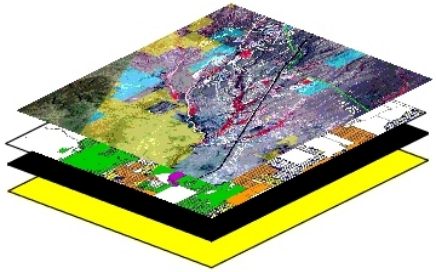
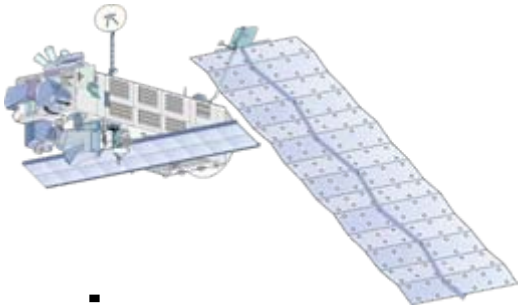




Overview of Remote Sensing Systems and Characteristics

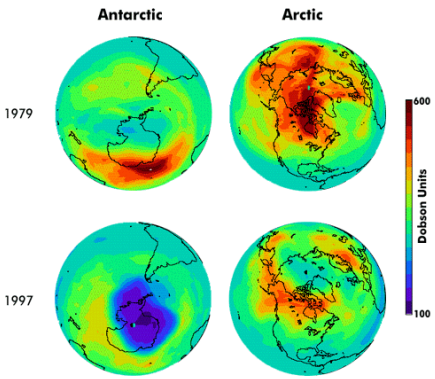
By

Thomas Budge

Earth Data Analysis Center

University of New Mexico

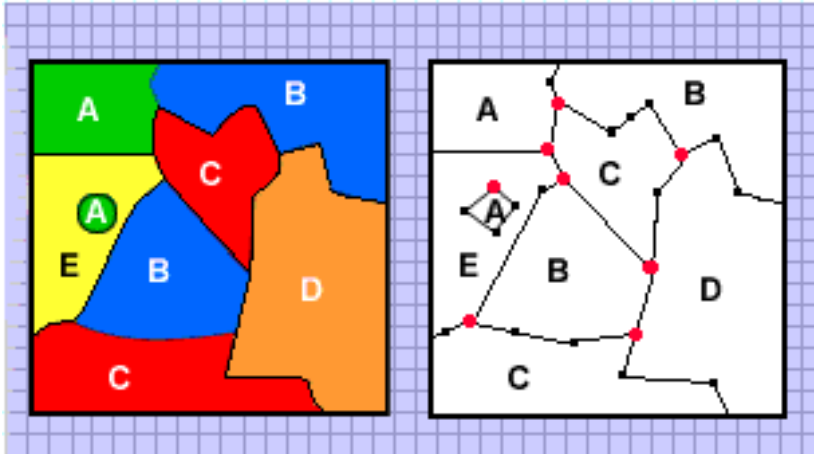
April 2001



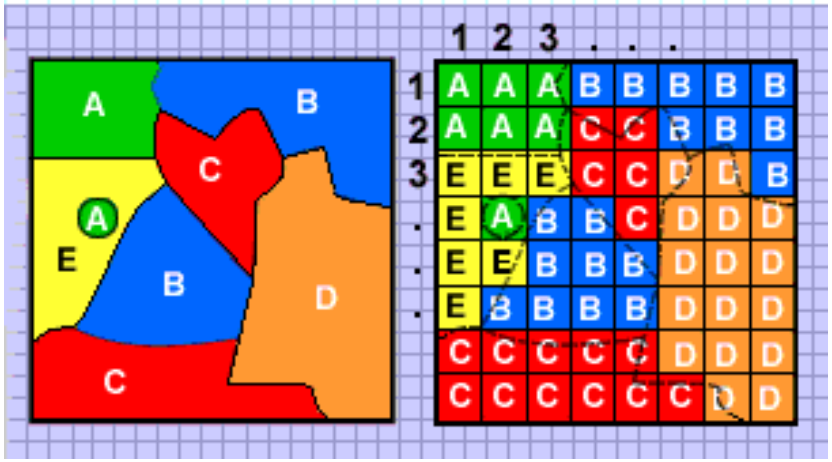
Presentation Overview

- Review of the Raster Concept
- Common GIS Raster Data Sets
- Review of Established Remote Sensing Systems
- Review of New Remote Sensing Systems
- Resolution comparisons
- Global Monitoring Remote Sensing Systems

Vector vs. Raster



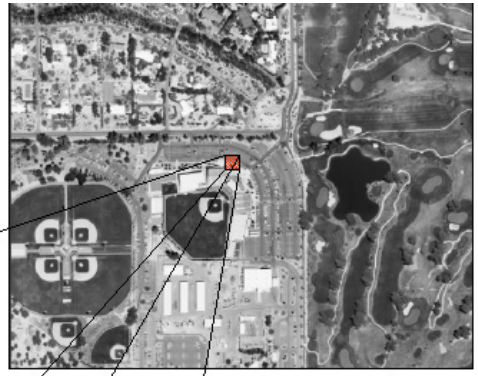
Vector Data - Represents spatial features by recording their map coordinates using lines, points, and polygons.



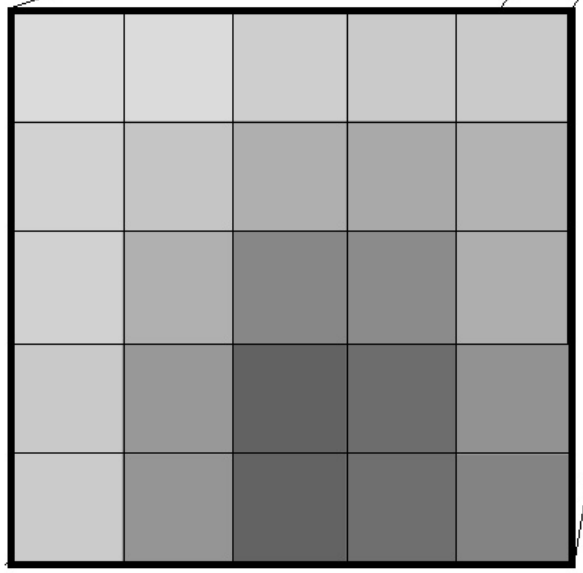
Raster Data - Represents spatial features using grid cells often referred to as picture elements, or pixels. Data can also be themes (map data) as well as images.

