More information in Simon Hook’s presentation on Thursday