597K: Earth Remote Sensing

SATELLITE TIMELINE FOR MONITORING OF LAND USE AND COVER

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Outline

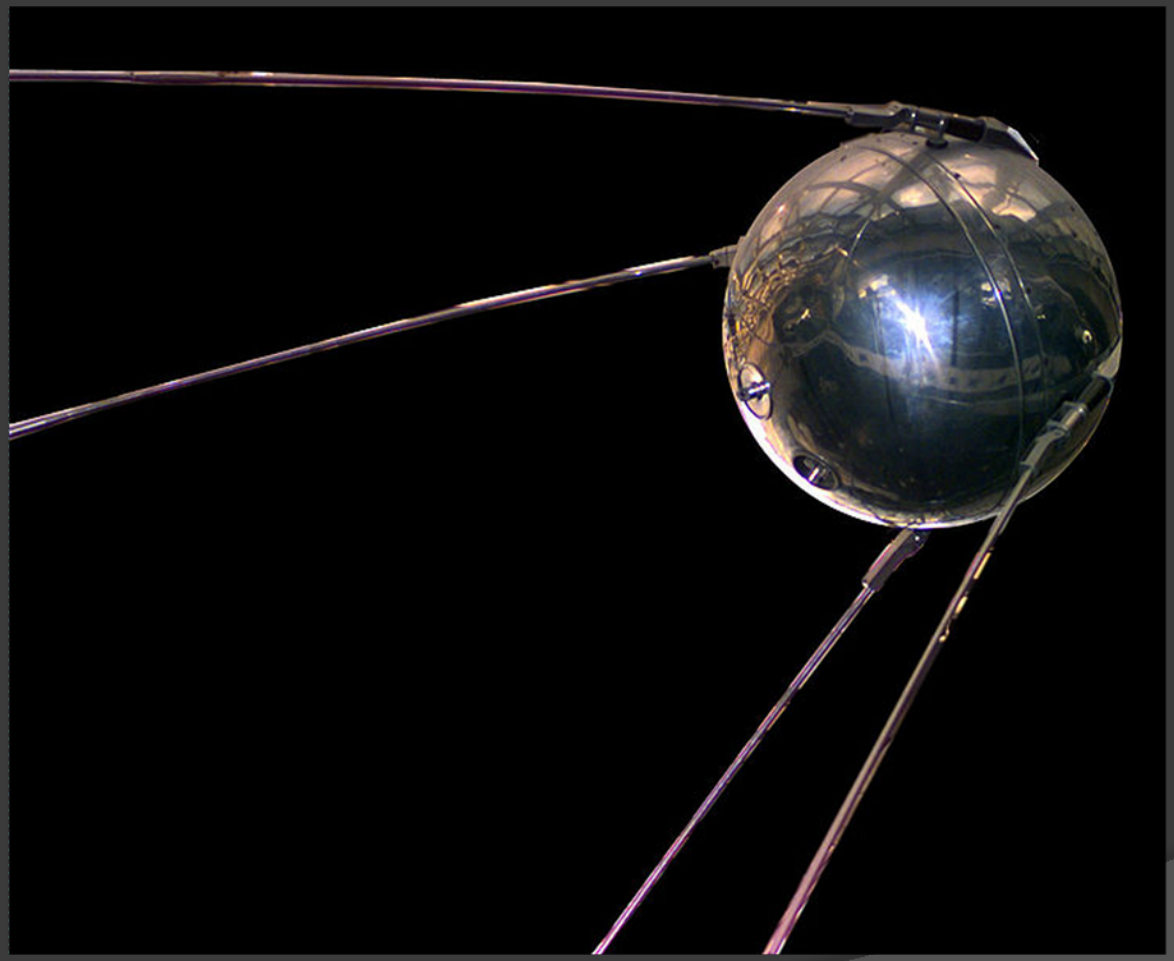
- General satellite history pre-Landsat era
- Commercial land monitoring satellites
- Multispectral land monitoring satellites
- Synthetic Aperture Radar (SAR) land monitoring satellites
- Hyperspectral land monitoring satellites

Early
Remote Sensing Systems
(Pre-Landsat)

Sputnik-1

- Launched October 4, 1957
- First Earth orbiting artificial sattelite
- Ignited the space race
- Mission duration was 3 months
  - Transmitted signals for 22 days after launch

Sputnik-1



Sputnik-1

- Orbital Period of 101.5 minutes
- Identified the upper atmospheric layer's density, through measuring the satellite's orbital changes.
- Provided data on radio-signal distribution in the ionosphere
- Pressurized nitrogen, in the satellite's body, provided the first opportunity for meteoroid detection.
- Emitted radio signals at 20.005 and 40.002 MHz

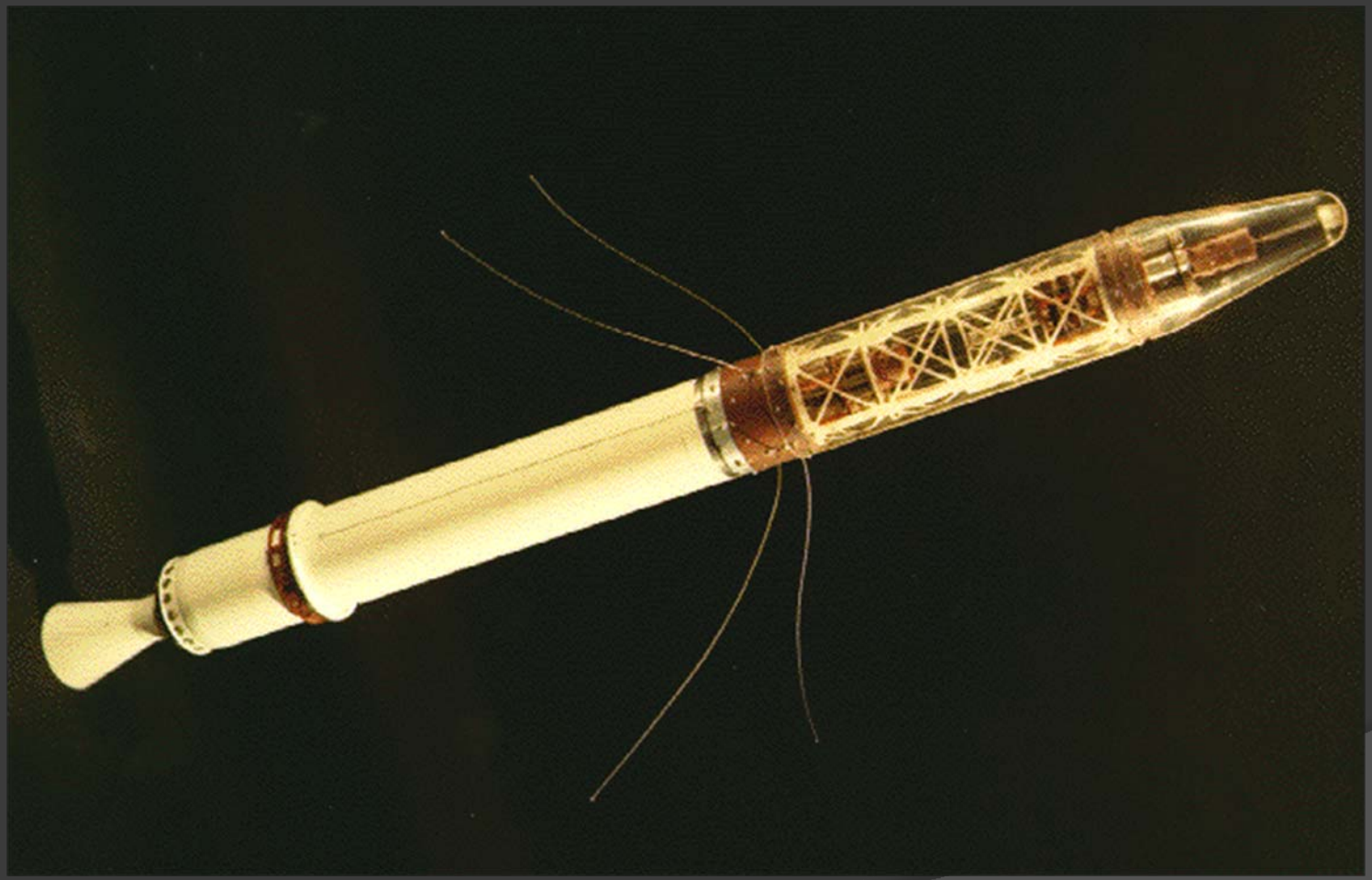
Sputnik 2

- Second artificial satellite in Earth orbit
- Launched November 3, 1957
- First to carry a living animal, a dog named Laika