(CCRS)

Human Eye vs. Computer



Picture Elements
(Pixels)



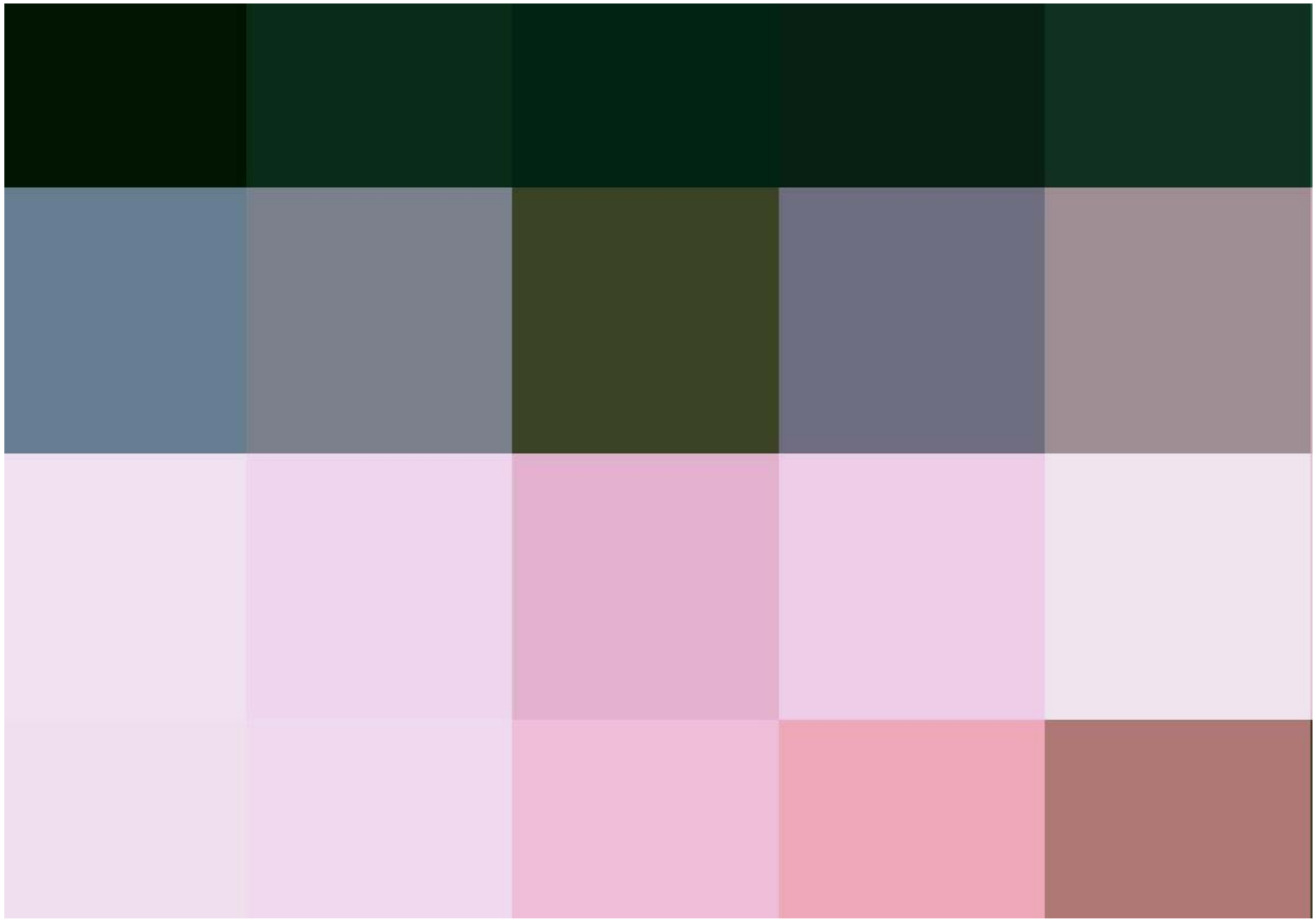
88	89	75	73	72
75	65	50	45	48
80	61	39	40	61
78	42	15	20	44
78	42	16	19	38

What the eye sees

What the computer sees

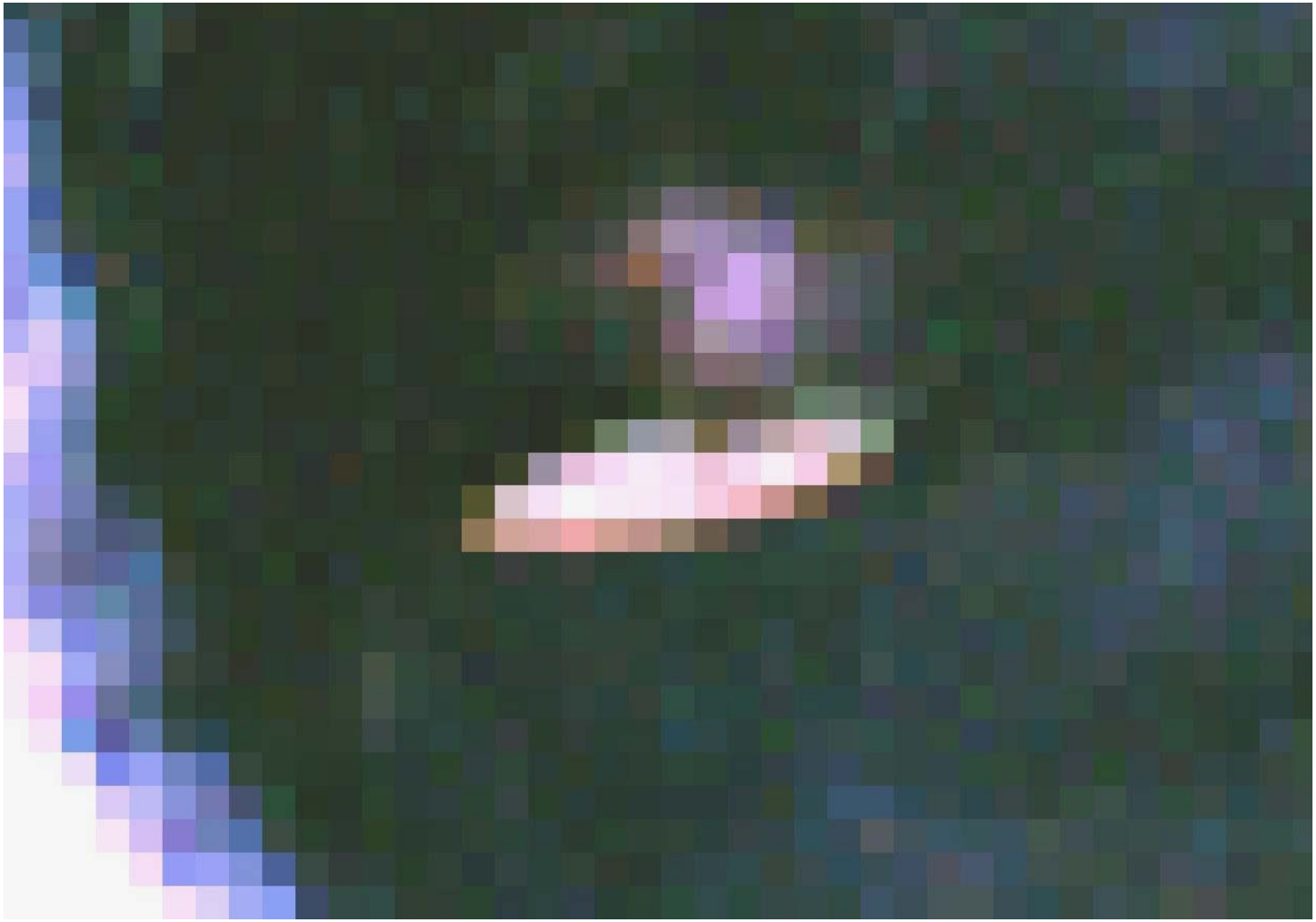
(GISVision)

