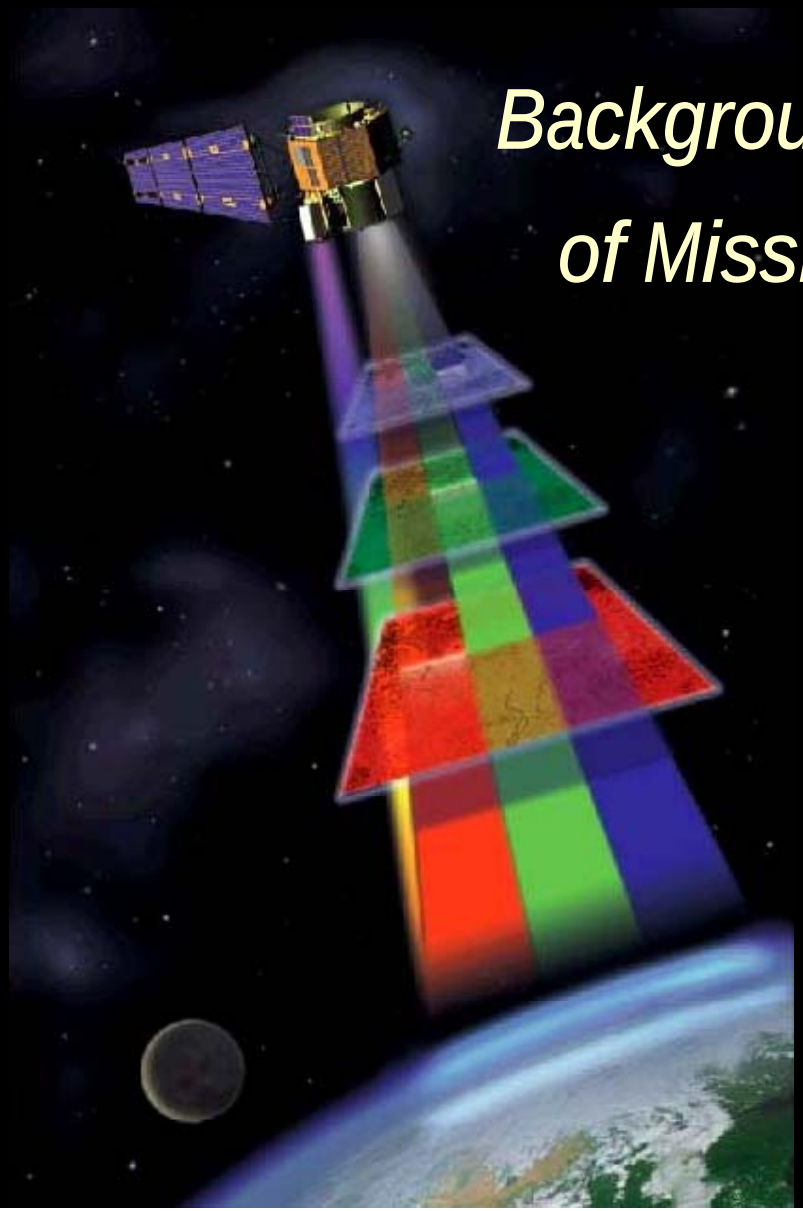
EO-1 Pathfinder to SensorWeb



Background of Mission

LAUNCH

Launch Date: Nov. 21, 2000

Launch Vehicle: Delta 7320

Co-manifested with SAC-C

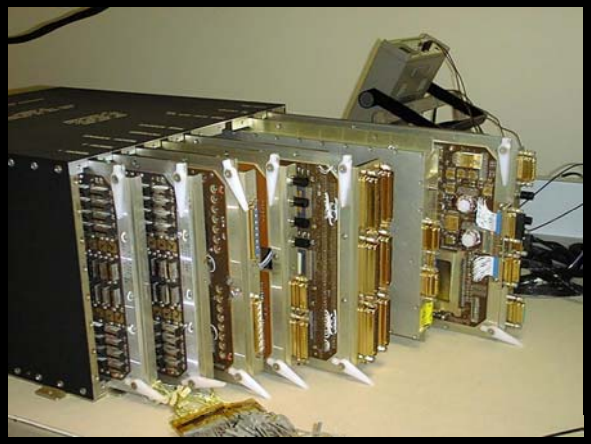
ORBIT

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

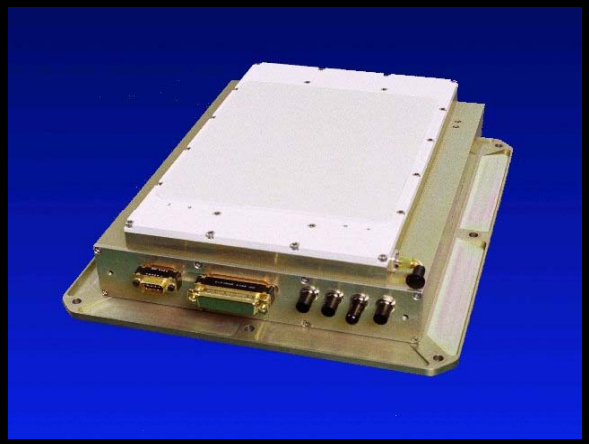
Descending node with an equatorial crossing about one minute behind Landsat 7

