



HyspIRI Comprehensive Mission Report



Robert O. Green and the HyspIRI Community

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2014 HyspIRI Guidance



1. Continue to build broad community understanding and support by conducting science and applications workshops and data product symposia;

2. Complete the science white paper specifying the value of the individual science measurements and the potential science return of individual instruments on separate platforms, including the ISS, if appropriate;

3. Use the planned airborne activities and resulting data to generate HyspIRI-like Level 2 data products (e.g., large-area 60m data sets providing surface reflectance, surface temperature and surface emissivity) to define the instrument capabilities and explore high-volume data management issues related to the HyspIRI VSWIR and TIR instruments. These efforts should include additional support for airborne mission management.

4. Carry out instrument mission trade studies, including smallsat and ISS opportunities, to provide lower cost and more adaptable instrument and/or mission approaches. The team should consider conducting TEAM-X or IDL studies to assist with this, in addition to enlisting the support of ESTO and the ESM SEWG.

5. Explore options to ensure the HyspIRI VSWIR and TIR instruments meet the Sustainable Land Imaging measurement requirement, including compatibility with heritage data product resolution.

6. Engage potential international and domestic partners in addressing opportunities to lower the cost of a potential mission while maintaining Level 1 mission requirements.

7. Support the Earth Systematic Missions (ESM) Systems Engineering Working Group (SEWG) studies on TRL definition and instrument cost studies;

8. Complete a comprehensive development report of the HyspIRI mission study activities as detailed below.





- Lead by Ernesto Diaz and Michael Mercury
 - Supported by the concept team and the science study group
- Approach: pull together the set of HyspIRI studies and reports since the inception of the HyspIRI Mission Concept Study
- Develop an Executive Summary that communicates the most important results
- The ES should include the critical global science and applications questions and objectives that are enabled by HyspIRI type measurements
- Compile the Comprehensive Mission Report and associated documents so that they can be accessed by the NASA and the upcoming Decadal Survey



CMR Outline



HyspIRI Comprehensive Development Report (Draft)

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Emphasis on the Science and Applications that HyspIRI will Address



÷	Table 1				
	Question #	Question			
	VQ1	What is the global spatial pattern of ecosystem and diversity distributions and how do ecosystems differ in their composition or biodiversity?			
	VQ2	What are the seasonal expressions and cycles for terrestrial and aquatic ecosystems, functional groups, and diagnostic species? How are these being altered by changes in climate, land use, and disturbance?			
	VQ3	How are the biogeochemical cycles that sustain life on Earth being altered/disrupted by natural and human-induced environmental change? How do these changes affect the composition and health of ecosystems and what are the feedbacks with other components of the Earth system?			
	vq4	How are disturbance regimes changing and how do these changes affect the ecosystem processes that support life on Earth?			
	VQ5	How do changes in ecosystem composition and function affect human health, resource use, and resource management?			
	VQ6	What are the land surface soil/rock, snow/ice and shallow-water benthic compositions			
	TQ1	How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?			
	TQ2	What is the impact of global biomass burning on the terrestrial biosphere and atmosphere, and how is this impact changing over time?			
	TQ3	How is consumptive use of global freshwater supplies responding to changes in climate and demand, and what are the implications for sustainable management of water resources?			
	TQ4	How does urbanization affect the local, regional and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?			
	TQ5	What is the composition and temperature of the exposed surface of the Earth? How do these factors change over time and affect land use and habitability?			
-	CQ1	How do Inland, Coastal, And Open Ocean Aquatic Ecosystems Change Due To Local and Regional Thermal Climate, Land-Use Change, And Other Factors?			
	CQ2	How are fires and vegetation composition coupled?			
	CQ3	Do volcanoes signal impending eruptions through changes in the temperature of the ground, rates of gas and aerosol emission, temperature and composition of crater lakes, or health and extent of vegetation cover?			
	CQ4	How do species, functional type, and biodiversity composition within ecosystems influence the energy, water and biogeochemical cycles under varying climatic conditions?			
	CQ5	What is the composition of exposed terrestrial surface of the Earth and how does it respond to anthropogenic and non-anthropogenic drivers?			
	CQ6	How do patterns of human environmental and infectious diseases respond to leading environmental changes, particularly to urban growth and change and the associated impacts of urbanization?			