Raster Image Formation – “Can’t see the forest for the trees”



Raster Image Formation

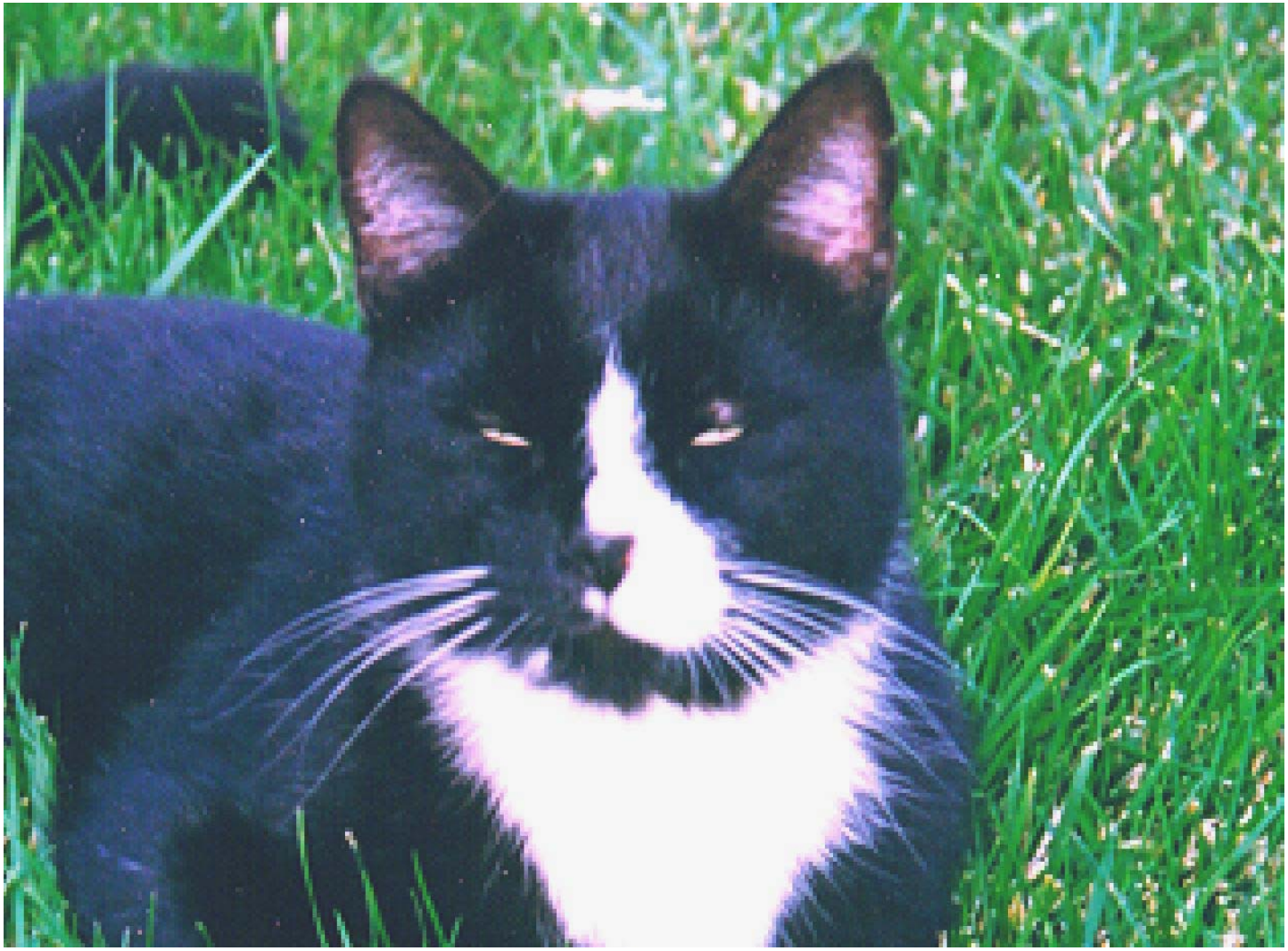
Raster Image Formation



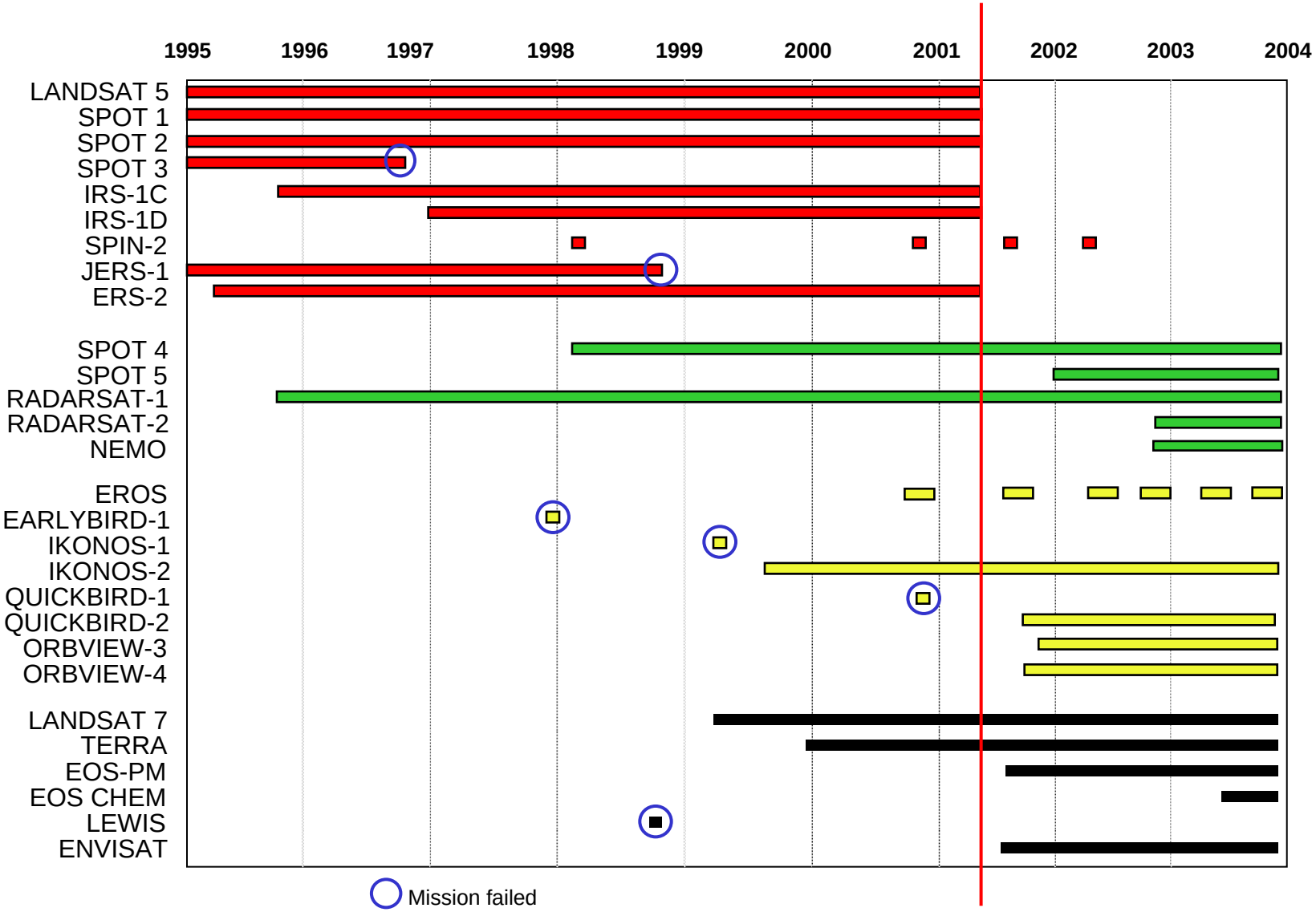
Raster Image Formation

Raster Image Formation

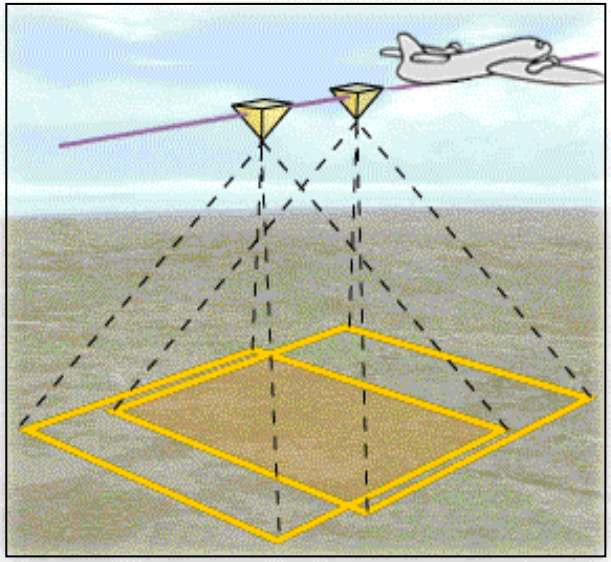
Raster Image Formation



Satellite Launches and Lifetimes

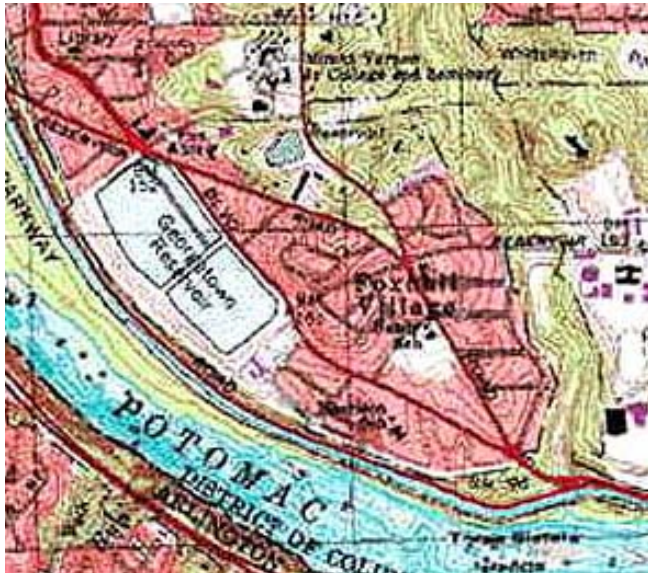


Digital Orthophoto Quadrangles (DOQ) - USGS



- Characteristics of a photo with the geometric qualities of a map