**** Current EO-1 altitude is ~690 Km***

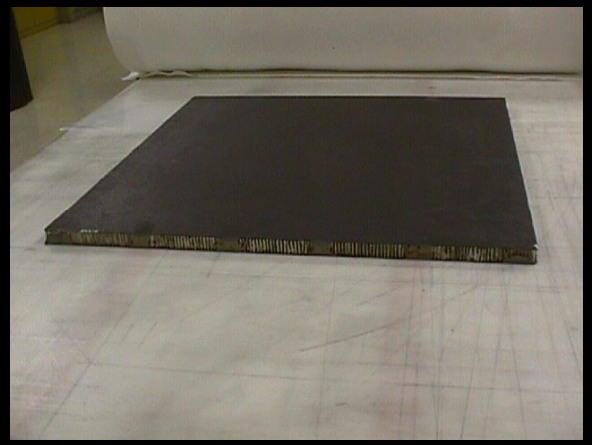
EO-1 Supporting Technologies



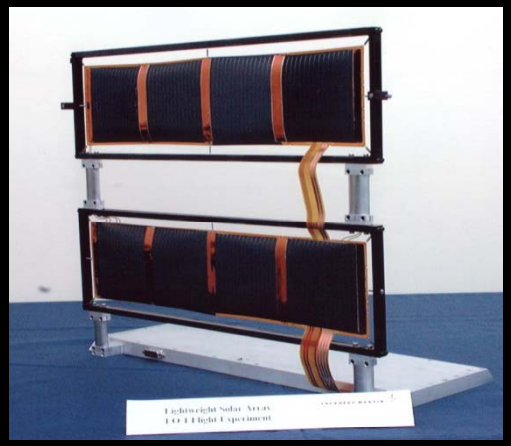
Wideband Advanced Recorder Processor



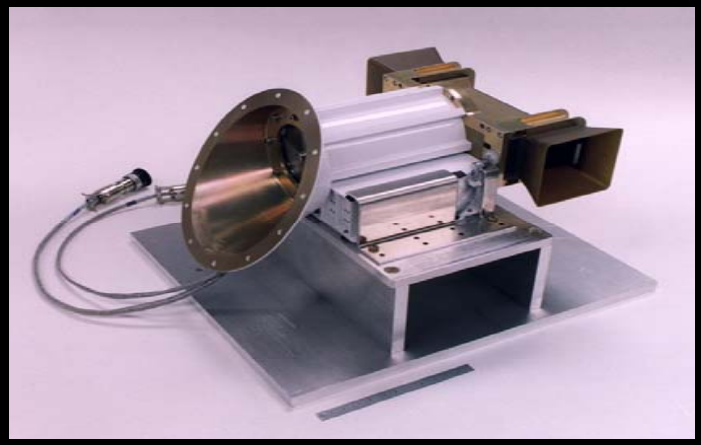
X-Band Phased Array Antenna



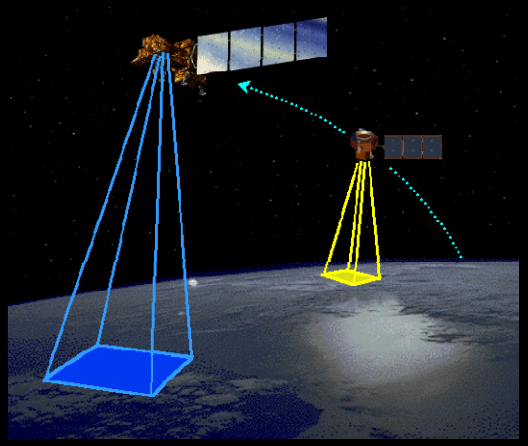
Carbon-Carbon Radiator



Lightweight Flexible Solar Array

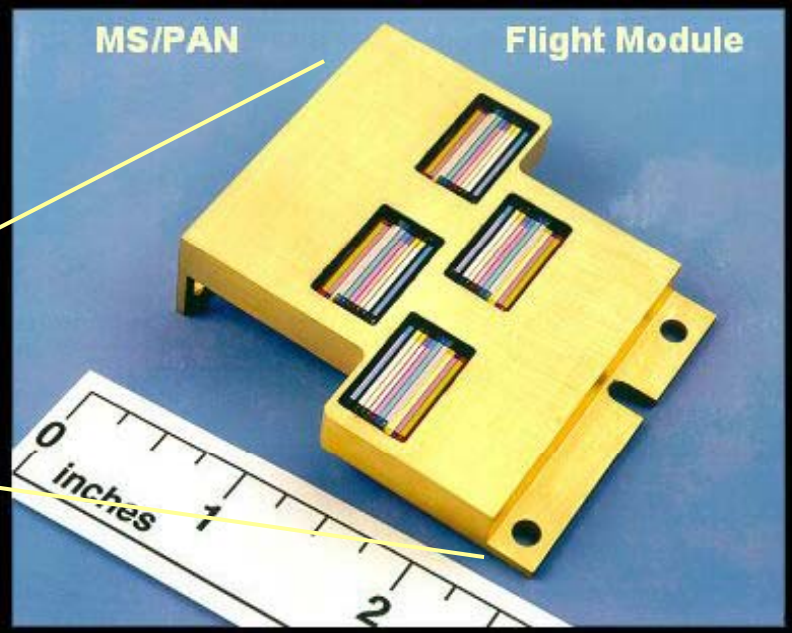


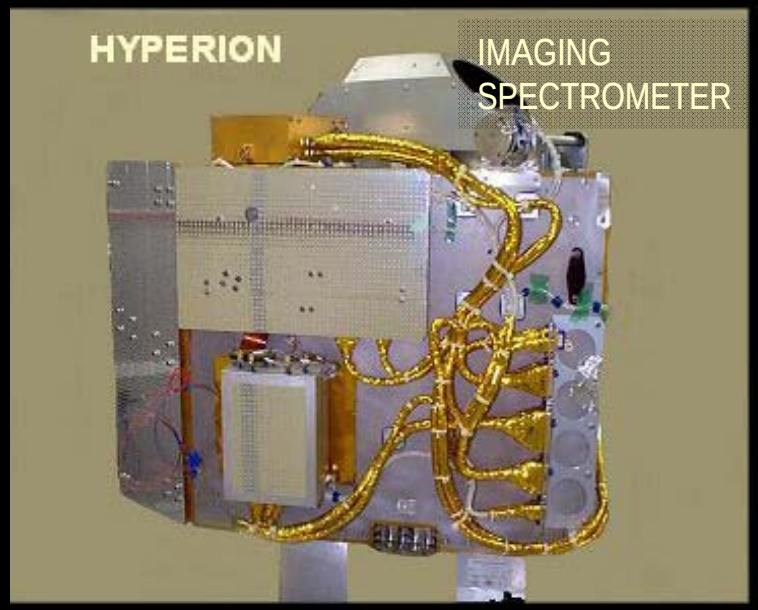
Pulse Plasma Thruster



Formation Flying

EO-1 Flight Instruments





EO-1 has evolved from a science-enabling Technology Pathfinder into a test-bed for both Science and Technology.

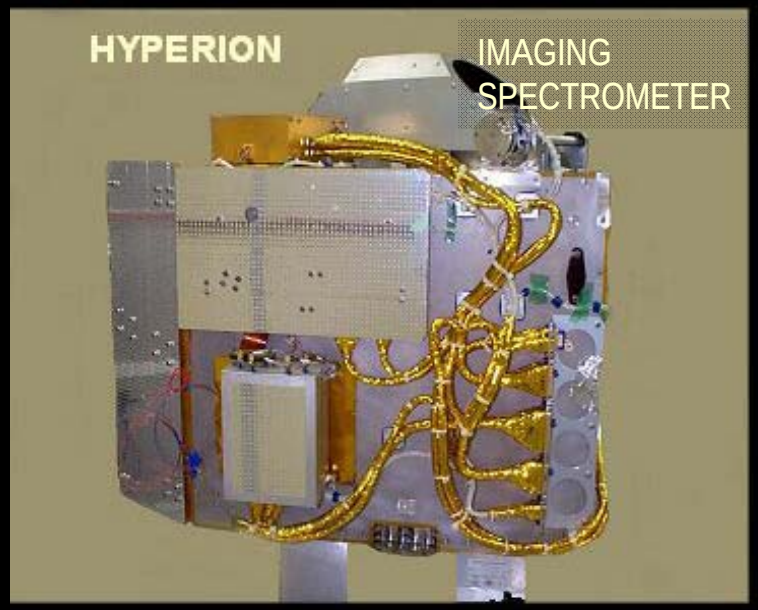
EO-1 Flight Instruments

Multispectral Properties

4 VIS bands	30m pixel-size/GSD
2 NIR bands	30m pixel-size/GSD
3 SWIR bands	30m pixel-size/GSD
1 Pan band	10m pixel-size/GSD

Spatial Properties
FOV: 37km

Radiometric Properties
Resolution: 12 bit



Spectral Properties
Range: 0.4μm – 2.5μm
Resolution: 10nm

Spatial Properties
FOV: 7.6km
GSD: 30m

Radiometric Properties
Resolution: 12 bit

EO-1 “First Light” Image

Sutton, Alaska - November 25, 2000

ALI served as the prototype for the multi-spectral push-broom Operational Land Imager (OLI) onboard Landsat 8

Why is the ALI pan band better than the ETM+ pan band?

Improved Radiometric resolution

- Superior signal-to-noise
- 12-bit versus 8-bit representation of dynamic range

Inherently higher contrast measurement

- ALI pan restricted to 480 – 690nm VIS spectral interval
- ETM+ spans vegetation transition rise (520 – 900nm)

Smaller pixel size (IFOV)

- ALI pan IFOV is 10 meters
- ETM+ is nominally 15 meters (effectively 18 meters)

Pearl Harbor
December 19, 2000
Pan Sharpened
ALI Real Color

Pearl Harbor
December 19, 2000
Arizona Memorial
Pan Sharpened
ALI Real Color

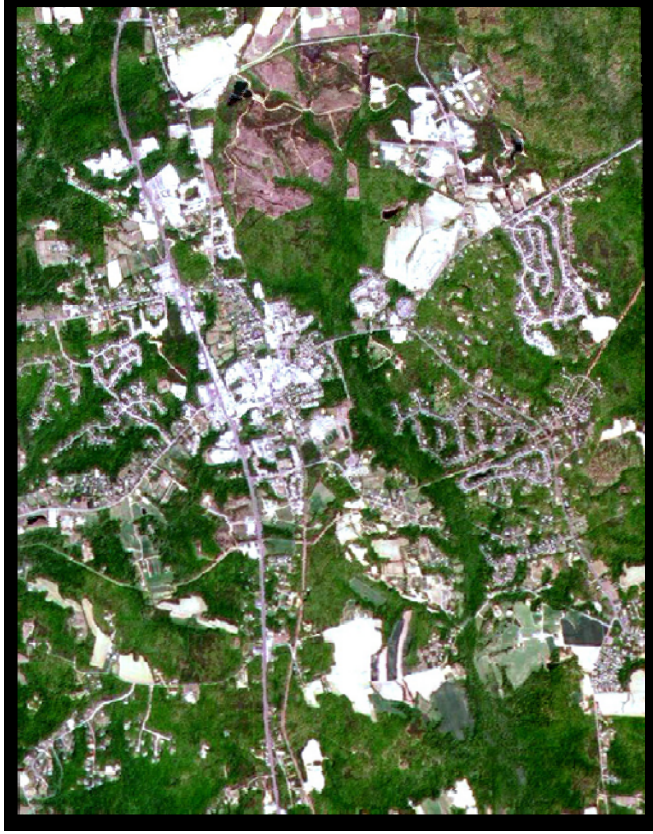
Pearl Harbor
December 19, 2000
Pan Sharpened
ALI Real Color

