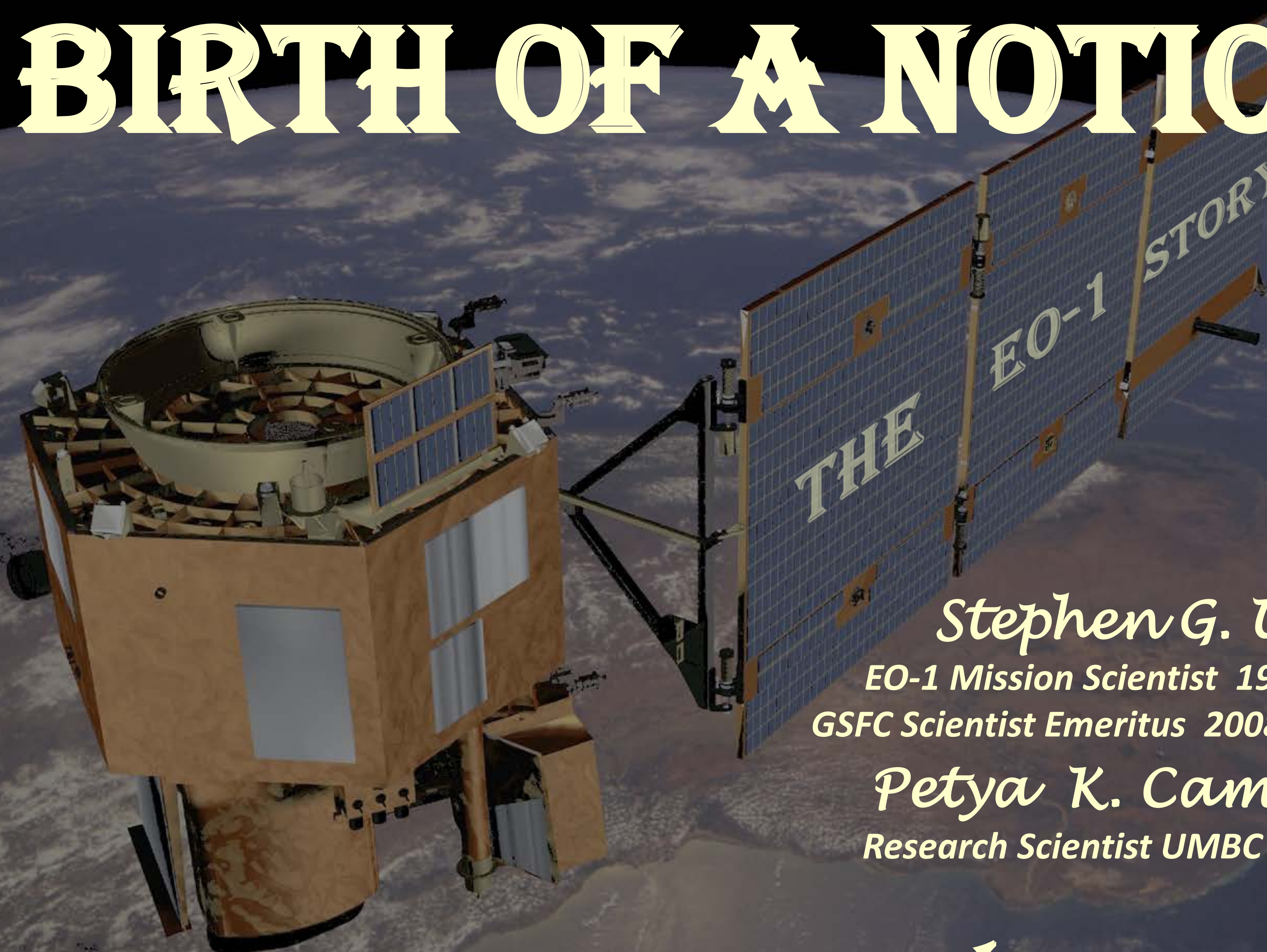
BIRTH OF A NOTION



Stephen G. Ungar
EO-1 Mission Scientist 1996 – 2008
GSFC Scientist Emeritus 2008 – ????
Petya K. Campbell
Research Scientist UMBC (at GSFC)

THE STORY OF EO-1 HYPERION

Early on, there was the GISS Airborne Spectroradiometer.

We flew transects in support of LACIE and mineral exploration.

ERIM and LARS also had "Field" Spectrometers

MATURE ALFALFA

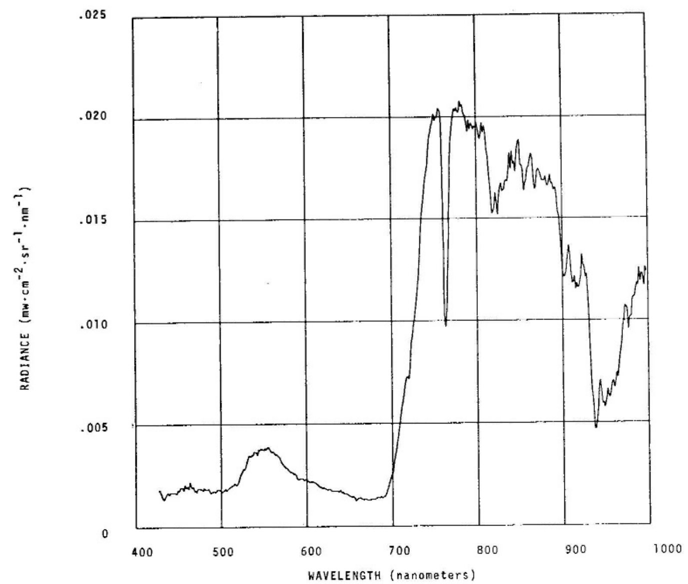
FIELD DESCRIPTION

30 to 34 inches high, 100% leaf cover, thick uniform canopy. Purple flowers, 1 to 3% of alfalfa plants. 2nd year crop. Soil dry. Imperial, light brown silty clay (7.5YR 6/4).

PHOTO INTERPRETATION

homogeneous tone, except furrows are slightly detectable; texture is absent or fine; high density; total cover; furrows run parallel with FL.

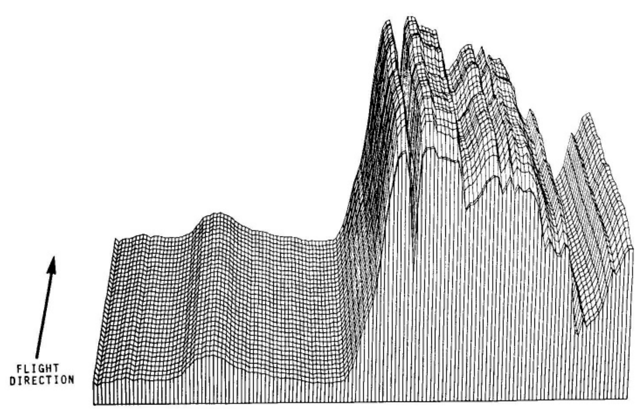
805



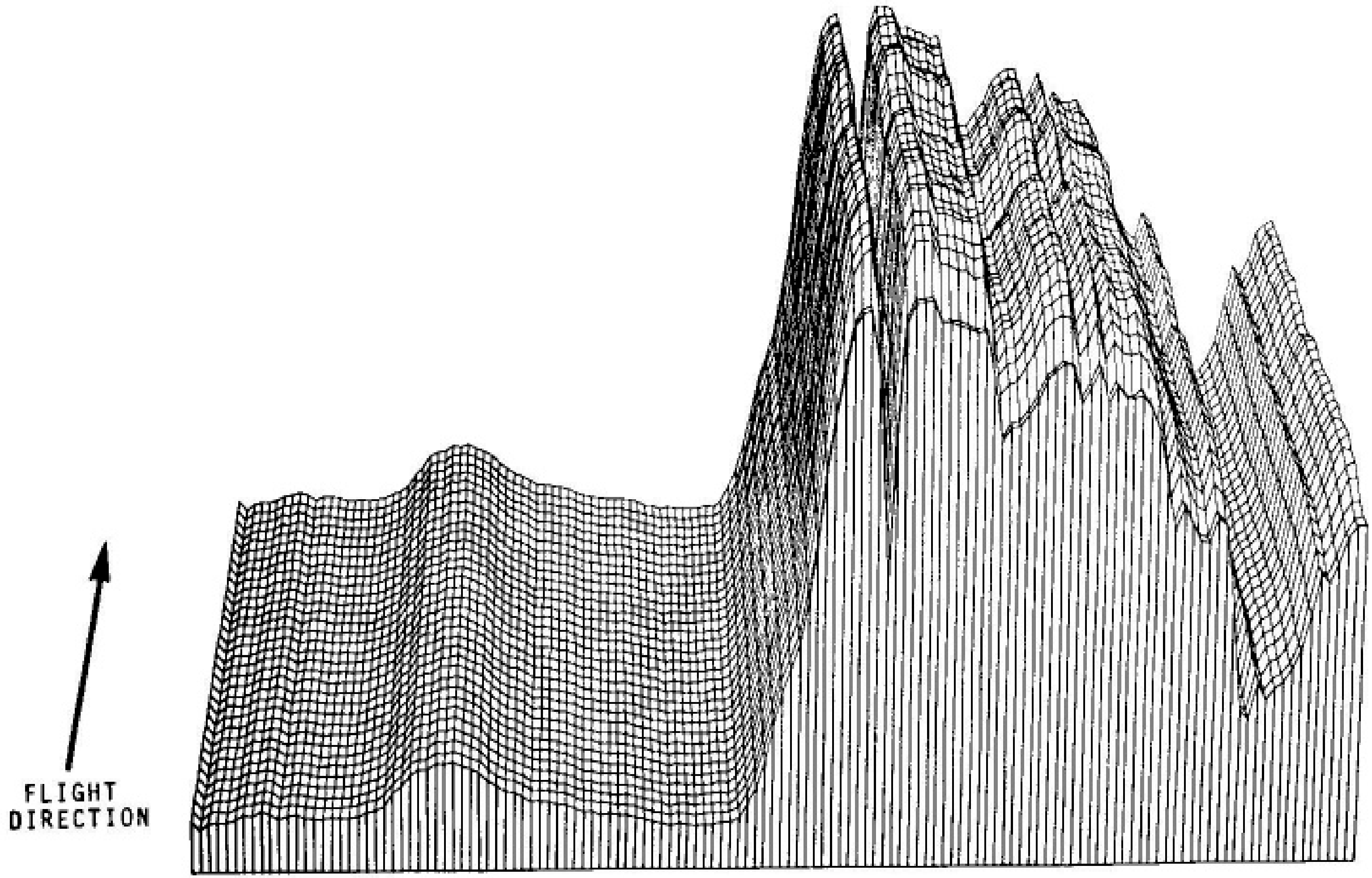
10:40 AM 5/16/75

SUN ELEV = 71°

779- 811



779- 811



MATURE ALFALFA

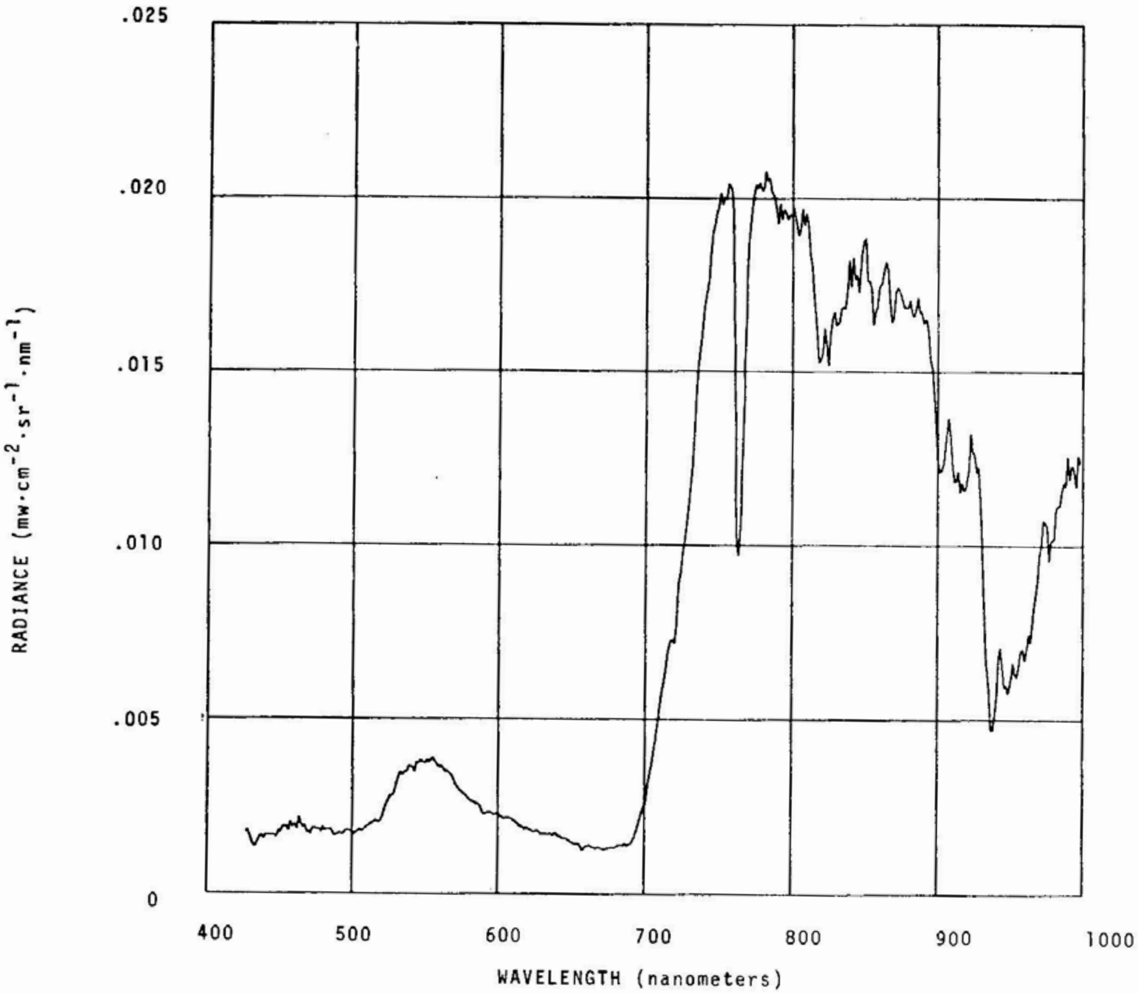
F I E L D   D E S C R I P T I O N

30 to 34 inches high, 100% leaf cover, thick uniform canopy. Purple flowers, 1 to 3% of alfalfa plants. 2nd year crop. Soil dry. Imperial, light brown silty clay (7.5YR 6/4).

