Hyperion Imaging Spectrometer on the New Millennium Program Earth Orbiter-1 System

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TRW

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As the first New Millennium Program Earth Orbiter Mission, EO-1 will demonstrate advanced land imaging instruments and high payoff spacecraft technologies.
Hyperion Hyperspectral Imager
Earth Orbiter - 1 Mission

Three revolutionary land imaging instruments on EO-1 will collect multi-spectral and hyperspectral scenes over the course of the EO-1 Mission in coordination with the Enhanced Thematic Mapper (ETM+) on Landsat-7. Detailed comparisons of the EO-1 and ETM+ images will be carried out to validate these instruments for follow-on missions.

Breakthrough technologies in lightweight materials, high performance integrated detector arrays and precision spectrometers will be demonstrated in these instruments.
Hyperion Imaging Spectrometer

Convex Grating spectrometers with CCD VNIR and HgCdTe SWIR detectors (60µm pixels)

30m spatial and 10nm spectral resolutions over 7.5km swath and 400-2500nm spectral range

Multiple calibration options: lamps, lunar, solar, ground imaging and laboratory

Hyperspectral Imaging Capability to address technology and Earth Observation applications
Advanced Land Imager (ALI)

- Objective is to validate pushbroom technologies for Landsat applications
- Pushbroom Multi-Spectral Sensor - 9 multi-spectral (MS) channels and a pan channel
- Spectral coverage enhances Landsat ETM+ but excludes LWIR channel
- Swath width is 37km and MS ground resolution is 30m.
- S/N is 100 or better
EO-1 ALI Optical Structure by SSG
LEISA Atmospheric Corrector

- Correction of multi-spectral surface imagery for atmospheric variability (water and aerosols).
- High spectral, moderate spatial resolution (250m), large swath (180km) hyperspectral imager using wedge filter technology.
- Spectral coverage of 0.89 - 1.6mm, bands selected for optimal correction of high spatial resolution images.
# EO-1 Instrument Overviews

<table>
<thead>
<tr>
<th>Parameters</th>
<th>EO-1</th>
<th>HYPERION</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral Range</td>
<td>0.4 - 2.4 μm</td>
<td>0.4 - 2.5 μm</td>
<td>0.9 - 1.6 μm</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>30 m</td>
<td>30 m</td>
<td>250 m</td>
</tr>
<tr>
<td>Swath Width</td>
<td>36 Km</td>
<td>7.5 Km</td>
<td>185 Km</td>
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<tr>
<td>Spectral Resolution</td>
<td>Variable</td>
<td>10 nm</td>
<td>6 nm</td>
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<tr>
<td>Spectral Coverage</td>
<td>Discrete</td>
<td>Continuous</td>
<td>Continuous</td>
</tr>
<tr>
<td>Pan Band Resolution</td>
<td>10 m</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Total Number of Bands</td>
<td>10</td>
<td>220</td>
<td>256</td>
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Hyperion Subsystems

Hyperion Electronics Assembly

Cryocooler Electronics Assembly

Hyperion Sensor Assembly (HSA)
Hyperion Sensor Assembly (HSA)
Hyperion HSA Subsystems

- Solar Baffle
- Telescope
- Spectrometer
- Cryocooler
Hyperion Electronics Assembly

Formatter Board
Processor Board
Telemetry Board

1773 Transceiver Board
Motor/Heater Drive Board
DC/DC Converter Assembly Bd

HEA
Hyperion Cryocooler Subsystem

![Image of Cryocooler Subsystem components: Cryocooler, LVDT Box, Pulse Tube Cooler, and Cryocooler Electronics Assembly]
Hyperion in Vacuum Chamber

Hyperion

Ground Support Equipment
MSTB Provides Absolute Radiometric and Spectral Calibration

Plan

Clean Room

Multi-Spectral Source Assembly

Hyperion

Cryovac Chamber

Monochromator
System SNR

Radiometric performance model base on 60° Solar zenith angle, 30% albedo, standard scene.