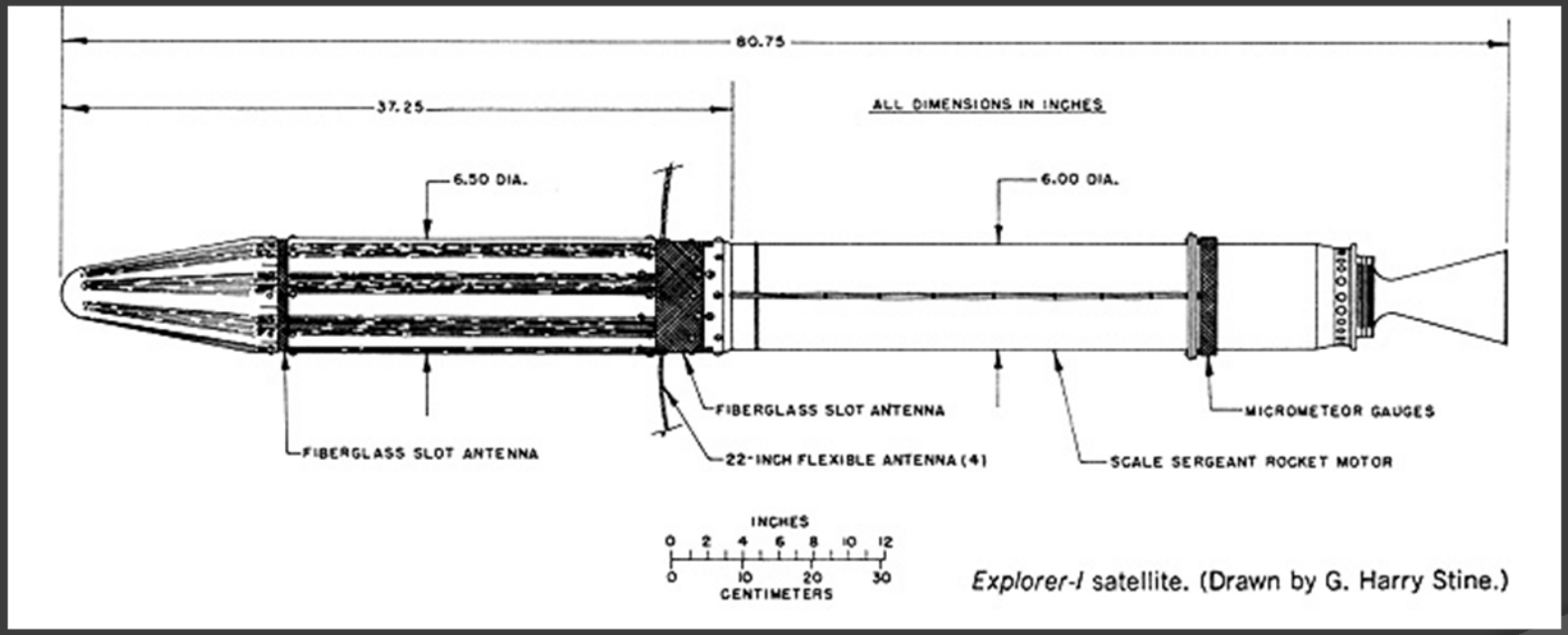
Explorer-1

- First Earth Satellite of the United States
- Launched on Feb 1, 1958
- Mission duration was 111 days
- First Spacecraft to detect the Van Allen Belts
- Orbital Period of 114.8 minutes

Explorer-1



Explorer-1



Explorer-I satellite. (Drawn by G. Harry Stine.)

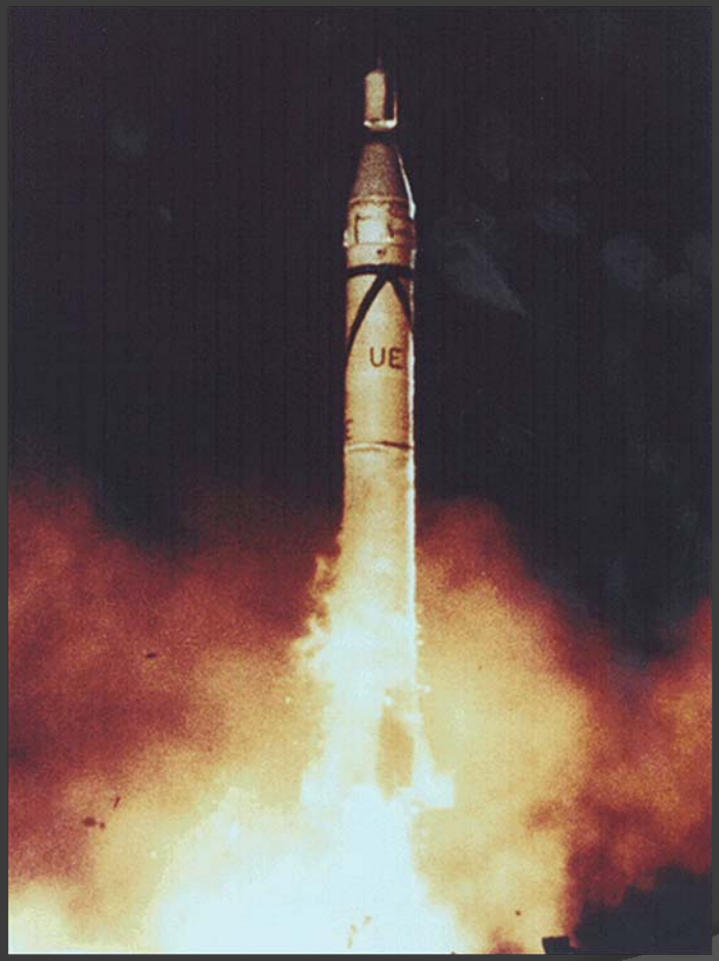
Explorer-1

- Wire grid detector used to detect micrometeorite impacts.
  - 12 parallel connected cards mounted in a fiberglass ring.
  - Could detect micrometeorites of at least 10μm
- Five temperature sensors
- Acoustic detector was also used to detect cosmic dust (micrometeorite) impacts.
  - Sensor Area was .075m^2 with a threshold sensitivity of 2.5 * 10^-3 g-cm/s
- Carried the Iowa Cosmic Ray Instrument
  - Consisted of A Geiger-Miller tube to detect Cosmic Rays
  - Could detect Protons with E > 30 MeV and electrons with E > 3 MeV – It was saturated most of the time
- Data was Transmitted by two antennas
  - 60 watt dipole antenna at 108.03 mhz
  - Four flexable whips forming a 10 milliwatt turnstile antenna at 108 mhz.

Explorer 3

- Oldest satellite still in orbit
- Orbital Period of 115.7 Minutes
- Same Mission as Explorer 1
- Launched March 26, 1958
- Orbit decayed after 93 days

Explorer-3



Sputnik 3

- Launched May 15, 1958
- Remained in Orbit until April 6, 1960
- Contained a radio-frequency quadrupole mass spectrometer.
  - Found that the upper atmosphere contained mostly atomic oxygen ions
- Measured the Atmospheric pressure
  - At a height of 266 km, the pressure was only 1/10,000 atm.
- Metal plates to detect meteorite impacts
  - Averaged 1 impact every 100 seconds
- First satellite with solar panels
- Also had cosmic ray detectors

Sputnik 3

Project Vanguard

- Vanguard-1 was launched March 17, 1958
  - First satellite to run on solar power
  - Oldest artificial satellite still orbiting the Earth
  - 134.2 minute orbit
  - Had a radio phase-comparison angle-tracking system
    - Showed that the earth was NOT spherical
  - Vanguard 2 and 3
    - Focused on atmospheric density, cloud cover, and x-rays