P H O T O   I N T E R P R E T A T I O N

homogeneous tone, except furrows are slightly detectable; texture is absent or fine; high density; total cover; furrows run parallel with FL.

805



10:40 AM 5/16/75

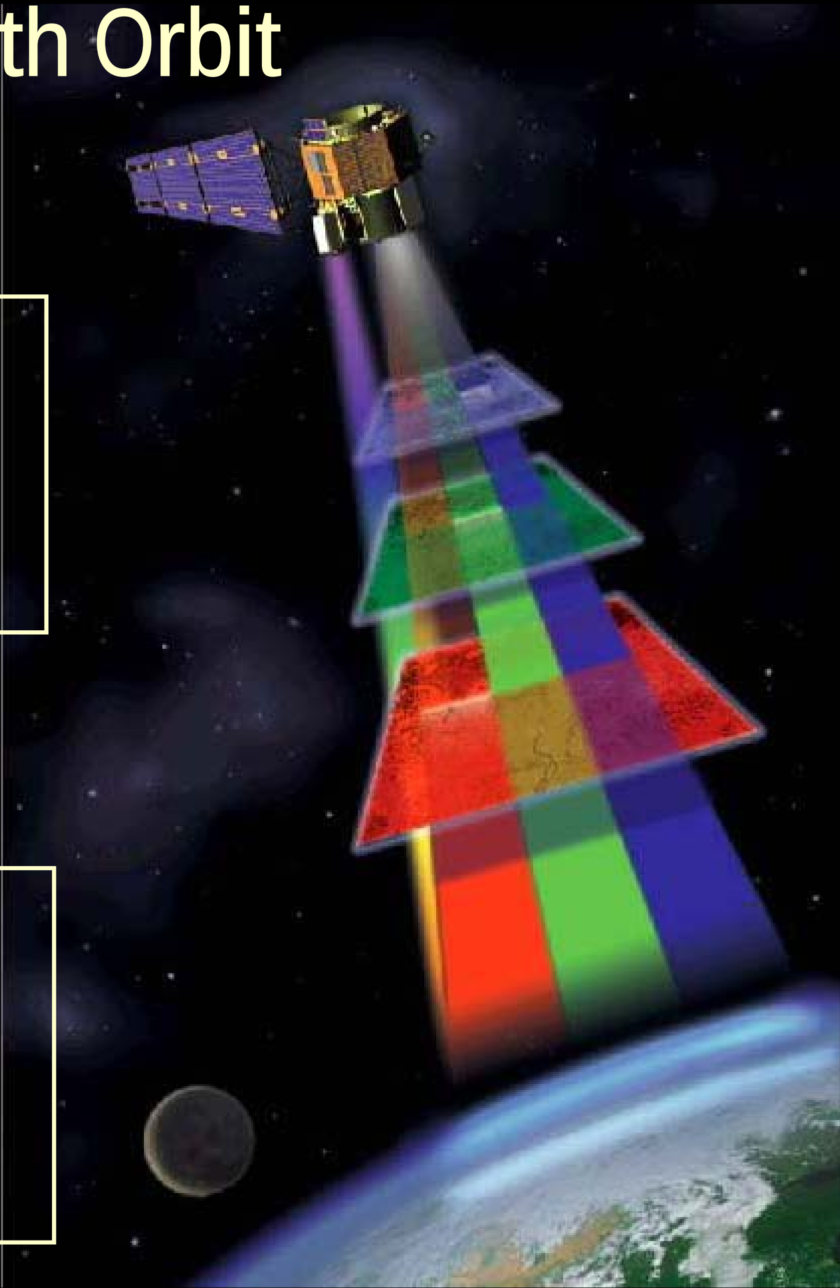
SUN ELEV = 71°

Then there was:

• GER(S)	Collins	~1980-82
• ASD	Goetz	~1981-83
• AVIRIS	Vane/Green	~1990
• HyMap	HyVista/Cocks	~1996-98
• Lewis *HSI & LEISA*	TRW/Pearlman	1997
• EO-1 *Hyperion & LAC*	NMP/Ungar et al	2000

Yes, I know there were many others as well !!

EO-1 Hyperion: Pathfinder to Imaging Spectroscopy from Low Earth Orbit



LAUNCH

Launch Date: Nov. 21, 2000

Launch Vehicle: Delta 7320

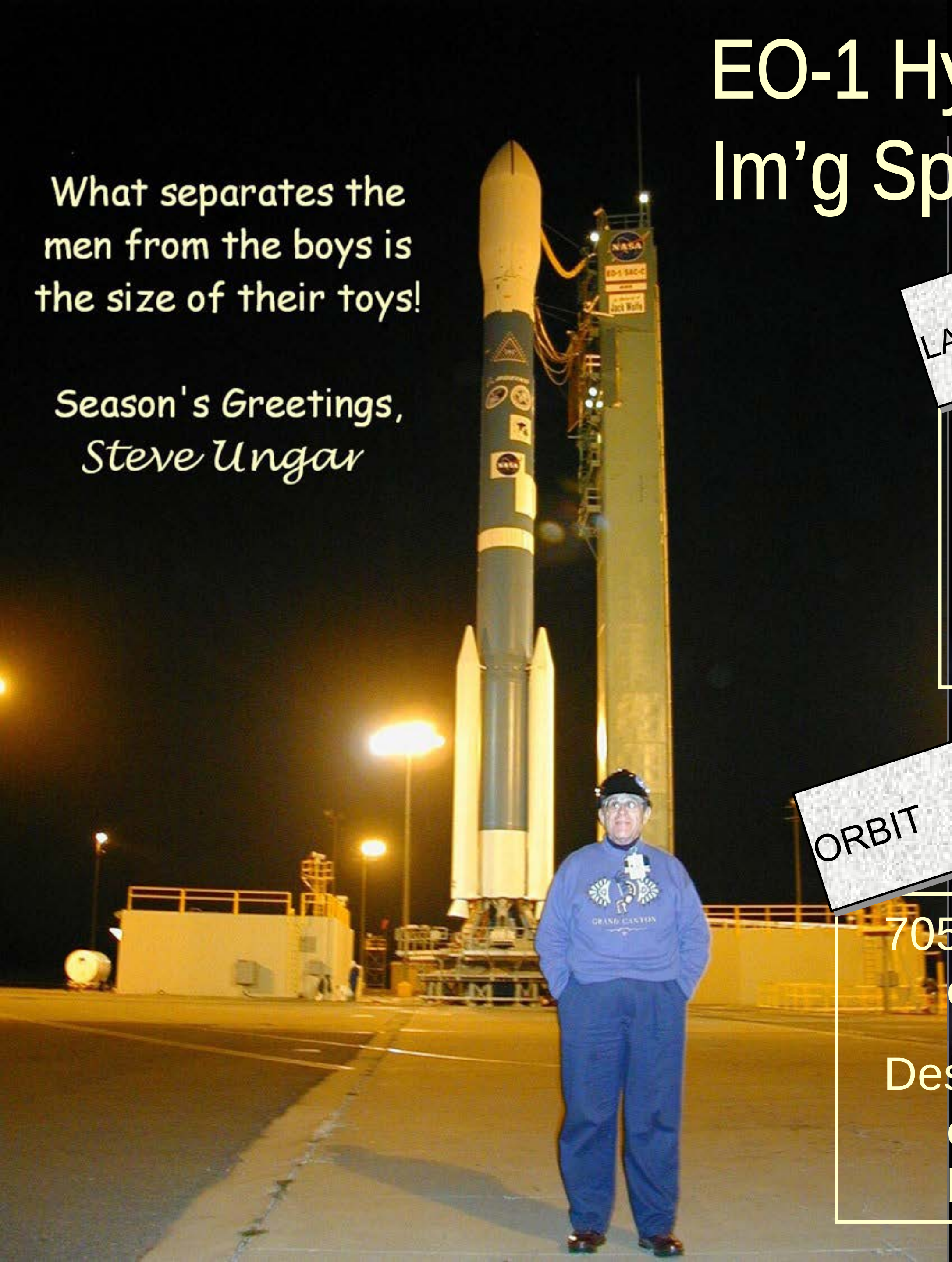
Co-manifested with SAC-C

ORBIT

705 Km altitude Sun-synchronous, circular orbit inclined at 98.2°

Descending node with an equatorial crossing about one minute behind Landsat 7

EO-1 Hyperion: Pathfinder to Im'g Spectroscopy from LEO



What separates the men from the boys is the size of their toys!

Season's Greetings,
Steve Ungar

LAUNCH

Launch Date: Nov. 21, 2000

Launch Vehicle: Delta 7320

Co-manifested with SAC-C

ORBIT

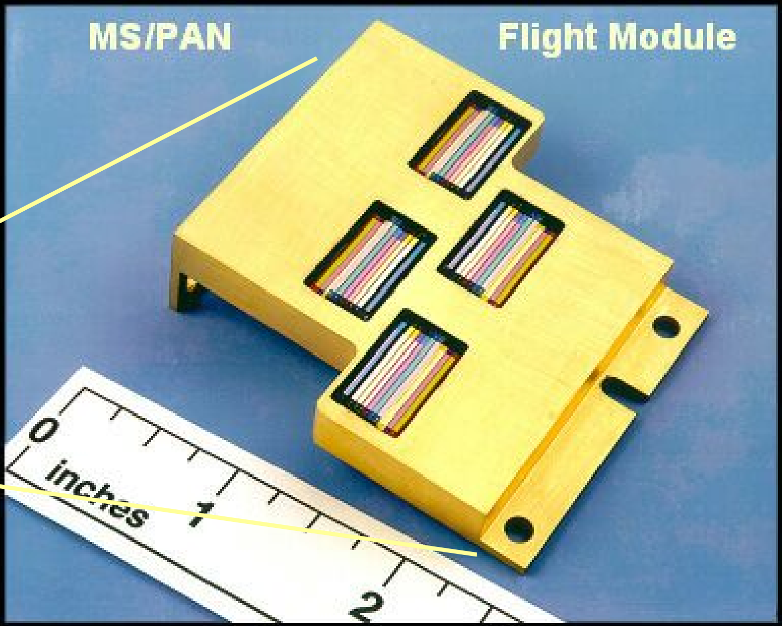
705 Km altitude Sun-synchronous, circular orbit inclined at 98.2°

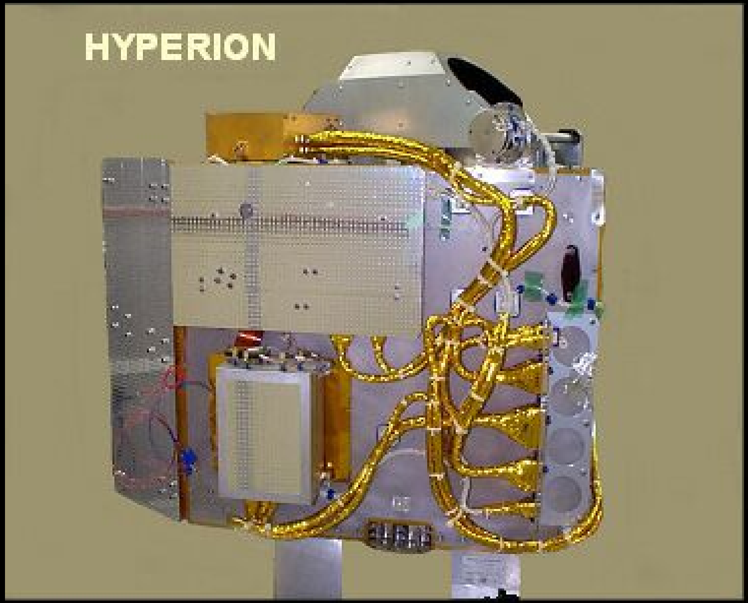
Descending node with an equatorial crossing about one minute behind Landsat 7


What separates the
men from the boys is
the size of their toys!
Season's Greetings,
Steve Ungar
NASA