Pearl Harbor
December 19, 2000
Pan Sharpened
ALI Real Color

La Plata, MD Tornado
Category F4 – April 28, 2002

After-effects are still visible one year later

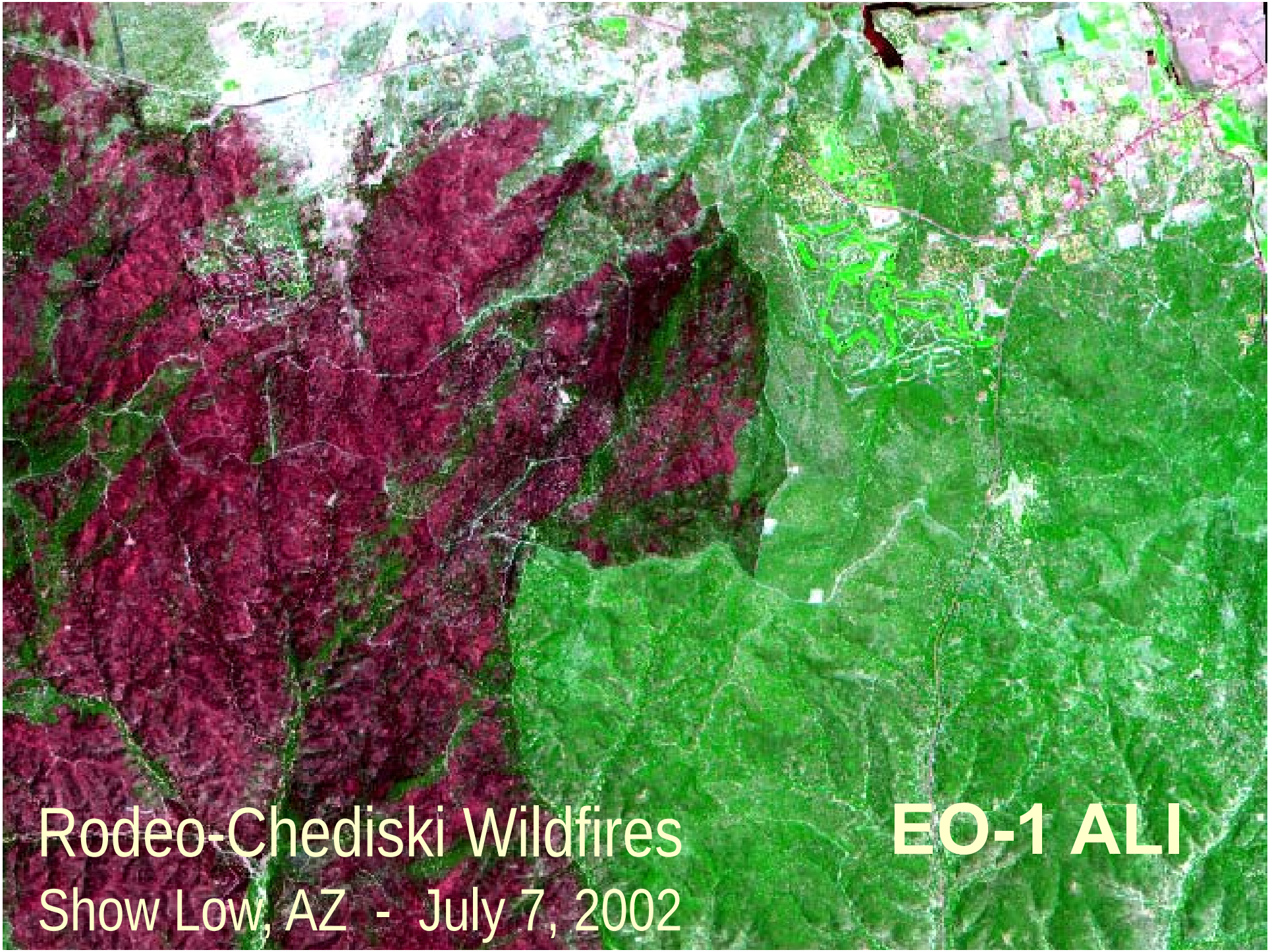
April 24, 2002



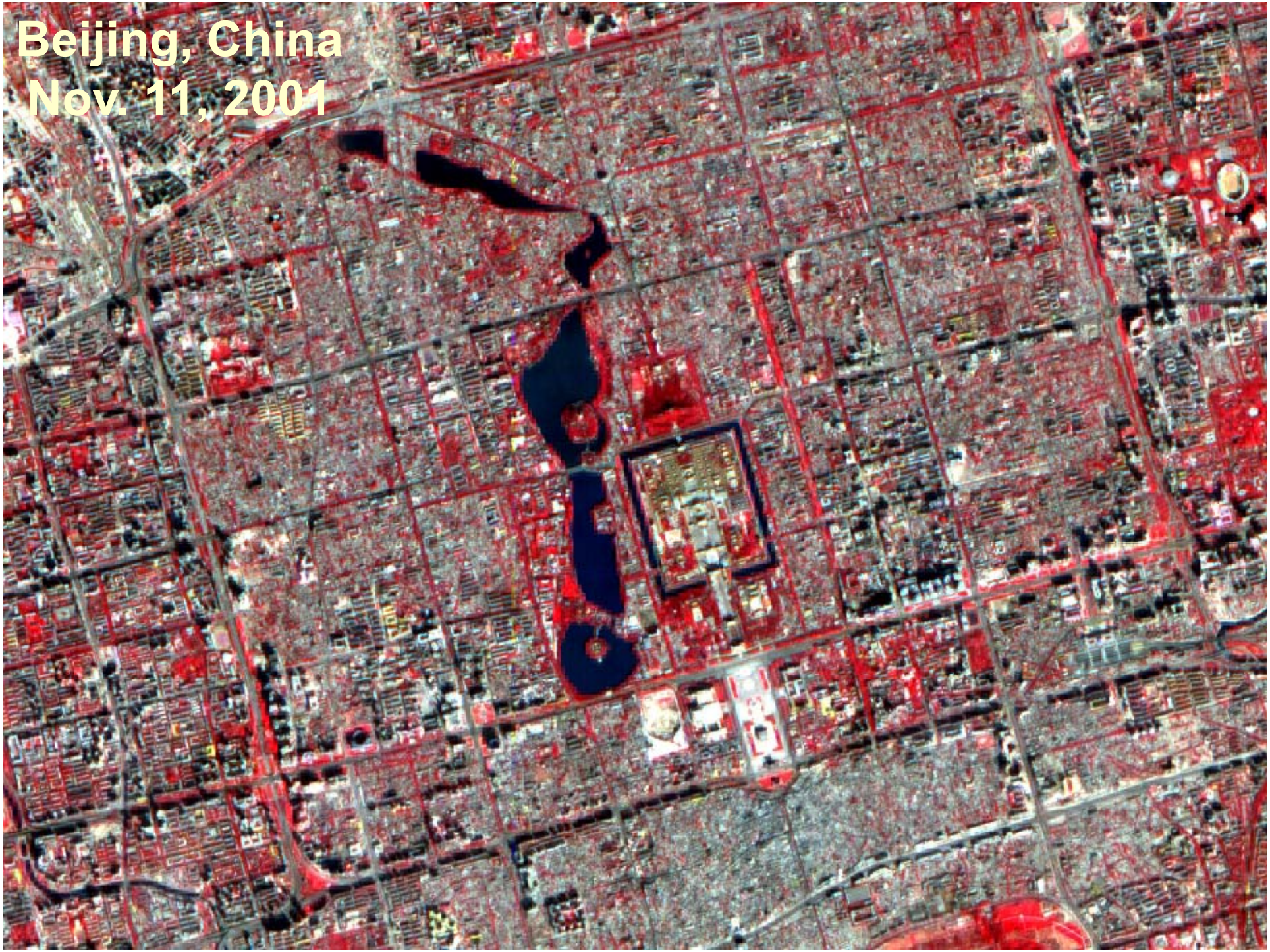
May 1, 2002

April 27, 2003

Rodeo-Chediski Wildfires
Show Low, AZ - July 7, 2002
L-7 ETM+


Rodeo-Chediski Wildfires
Show Low, AZ - July 7, 2002
EO-1 ALI

Beijing, China
Nov. 27, 2001


Beijing, China