Project Vanguard

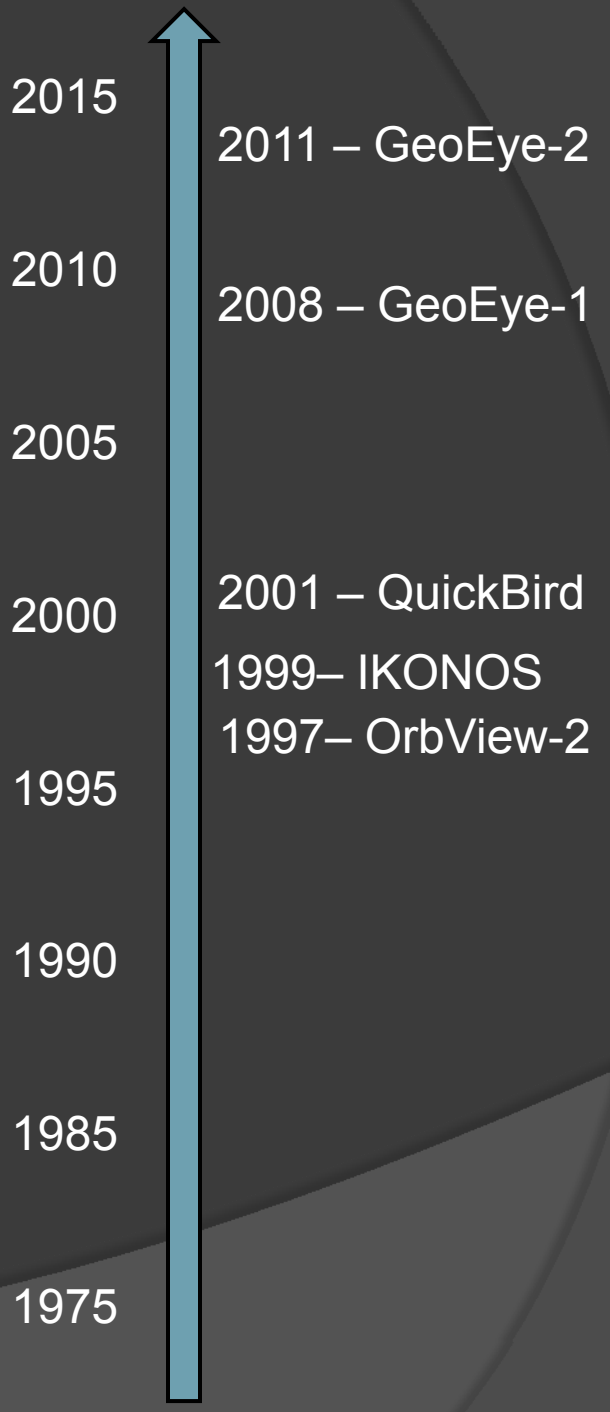
Project Nimbus

- 7 Nimbus Satellites in Total
- Launched from 1964 to 1978
- Focused on
  - Earth's Radiation Budget
  - Sea Ice
  - Ozone Layer
- The Nimbus project was also a precursor to GPS by having instruments able to locate weather stations on Earth

Project Nimbus

Commercial Imaging Systems

Timeline of Major Commercial Missions



Satellite: GeoEye 1

Spatial Res	Spectral Bands /Modes	Spectral Range /No Beams
1.65 m	1	450-520 nm
	2	520-600 nm
	3	625-695 nm
	4	760-900 nm
.41 m	Pan	450-900 nm

Satellite: IKONOS

Spatial Res	Spectral Bands /Modes	Spectral Range /No Beams
3.2 m	1	445-516 nm
	2	506-595 nm
	3	632-698 nm
	4	757-853 nm
.82 m	Pan	450-900 nm

Satellite: QuickBird

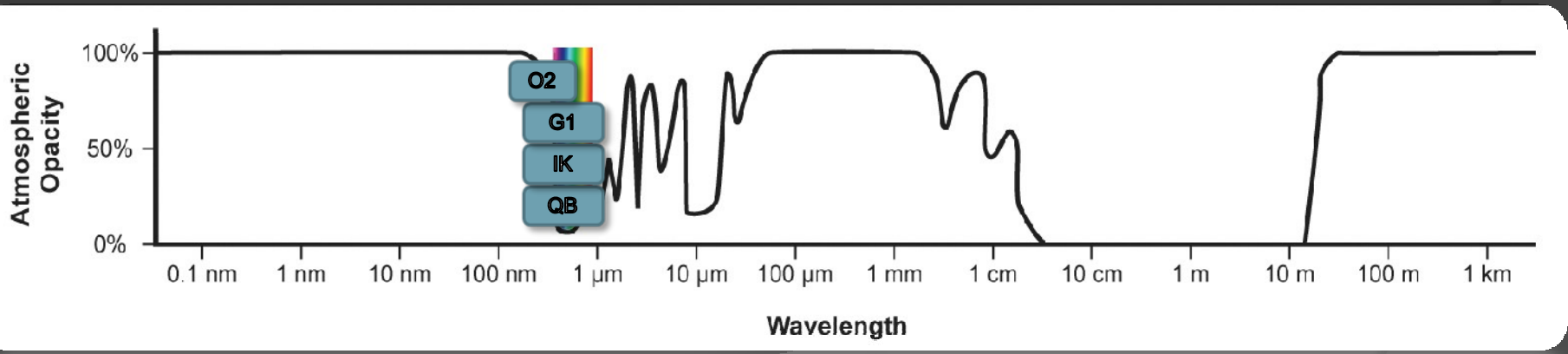
Spatial Res	Spectral Bands /Modes	Spectral Range /No Beams
2.4 m	1	450-520 nm
	2	520-600 nm
	3	630-690 nm
	4	760-900 nm
60 cm	Pan	445-900 nm

Satellite: OrbView-2

Spatial Resolution	Spectral Bands	Wavelength
2.4 m	1	402-422 nm
	2	433-453 nm
	3	480-500 nm
	4	500-520 nm
	5	545-565 nm
	6	660-680 nm
	7	745-785 nm
	8	845-885 nm

G1 GeoEye-1 IK IKONOS

O2 OrbView-2 QB QuickBird



QuickBird

Sensors

* 60 cm (24 in) (1.37 µrad) panchromatic at nadir
* 2.4 m (7.9 ft) (5.47 µrad) multispectral at nadir
    - MS Channels: blue (450-520nm), green (520-600nm), red (630-690nm), near-IR (760-900nm)

Swath width and area size

* Nominal swath width: 16.5 km at nadir
* Accessible ground swath: 544 km centered on the satellite ground track (to 30° off nadir)
* Area of interest
    - Single area: 16.5 km by 16.5 km
    - Strip: 16.5 km by 165 km

Orbit

* Altitude: 450 km – 98 degree sun synchronous inclination
* Revisit frequency: 1 to 3.5 days depending on latitude at 60 cm resolution
* Viewing angle: Agile spacecraft, in-track and cross-track pointing
* Period 93.4 minutes

Onboard storage

* 128 Gibibit (137 Gigabit) capacity (approximately 57 single area images)

Spacecraft

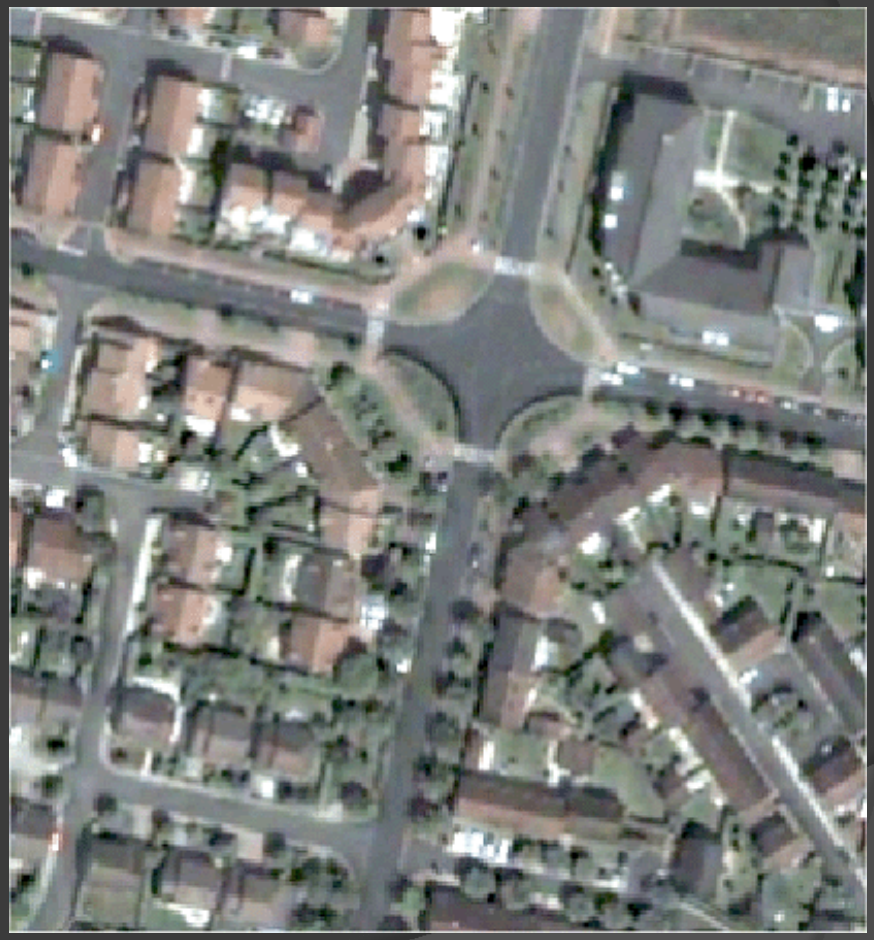
* Fueled for 7 years
* Launch Date: October 18, 2001

QuickBird

QuickBird

Offers Sub-meter pixel imaging

Extremely high spatial resolution imaging



IKONOS

Spatial resolution

* 0.8 m panchromatic (1-m PAN)
* 4-meter multispectral (4-m MS)
* 1-meter pan-sharpened (1-m PS)

Spectral Resolution

Band	1-m PAN	4-m MS & 1-m PS
1 (Blue)	0.45-0.90 µm	0.445-0.516 µm
2 (Green)	*	0.506-0.595 µm
3 (Red)	*	0.632-0.698 µm
4 (Near IR)	*	0.757-0.853 µm

Temporal resolution

The revisit rate for IKONOS is 3 to 5 days off-nadir and 144 days for true-nadir.