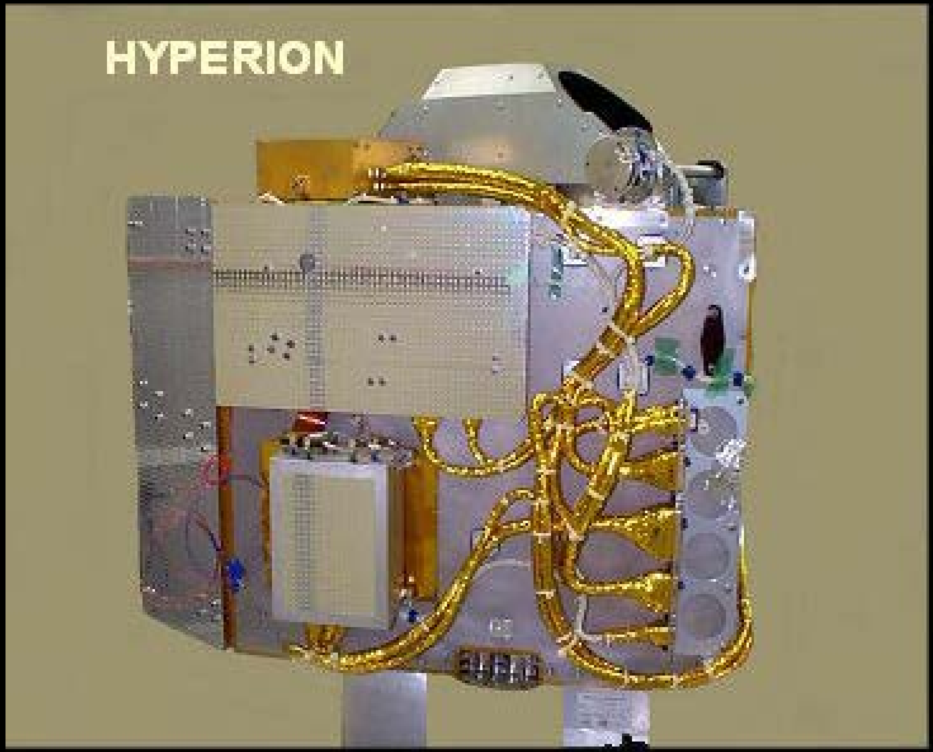

NASA
EO-1 SAC-C
Jack Wolfe

EO-1 Flight Instruments





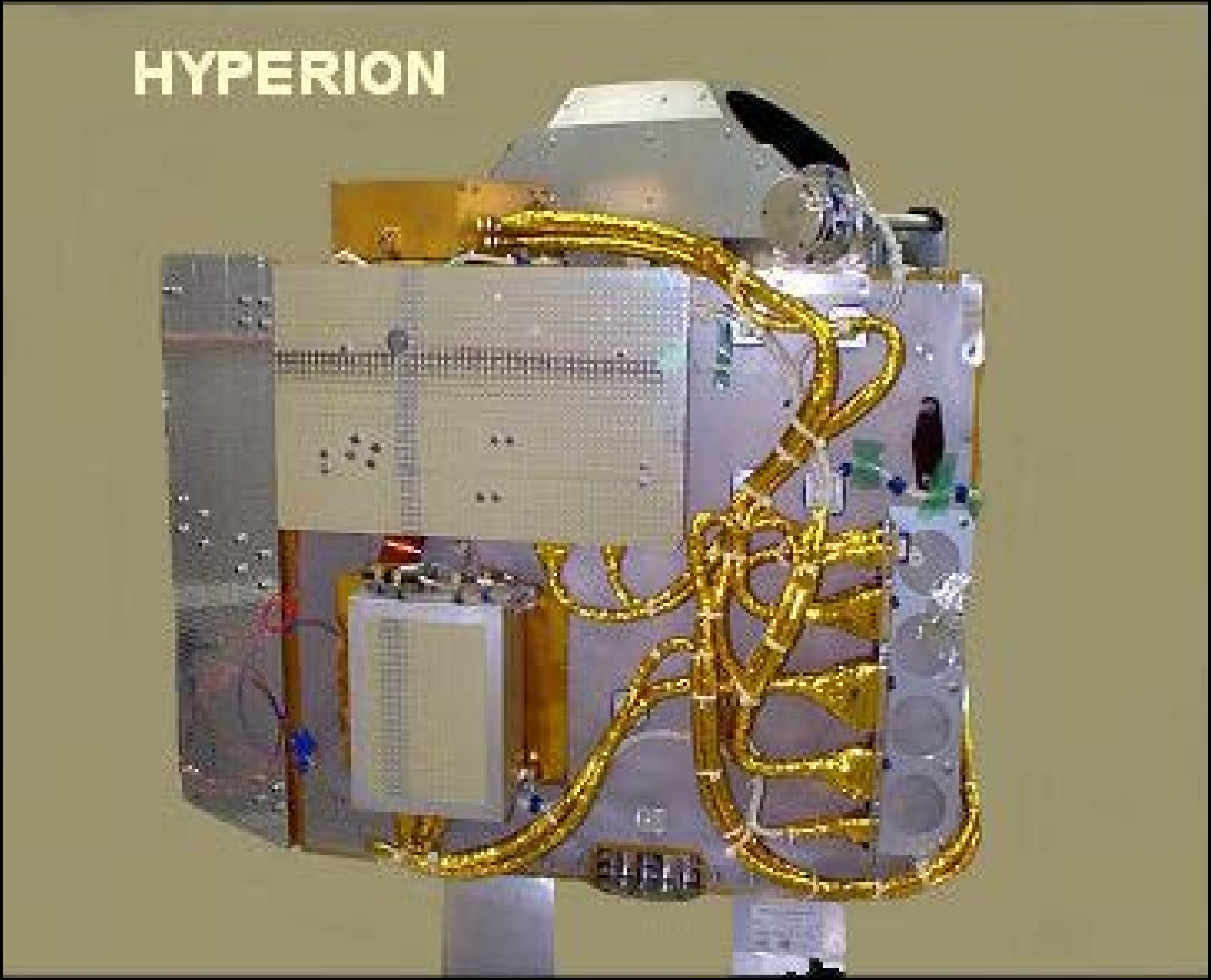
EO-1 Spectrometers



1X VNIR + 1X SWIR

3X NIR

EO-1 Grating Spectrometer



EO-1 Instrument Overviews

Parameters	Landsat 7 ETM+	EO-1 ALI	EO-1 HYPERION	EO-1 LAC
Spectral Range	0.4 - 2.4 µm*	0.4 - 2.4 µm	0.4 - 2.5 µm	0.9 - 1.6 µm
Spatial Resolution	30 m	30 m	30 m	250 m
Swath Width	185 Km	37 Km	7.7 Km	185 Km
Spectral Resolution	Variable	Variable	10 nm	3 - 9 nm**
Spectral Coverage	Discrete	Discrete	Continuous	Continuous
Pan Band Resolution	15 m	10 m	N/A	N/A
Number of Bands	7	10	220	256

*** Excludes thermal channel***

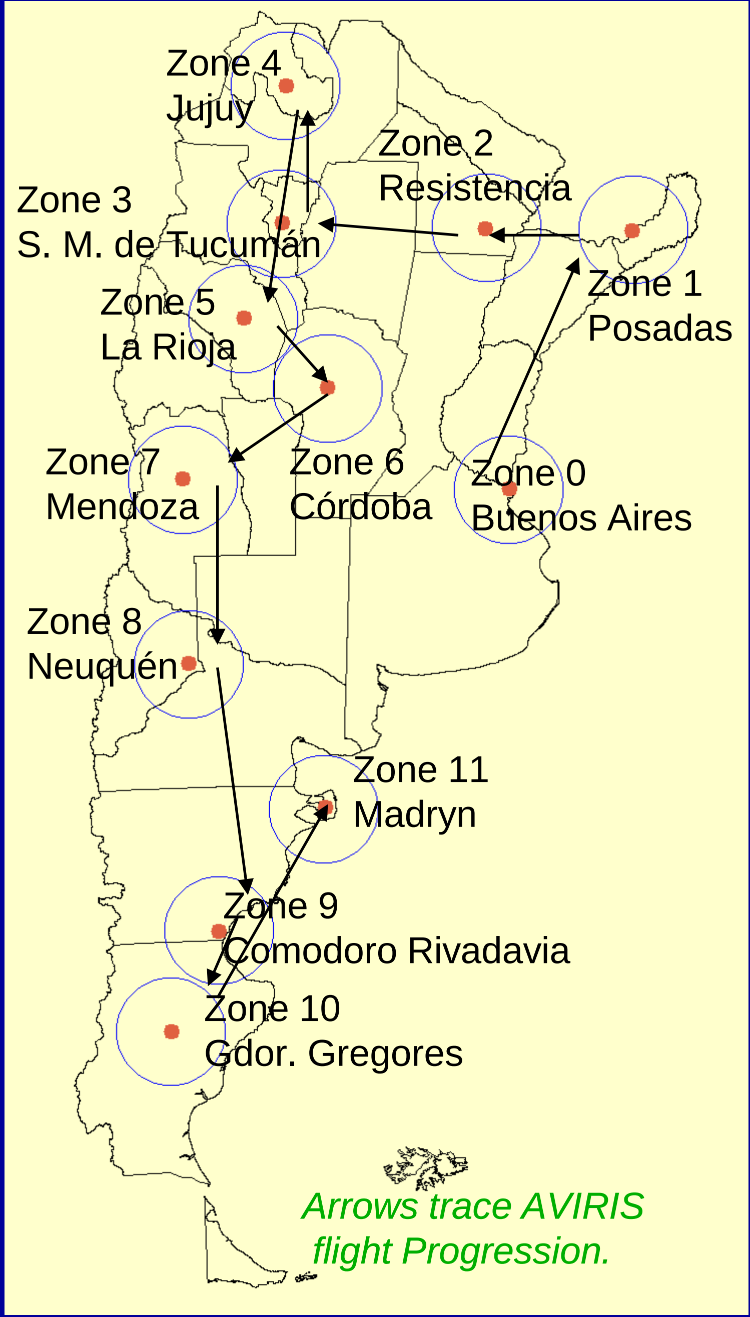
***** 35/55 cm^{-1} constant resolution***

EO-1 Imaging Spectrometer Overviews

Parameters	EO-1	
	HYPERION	LAC
Spectral Range	0.4 - 2.5 µm	0.9 - 1.6 µm
Spatial Resolution	30 m	125/250 m
Swath Width	7.7 Km	185 Km
Spectral Resolution	10 nm	3 - 9 nm
Spectral Coverage	Continuous	Continuous
Pan Band Resolution	N/A	N/A
Number of Bands	220	256

EO-1 Accelerated Mission Southern Hemisphere Field Campaigns *January – February 2001*

Australian Test Sites



Argentine/AVIRIS Sites


Kakadu
Lake Argyle
Cooper Creek
Cape Tribulation
Daintree
Batt Reef
Mossman
Townsville Reef
Port Hedland
Goldsworthy
Panorama
Kunoth
Amburla
Lake Eyre
Moreton Bay
Mt Fitton *
Tinga tingana
Toolabin
EOC Hyperspectral Sites
EOC HS Task Sites
Hyperion Sites
* Potential 1st 60 days Sites
X band sites
* Uardry
Lake George
Majura Valley
*Kioloa
Tanjil Bren

Investigator Research Topics

Southern Hemisphere Campaign: ARGENTINA – AUSTRALIA – ELSEWHERE

Research Topic	Principal Investigator
Forest Logging in Amazonia	Asner, G. P., University of Colorado
Desertification	Asner, G. P., University of Colorado
Forest Composition & Function	Martin, M., University of New Hampshire
Inter-Sensor Calibration	Huete, A. R., University of Arizona, Tucson
Arid Vegetation Abundance	Mustard, J. F., Brown University.
Tropical Forest Burn Scars	Liew, S. C., National University of Singapore
Forest Composition/Structure	Townsend, P. A., University of Maryland
Land Cover/Land Use	White, W. A., Crawford, M., University of Texas at Austin
Sustainable Forest Development	Goodenough, D. G., Natural Resources Canada
Monitoring Forest & Rangeland	Gong, P., University of California, Berkeley
Non-Native Plant Species	McGwire, K. Desert Research Institute

Investigator Research Topics (continued)

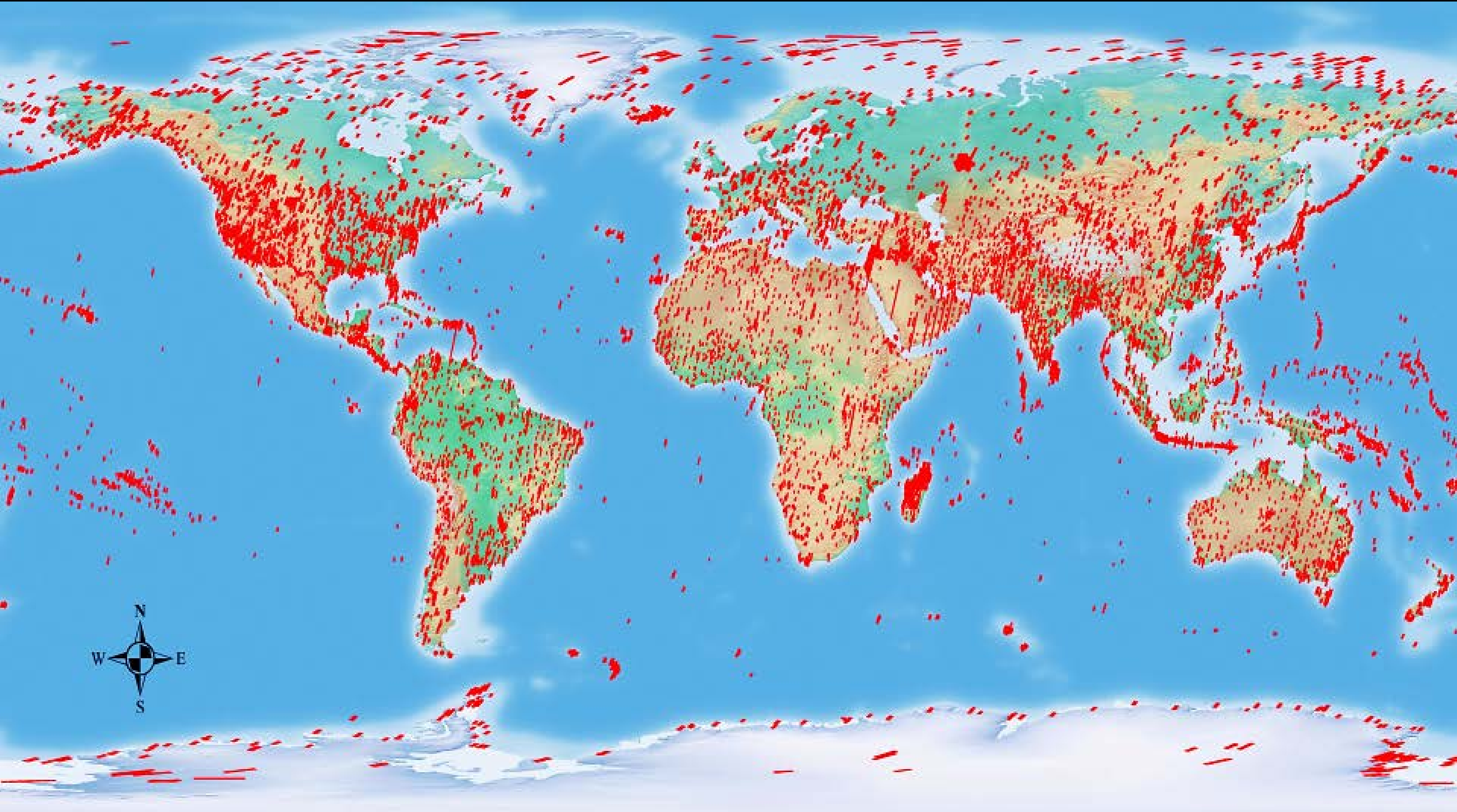
Research Topic	Principal Investigator
Ecological Applications in Yellowstone National Park	Boardman, J. W., AIG, Colorado
Commercial Applications	Cassady, P. E., Boeing, Washington
Radiometric and Spatial Evaluation of ALI and Hyperion	*Biggar, S. F., University of Arizona (Kurt Thome)*
Atmospheric Correction	Carlson, B. E., NASA /GISS, New York
Atmospheric Correction and Sparse Vegetation Mapping	Goetz, A. F. H., University of Colorado
Australian Hyperspectral Calibration and Validation Sites	Jupp, D. L. B., CSRIO, Australia
Integrated Assessment of EO-1 and Landsat Instrument Suites	Meyer, D. J., EDC, South Dakota
Canopy Temperature Estimation	Smith, J. A., NASA GSFC, Maryland
Lunar Calibration	Kieffer, H., USGS, Flagstaff, AZ