- Topographic distortion is removed
- 1 meter pixel size
- NAPP or NAPP-like photography are used
- Quarter-quad centered at 1:40,000 scale
- http://edcwww.cr.usgs.gov, rgis.unm.edu

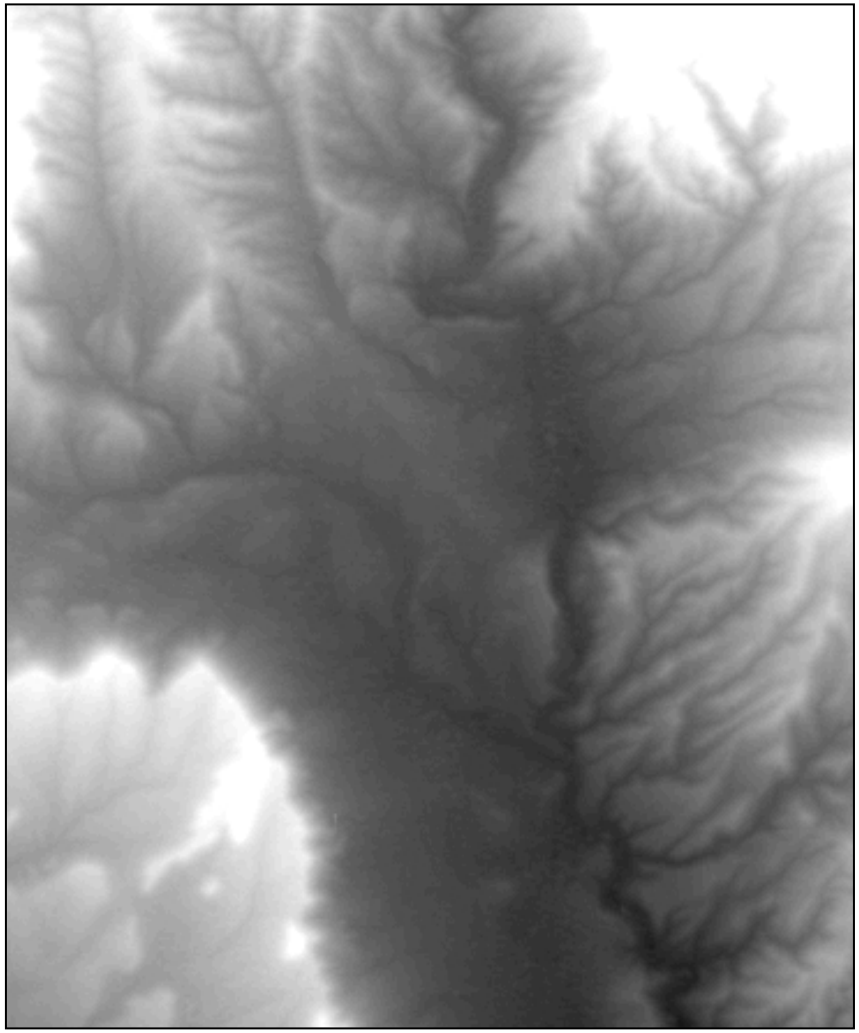
Digital Raster Graphics (DRG) - USGS



- Scanned image of a USGS topo map
- Georeferenced to UTM
- Geotiff format, ftp download
- Pixel size of 2.4+ meters
- Accompanied by metadata file compliant to FGDC standards
- http://mapping.usgs.gov , rgis.unm.edu