Radiometric resolution

The sensor collects data with a 11-bit (0-2047) sensitivity and are delivered in an unsigned 16-bit (0-65565) data format. From time-to-time the data are rescaled down to 8-bit (0 - 255) to decrease file size. When this occurs much of the sensitivity of the data needed by Remote Sensing scientists is lost.

Swath

11 km x 11 km (Single Scene)

Launched Sept 24, 1999

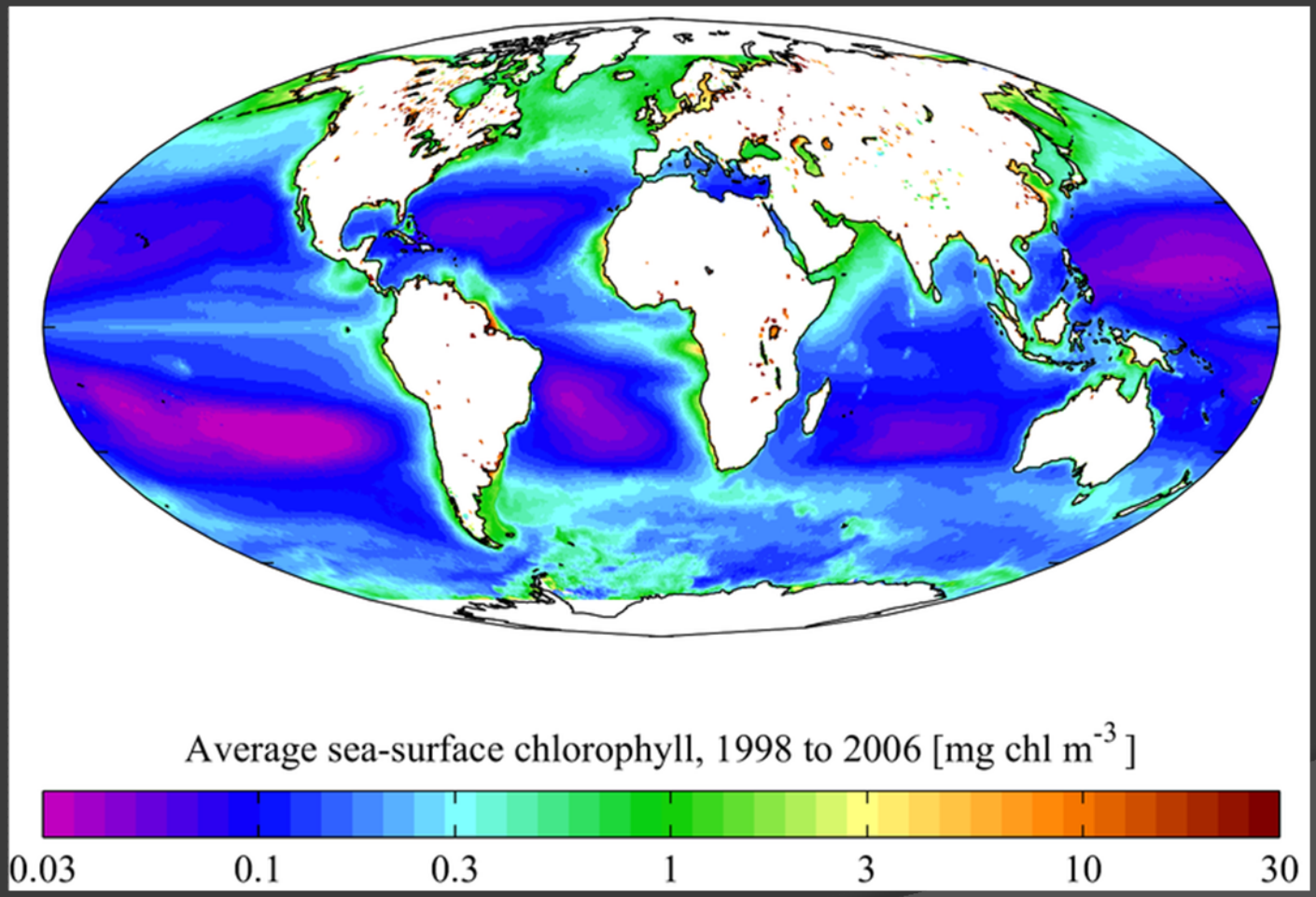
IKONOS

Orbview-2

- Also called SeaStar
- Launched in 1997
- collects color imagery of the Earth's entire land and ocean surfaces on a daily basis
- 2,800 kilometer-wide swaths, which are routinely used in naval operations, environmental monitoring, and global crop assessment applications.
- Carries NASA's SeaWIFS sensor
- The sensor resolution is 1.1 km (LAC), 4.5 km (GAC). The sensor records information in the following optical bands:
- Band Wavelength
- 1 402-422 nm
- 2 433-453 nm
- 3 480-500 nm
- 4 500-520 nm
- 5 545-565 nm
- 6 660-680 nm
- 7 745-785 nm
- 8 845-885 nm

- The instrument has been specifically designed to monitor ocean characteristics such as chlorophyll-a concentration and water clarity.

OrbView-2

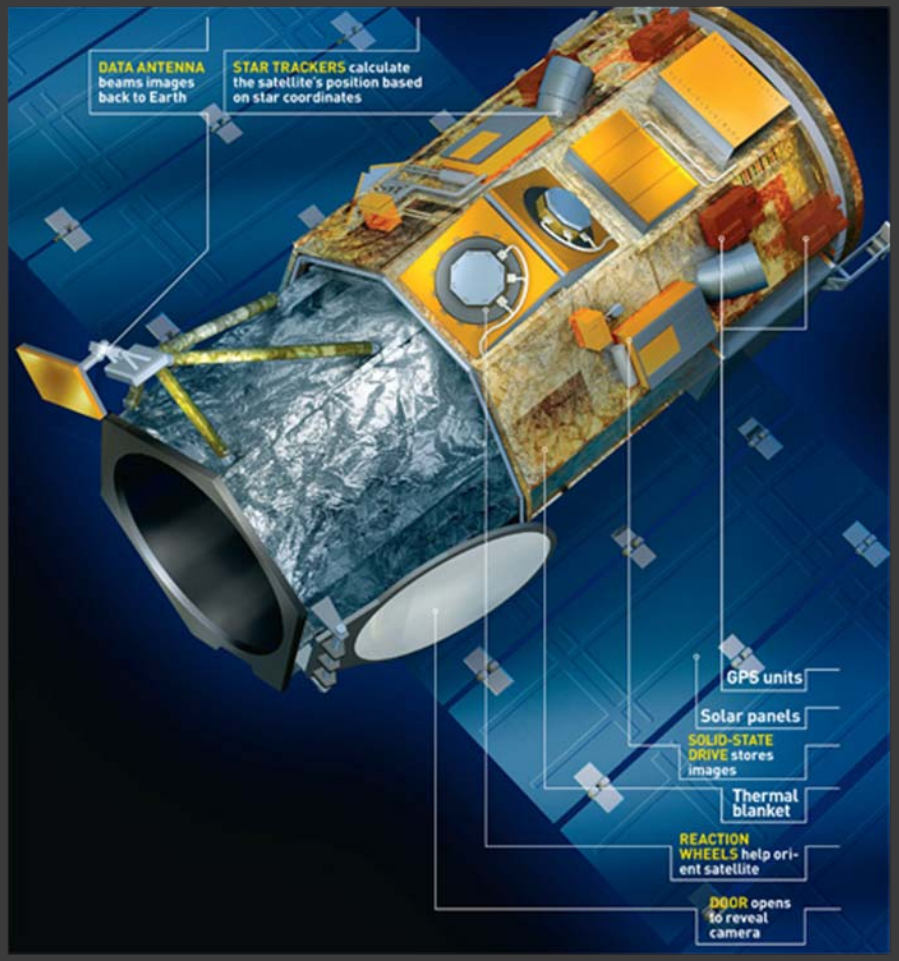

Average sea-surface chlorophyll, 1998 to 2006 [mg chl m-3]
0.03
0.1
0.3
1
3
10
30