Investigator Research Topics (continued)

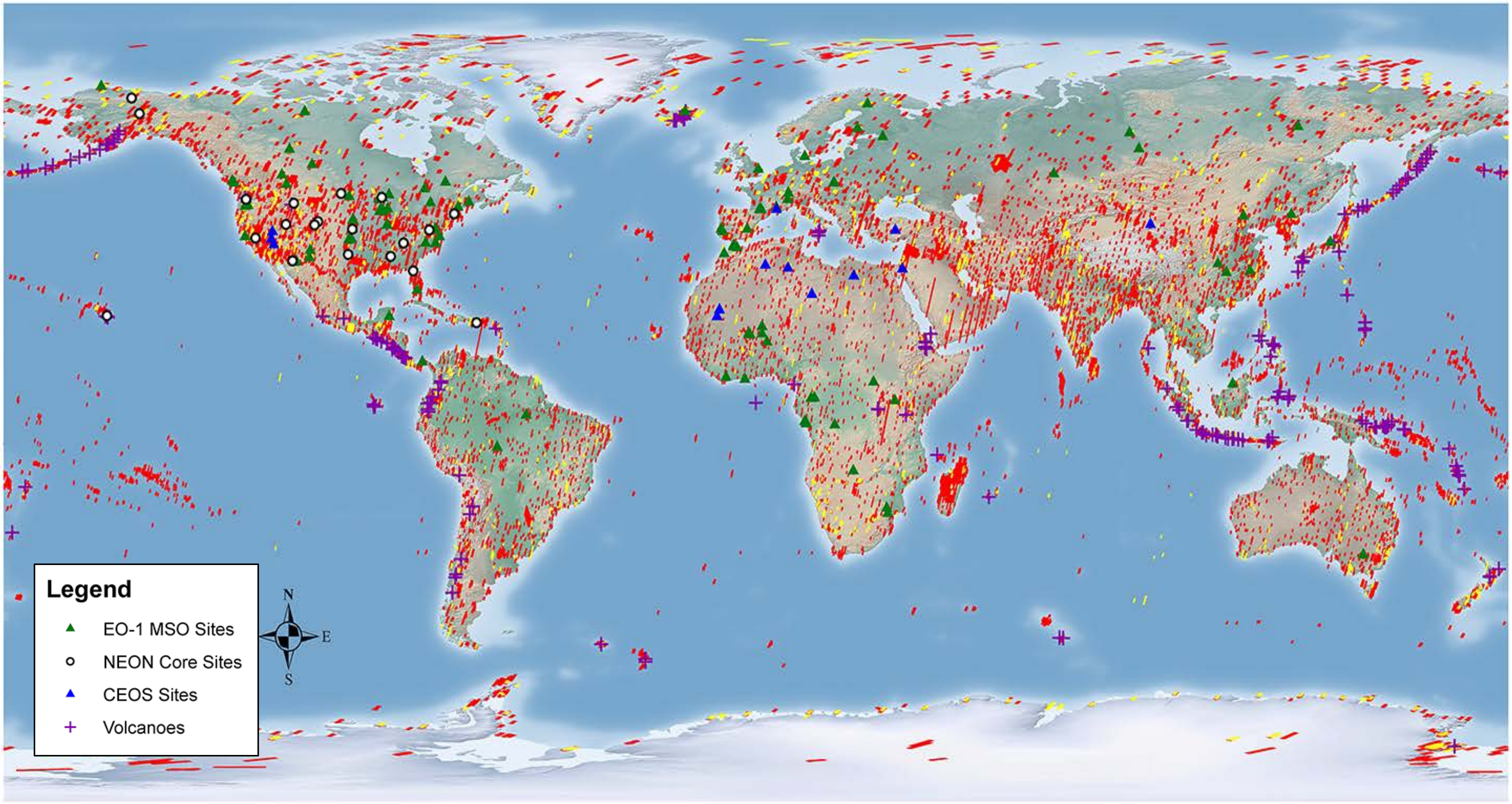
Research Topic	Principal Investigator
Invasive Plants: Chinese Tallow	Ramsey III, E. W., USGS, Denver
Invasive Leafy Spurge	Root, R., USGS
Agricultural Monitoring	Liang, S., USDA, Maryland
Inter-Satellite Comparison	Moran, M. S. USDA, Tucson, Arizona.
Fire Hazard Assessment	Roberts, D. A., University of California, Santa Barbara
Geologic Validation of Hyperion	Kruse, F. A., AIG, Boulder, Colorado
Volcanic Debris flow Hazards	Crowley, J. K., USGS, Reno, Nevada
Analysis of Hot Spots	Flynn, L., University of Hawaii *(R. Wright)*
Environmental Monitoring of Coastal/Inland Water in Japan	Matsunaga, T., Tokyo Institute of Technology.
Oceanography, Pollution and Urban Mapping	Abrams, M. J., JPL, California; R. Bianchi and L. Alberotanza, NRC, Italy.
Glaciological Applications	Bindschadler, R., NASA/GSFC, Maryland

EO-1 Acquisitions Since Launch

EO-1 has acquire more than 90,000 Hyperion scenes (As of September 2016).

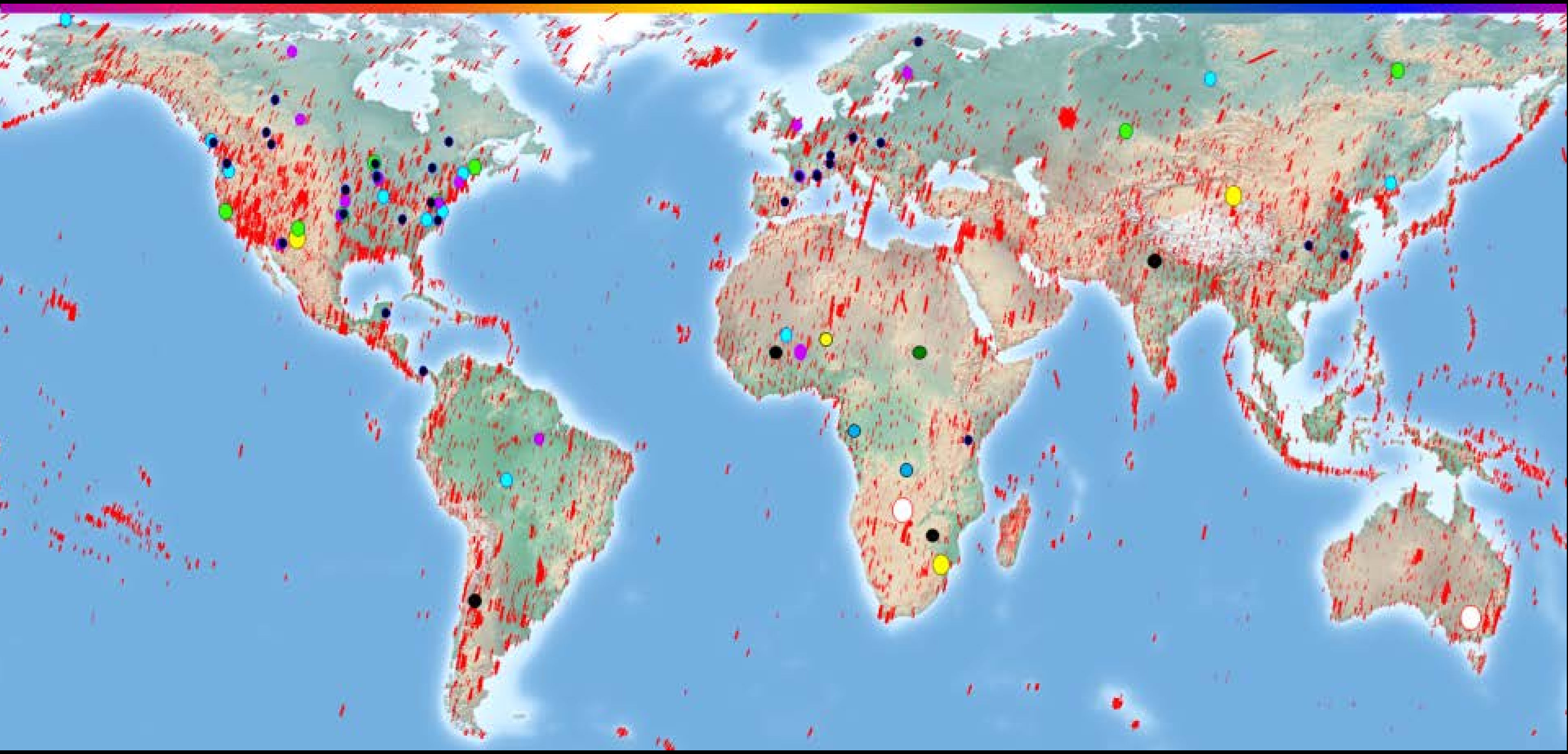


The EO-1 Image Collections



The user community includes science, disasters, technology developments, volcanoes, etc.