Digital Elevation Models (DEM) - USGS

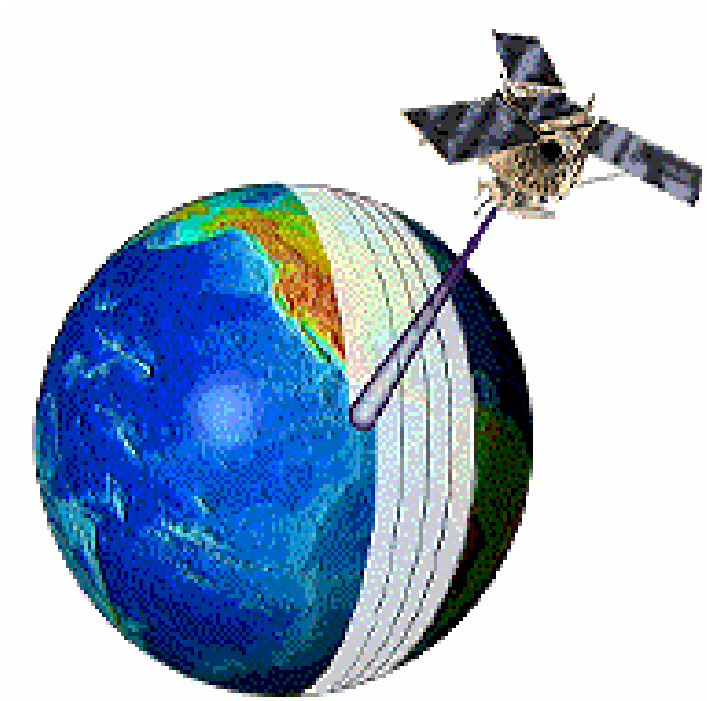
- Digitized elevation based on 1:24 K,1:100 K, 1:250 K map quads
- USGS ASCII format, ftp download
- 16 bit B&W, resolution of 30, 60, 90 meters
- Georeferenced to UTM
- http://mapping.usgs.gov, rgis.unm.edu