OrbView-2

GeoEye-1

- Launched Sept 6, 2008
- GeoEye-1 provides 41 centimetres (16 in) panchromatic
- 1.65 meter multispectral imagery
- 15.2km swaths
- The spacecraft is intended for a sun-synchronous orbit
- Altitude of 425 miles (684 km)
- Inclination of 98 degrees
  - 10:30 a.m. equator crossing time
- GeoEye-1 can image up to 60 degrees off nadir
- Significant financial contributions from Google and the National Geospatial Intelligence Agency

GeoEye-1


DATA ANTENNA beams images back to Earth
STAR TRACKERS calculate the satellite's position based on star coordinates
GPS units
Solar panels
SOLID-STATE DRIVE stores images
Thermal blanket
REACTION WHEELS help orient satellite
DOOR opens to reveal camera


Google

GeoEye-1

GeoEye-2

- Due to launch in 2011-2012
- Satellite will have a resolution of 25cm, making it the highest resolution commercial Earth observation satellite in orbit
- Only 50cm resolution will be available to other users

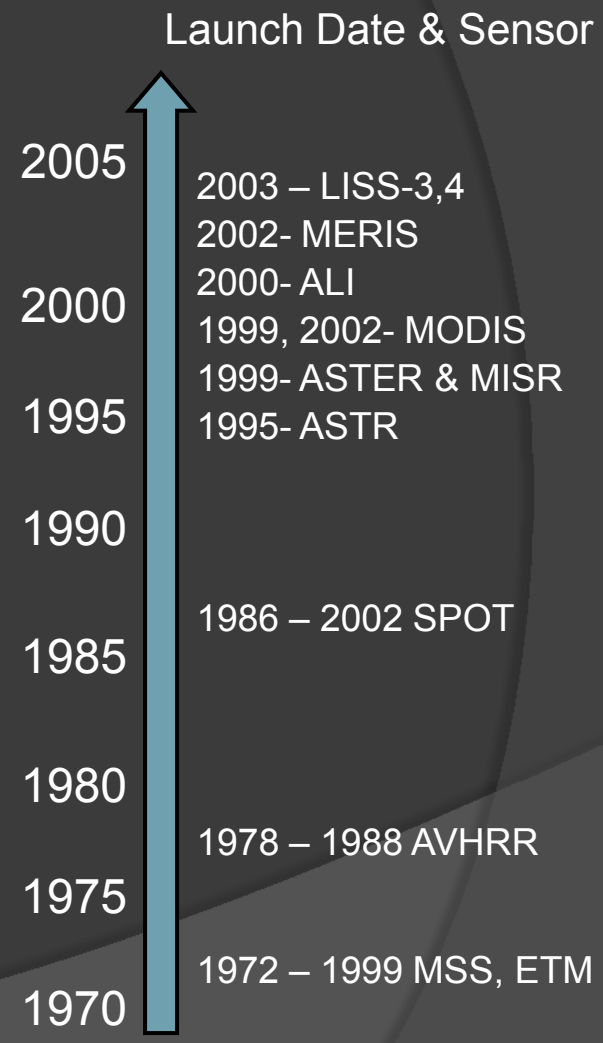
Multispectral Imaging Systems

Applications of Multispectral Satellite Imaging for LULC

- Fire detection & mapping
- Land cover type and extent
- Surface Temperature
- Leaf area index
- Snow cover and ice extent
- NDVI (normalized vegetation index)
- Crop Growth Stage
- Landcover usage (NLCD)
- Soil Brightness Index (SBI)
- Green Vegetation Index (GVI)
- Deforestation monitoring

Multispectral Sensor Timeline

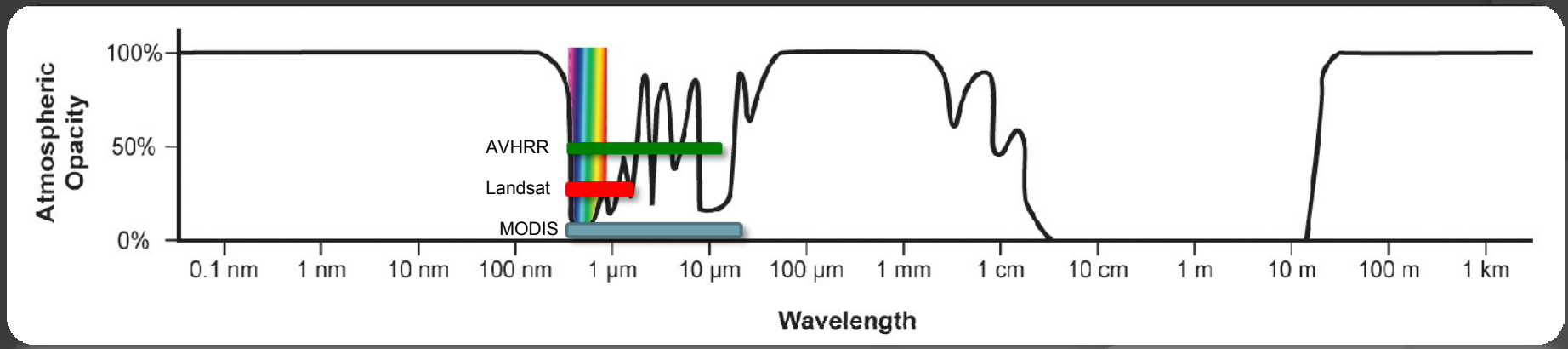
SENSOR	PLATFORM	Spatial Res.	Country
MSS, ETM	Landsat 1-7	30 m	USA
AVHRR	NOAA POS	1 – 25 km	USA
SPOT		2.5 – 20 m	France
ATSR	ERS-2		ESA
MODIS	Terra, Aqua	2 bands: 250 m, 5 bands: 500 m and 29 bands: 1 km	USA
ASTER	Terra	15- 90 m	USA
MISR	Terra	275 m	USA
ALI	EO-1	10-20 m	USA
LISS-3,4	ResourceSat		India
MERIS	Envisat	300 m and 600 m	ESA



Example Bands from Multispectral Platforms

Key (in μm)

- MODIS 36 bands: 0.4 –14.4
- Landsat Band 1: 0.5 - 0.6
  Band 2: 0.6 - 0.7
  Band 3: 0.7 - 0.8
  Band 4: 0.8 - 1.1
- AVHRR Band 1: 0.58 - 0.68
  Band 2: 0.7 – 1
  Band 3: 3.55-3.93
  Band 4: 10.2 – 11.3
  Band 5: 11.5 – 12.5



Picture Source:
http://en.wikipedia.org/wiki/File:Atmospheric_electromagnetic_transmittance_or_opacity.jpg

Landsat Platform

- Satellites launched from 1972-1999
- Out of the 7 satellites, only 5 and 7 are still functioning
- Multispectral (MSS) on Landsat 1-5
- Thematic mapper (TM) on 4 & 5
- Enhanced Thematic mapper (ETM) on 7
- Landsat 5: TM, MSS, 16 day revisit, provides archive of satellite images
- Landsat 7: ETM+, 16 day revisit, 15m reolution, 60 m thermal resolution, cloud-free imagery and current images