Hyperion Spectral Time Series at FLUX Sites

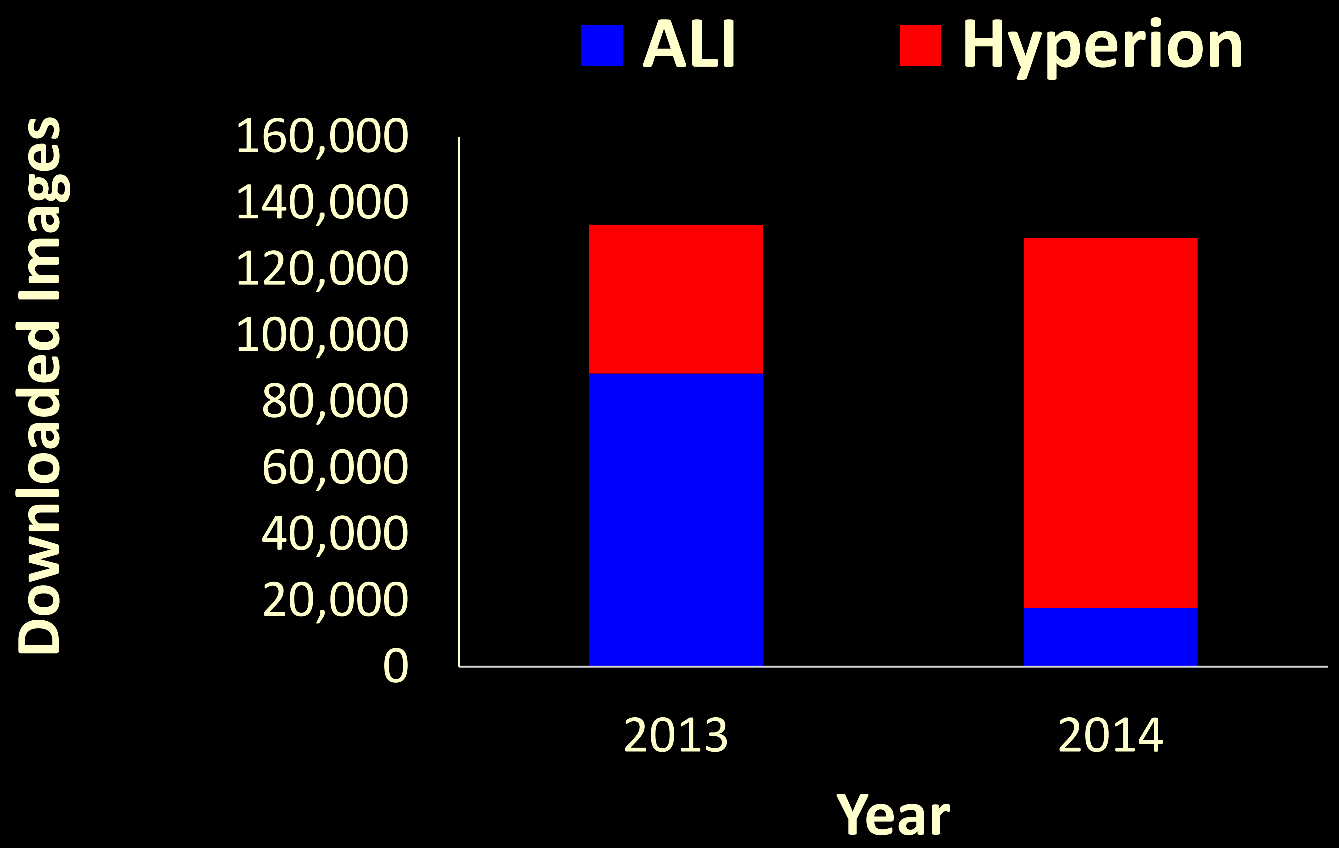


Number of cloud free images at FLUX sites

1 - 7	40 - 60
8 - 20	60 - 90
20 - 40	90 - 135

EO-1 Data Product Usage*

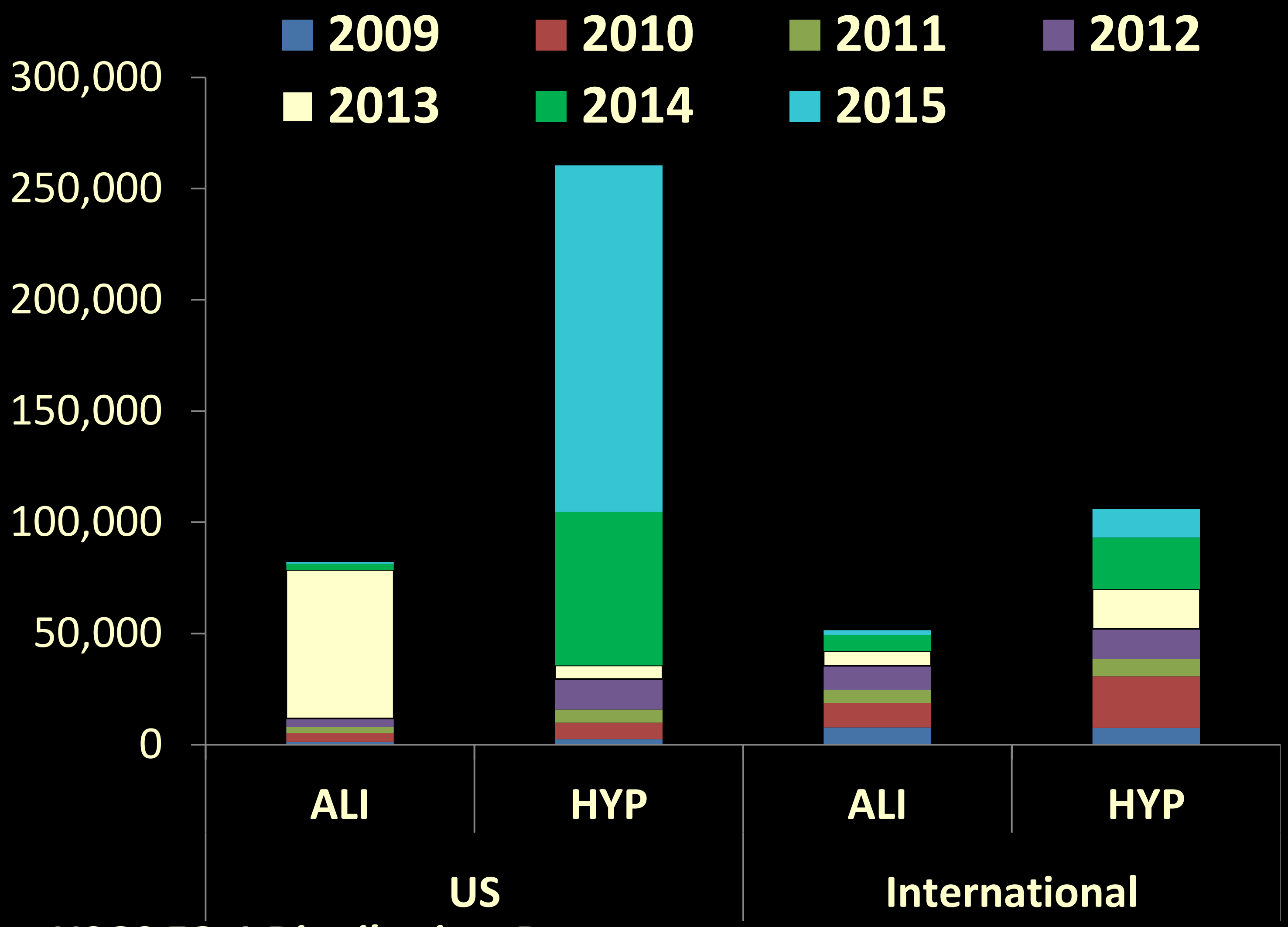
After Landsat 8 data became available in 2013 there was a large drop in ALI requests and downloads. There was an equally large increase in Hyperion downloads in 2014, ……..



** Based on USGS EO-1 Distribution Reports*

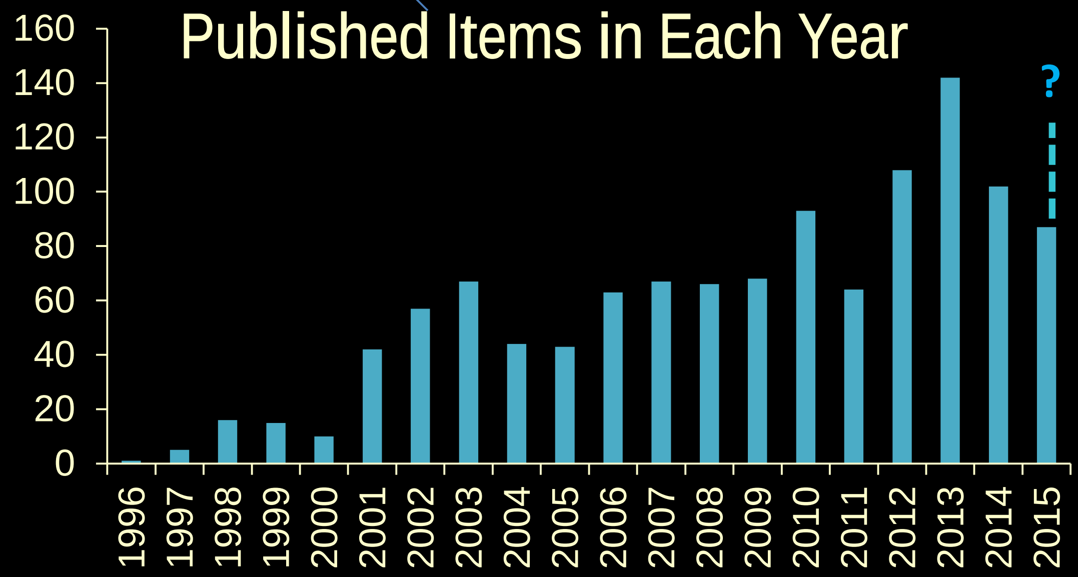
EO-1 Data Product Usage*

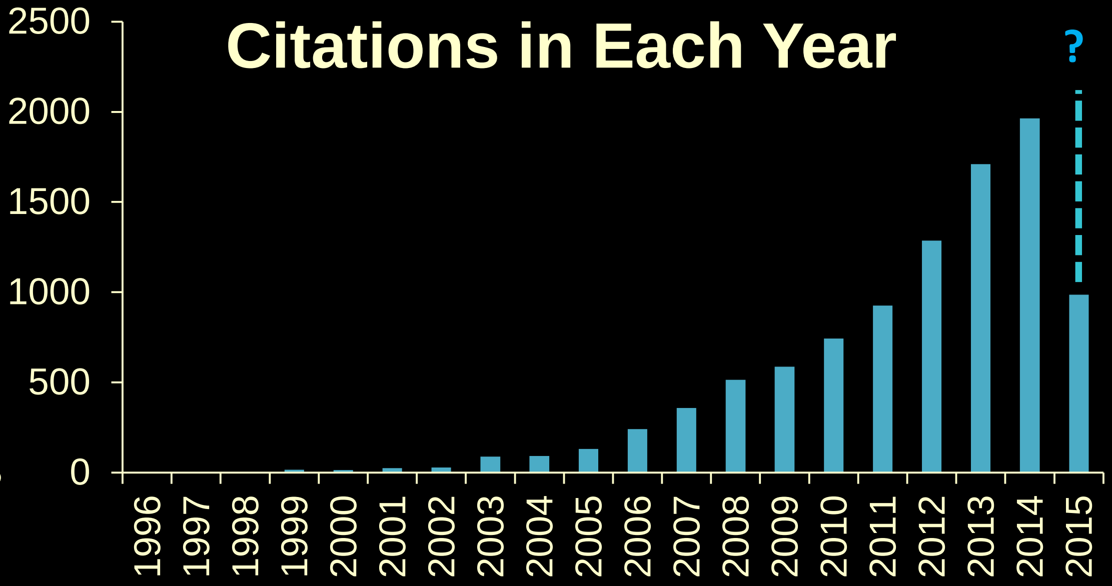
……. and even larger increase in Hyperion downloads in 2015.



** Based on USGS EO-1 Distribution Reports*

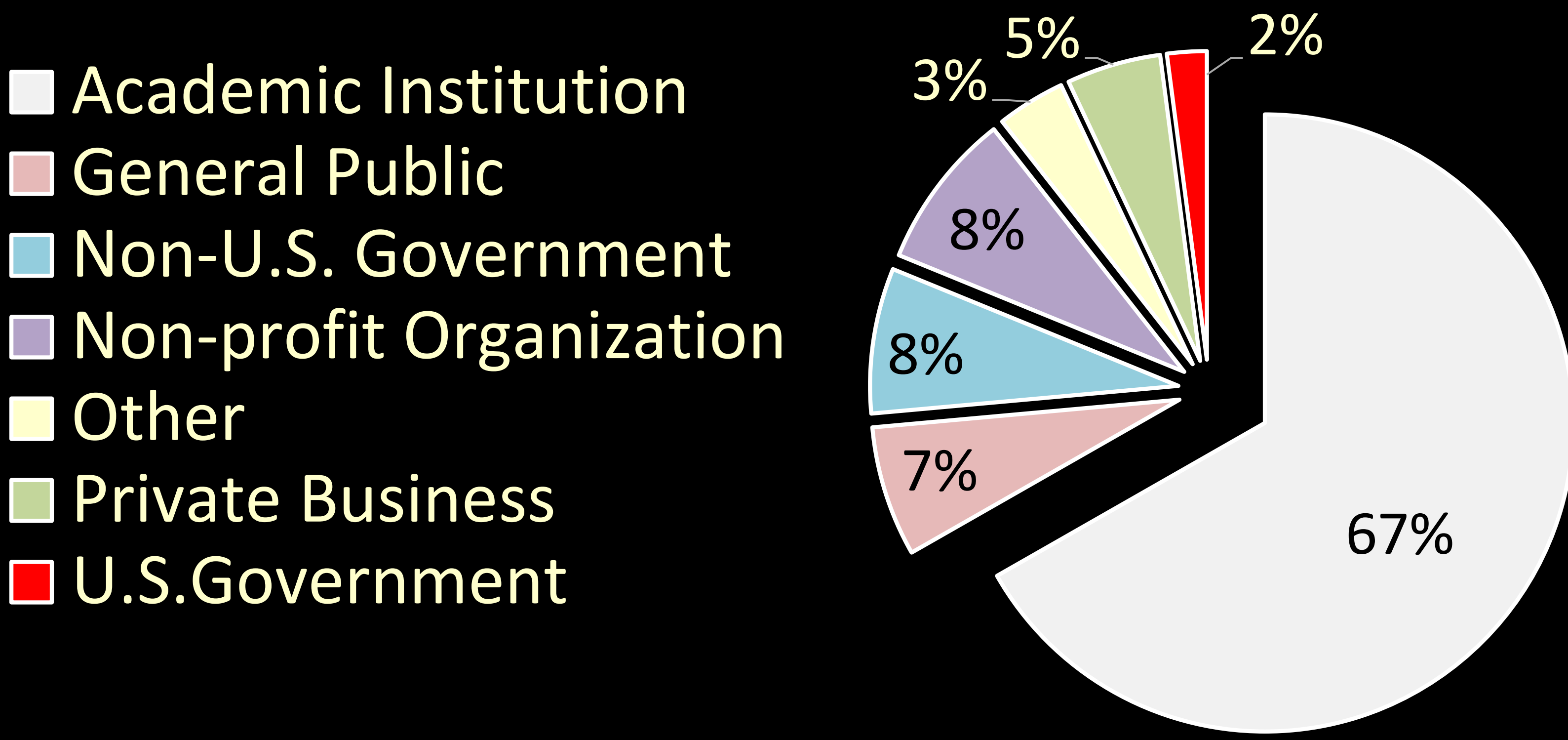
The EO-1 Publications and Citations*





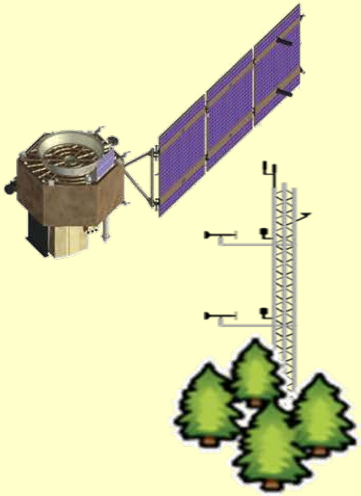
**** Based on Web of Science (as of January 2016???)***

EO-1 User Community



Larger EO-1 users include: The disaster support, “cloud prediction support” study for GeoCape (Decadal Survey Mission), EnMAP pre-launch support (Hyperion), Landsat 8 support, Sentinel-2, science requests for time series and/or large scale mapping for: mineralogy, tropical spectral diversity, terrestrial ecology, signal processing, and simulations for HyspIRI, Sentinel-3, and EnMAP.

Hyperion Spectral Time Series at FLUX Sites



EO-1 Hyperion seasonal time series (TOA rad)

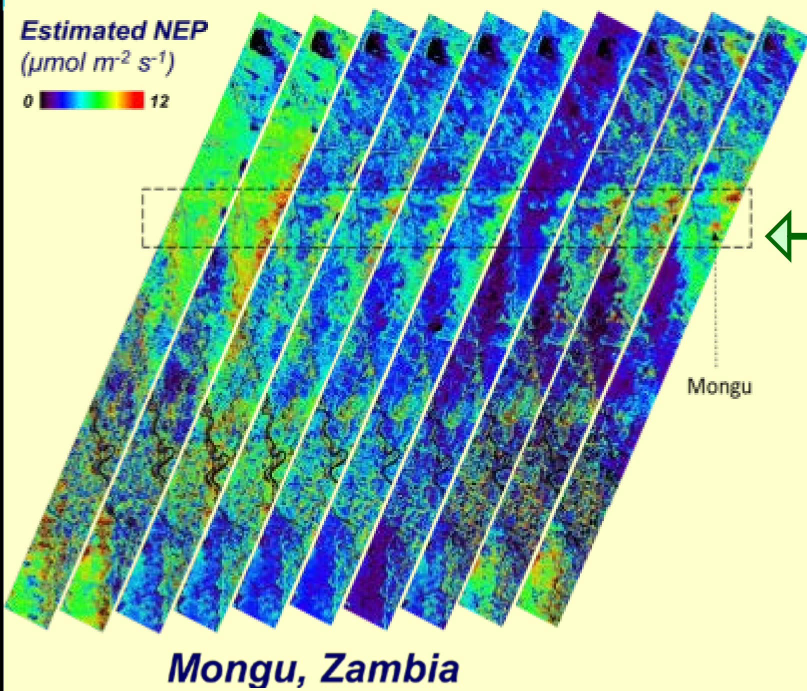
Atmospheric correction, Pre-processing (TOC reflectance)

Hyperion Spectral Bio-Indicators (SBIs)

FLUX tower measurements (CO_2 flux, µmol m^{-2} s^{-1})

CO_2 FLUX parameters (**NEP**, GEE, etc.)