Nov. 11, 2001

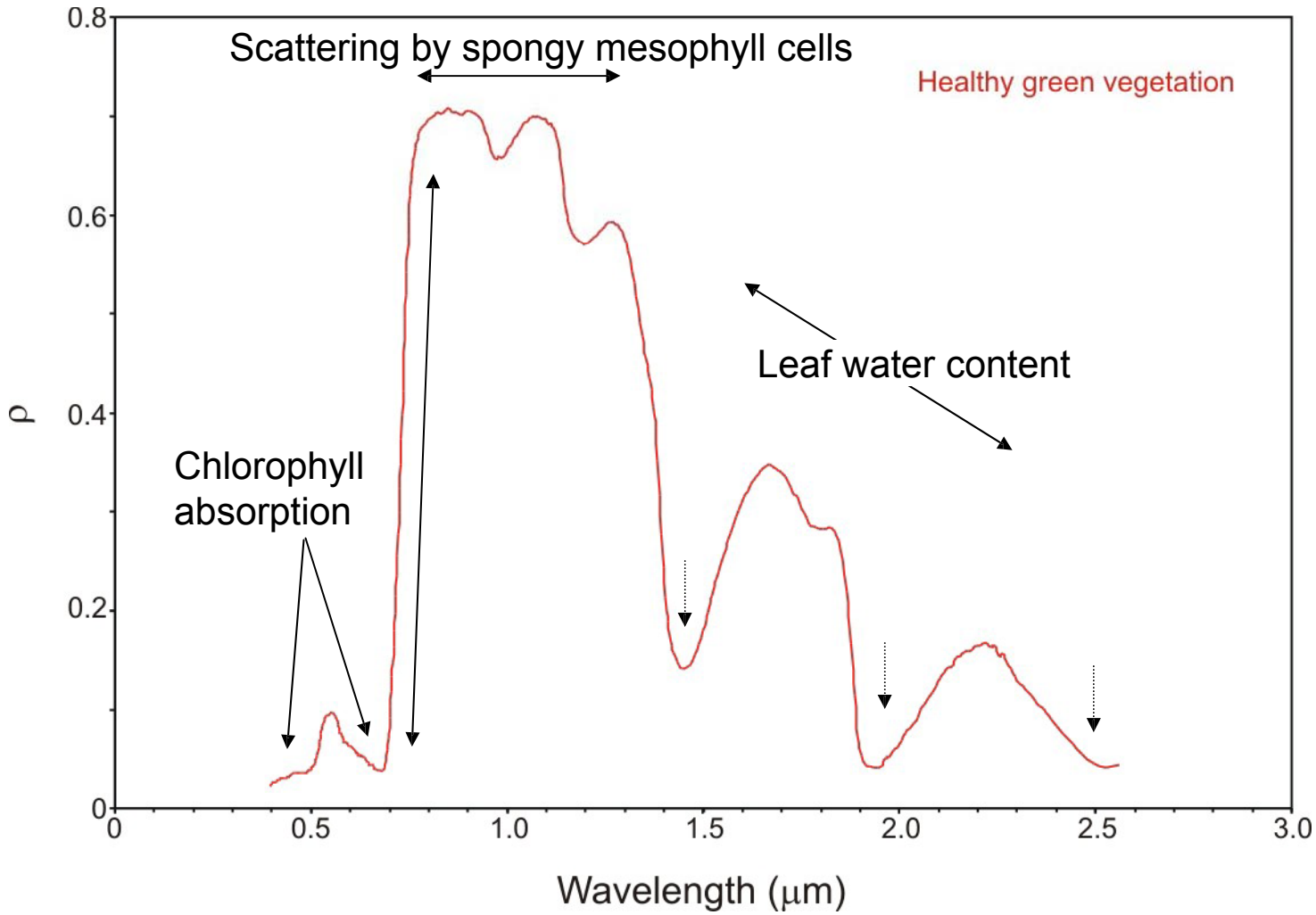
Manhattan, New York - EO-1 ALI Pan Band

March 13, 2001

September 12, 2001

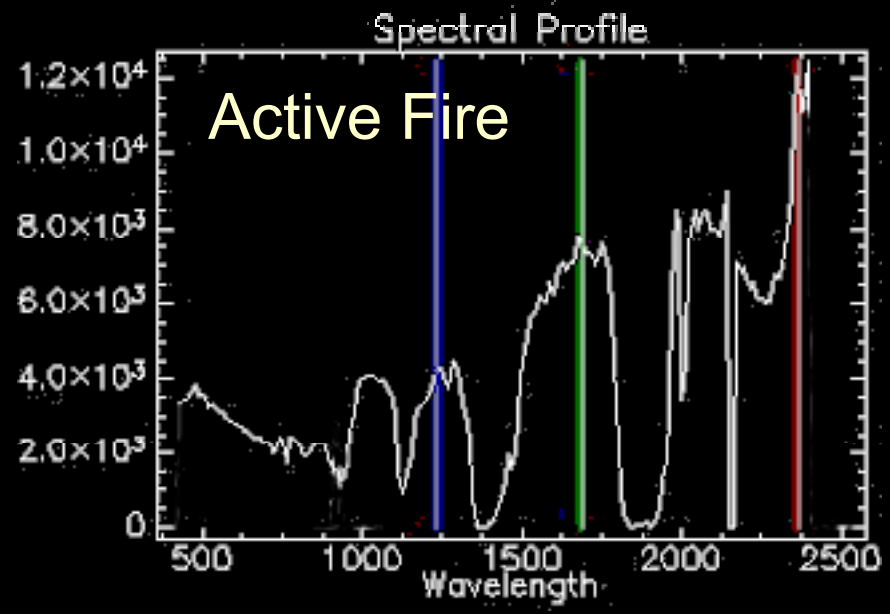
NYC – Sept. 12, 2001
EO-1/ALI Pan Enhanced
3-2-1 Color Composite

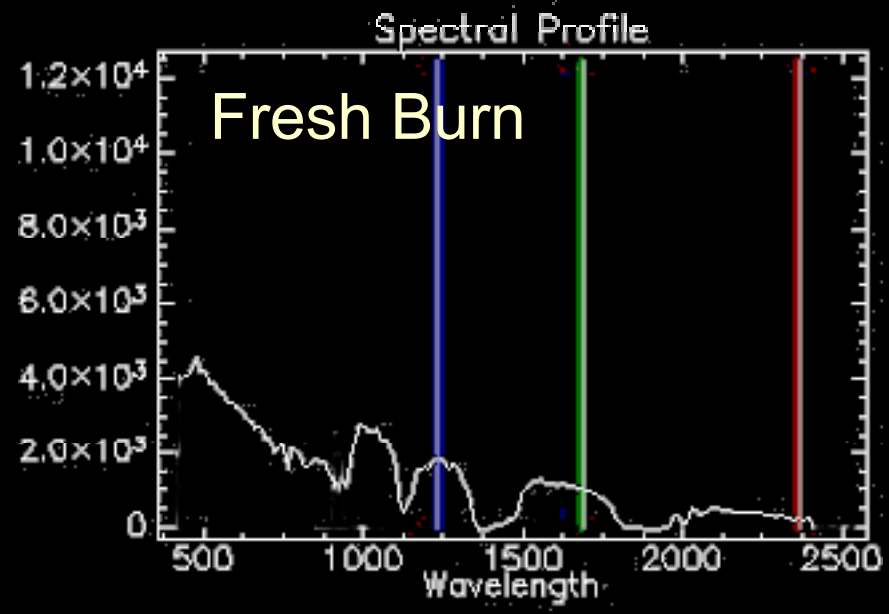
Exploiting Spectral Characteristics

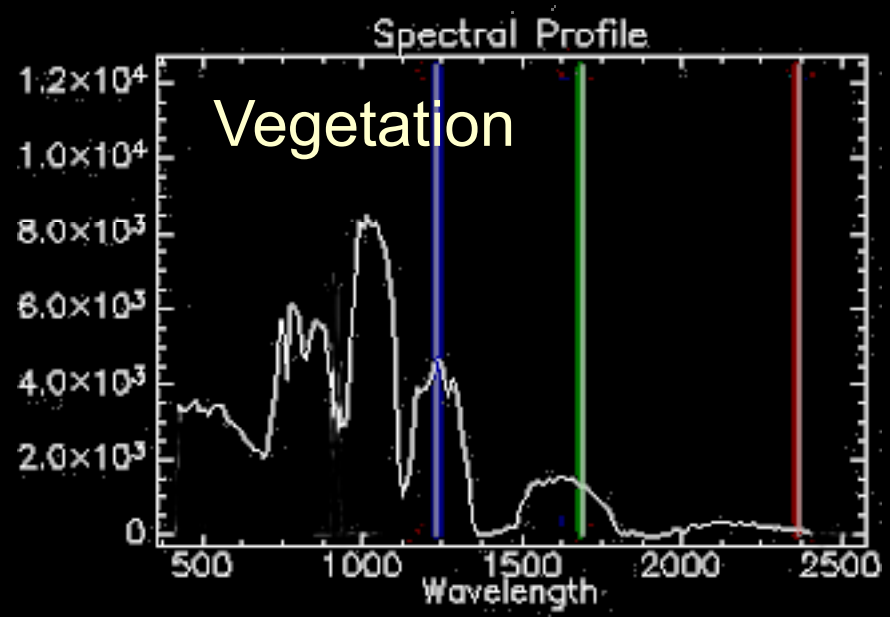


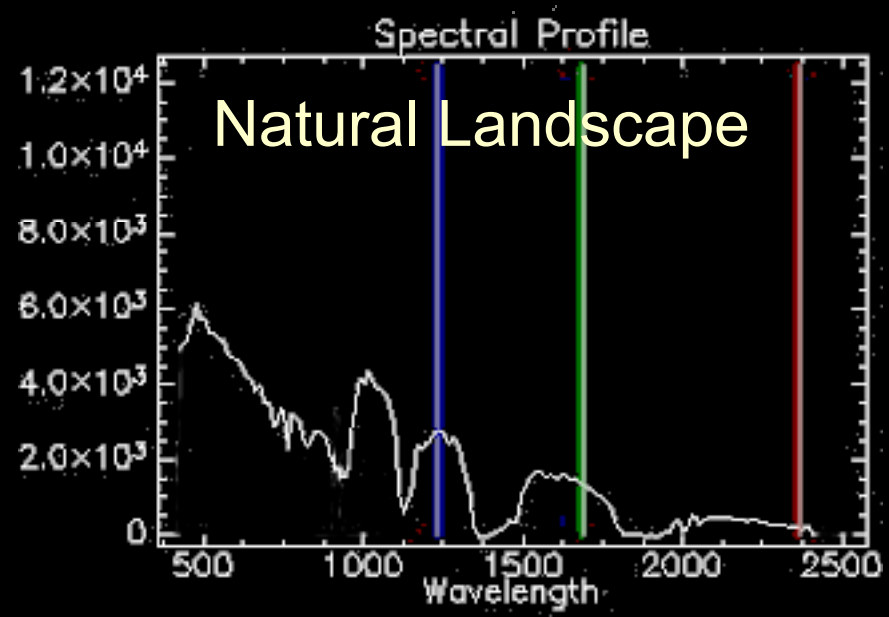
Hyperion Spectra Extracted from Area of Fire