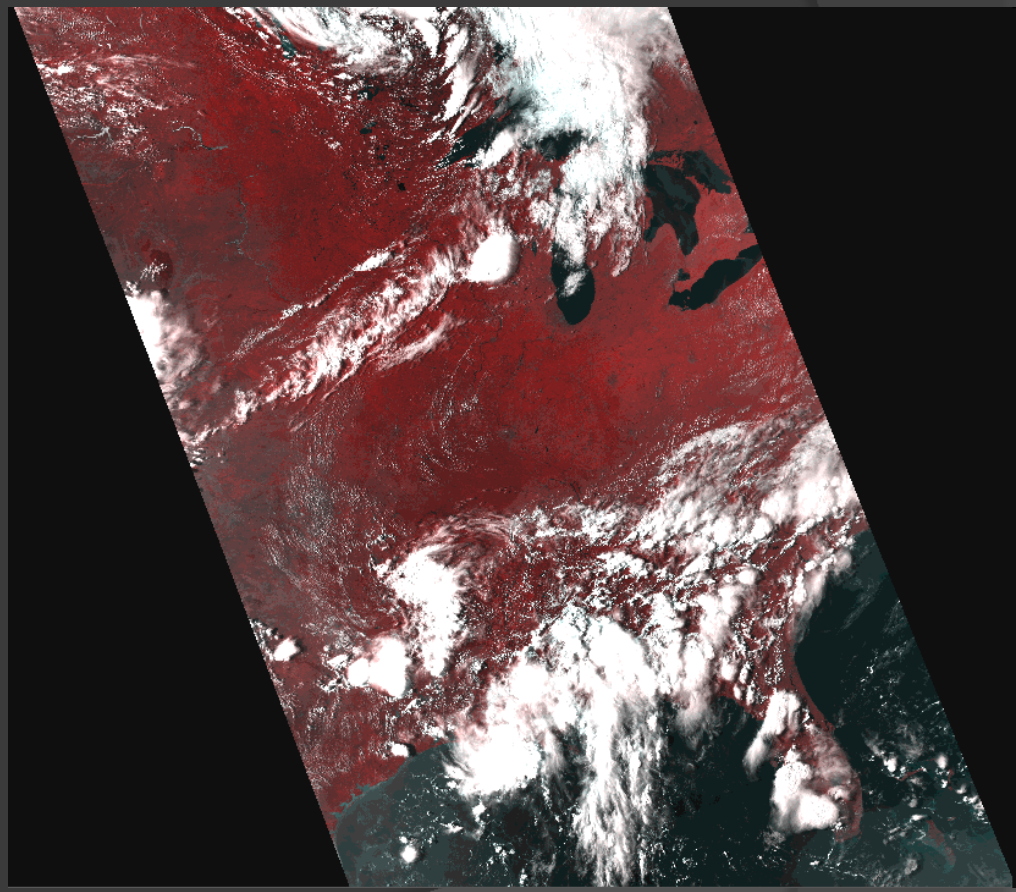
MODIS

Spatial Resolution: 250 m (bands 1-2), 500 m (bands 3-7)
Launched: May 4, 2002
Swaths: 60 – 80 km, 26-day repeat cycle for nadir viewing
On board NASA's Terra Satellite

Snow and Fog in the Pacific Northwest, 1/28/09

Advanced Very High Resolution Radiometer (AVHRR)

- Provides 4-6 band multispectral data from NOAA polar-orbit satellites
- Continuous coverage from 1979 to current; one of the most comprehensive & long-term collections of data over the high arctic
- Resolution: 1.1 km at nadir



ASTER

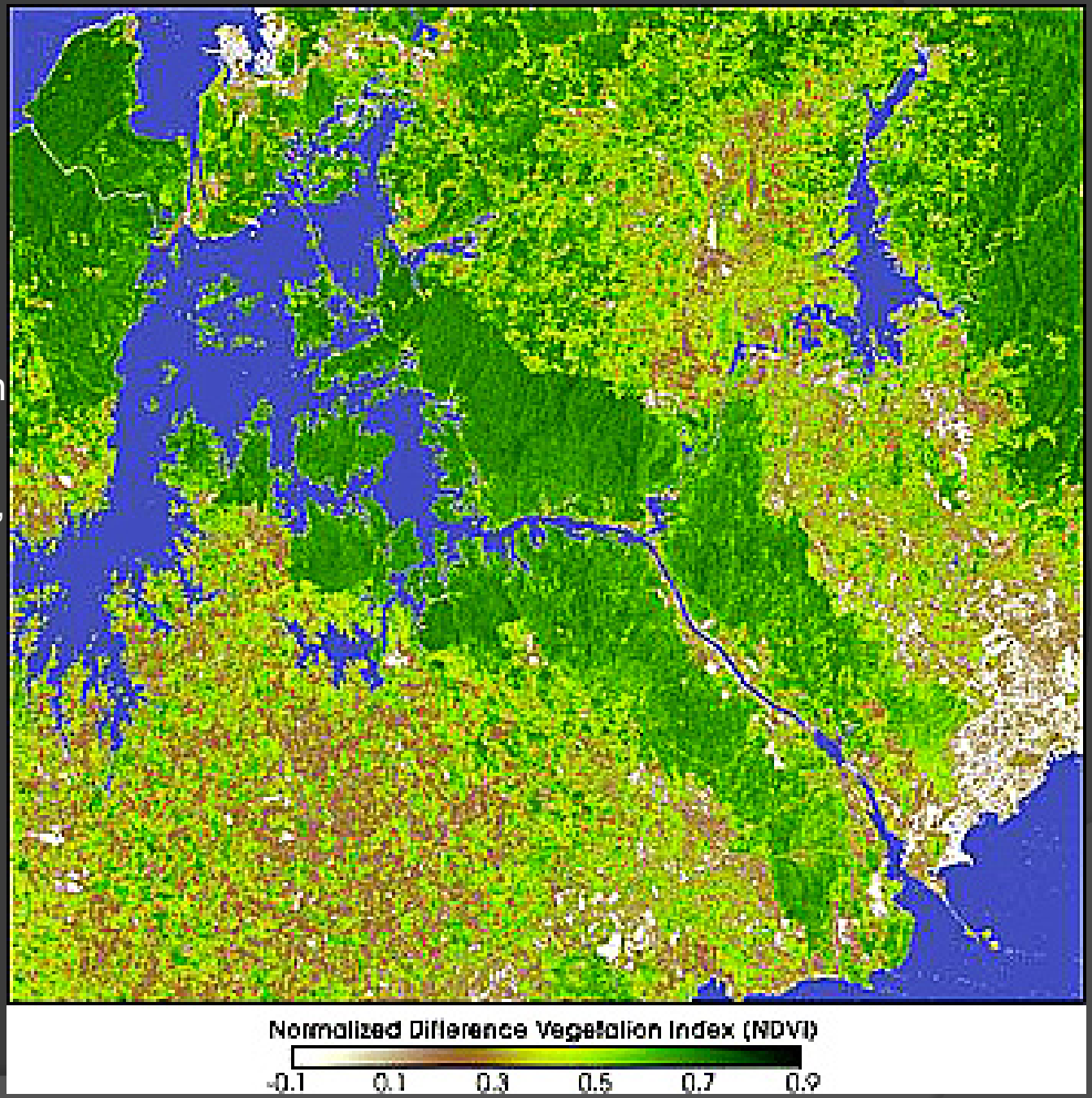
- Highest spatial resolution surface spectral reflectance, temp, and emissivity data
- Has multispectral thermal IR data in the 8 – 12 micron region, globally
- Launched: Dec 18, 1999
- On board the Terra satellite, which as a polar orbit, crossing the equator each morning at 10:30
- Swath width: 60 km

Multispectral Satellite Application…NDVI

- NDVI used extensively to detect and monitor vegetation conditions
- Often compare AVHRR and MODIS NDVI data
- What is it? Normalized Difference Vegetation Index, using two satellite channels:
- Ex: Use two different bands in AVHRR (Vis and NIR) and NDVI = (NIR – VIS)/(NIR +VIS)
- Range is between -1 and 1; healthier vegetation is near 1 and unhealthy near -1 or 0

NDVI

NDVI of the Panama Canal, most have high NDVI values because of the tropical “jungle’ vegetation characteristics



Synthetic Aperture RADAR Imaging Systems

Synthetic Aperture RADAR

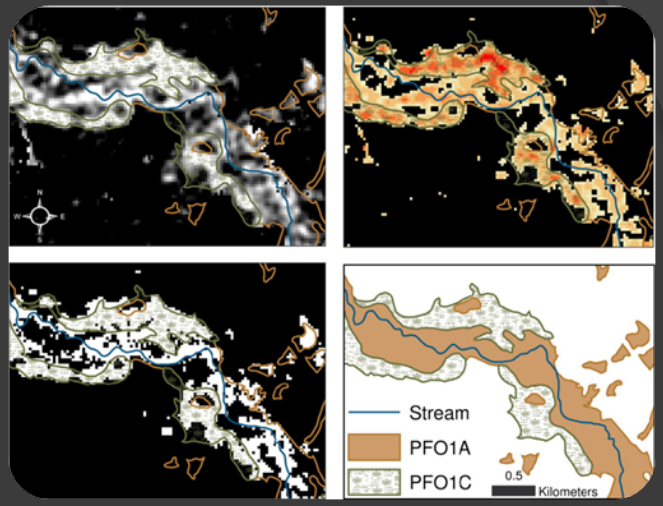
- Active remote sensing
- Operates in microwave portion of EM
- Can penetrate atmosphere in almost all conditions
- Can detect geometric structure, surface roughness, and moisture content