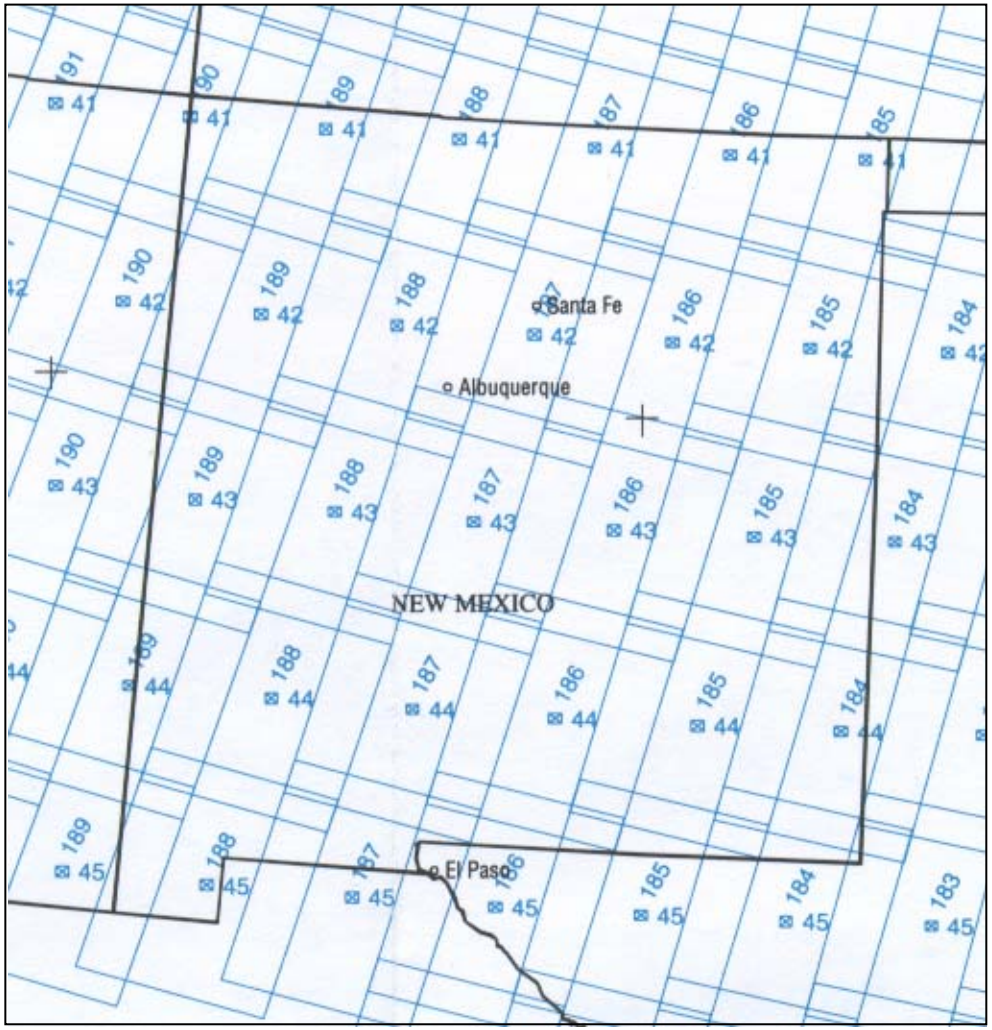


General Characteristics of Established Systems

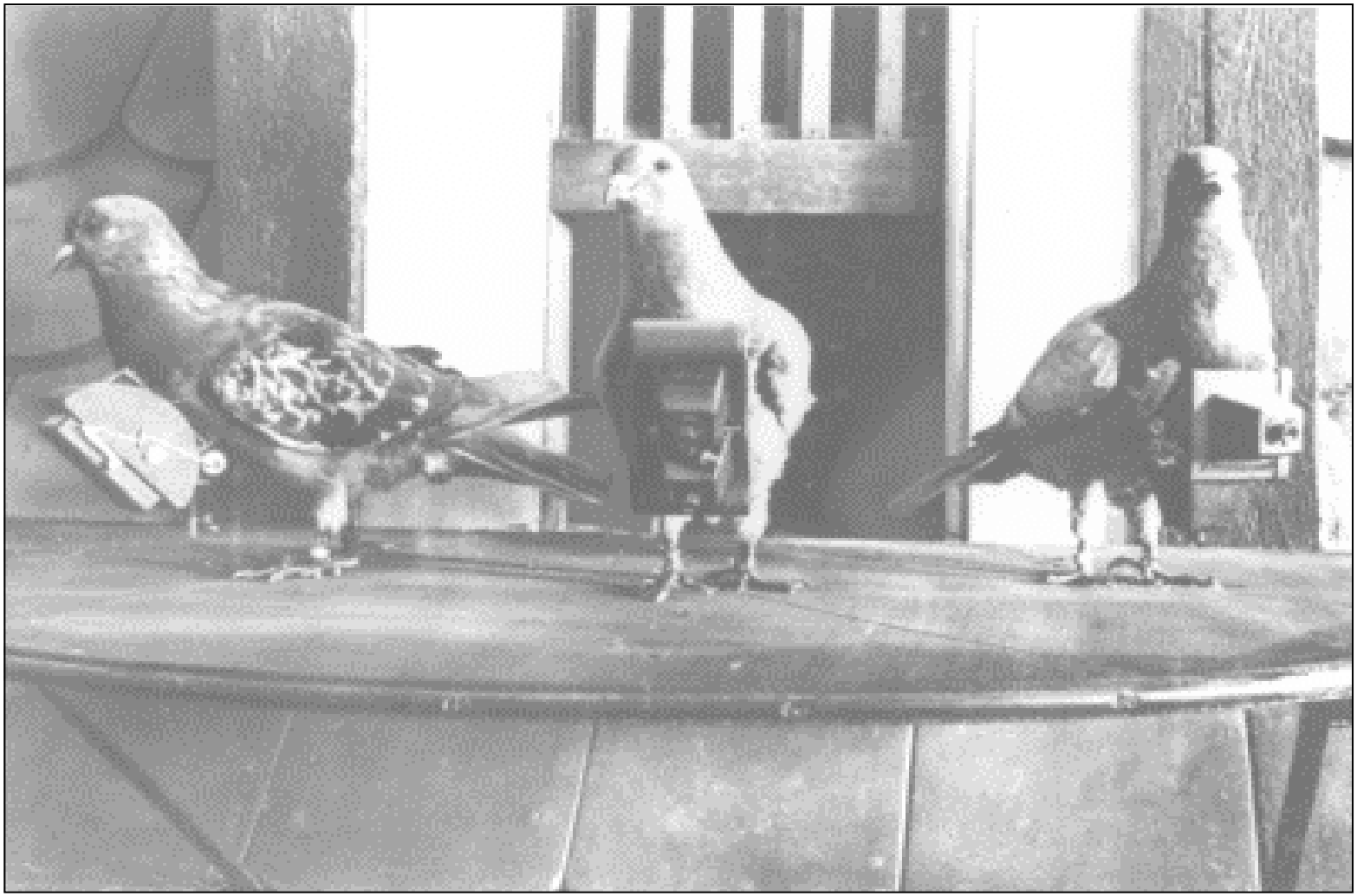
- Generally designed for mapping natural resources
- Large image area coverage (185 x 185 km, 60 x 60 km)
- Relatively coarse resolution (30 - 2 m)
- Stereo view only possible using images of different dates
- Long turnaround time (1-4 weeks or longer)
- Tasking an image from a specific sensor can be difficult
- Long revisit times (days to weeks)
- Extensive archives of images