Relationship between CO_2 FLUX parameters & Hyperion SBIs



GEE = gross ecosystems exchange

NEP = GEE – Re, NEE = -NEP

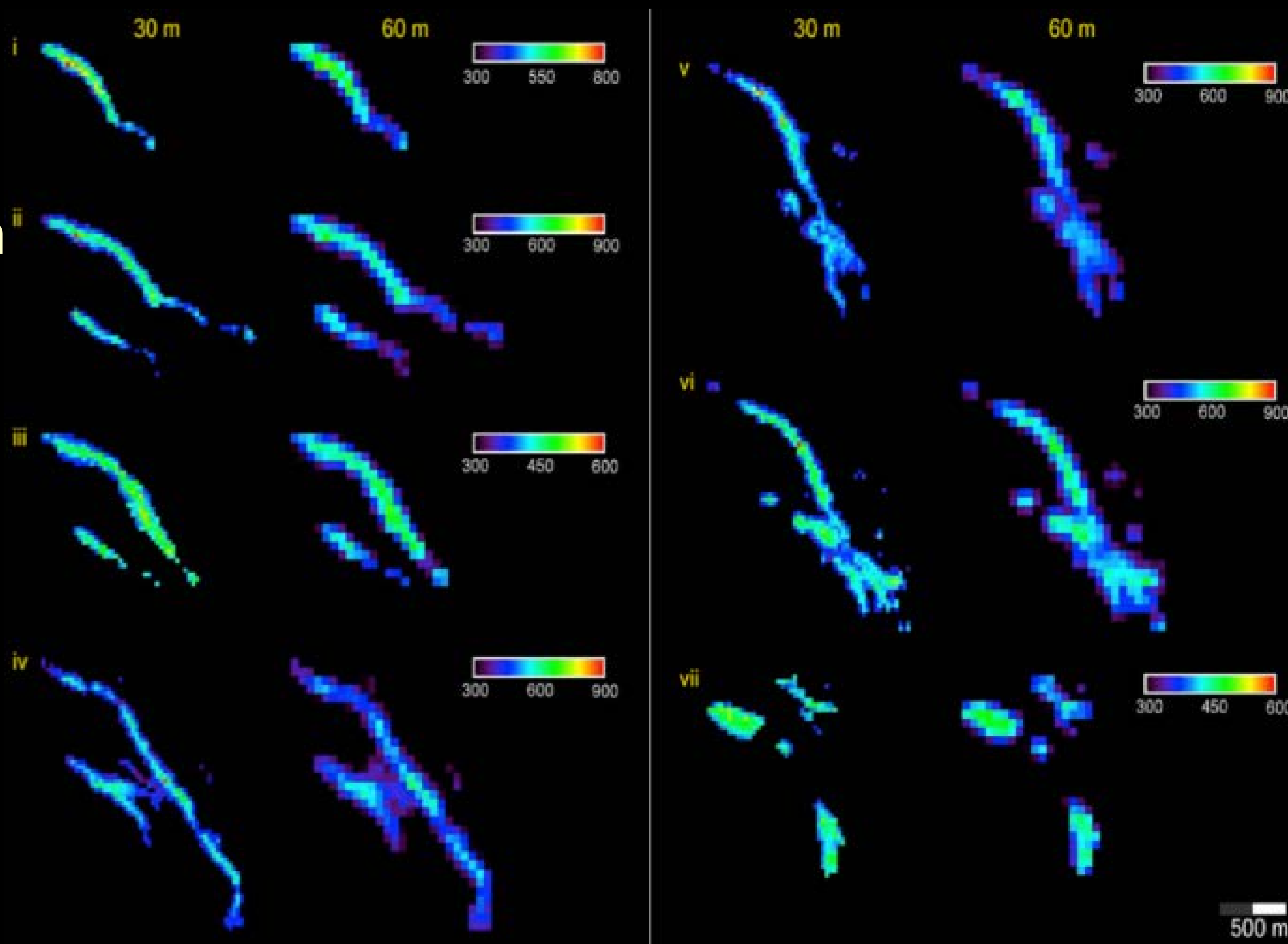
- Gross Primary Production (GPP = GEP, µmol m^{-2} s^{-1})
- Ecosystem Respiration (Re) -calculated from relationships between nighttime Net Ecosystem Exchange (NEE) and air temperature
- Net Ecosystem Production -> from the observed GEE and Re

IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING, VOL. 6, NO. 2, APRIL 2013 375

Using EO-1 Hyperion Data as HyspIRI Preparatory Data Sets for Volcanology Applied to Mt Etna, Italy

Michael Abrams, Dave Pieri, Vince Realmuto, and Robert Wright

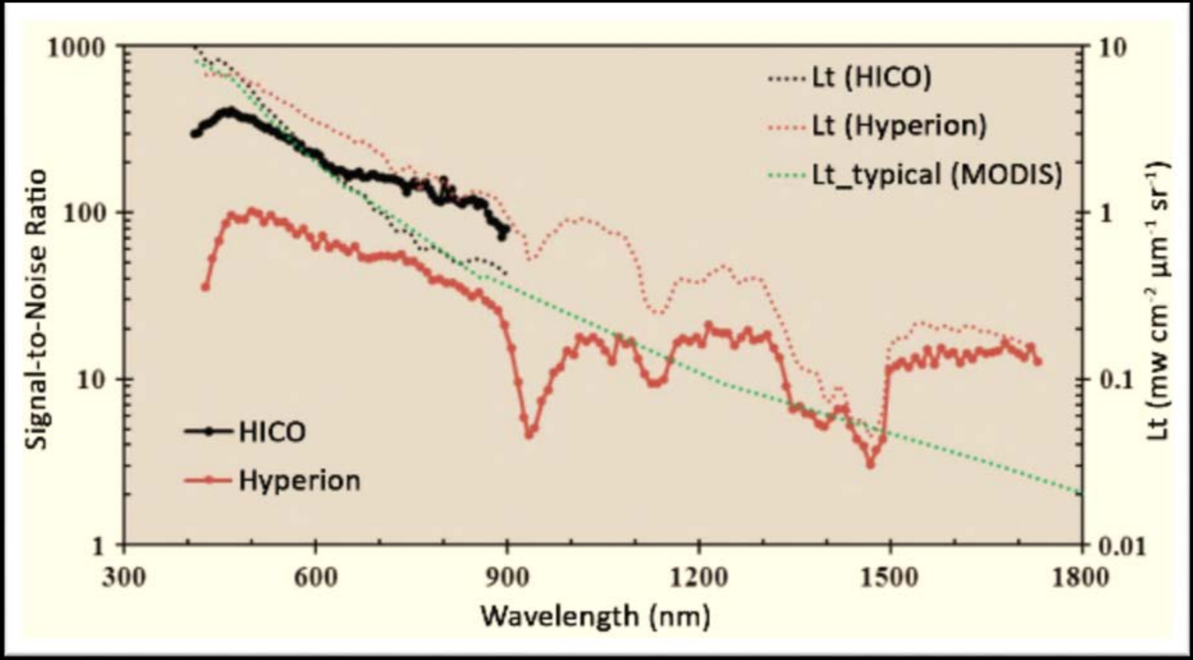
Hyperion images used to generate these results were acquired on (i) 12 Sep 2004, (ii) 14 Sep 2004, (iii) 16 Sep 2004, (iv) 23 Sep 2004, (v) 7 Oct 2004, (vi) 9 Oct 2004, and (vii) 3 Dec 2004.



Use of Hyperion for Aquatic Remote Sensing

- ❑ Hyperion has been useful to develop techniques for future global applications for missions such as HyspIRI, PACE, and GeoCAPE.
- ❑ Hyperion data were collected Sept 2015 to support cruises near the the Florida Key to further hyperspectral algorithms.
- ❑ Lunar observations with Hyperion could be valuable to improving consistent calibration techniques across NASA's ocean color climate data record.

Top-of-Atmosphere Radiance (Lt)



SHALLOW/TURBID WATER FOCUS

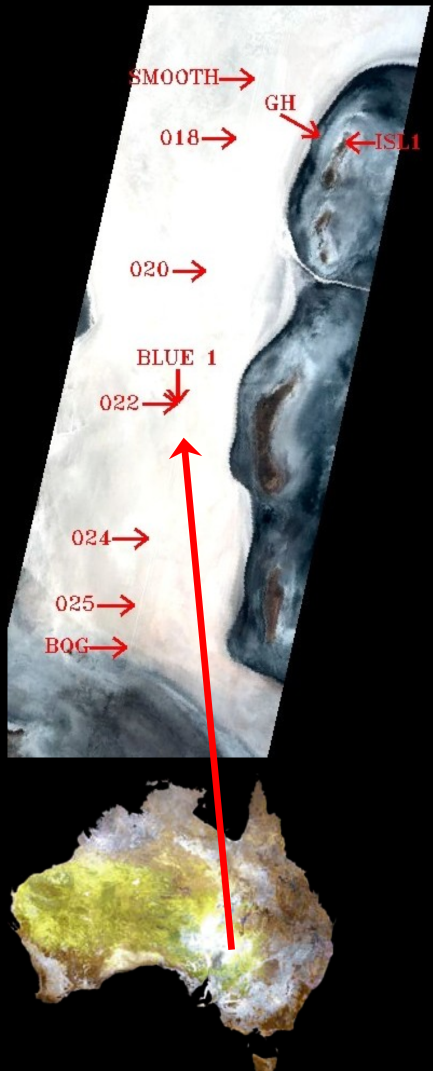
Hyperion spatial and spectral resolution is useful for coastal and inland aquatic applications.

Hyperion Signal-to-Noise Ratio (SNR) is lower than the Hyperspectral Imager for the Coastal Ocean (HICO).

So, spectral (or spatial) aggregation is necessary for the dark water of the open ocean.

Desert Sites used for Vicarious Calibration

Lake Frome



RR Valley

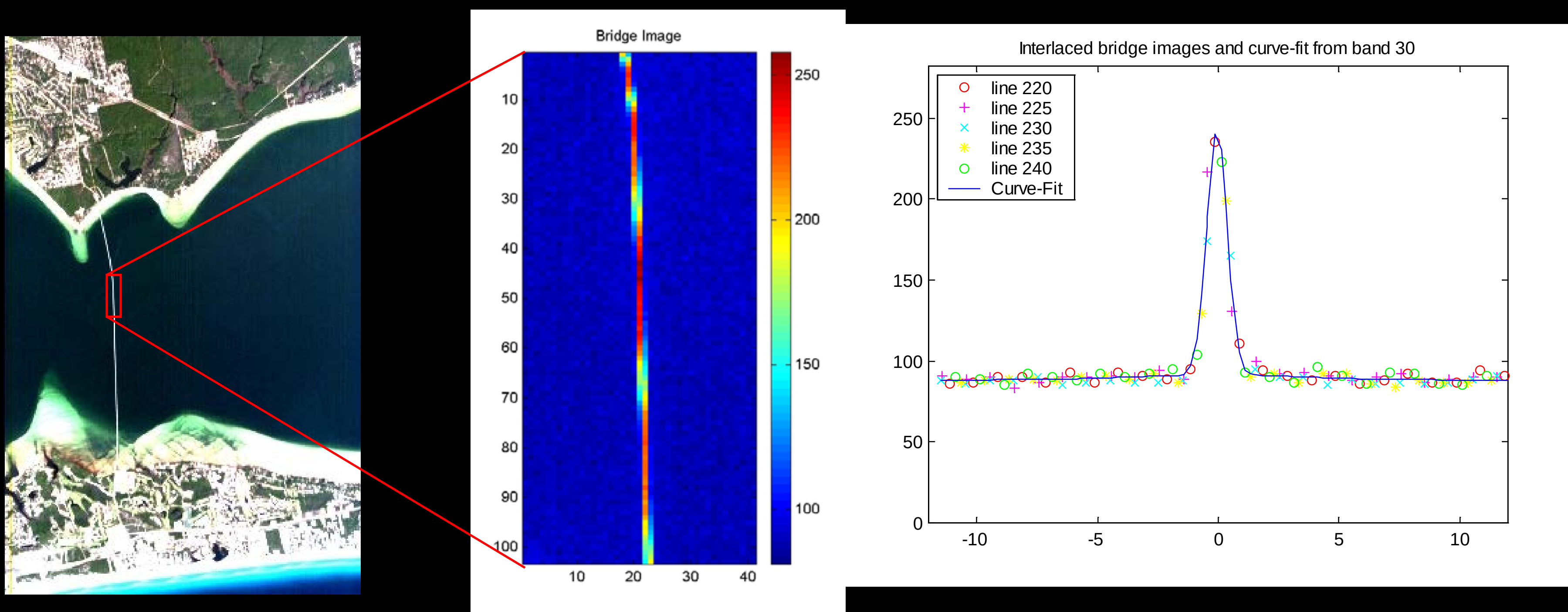
Arizaro/Barreal Blanco

Post Launch MTF Approach

- **Calculate cross-track and in-track MTF using a step response and impulse response example**
- **Results of on-orbit analysis give good agreement with the pre-launch laboratory measurements**

Example: Cross-track MTF

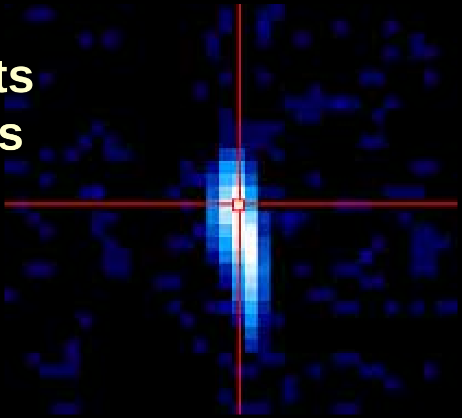
- Scene is Port Eglin from Dec 24, 2000. Bridge is the Mid-bay bridge . Bridge width is 13.02 meters.
- Bridge angle to the S/C direction is small so every 5th line is used to develop the high resolution bridge image.
- MTF result at Nyquist is between 0.39 to 0.42 while the pre-flight measurement was 0.42.