HyspIRI Contiguous 10 nm Spectral Channels 1 0.9 0.8 0.7 Reflectance 0.6 0.5 0.4 0.3 Grassland -Dryland Vegetation non-Photosynthetic 0.2 —Conifer Broadlea 0.1 Nitrogen Factor 0 700 400 1000 1300 1600 1900 2200 2500 Wavelength (nm) 0.9 -H1 (m21) 0.8 0.7 0.7 0.6 - H2 (m28) H3 (a10) -H4 (a11) **Spectral** 0.5 0.4 -H5 (a12) H6 H7 0.3 0.2 - H8 (m32) 0.1 Λ 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00 12.00 13.00 Wavelength (um)

HyspIRI is a global mission, measuring land and shallow aquatic habitats at 60 meters and deep oceans at 1km every 5 days (TIR) and every 19 days (VSWIR)

HyspIRI's VSWIR imaging spectrometer directly measures the full solar reflected spectrum of the Earth from 380 – 2500 nm at 10 nm with a high signal-to-noise ratio



HyspIRI's TIR directly samples the Earth's emitted thermal energy in 7 bands between 7.5-12 μ m, & 1 band between 3-5 μ m



To achieve the HyspIRI Science and Applications Global Coverage is Required for both VSWIR and TIR





EO-1 Hyperion acquisitions in 10 years. Technology demonstration

- HyspIRI VSWIR provides
 complete terrestrial coverage every
 19 days.
 - It would take **Hyperion 100** years to acquire what HyspIRI measures in 1 year.
 - HyspIRI TIR provide terrestrial coverage every 5 days





Level 1 Requirements





VSWIR

a) To address the Decadal Survey and community identified science and application questions related to terrestrial and coastal ocean ecosystem composition, function, and change as well as surface composition (DS113-115), the baseline science mission shall provide global mapping measurements of the surface reflectance or remote sensing reflectance for shallow water regions across the solar reflected spectrum from 380 to 2500 nm at ≤10 nm sampling at the specified signal-to-noise ratio and accuracy with >95% spectral/spatial uniformity at ≤60 m nadir spatial sampling with <20 day revisit to provide >60% seasonal and >80% annual coverage of the terrestrial and shallow water regions of the Earth for at least three years with a subset of measurements available near-real-time for designated science and applications.

Level 1 Requirements (VSWIR)





Spectral Cross-Track

Spectral-IFOV-Variation

>95% cross-track uniformity {<0.5 nm min-max over swath}

>95% spectral IFOV uniformity {<5% variation over spectral range}



VSWIR Cloud Cover Analysis





Mercury, M., R. Green, S. Hook, B. Oaida, W. Wu, A. Gunderson, M. Chodas, "Global cloud cover for assessment of optical satellite observation opportunities: A HyspIRI case study," Remote Sensing of Environment, Volume 126, November 2012, Pages 62–71





TIR

b) To address the Decadal Survey and community-identified science and application questions related to volcanoes, wild fires, water usage, urbanization and surface composition (DS113-115), the baseline science mission shall provide global mapping measurements of the surface radiance, temperature and emissivity with 8 spectral bands from the 3-5 micron and 8-12 micron regions of the spectrum at the specified noise-equivalent-delta-temperature and accuracy at ≤60 m nadir spatial sampling with ≤5 day revisit to provide >60% Monthly, >70% seasonal and >85% annual coverage of the terrestrial and shallow water regions of the Earth for at least three years with a subset of measurements available near-real-time for designated science and applications.