Hyperion Views Tucson Wildfires - July 3, 2003

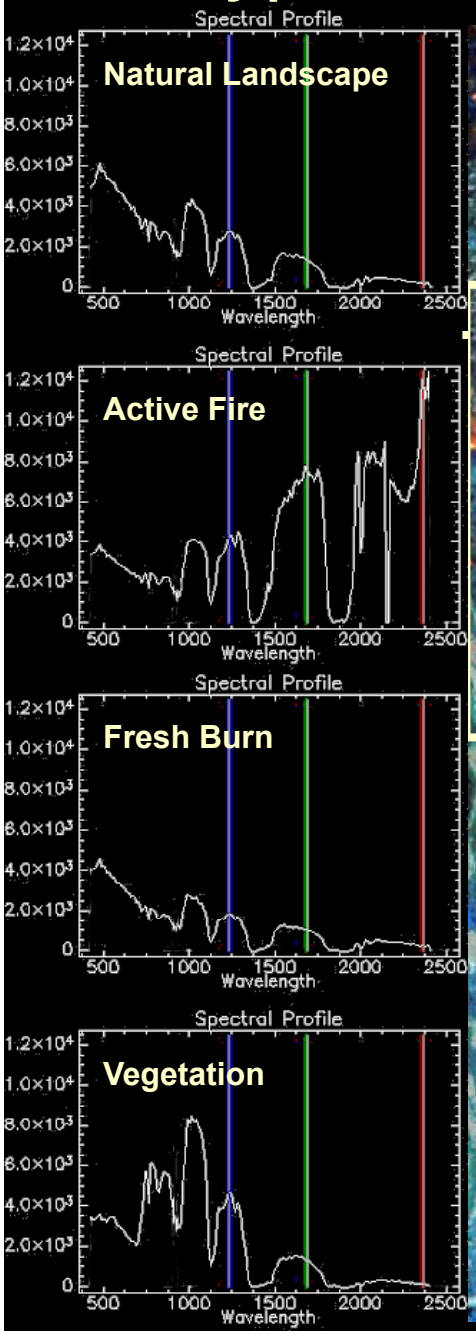


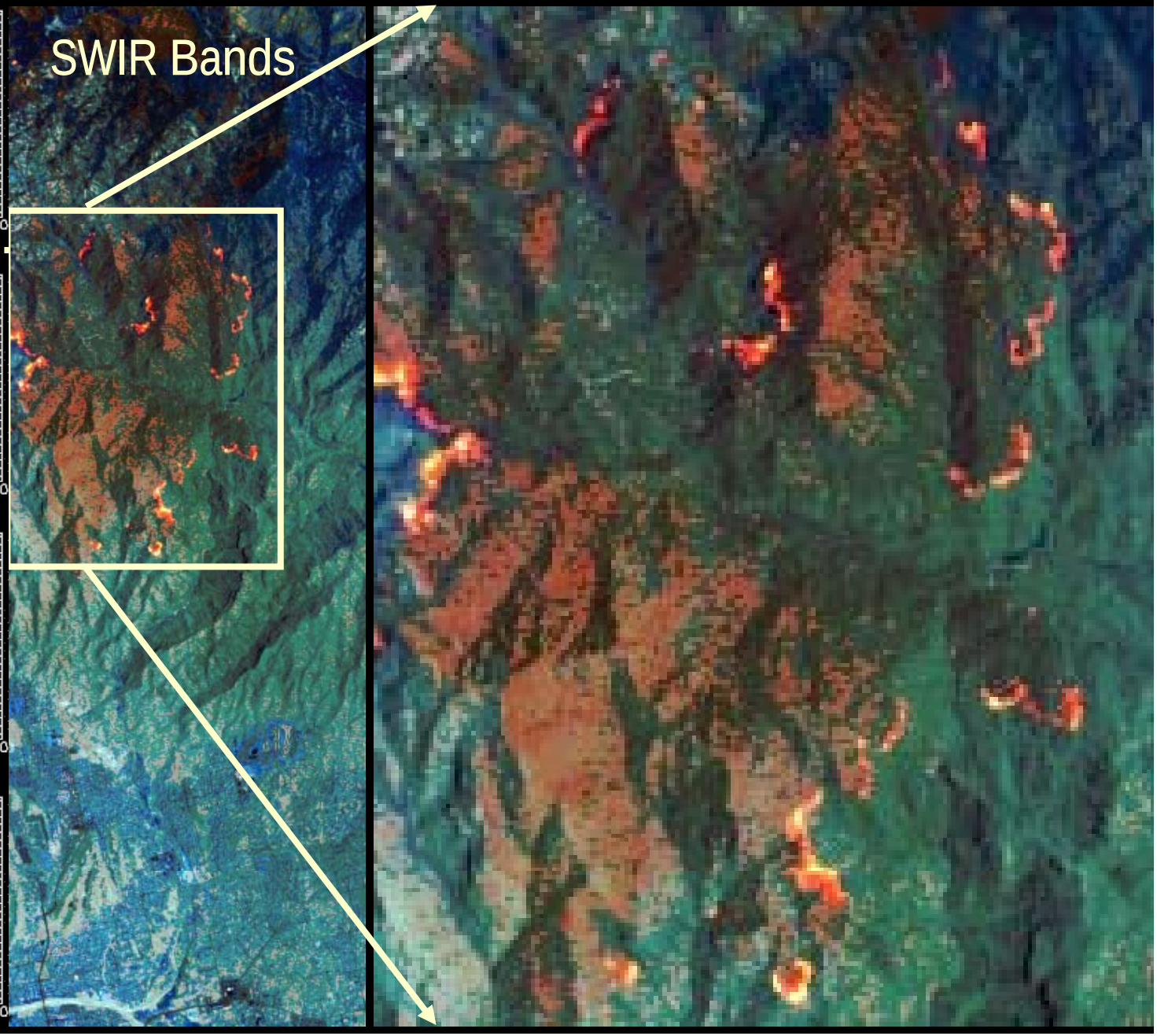




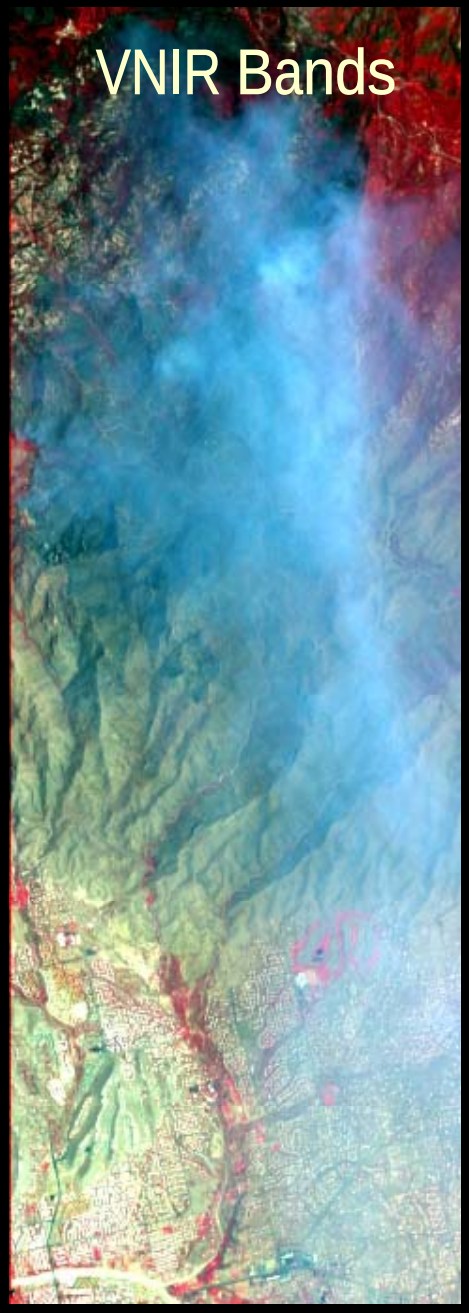


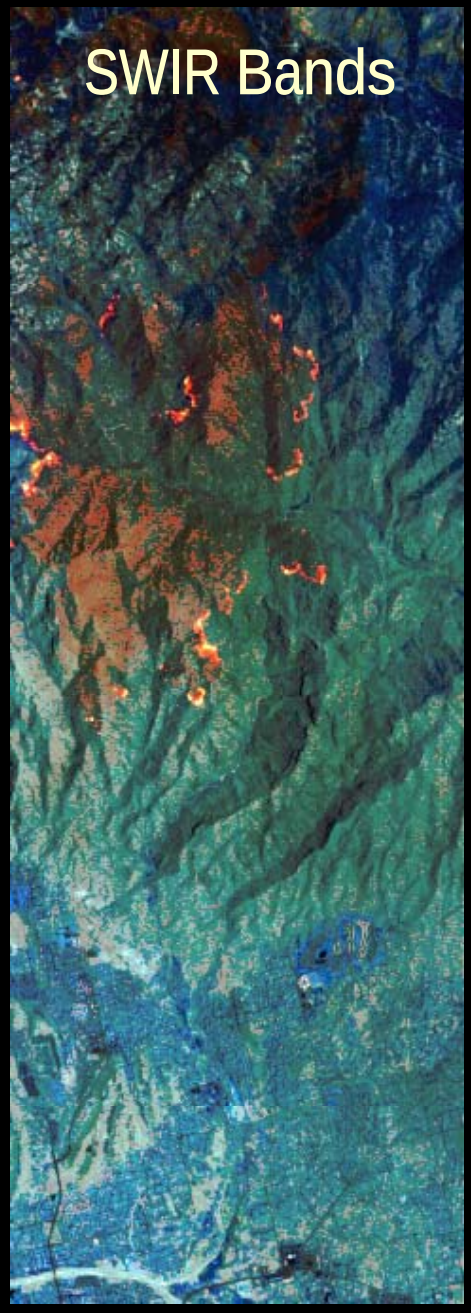
Hyperion Views Tucson Wildfires - July 3, 2003