SAR
General Land Applications

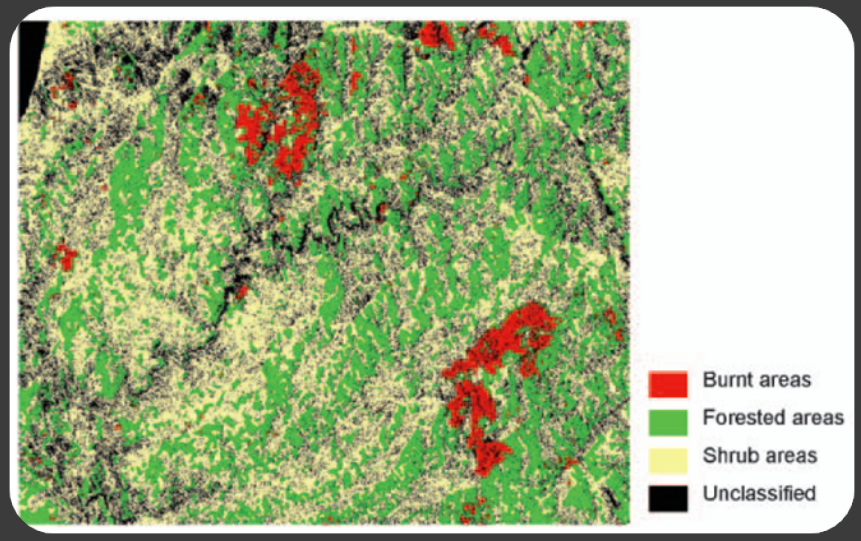
- Soil moisture and surface roughness
- Flood monitoring
- Delineation of burned areas and clear cuts
- Watershed modeling
- Map land cover in areas often not suitable for optical (e.g.—rainforests)
- Deformation detection and DEM generation (using InSAR)

Examples of SAR applications…

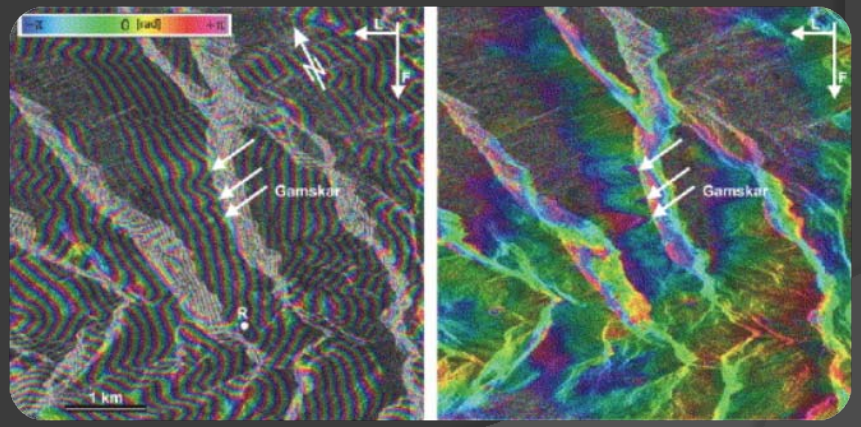
SAR/Optical urban mapping (Corbane et al. 2008)



Wetland Mapping (Lang et al. 2008)



Wildfire Perimeter Delineation (Gimeno et al. 2004)

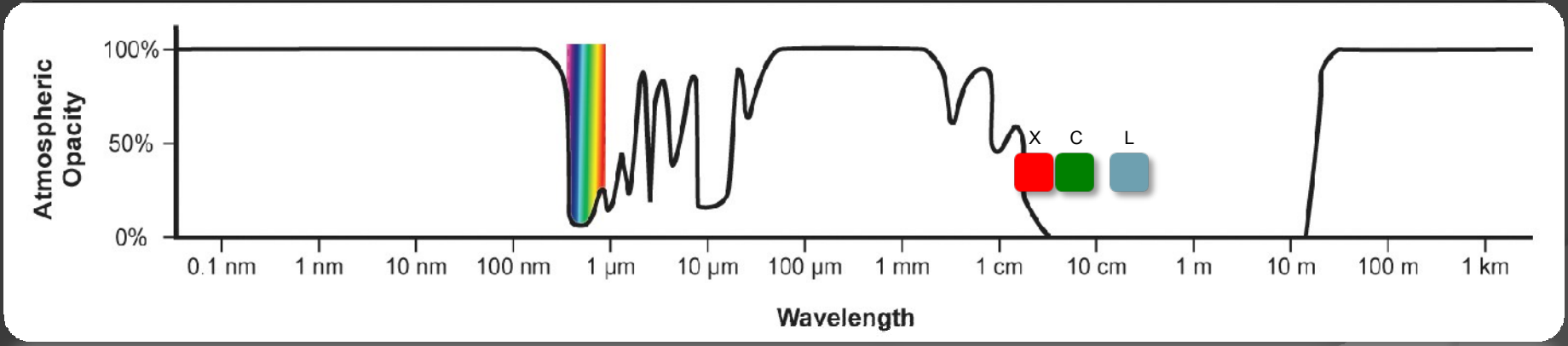


Landside deformation detection with InSAR (Rott and Nagler 2006)

Main Bands In Use for SAR

Key

- X Band (2.5cm – 3.75cm)
- C Band (3.75cm – 7.5cm)
- L Band (15cm – 30cm)

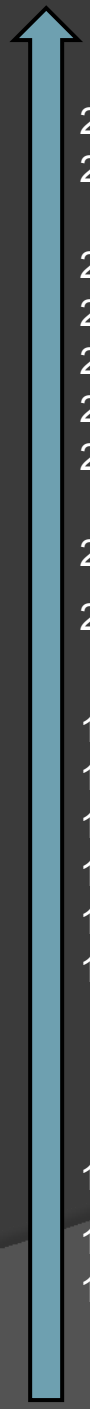


Picture Source:
http://en.wikipedia.org/wiki/File:Atmospheric_electromagnetic_transmittance_or_opacity.jpg

Timeline of SAR Missions

If mission has ended, end date in parentheses

Sensor	Satellite	Band	Spatial	Temporal	Country/Agency
SAR	SEASAT	L	25m	3-17 days	USA
SIR-A	Space Shuttle	L	40m	NA	USA
SIR-B	Space Shuttle	L	25m	NA	USA
SAR	ALMAZ-1	S	10m - 30m	1 - 3 days	USSR
AMI	ERS-1	C	30m	3, 35, 168 days	ESA
SAR	JERS-1	L	18m	44 days	Japan
SIR-C	Space Shuttle	C,L,X	10m - 200m	NA	USA
AMI	ERS-2	C	30m	35 days	ESA
SAR	RADARSAT-1	C	8m - 100m	1-3, 24 days	Canada
SRTM	Space Shuttle	C, X	30m	NA	USA
ASAR	Envisat	C	30m - 1000m	35 days	ESA
PALSAR	ALOS	L	10m - 100m	46 days	Japan
SAR	RADARSAT-2	C	3m - 100m	1-3, 24 days	Canada
SAR	TerraSAR-X	X	1m - 16m	1-3, 11 days	Germany
SAR	COSMOSkyMed	X	1m - 100m	16 days	Italy
SAR	TanDEM-X	X	1m - 16m	1-3, 11 days	Germany
InSAR	DESDynl	L	< 35m		USA
SAR	SMAP	L	1km - 3km	2 - 3 days	USA



2010/13 – DESDynl
2010/13 – SMAP

2009 – TanDEM-X
2007 – COSMO-SkyMed
2007 – TerraSAR-X
2007 – RADARSAT-2
2006 – ALOS

2002 – Envisat

2000 – SRTM (2000)

1995 – RADARSAT-1
1995 – ERS-2
1994 - SIRC (1994)
1992 – JERS-1 (1998)
1991 – ERS-1 (2000)
1991 – ALMAZ-1 (1992)

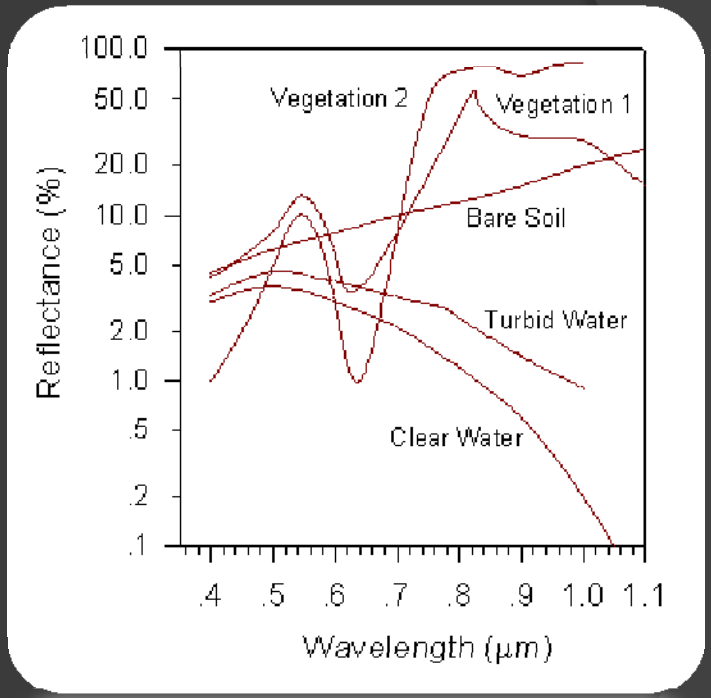
1984 - SIRB (1984)