Specified NEdT



	Wavelength	Spectral	Radiance and	Max Nominal Radiance and	NEGT at Min nominal	NEGT at Max Nominal	
		Bandwidth	Temperature	Temperature	Temperature	Temperature	NEdT at 300 K
	(microns)	(microns)	(W/m^2/micron/sr)	(W/m^2/micron/sr)	Kelvin	Kelvin	Kelvin
Band 1	3.98	0.08	14 (400 K)	9600 (1400 K) 1	0.12	11.2
Band 2	7.35	0.32	0.34 (200 K)	110 (500 K) 2.8	0.22	0.28
Band 3	8.28	0.34	0.45 (200 K)	100 (500 K) 2	0.22	0.24
Band 4	8.63	0.35	0.57 (200 K)	94 (560 K) 1.6	0.24	0.24
Band 5	9.07	0.36	0.68 (200 K)	86 (500 K) 1.2	0.24	0.22
Band 6	10.53	0.54	0.89 (200 K)	71 (500 K) 0.64	0.22	0.16
Band 7	11.33	0.54	1.1 (200 K)	58 (500 K) 0.56	0.26	0.16
Band 8	12.05	0.52	1.2 (200 K)	48 (500 K) 0.52	0.3	0.18

Digitization @ min Digitization @ max radiance		Digitization @ 300 K
(W/m^2/micron/sr)	(W/m^2/micron/sr)	(W/m^2/micron/sr)
4.0e-2 (0.12 K)	4.0e-2 (0.01 K)	5.0e-2 (1.4 K)
5.6e-3 (0.30 K)	5.6e-3 (0.009 K)	5.6e-3 (0.03 K)
4.8e-3 (0.23 K)	4.8e-3 (0.009 K)	4.8e-3 (0.03 K)
4.5e-3 (0.19 K)	4.5e-3 (0.009 K)	4.5e-3 (0.03 K)
4.1e-3 (0.15 K)	4.1e-3 (0.010 K)	4.1e-3 (0.03 K)
2.5e-3 (0.08 K)	2.5e-3 (0.008 K)	2.5e-3 (0.02 K)
2.2e-3 (0.07 K)	2.2e-3 (0.010 K)	2.2e-3 (0.02 K)
2.1e-3 (0.06 K)	2.1e-3 (0.012 K)	2.1e-3 (0.02 K)

Notes

Center wavelength is the average of the max and min wavelengths at the FWHM Spectral bandwidth is the FWHM

Minimum nominal radiance is 200K except for 4 um band where it is 400K Maximum nominal radiance is 500K except for 4 um band where it is 1400K



Performance







Number of daytime cloud-free views by TIR each month





Top Row: Jan, Feb, Mar Apr Middle Row: May, Jun, Jul, Aug Bottom Row: Sep, Oct, Nov, Dec





COMBINED

c) To address Decadal Survey and community-identified science and application questions (DS113-115), requiring combined reflectance, emissivity and temperature measurements, the baseline mission shall provide combined global mapping data sets.





Baseline	Minimum (Threshold)
380 to 2500 nm at <10 nm sampling at the specified signal-to-noise ratio and accuracy with \geq 95% spectral/ spatial uniformity at <60 m nadir spatial sampling with <20 day revisit to provide	380 to 2500 nm at \leq 10 nm sampling at \geq 80% of the specified signal-to-noise ratio and accuracy with \geq 90% spectral/spatial uniformity at \leq 60 m nadir spatial sampling with $<$ 20 day revisit to provide
>60% seasonal and >80% annual coverage of the terrestrial and shallow water regions of the Earth	> 50% seasonal and >70% annual coverage of the terrestrial and shallow water regions of the Earth
<u>three years</u> with a subset of measurements available <u>near-real-time</u> for designated science and applications.	<u>two years.</u>
8 spectral bands from the 3-5 micron and 8-12 micron regions of the spectrum at the specified noise- equivalent-delta-temperature and accuracy at ≤60 m nadir spatial sampling	8 spectral bands from the 3-5 micron and 8-12 micron regions of the spectrum at \geq 80% the specified noise-equivalent-delta-temperature and accuracy at \leq 60 m nadir spatial sampling with \leq 5 day revisit
<u>>60%</u> Monthly, <u>>70%</u> seasonal and <u>>85%</u> annual coverage of the terrestrial and shallow water regions of the Earth	<u>> 40%</u> Monthly, <u>> 60%</u> seasonal and <u>>70%</u> annual coverage of the terrestrial and shallow water regions of the Earth