Hyperion Views Tucson Wildfires - July 3, 2003





Eruption of Mt. Etna, Sicily

July 22, 2001

ALI Pan Enhanced
Bands 3-2-1

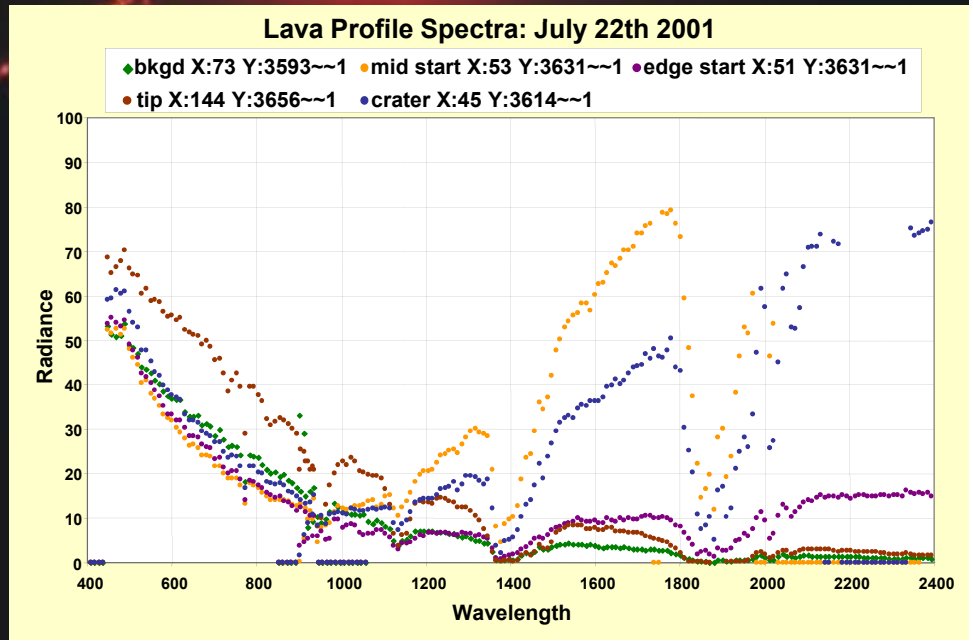
Hyperion
7-5-4 Equiv

EO-1 ALI
Bands 7-5-5'

Hyperion Temperatures for Etna

Spectrum	Crust Temp	Hot Temp	Area Hot
J 13 - CTB	346 C	994 C	0.0025
J 13 - MM	874 C	876 C	0.45
J 13 - CTS	976 C	978 C	0.47
J 13 - TipX	210 C	900 C	0.00034
J 22 - MS	726 C	1075 C	0.090
J 22 - CX	487 C	1075 C	0.022
J 22 - RS*	1054 C	1058 C	0.690

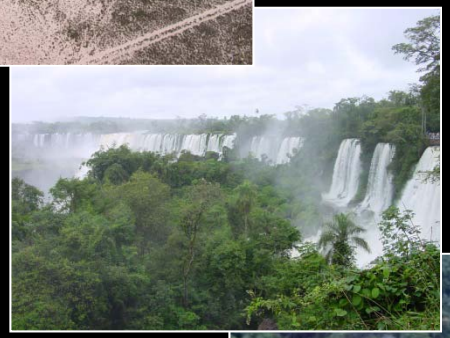
EO-1 Hyperion Spectra



What does imaging spectroscopy provide beyond multi-spectral?

Quantitative vegetation and NPV cover in arid regions

Tropical forest canopy chemistry



Logging damage in tropical forests

Aggregated Classifications of ETM+, AVIRIS, Hyperion and ALI

	Aggregated classification accuracies			
	ETM+	**AVIRIS**	**Hyperion 1b** (2-12)	**ALI**
Class Label	**Accuracy %**	**Accuracy %**	**Accuracy %**	**Accuracy %**
Exposed land	100	100	100	100
Water	100	99.4	99.8	100
Shrub low	100	99.4	100	99.0
Farmer's field	93.5	100	100	100
Swamp	92.0	94.5	97.1	98.6
Red Alder	62.7	89.4	91.5	79.7
Hemlock	65.2	88.8	83.0	63.4
Lodgepole Pine	38.0	89.4	87.7	62.6
Western Red Cedar	83.3	88.2	83.3	75.0
Douglas Fir	68.8	90.5	92.5	85.0
Overall accuracy of training site data (70% of study area)	77.5	94.0	94.2	87.5
Accuracy of test site data (30% of area)	**75.0**	**92.1**	**90.0**	**84.8**

Summary of Sensor Capabilities for Selective Logging Studies

Sensor`	Spatial Resolution	Number of Optical Channels Used	Geographic Cover (freq., footprint, etc)	% of Damage Classes Obtained	Precision of Logging Analysis
EO-1 Hyperion	30 m	180	Low	95%	85-95%
Landsat 7 ETM+	30 m	6	Medium	50%	70-75%
EO-1 Advanced Land Imager	30 m	9	Low	50%	70-75%
Landsat 5 TM	30 m	6	Medium	40%	50-60%
SPOT MSS	20 m	3	Low	40%	60-70%
CBERS - 2	20 m	4	Medium	30%	40-50%
MODIS	1000 m	7	High	10%	---
MISR	1000 m	4 (multi-angle)	Medium-high	20%	---

ho·lis·tic *adjective* \hō-ˈlis-tik\

Definition of *HOLISTIC*

1: of or relating to holism

2: relating to or concerned with wholes or with complete systems rather than with the analysis of, treatment of, or dissection into parts <*holistic* medicine attempts to treat both the mind and the body> <*holistic* ecology views humans and the environment as a single system>

— **ho·lis·ti·cal·ly** \-ti-k(ə-)lē\ *adverb*

See holistic defined for English-language learners »

See holistic defined for kids »

Examples of *HOLISTIC*

Holistic medicine attempts to treat both the mind and the body.

We need to take a more *holistic* approach to improving our schools.

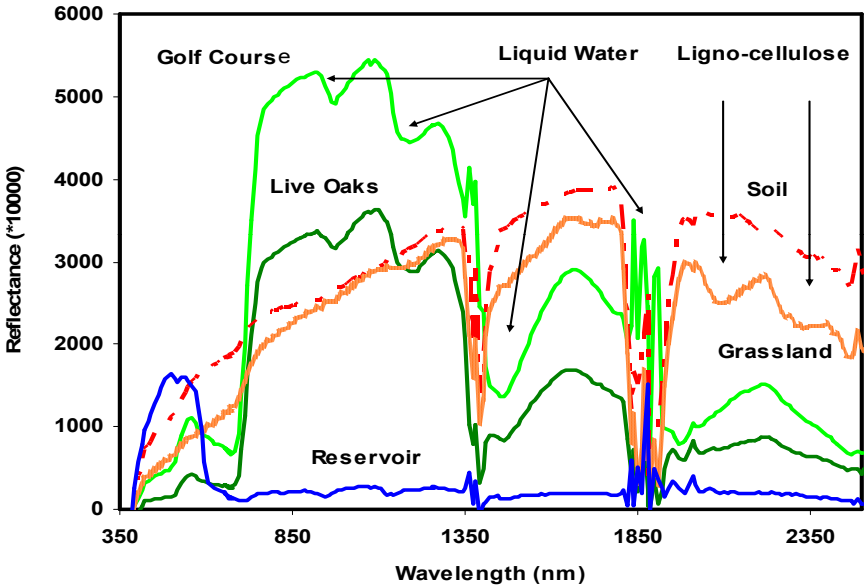
In a world of specialization, we have been trained to think of medicine as a separate world—when we are sick, we go to doctors and follow their advice. This is starting to change, with the increasing popularity of alternative and holistic approaches to overall health and well-being. —Gareth Cook, *Boston Globe*, 9 June 2002

What do I mean by *Holistic* Remote Sensing*?*

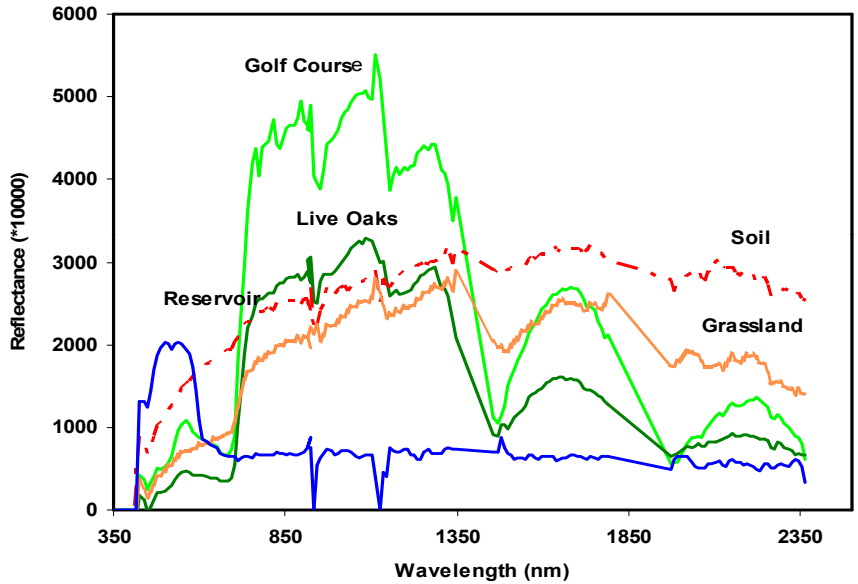
- Comprehensively address specific needs of intended *end-users:*
  - Facilitate coordinated collection of **appropriate data**;
  - Enable transformation of data to **useful information**;
  - Provide distribution of **relevant information** consistent with meeting the end-user's needs.
- Provide a characterization of the data and derived information sufficient to allow end-users to assess and wisely apply this information to address their needs.
- Build new paradigms resulting in algorithms that fully exploit **all** the information.