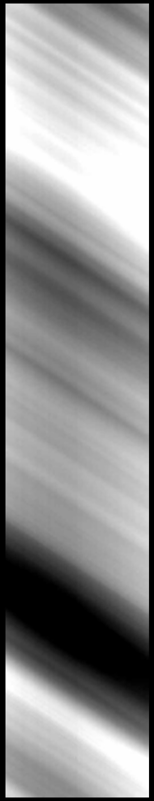
Special targets for characterization

Searchlights
-California

Planets
-Venus



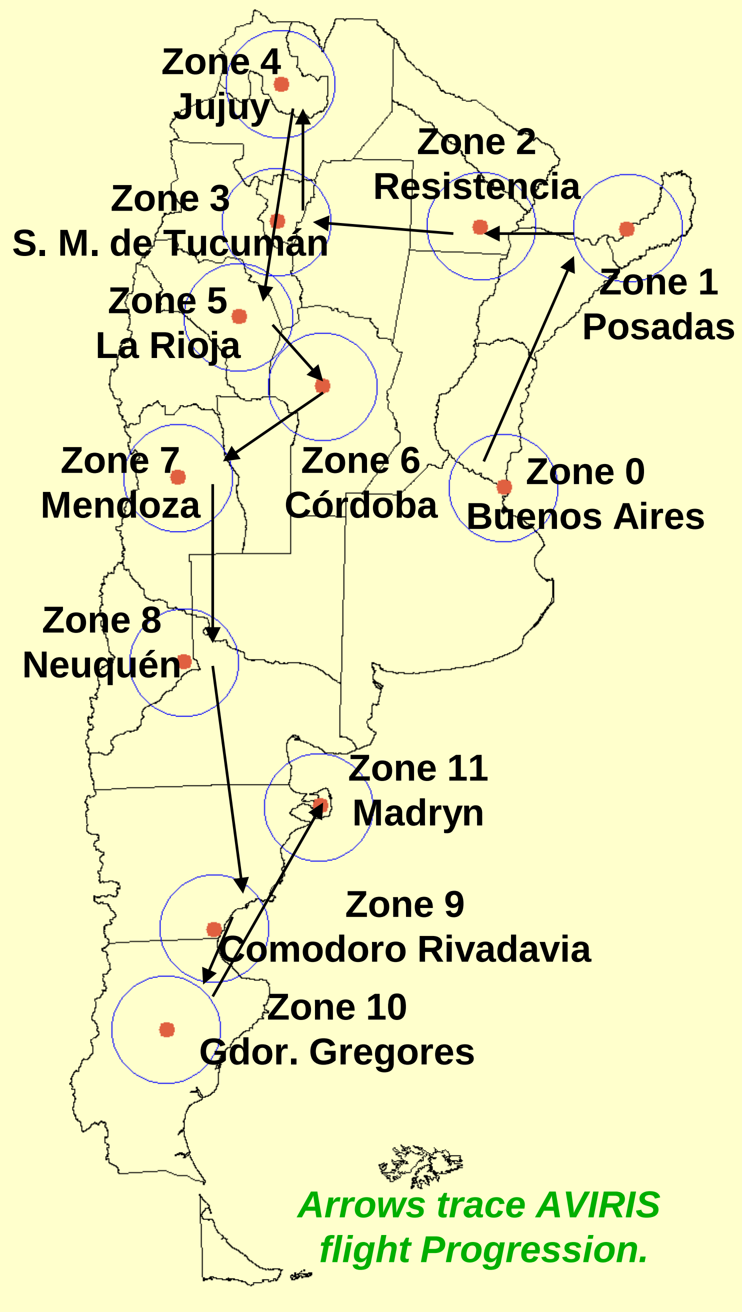
Gas Flares
-Moomba



90 deg
Yaw

EO-1 Accelerated Mission Southern Hemisphere Field Campaigns

January – February 2001



AVIRIS Twin Otter Aircraft | **Argentine/AVIRIS Sites**

The EO-1 2001 Field Campaign

AVIRIS Overflights

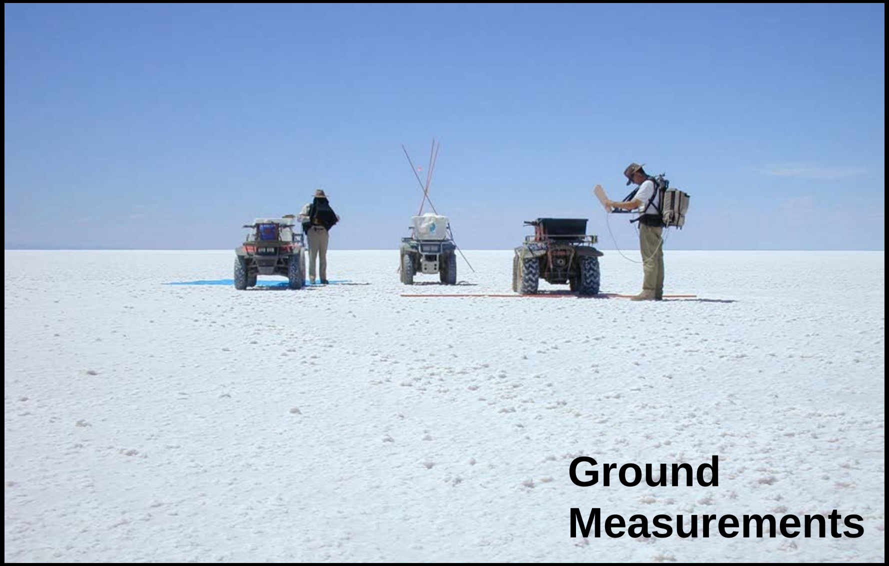
The EO-1 2001 Field Campaign

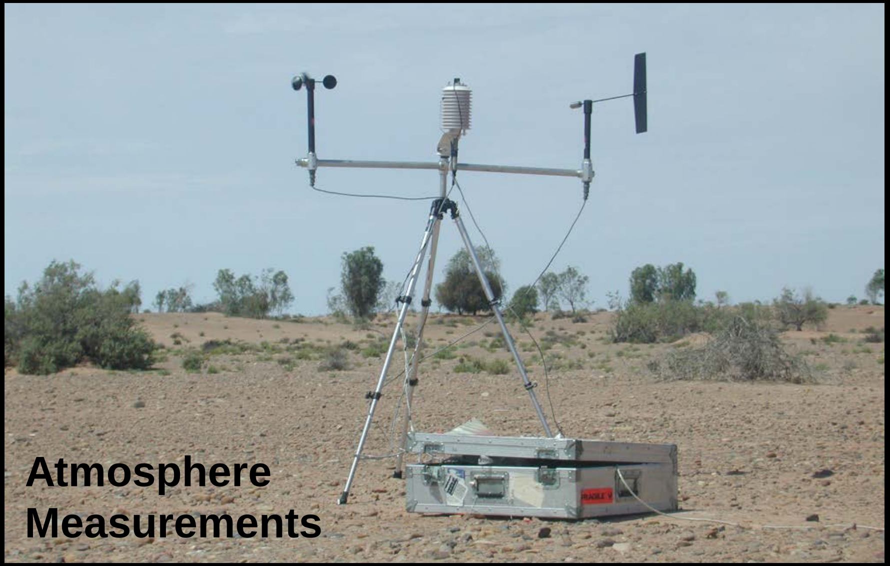
Barreal Blanco

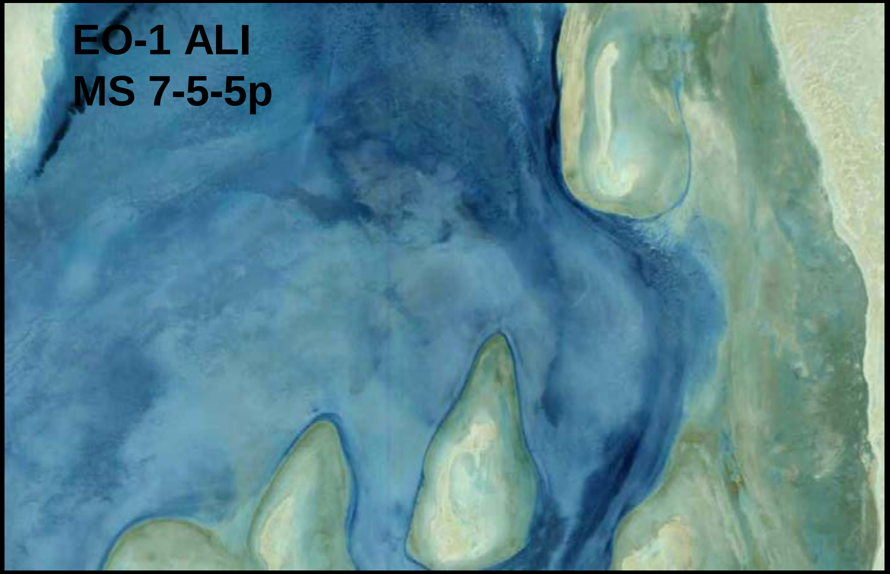
Radiometric Calibration

- Ground Truth Referencing
  - Lake Frome, Au ground truth collected by CSIRO.
  - Barreal Blanco and Arizaro Argentina ground truth collected by U. of Arizona and U. of Colorado
  - Ivanpah Playa ground truth collected by U. of Arizona
  - AVIRIS underflights

Ground Truth Site: Lake Frome, Au







The EO-1 2001 Field Campaign

Central Australia

The EO-1 2002 Field Campaign

Salar de Arizaro - 11 Dec. 2002

EO-1 … The Mission Continues!

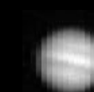
Where we've been!

Accelerated Mission

Where we're at!

Forest Inventory

Where are we going?



Spectral Science & Applications Terrestrial Carbon Mission

Investigating the use of spectral information in the reflective region (0.4 – 2.5 µm) to assess significant contributors to the global carbon budget.

Science Theme: **Carbon Sequestration**

Ecosystem response to disturbance and recovery

Vegetation functional groups

Applications Theme: **Carbon Management**

Wildfire Detection

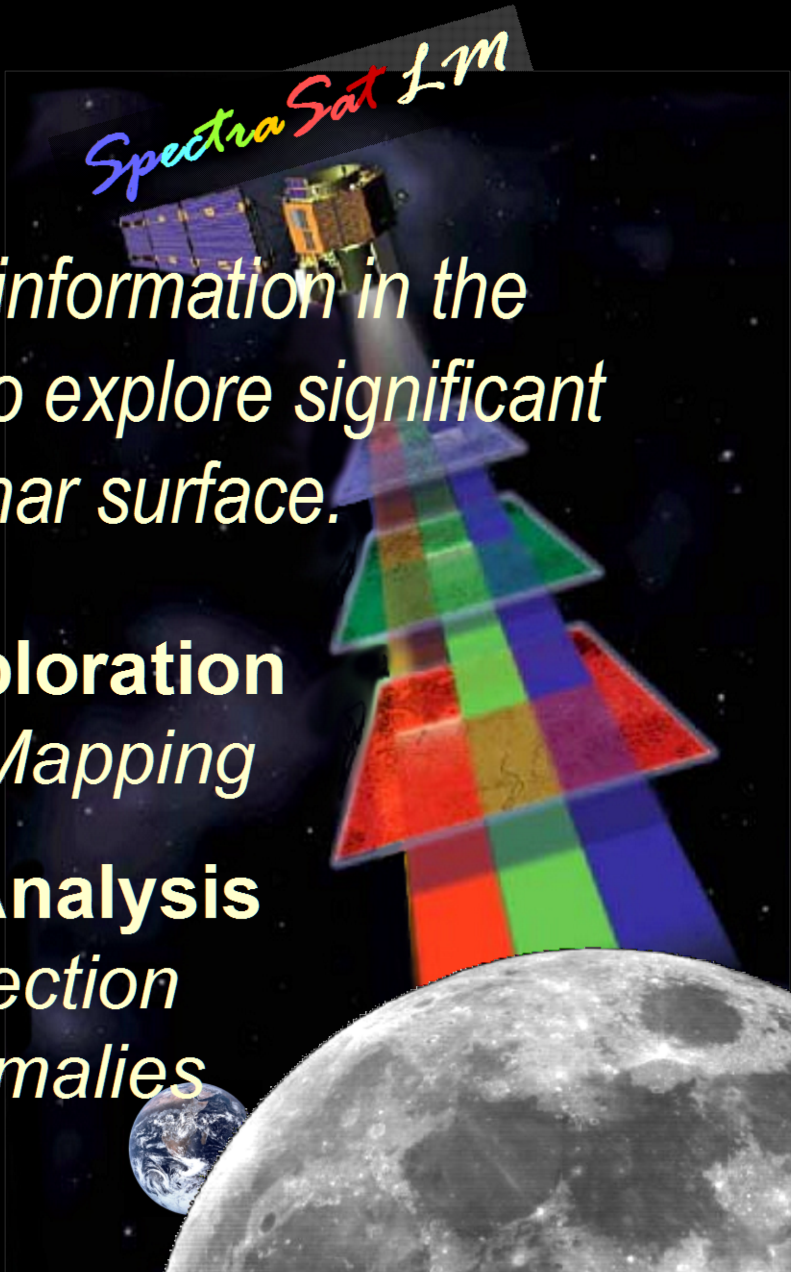
Wildfire Remediation

SpectraSat GCM &
Carbon Cycle Science

Investigate important Carbon Science Hypotheses related to

- Ecosystem response to disturbance and recovery
  - Decompose the scene into continuous fields of sunlit & shaded over story, sunlit & shaded under story, hence biomass density.
- Vegetation functional groups
  - Decompose the scene into continuous fields of percent bare, herbaceous, water, trees (deciduous, evergreen, broadleaf, needleleaf)

SpectraSat Lunar Mission



Investigating the use of spectral information in the reflective region (0.4 – 2.4 µm) to explore significant features and properties of the lunar surface.