Note: We will keep you informed of any changes such as the change in the saturation limit of the MIR band to 1200K

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- HyspIRI Mission pre-Phase A Status
 - (1) Full combined Mission
 - (2) ISS option
 - (3) Separate platform options





(2) As Part of the HyspIRI Concpet Study, The Team has looked at ISS Options





TIR



+IPM







(3) HyspIRI SmallSat Landsat Compatibility



VSWIR-Dyson



- o 30 meter spatial resolution
- o 16 day revisit
- VSWIR spectra may be convolved to all Landsat bands going back to Landsat MSS providing excellent data continuity





- Landsat has:
 - \circ 60-120 meter spatial resolution
 - 16 day revisit (day + night)

TIR

- \circ 1-2 bands
- HyspIRI TIR has:
 - 60 m spatial resolution
 - 5 day revisit (day + night)
 - o 8 bands
- HyspIRI-TIR matches all Landsat bands





- 50 page report summarizes all of HyspIRI's activites since 2008
- ~6000 page on-line appendix includes the key reports and documents that HyspIRI has generated through present
- In FY15 we are expecting to work on a companion report, "HyspIRI Science and Applications in the Looking Forward." This report will be based on the science, applications, as well as technical/programmatic results from the HyspIRI Mission Concept. Results from the preparatory airborne campaign will be featured

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Thank You





Key Science and Science Applications

Climate: Ecosystem biochemistry, condition & feedback; spectral albedo; carbon/dust on snow/ice; biomass burning; evapotranspiration

Ecosystems: *Global* biodiversity, plant functional types, physiological condition, and biochemistry including agricultural lands

Fires: Fuel status; fire frequency, severity, emissions, and patterns of recovery *globally*

Coral reef and coastal habitats: *Global* composition and status **Volcanoes:** Eruptions, emissions, regional and *global* impact **Geology and resources:** *Global* distributions of surface mineral resources and improved understanding of geology and related hazards

Applications: Disasters, EcoForecasting, Water, Health/AQ

Measurement

Imaging Spectrometer (VSWIR)

- 380 to 2500nm in \leq 10nm bands
- 60 m spatial sampling*
- 19 days revisit*
- Global land and shallow water **Thermal Infrared (TIR):**
- 8 bands between 4-12 µm
- 60 m spatial sampling
- 5 days revisit; day/night
- Global land and shallow water IPM-Low Latency data subsets





Mission Urgency

The HyspIRI science and applications objectives are critical today and uniquely addressed by the combined imaging spectroscopy, thermal infrared measurements, and IPM direct



Mission Concept Status

Level 1 Measurement Requirements: Vetted by community and stable

Payload: VSWIR Imaging Spectrometer, TIR Multi-spectral Radiometer, and Intelligent Payload Module (IPM) Full Mission original option: Mature

Separate Small Mission option: Pegasus-based solutions identified and studied

*SLI Support: HyspIRI VSWIR evolving to 30m at 185km swath ECOSTRESS TIR: Selected EVI for ISS VSWIR Dyson Option: Technology/Science ISS Demonstration Summary: The HyspIRI mission measurement requirements and baseline instruments approach are mature and stable with good heritage, low risk and modest cost. Now exploring a range of instrument and data options to save cost, per guidance letter.