Image Swath and Footprint

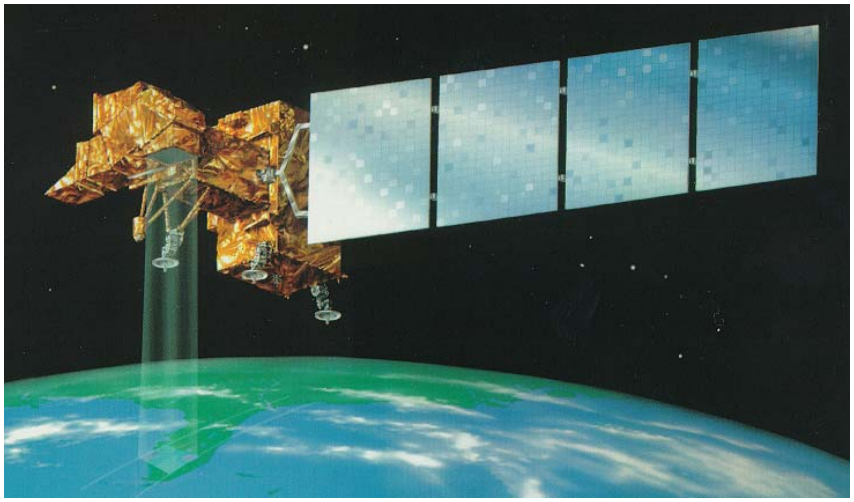




Original Remote Sensing System

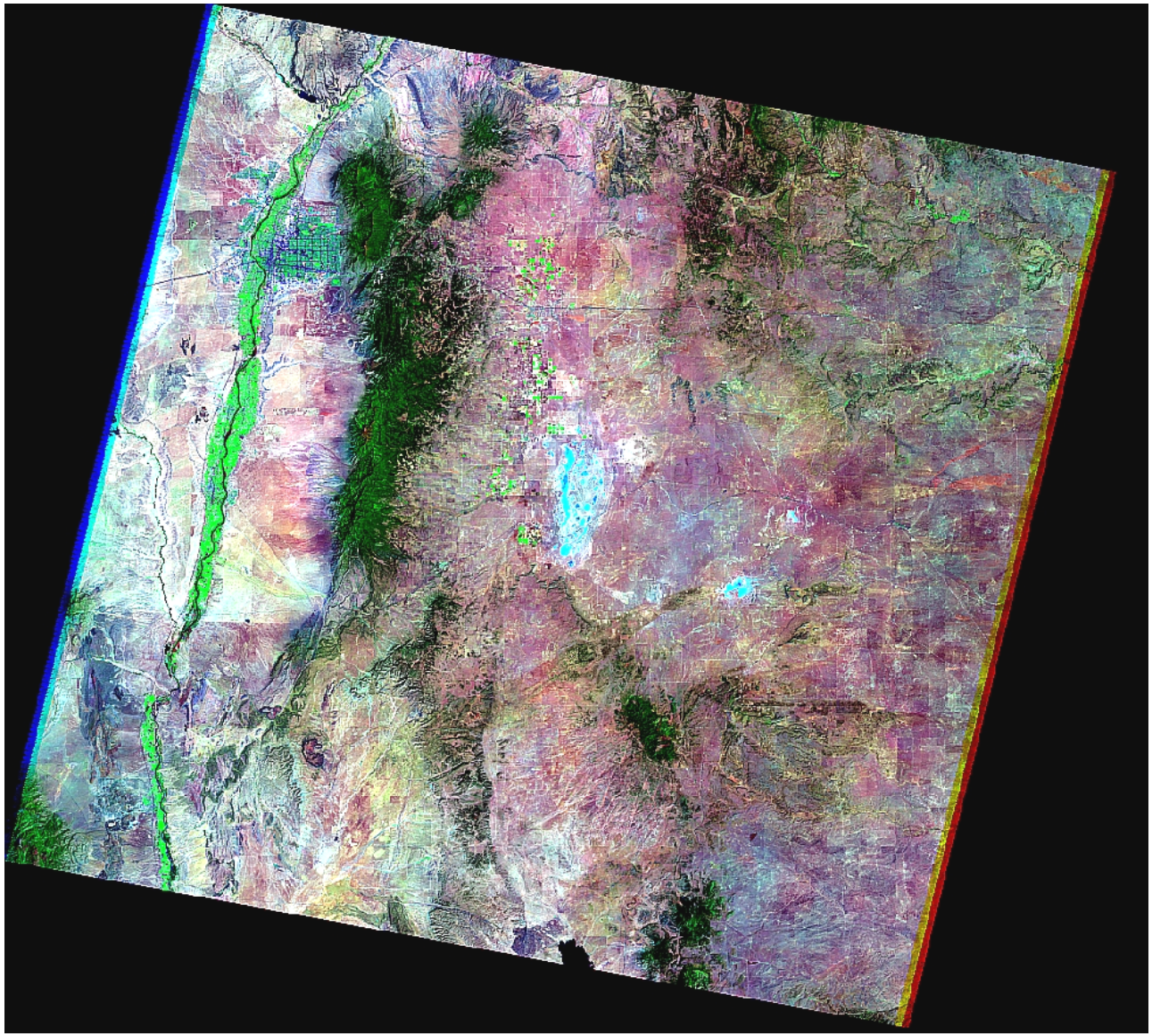


Landsat (US) - Space Imaging and USGS



- Thematic Mapper (TM)
- Seven spectral bands -
  three visible, one near IR,
  two Mid IR, one thermal
- Reflective bands - 30 meter resolution
- Thermal band - 60 and 120 meter resolution
- 15 meter panchromatic band (Landsat 7)
- www.eosgateway.usgs.gov, www.spaceimaging.com

Landsat 7 Image - 170 x 185 km

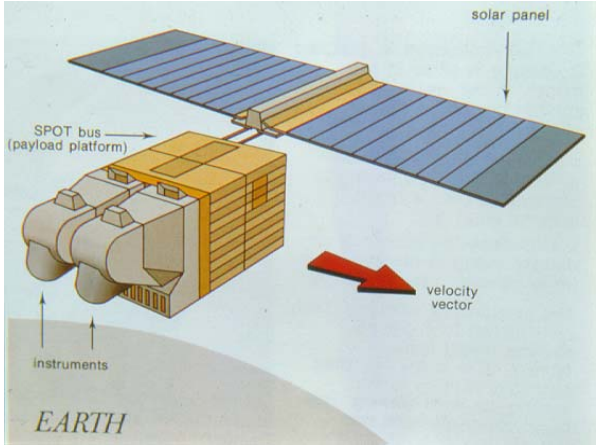


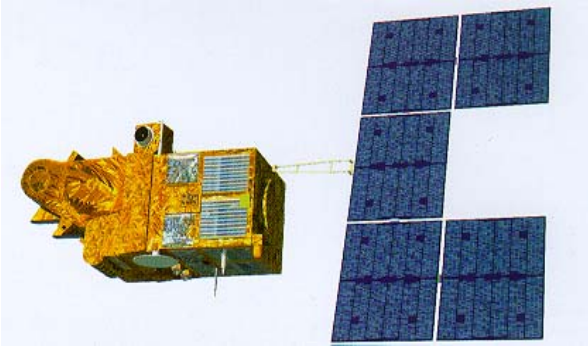
The University of New Mexico

(USGS)