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Hyperion Measured SNR</th>
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<tbody>
<tr>
<td>550 nm</td>
<td>161</td>
</tr>
<tr>
<td>650 nm</td>
<td>144</td>
</tr>
<tr>
<td>700 nm</td>
<td>147</td>
</tr>
<tr>
<td>1025 nm</td>
<td>90</td>
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<tr>
<td>1225 nm</td>
<td>110</td>
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<tr>
<td>1575 nm</td>
<td>89</td>
</tr>
<tr>
<td>2125 nm</td>
<td>40</td>
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</table>
Image Quality Assessment (MTF)

Cross-Track MTF Measured using the knife-edge and slit techniques

- Knife-edge perpendicular to the entrance slit of Hyperion
- Over-sampling by tilting steering mirror in fractional-pixel steps
- Derivative of Knife-Edge Data is the PSF
- MTF is the Fourier transform of PSF.

Along-Track MTF is the Fourier transform of the convolution of PSF and along-track smear.

<table>
<thead>
<tr>
<th>Measured Average Along-Track MTF Values</th>
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<th></th>
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<tr>
<td>500 nm</td>
<td>0.26</td>
<td>0.26</td>
<td>0.24</td>
<td>0.28</td>
<td>0.28</td>
<td>0.26</td>
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<tr>
<td>630 nm</td>
<td>0.26</td>
<td>0.26</td>
<td>0.24</td>
<td>0.28</td>
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<tr>
<td>900 nm</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1050 nm</td>
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<tr>
<td>1250 nm</td>
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</tr>
<tr>
<td>1650 nm</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2200 nm</td>
<td></td>
<td></td>
<td></td>
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Spatial Co-Registration of Spectral Channels

Measured with broadband point source at 20 locations on each focal plane array

Steering mirror used to move the image of the point source along cross-track spatial direction in fractional pixel increments

Point source created by a narrow slit located at MSTB image plane, oriented perpendicular to the spectrometer slit of Hyperion.

View of the image on the focal plane array.

SCSC Error

Spectral Direction

Spatial Direction

FOV Pixel Number

SCSC Error (pixel)

0.3
0.25
0.2
0.15
0.1
0.05
0

0 50 100 150 200 250 300

VH1R

SWIR

Requirement
# VNIR Spectral Response

## VNIR Channel Center Wavelengths (nm, accuracy +/- 0.5 nm)

<table>
<thead>
<tr>
<th>FOV #</th>
<th>Spectral channel</th>
<th>13</th>
<th>31</th>
<th>40</th>
<th>48</th>
<th>57</th>
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<tbody>
<tr>
<td>6</td>
<td></td>
<td>477.40</td>
<td>656.46</td>
<td>753.6</td>
<td>834.29</td>
<td>925.38</td>
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<tr>
<td>71</td>
<td></td>
<td>478.45</td>
<td>657.45</td>
<td>754.12</td>
<td>834.91</td>
<td>925.14</td>
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<tr>
<td>136</td>
<td></td>
<td>477.97</td>
<td>656.83</td>
<td>753.66</td>
<td>834.40</td>
<td>925.29</td>
</tr>
<tr>
<td>196</td>
<td></td>
<td>476.75</td>
<td>655.69</td>
<td>752.83</td>
<td>833.41</td>
<td>924.38</td>
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<tr>
<td>251</td>
<td></td>
<td>475.15</td>
<td>654.59</td>
<td>751.3</td>
<td>831.94</td>
<td>922.77</td>
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## VNIR FWHM of Spectral Response Functions (nm)

<table>
<thead>
<tr>
<th>FOV #</th>
<th>Spectral channel</th>
<th>13</th>
<th>31</th>
<th>40</th>
<th>48</th>
<th>57</th>
</tr>
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<tbody>
<tr>
<td>6</td>
<td></td>
<td>11.23</td>
<td>10.51</td>
<td>10.6</td>
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<td>11.11</td>
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<td>11.38</td>
<td>10.21</td>
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<td>11.3</td>
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<tr>
<td>251</td>
<td></td>
<td>11.25</td>
<td>10.16</td>
<td>10.62</td>
<td>11.28</td>
<td>11.23</td>
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## SWIR Spectral Response