Exploiting Spectral Characteristics

AVIRIS (State of the Art 2002-2004)



Hyperion Performance (~AVIRIS 1992)

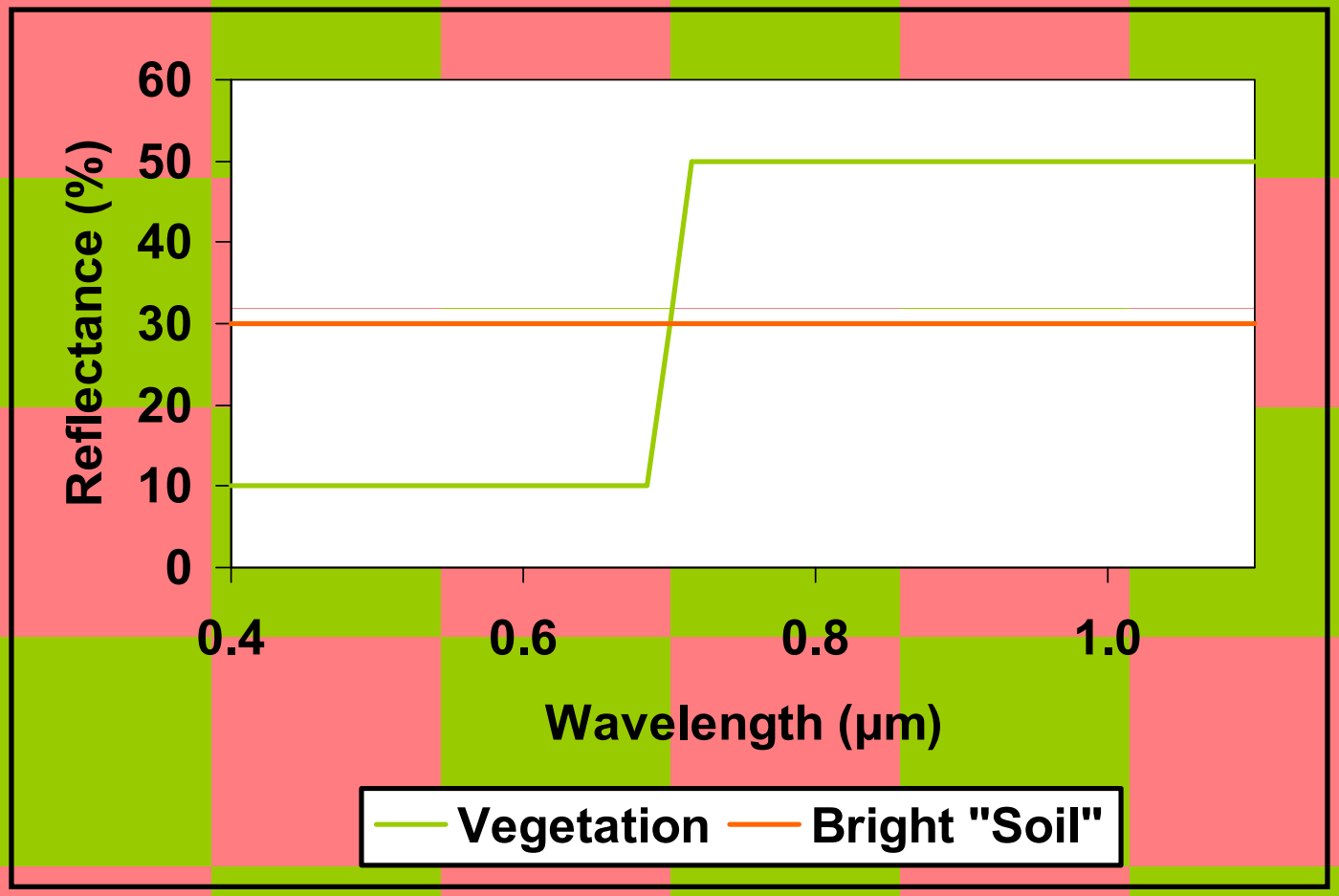


Dan's WCPS provides a toolbox enabling the community to create their own products. The following is a current list of available *spectral indices* provided by the community:

ari (1,2), arvi, cai, cri (1,2), evi, lwi, msi, msr, ndii, ndli, ndni, ndsi, ndvi, ndwi, pri, psri, sipi, smi, sr, siwi, gndvi, mndvi_705, savi, osavi, mcari, mcari_osavi, tcari, tcari_osavi, vog (1,2,3), wbi

Spectral Indices are based on ratios involving two (or in a few cases 3) bands. Ratios are in fact the surrogate measurement needed

Synthetic Scene Composition



Landscape Reflectance Values
Synthetic Scene Scenario

.3	.1	.3	.1
.1	.3	.1	.3
.3	.1	.3	.1
.1	.3	.1	.3

VIS Reflectance

.3	.5	.3	.5
.5	.3	.5	.3
.3	.5	.3	.5
.5	.3	.5	.3

NIR Reflectance

Landscape Reflectance Ratios
Synthetic Scene Scenario

NIR Reflectance

.3	.5	.3	.5
.5	.3	.5	.3
.3	.5	.3	.5
.5	.3	.5	.3

VIS Reflectance

.3	.1	.3	.1
.1	.3	.1	.3
.3	.1	.3	.1
.1	.3	.1	.3

=

1	5	1	5
5	1	5	1
1	5	1	5
5	1	5	1

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

“Scene” Reflectance Ratio
Synthetic Scene Scenario

NIR Reflectance

.3	.5	.3	.5
.5	.3	.5	.3
.3	.5	.3	.5
.5	.3	.5	.3

VIS Reflectance

.3	.1	.3	.1
.1	.3	.1	.3
.3	.1	.3	.1
.1	.3	.1	.3

=

1	5	1	5
5	1	5	1
1	5	1	5
5	1	5	1

3

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

Ratio of Scene Reflectance
Synthetic Scene Scenario

NIR Reflectance

.3	.5	.3	.5
.5	.3	[illegible]	.3
.3	[illegible]	[illegible]	.5
.5	.3	.5	.3

4

VIS Reflectance

.3	.1	.3	.1
.1	.3	[illegible]	.3
.3	[illegible]	[illegible]	.1
.1	.3	.1	.3

2

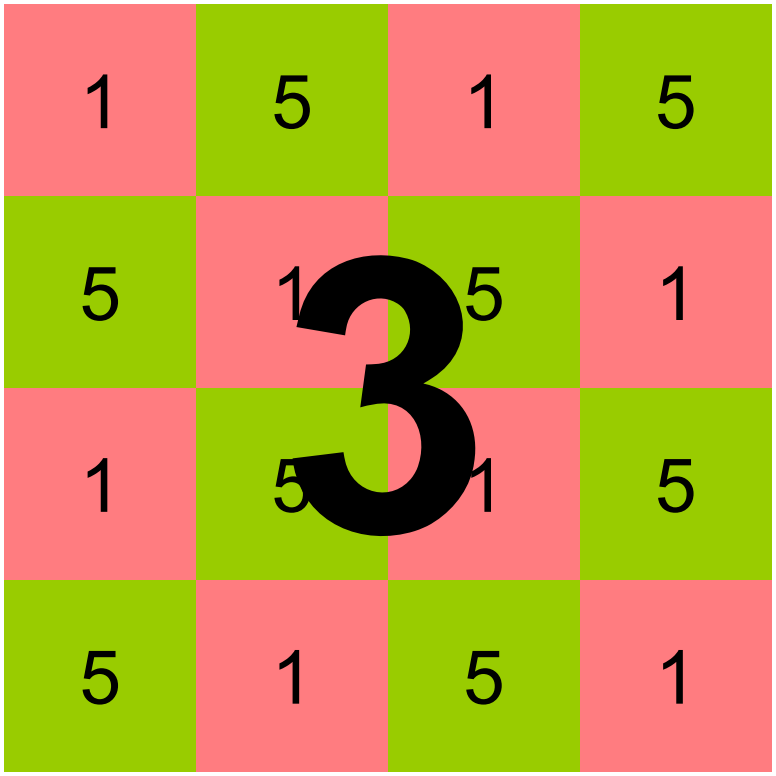
=

2

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

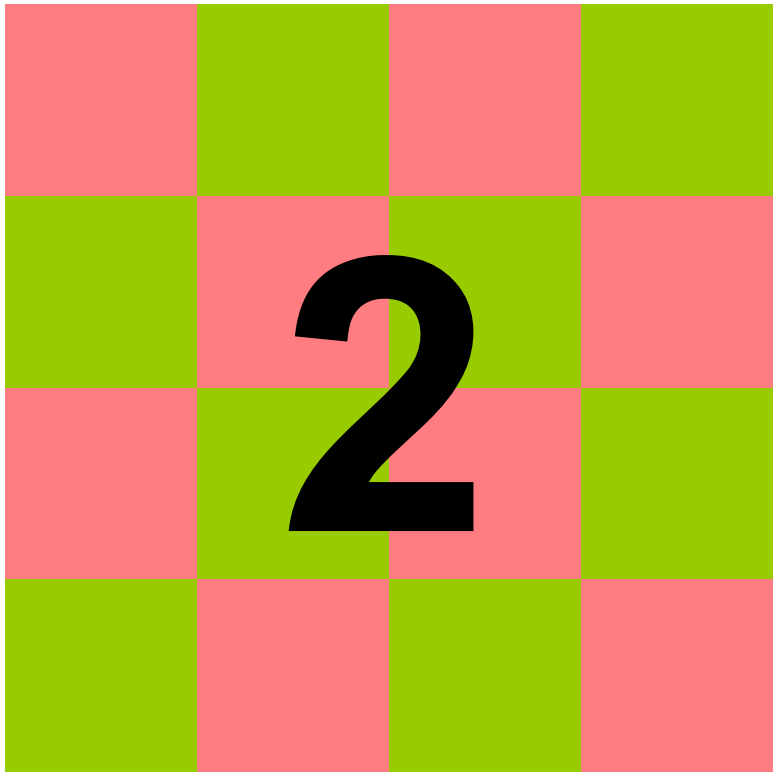
Synthetic Scene Scenario

"Scene" Reflectance-Ratio



$$\left\langle \frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} \right\rangle$$