Major Theme: **Mineral Exploration**
Geological Mapping

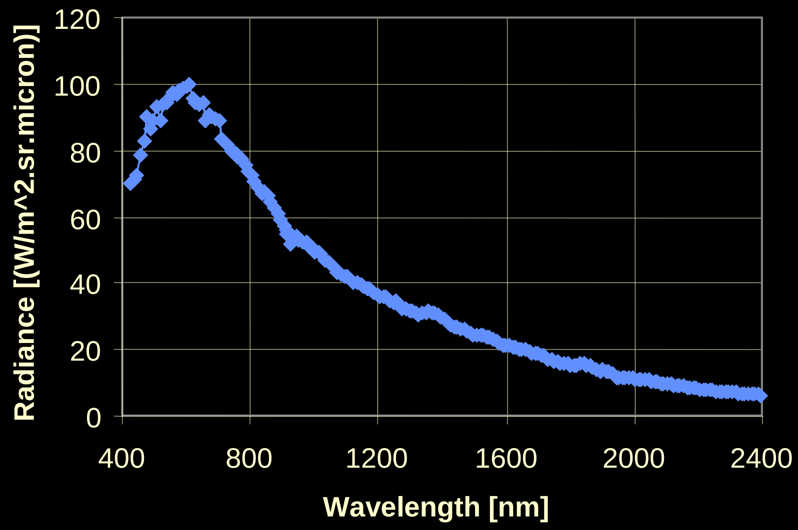
Ancillary Theme: **Resource Analysis**
“Water” Detection
Identify Anomalies

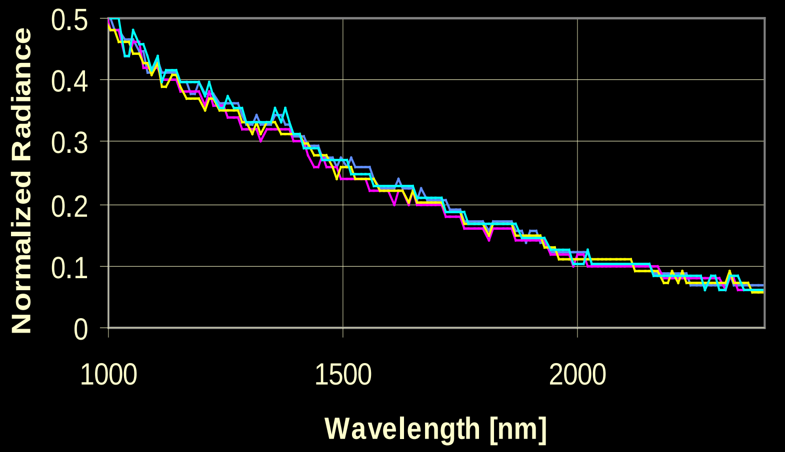
EO-1 has viewed the moon!

(EO-1 ALI Pan band)

Full Moon

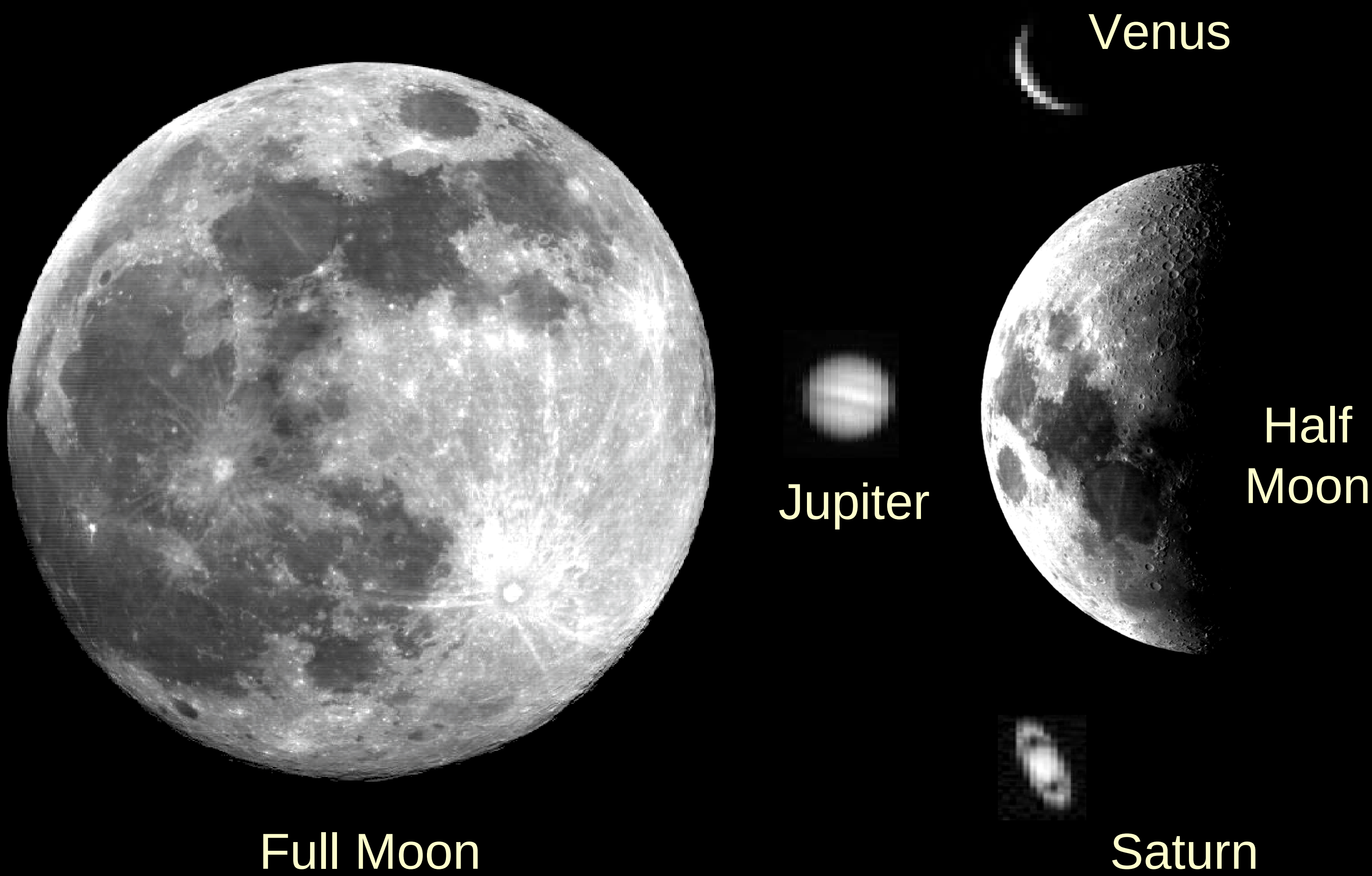
(EO-1 Hyperion)





Out of This World!

(Views with the EO-1 ALI Pan band)



Flora Carbon Science

Flora- Goddess of Spring and Flowers

Proposed Mission Overview

Stephen Ungar
Mission Scientist

IGARSS- 2004
Anchorage, AK
Sept. 26, 2004

SpectraSat measurements enable global change science.

Fractional Vegetation Cover

- Global carbon cycle
  - Sink activity & feedbacks
  - Aboveground C stocks
  - C management
- Ecosystem responses to global change
- Land surface energy exchanges
  - Climate variability and change
  - Global water cycle

Plant Functional Types

- Global carbon cycle
  - Sink activity & feedbacks
  - C stocks and turnover
- Ecosystem responses to global change
- Biodiversity/biocomplexity

Disturbance Responses & Vegetation Condition

- Global carbon cycle
  - Regional C sources and sinks
- Ecosystem responses to global change
- Land use/land cover change
- Sustainability of ecosystem services

Science Team Members

Greg Asner, Stanford – PI, Science Team Leader
– fractional cover, condition

Stephen Ungar, GSFC – Project Scientist

Robert O. Green, JPL – Inst. Science, calibration

Forrest Hall, UMBC – global data products, disturbance

Alfredo Huete, U of Arizona – cover and condition

Robert Knox, GSFC – Deputy Project Scientist
– ecosystem dynamics

Mary Martin, UNH – function and condition (biochemistry)

Betsy Middleton, GSFC – function and condition (photobiology)

Dar Roberts, UCSB – functional type and condition

Susan Ustin, UC-Davis – functional type & condition, wetlands

Others TBD - atmospheric characterization, coastal zone

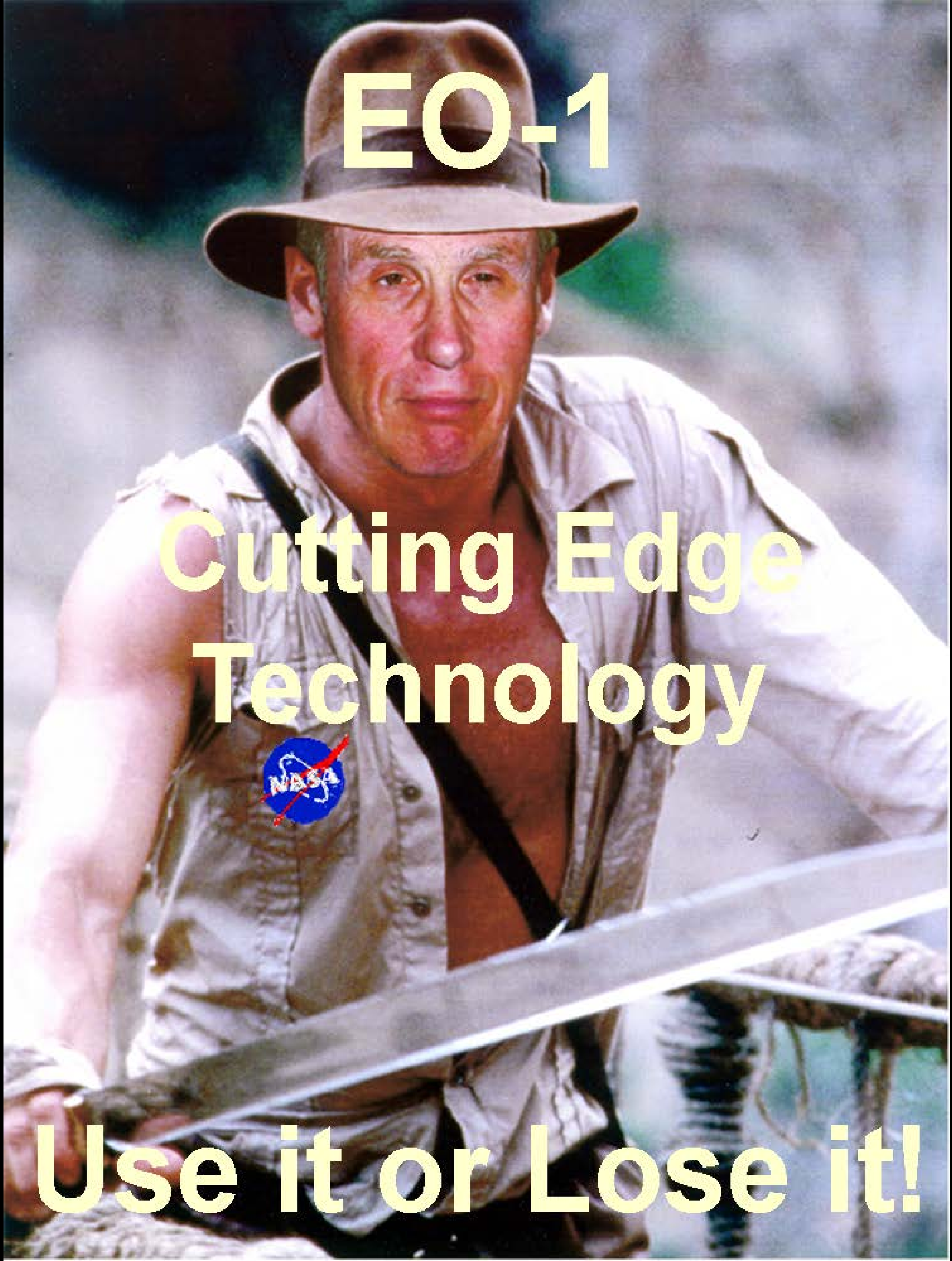
Full Spectral Landsat Swathwidth

Basic Imaging Spectrometer Characteristics

	Module	Observatory
Spectral Range	0.4 – 2.5 µm	210 Channels
Sampling Interval	10 nm	10 nm/Ch
Swath Width	20 km (640 pixels)	9 modules (180 km)
Pixel Size	31.25 m	31.25 m
SNR (ZA=60º, R=30%)	VNIR - 600 SWIR - 450	VNIR - 600 SWIR - 450
Digitization	12 bit	12 bit
Radiometric Range	-0.1 to 1.1 L_{max}	-0.1 to 1.1 L_{max}
Spectral Uniformity	>95%	>95%
Spatial Uniformity	>95%	>90%

Flash-Forward

- The Flora White Paper, submitted to the NAS committee responsible for creating the NASA Decadal Survey, increased pixel size to 45 meters, accommodating:
  - Higher SNR
  - Larger FOV
- The white paper was used by the NAS as the basis for the VSWIR portion of their proposed HyspIRI mission.
- The NASA HyspIRI Concept team, consistent with objectives as stated in the Decadal Survey, has further increased the pixel size to 60 meters allowing for exploitation of larger focal plane arrays to reduce the number of spectrometers, as well as providing:
  - Still higher SNR
  - Much larger FOV
  - More frequent re-visit time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