<table>
<thead>
<tr>
<th>FOV #</th>
<th>Special channel</th>
<th>SWIR channel Center Wavelengths (nm +/- 0.5 nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>27</td>
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<tr>
<td>6</td>
<td>2314.08</td>
<td>2012.19</td>
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<td>71</td>
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<td>136</td>
<td>2313.97</td>
<td>2012.19</td>
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<tr>
<td>196</td>
<td>2313.9</td>
<td>2012.1</td>
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<tr>
<td>251</td>
<td>2313.66</td>
<td>1711.07</td>
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</table>

<table>
<thead>
<tr>
<th>FOV #</th>
<th>Special channel</th>
<th>SWIR FWHM of Spectral Response Function (nm)</th>
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<tbody>
<tr>
<td></td>
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<td>27</td>
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<tr>
<td>6</td>
<td>10.44</td>
<td>10.64</td>
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<td>71</td>
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<td>196</td>
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<td>11.05</td>
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<tr>
<td>251</td>
<td>10.19</td>
<td>11.33</td>
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Hyperion Data Flow

- **Mission Operations Center (MOC)**
  - Tape Handling and Data Distribution
  - Data Processing System (DPS)

- **Mission Planning Office**
  - GSFC

- **Hyperion Support**
  - Process to level 1 data
  - Performance monitoring
  - TRW

- **EO-1 Science Validation Facility**
  - Level-1 ALI & AC Processing
  - Science Data Archive
  - Data Distribution
  - Image Assessment
  - Calibration
  - GSFC

- **Commercialization**
  - Planning and coordination
  - Interim Commercial Archive
  - SSC

- **Long Term Archive**
  - EDC

- **X-band Science Data**

- **Commercial**

- **Educational**
Early Orbit Checkout -- Objectives

Instrument Activation and Checkout
- Activate to full functionality
- Monitor SOH telemetry
- Calibration check
- Spacecraft-related checkout
  - Geo-reference
  - Impact of jitter & pointing
- Comparison with pre-flight characterization

Products
- On-orbit characterization
- Calibration sites/maintenance schedule recommendations
Early Orbit Checkout -- Data Collections

Solar Calibration
  • 3X per week initially

Lunar Calibration
  • Near-full moon, ± 6 days

Geo-referencing / Jitter Assessment Scenes
  • San Francisco Bay, Panama Canal, Iowa farm roads

Calibration / Characterization Scenes
  • Ground truth
  • Under flights
  • Reference sites
Early Orbit Checkout -- Characterization Sites

Radiometric calibration
- Tinga Tingana, Australia
- Lake George, Australia
- Uardry, Australia
- Amburla, Australia
- White Sands
- Salton Sea
- Edwards AFB
- Blythe
- Stennis Space Center

Ground sample distance
- Burdekin, Australia
- Panama Canal
- San Francisco Bay
- Artificial night site
- Iowa farm roads

Spatial co-registration / MTF
- Moon
- Burdekin, Australia
- San Francisco Bay
- S. Chilean coast

Straylight / Dynamic range
- Moon
- Clouds over ocean (Lanai)
- Mauna Kea

Cross track spectral error
- Solar calibration
- Mt. Fitton, Australia

Spectral sites
- Mt. Fitton, Australia
- Las Vegas
- Artificial night site
**EO-1 Mission Highlights**

*Orbit*

- 705 Km altitude Sun-synchronous, circular orbit inclined at 98.2°
- Descending node - equatorial crossing about one minute behind Landsat 7

*Launch Vehicle*

- Launch Vehicle: Delta 7320
- Launch Date: Winter 2000
- Co-manifested with SAC-C
Less Than 1 Minute

Landsat Multi-Spectral Images (185 km @ 30 m)

EO-1 Orbit

Hyperspectral Images (7.5 km @ 30 m)

Hyperspectral Atmospheric Correction (185 km @ 125 / 250 m)

Multi-Spectral Images (37 km @ 30 m)

705 km Altitude

Landsat Multi-Spectral Images (185 km @ 30 m)

Hyperion Hyperspectral Images (7.5 km @ 30 m)