Ratio of Scene Reflectances



$$\frac{\langle \text{NIR-Reflectance} \rangle}{\langle \text{VIS-Reflectance} \rangle}$$

Pixel Reflectance Values
Aligned Bands Scenario

.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3

Nominal Position VIS Band

.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	..5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	..5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3

Nominal Position NIR Band

Study Basis

bands perfectly aligned

Nominal Position NIR Band

.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	..5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.3	.3	.3	.5	.5	.5	.3	.3	.3	.5	.5	.5
.5	..5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3
.5	.5	.5	.3	.3	.3	.5	.5	.5	.3	.3	.3

Nominal Position VIS Band

.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.3	.3	.3	.1	.1	.1	.3	.3	.3	.1	.1	.1
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3
.1	.1	.1	.3	.3	.3	.1	.1	.1	.3	.3	.3

=

1	1	1	5	5	5	1	1	1	5	5	5
1	1	1	5	5	5	1	1	1	5	5	5
1	1	1	5	5	5	1	1	1	5	5	5
5	5	5	1	1	1	5	5	5	1	1	1
5	5	5	1	1	1	5	5	5	1	1	1
5	5	5	1	1	1	5	5	5	1	1	1
1	1	1	5	5	5	1	1	1	5	5	5
1	1	1	5	5	5	1	1	1	5	5	5
1	1	1	5	5	5	1	1	1	5	5	5
5	5	5	1	1	1	5	5	5	1	1	1
5	5	5	1	1	1	5	5	5	1	1	1
5	5	5	1	1	1	5	5	5	1	1	1

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

Shifted Scenario

"Half-pixel" Shift NIR Band

.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.5	.5	.4	.3	.3	.4	.5	..5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.5	.5	.4	.3	.3	.4	.5	..5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4

"Half-pixel" Shift VIS Band

.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2

=

1	1	2	5	5	2	1	1	2	5	5	2
1	1	2	5	5	2	1	1	2	5	5	2
1	1	2	5	5	2	1	1	2	5	5	2
5	5	2	1	1	2	5	5	2	1	1	2
5	5	2	1	1	2	5	5	2	1	1	2
5	5	2	1	1	2	5	5	2	1	1	2
1	1	2	5	5	2	1	1	2	5	5	2
1	1	2	5	5	2	1	1	2	5	5	2
1	1	2	5	5	2	1	1	2	5	5	2
5	5	2	1	1	2	5	5	2	1	1	2
5	5	2	1	1	2	5	5	2	1	1	2
5	5	2	1	1	2	5	5	2	1	1	2

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

Shifted Scenario

misalignment "corrected"

"Half-pixel" Resampled NIR Band

.35	.3	.35	.45	.5	.45	.35	.3	.35	.45	.5	.45
.35	.3	.35	.45	.5	.45	.35	.3	.35	.45	.5	.45
.35	.3	.35	.45	.5	.45	.35	.3	.35	.45	.5	.45
.45	.5	.45	.35	.3	.35	.45	.5	.45	.35	.3	.35
.45	.5	.45	.35	.3	.35	.45	.5	.45	.35	.3	.35
.45	.5	.45	.35	.3	.35	.45	.5	.45	.35	.3	.35
.35	.3	.35	.45	.5	.45	.35	.3	.35	.45	.5	.45
.35	.3	.35	.45	.5	.45	.35	.3	.35	.45	.5	.45
.35	.3	.35	.45	.5	.45	.35	.3	.35	.45	.5	.45
.45	.5	.45	.35	.3	.35	.45	.5	.45	.35	.3	.35
.45	.5	.45	.35	.3	.35	.45	.5	.45	.35	.3	.35
.45	.5	.45	.35	.3	.35	.45	.5	.45	.35	.3	.35

"Half-pixel" Resampled VIS Band

.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25
.15	.1	.15	.3	.3	.25	.15	.1	.15	.25	.3	.25
.15	.1	.15	.3	.3	.25	.15	.1	.15	.25	.3	.25
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.25	.3	.25	.15	.1	.15	.25	.3	.25	.15	.1	.15
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25
.15	.1	.15	.25	.3	.25	.15	.1	.15	.25	.3	.25

=

1.4	1	1.4	3	5	3	1.4	1	1.4	3	5	3
1.4	1	1.4	3	5	3	1.4	1	1.4	3	5	3
1.4	1	1.4	3	5	3	1.4	1	1.4	3	5	3
3	5	3	1.4	1	1.4	3	5	3	1.4	1	1.4
3	5	3	1.4	1	1.4	3	5	3	1.4	1	1.4
3	5	3	1.4	1	1.4	3	5	3	1.4	1	1.4
1.4	1	1.4	3	5	3	1.4	1	1.4	3	5	3
1.4	1	1.4	3	5	3	1.4	1	1.4	3	5	3
1.4	1	1.4	3	5	3	1.4	1	1.4	3	5	3
3	5	3	1.4	1	1.4	3	5	3	1.4	1	1.4
3	5	3	1.4	1	1.4	3	5	3	1.4	1	1.4
3	5	3	1.4	1	1.4	3	5	3	1.4	1	1.4

$$\frac{\text{NIR-Reflectance}}{\text{VIS-Reflectance}} = \text{VI}$$

Shifted Scenario

"Half-pixel" Shift NIR Band

.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.5	.5	.4	.3	.3	.4	.5	..5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.3	.3	.4	.5	.5	.4	.3	.3	.4	.5	.5	.4
.5	.5	.4	.3	.3	.4	.5	..5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4
.5	.5	.4	.3	.3	.4	.5	.5	.4	.3	.3	.4

"Half-pixel" Shift VIS Band

.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.3	.3	.2	.1	.1	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.3	.3	.2	.1	.1	.2	.1	.1	.2	.1	.1	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2
.1	.1	.2	.3	.3	.2	.1	.1	.2	.3	.3	.2

=

1	1	2	5	5	3	1	1	2	5	5	2
1	1	2	5	5	2	1	1	2	5	5	2
1	1	2	5	5	2	1	1	2	5	5	2
5	5	2	1	1	2	5	5	2	1	1	2
5	5	2	1	1	2	5	5	2	1	1	2
5	5	2	1	1	2	5	5	2	1	1	2
1	1	2	5	5	2	1	1	2	5	5	2
1	1	2	5	5	2	1	1	2	5	5	2
1	1	2	5	5	2	1	1	2	5	5	2
5	5	2	1	1	2	5	5	2	1	1	2
5	5	2	1	1	2	5	5	2	1	1	2
5	5	2	1	1	2	5	5	2	1	1	2

Mixture Model $\left\langle \frac{R_{NIR}}{R_{VIS}} \right\rangle = VI$

Results of half pixel misalignment and *"correction"* through resampling/unmixing

Pixel Shift Scenario	Category 1 Ratio Value	Category 1 Discrepancy	Category 2 Ratio Value	Category 2 Discrepancy
VIS and NIR ½ pixel shift	*1.33*	*+33%*	*4.00*	*-20%*
VIS and NIR resampled	1.27	+27%	3.67	-26%
VIS and NIR unmixed	1.00	0%	5.00	0%

Pixel-shift/Band-misalignment Study Results

Averaged Scene Ratios	Ratio Value	Discrepancy
VIS and NIR co-aligned	3.00	0%
VIS and NIR both shifted	2.67	-11%
Shifted pixels re-sampled	2.47	-18%
Shifted pixels unmixed	3.00	0%

Pixel-shift/Band-misalignment Study Results

Averaged Scene Ratios	Ratio Value	Discrepancy
VIS and NIR co-aligned	3.00	0%
VIS and NIR both shifted	2.67	-11%
Shifted pixels re-sampled	2.47	-18%
Shifted pixels unmixed	3.00	0%

Inherent spectral/spatial integrity, required for HyspIRI, allows for substantially more accurate parameter determination than is possible with *currently planned* sequentially sampled pushbroom multispectral systems.

Unlike these multispectral systems, the rich spectral content offered by HyspIRI has the potential to mitigate the impact of temporal sampling offsets as well as to address mixed pixels.

Band-to-Band Registration
The Bottom Line

$$\left\langle \frac{R_{NIR}}{R_{VIS}} \right\rangle \neq \frac{\langle R_{NIR} \rangle}{\langle R_{VIS} \rangle}$$

Old "New" Paradigm

- Remotely sensed multispectral data is **ideally** obtained by sampling at contiguous ground locations to characterize a specifiable earth surface area. ***Pixel-Size ≈ GSD***
- Radiometric precision is limited by SNR and the number of bits used in returning data should adequately represent the full precision, but can not improve it.
- Therefore, both radiometric value and distribution of remotely sensed data is inherently ***discrete*** and represent contiguous samples of radiance and spatial domains.
- To fully exploit the spectro-radiometric properties of the Earth's surface, it is necessary to treat (and think of) *hyperspectral data* as sampling the spectra at specified contiguous intervals as opposed to an extremely large number of narrow-width bands.
- **Nyquest sampling is not generally applicable.**