1981 - SIRA (1981)
1978 - Seasat (1978)

Hyperspectral Imaging Systems

Hyperspectral

- Produce data in many narrow, contiguous spectral bands
  - Much finer spectral resolution than coarse multispectral data
- Can provide material identification and abundance estimates based on reflectance spectra

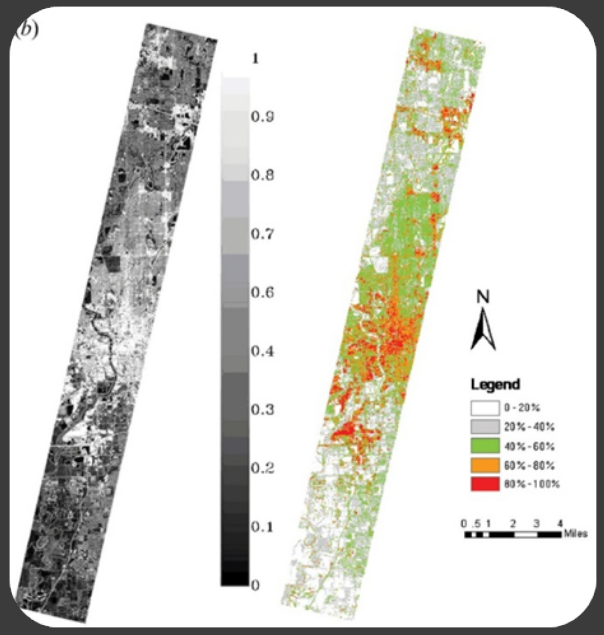


Picture Source: http://www.crisp.nus.edu.sg/~research/tutorial/optical.htm

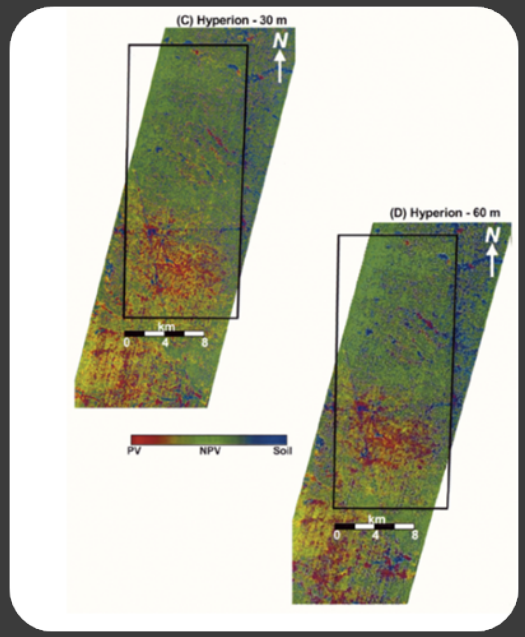
Hyperspectral General Land Applications

- Surface mineralogy
- Soil type and erosion
- Vegetation types
- Forest structure/function condition
- Plant stress
- Leaf water content
- Canopy chemistry
- Crop types and conditions
- Land degradation monitoring

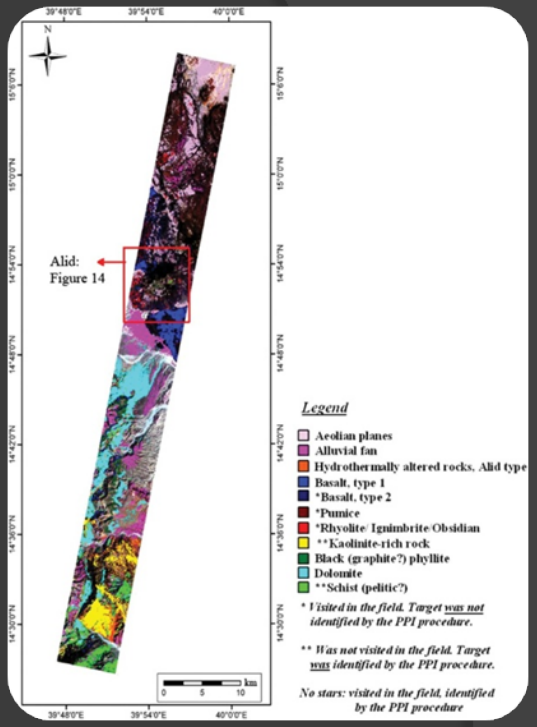
Examples of spaceborne hyperspectral applications…



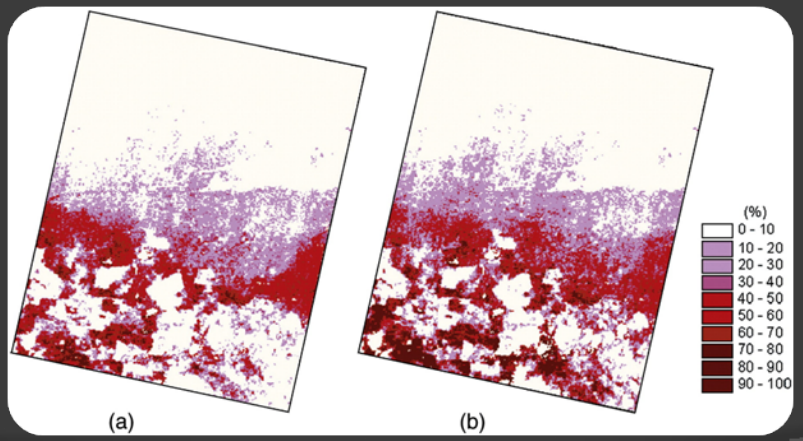
Impervious Surface Mapping
(Weng, Hu, and Lu 2008)



Soil and vegetation fraction mapping
(Asner and Heidebrecht 2003)



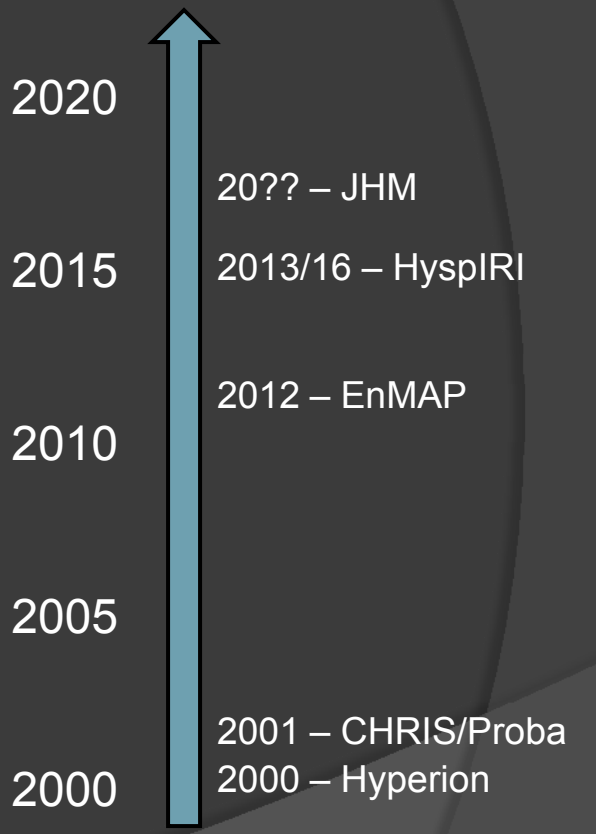
Mapping of hydrothermally altered rocks
(Gersman et al. 2008)



Invasive species abundance
(Walsh et al. 2008)

Timeline of Hyperspectral Missions

Sensor	Satellite	Bands	Spatial	Temporal	Country/Agency
Hyperion	EO-1	242 bands; Range 0.36µm - 2.6µm; Resolution 0.010µm - 0.011µm	30m	16 days	USA
CHRIS	Proba	62 bands; Range 415-1050 nm; Resolution 5-12 nm; 19 bands full resolution	17-34m	7 days	ESA
HSI	EnMAP	200+ bands; VNIR (420-1000 nm): 0.005nm; SWIR I (900-1390 nm) 0.003nm; SWIR II (1480- 1760 nm): 0.003nm; SWIR III (1950-2450 nm): 0.001nm	30m	4 days	Germany
HyspIRI	HyspIRI	380 to 2500 nm in 10nm bands	60m	19 days	USA
	Joint Hyper Mission				Canada/Italy



References

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