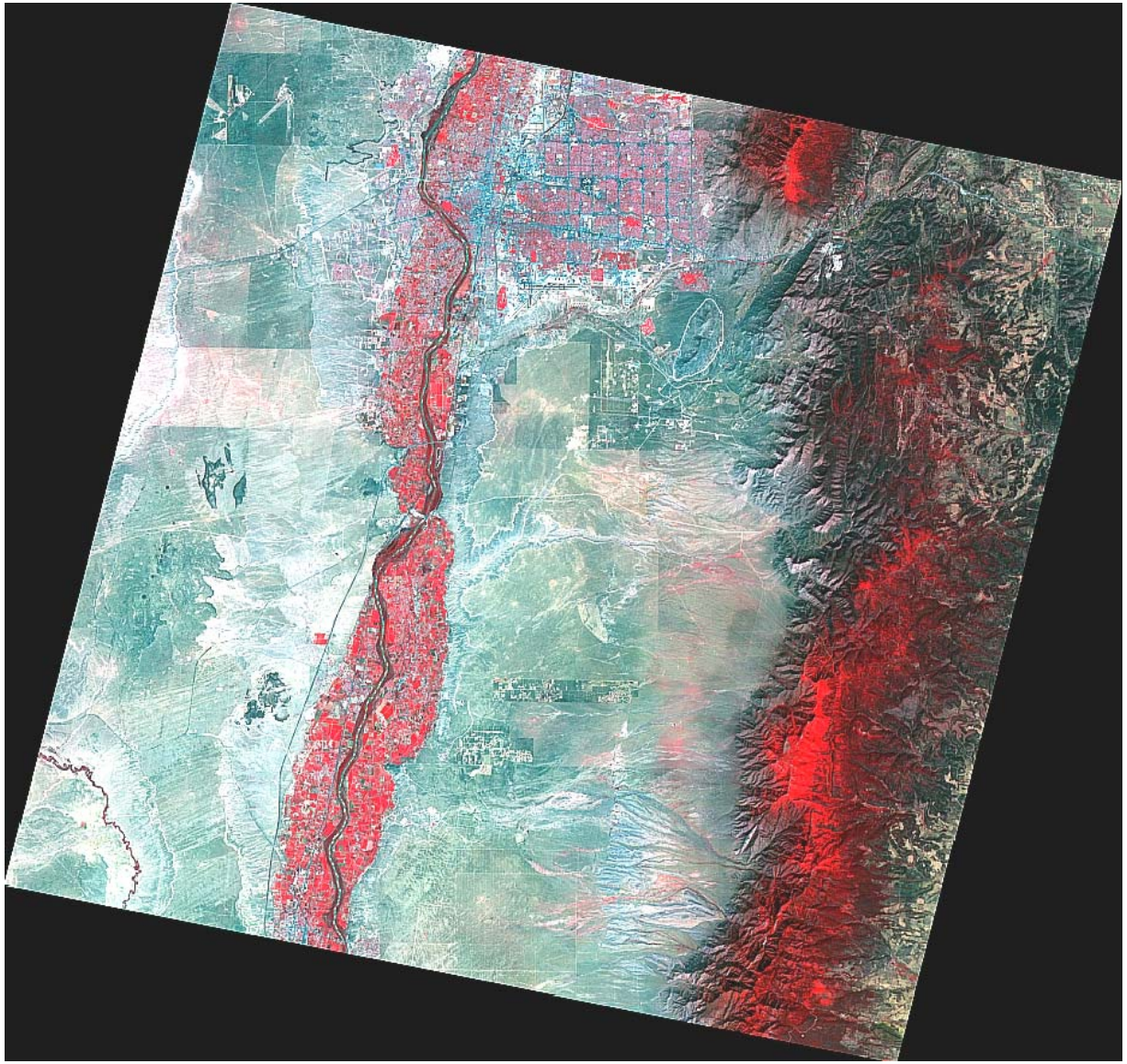
SPOT (France) - Spot Image

- First launched in 1986
- Two satellites in operation, one in reserve
- 10 meter resolution panchromatic
- 20 meter resolution in multispectral - two in visible, one near IR
- “Vegetation” sensor – 1 kilometer resolution, 4 bands
- First to view off-nadir
- www.spot.com





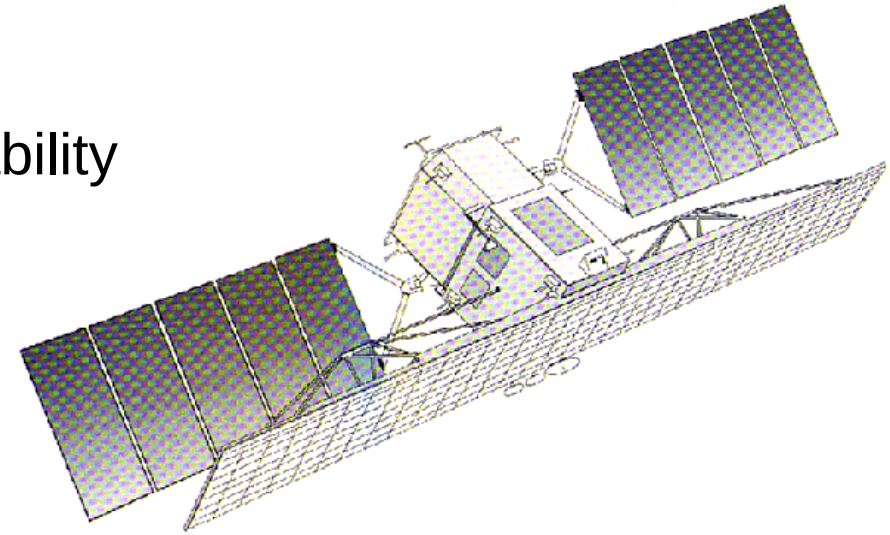
SPOT Multispectral Image – 60 x 60 km



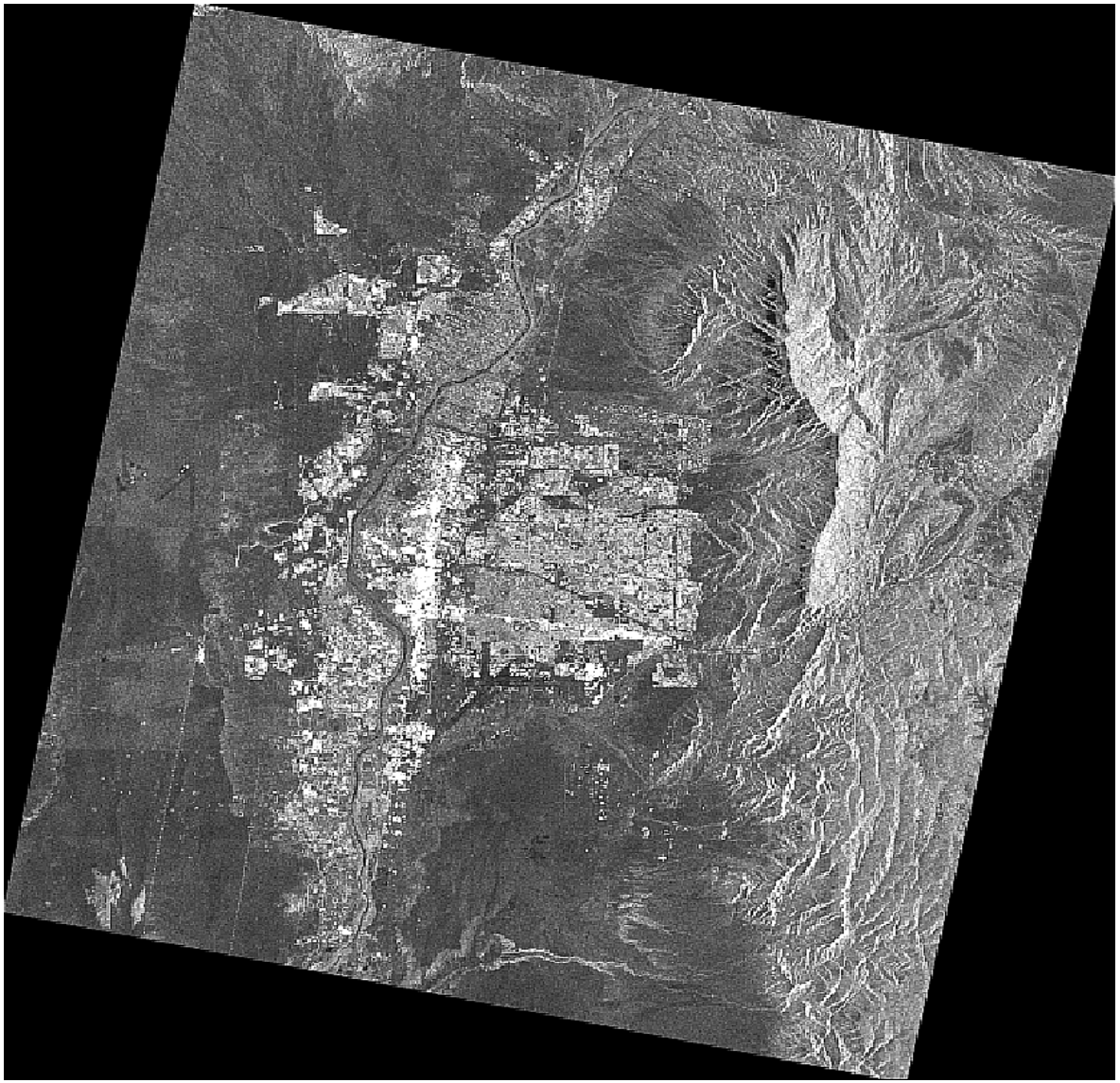
(Spot Image)

Radarsat-1 (Canada) - Radarsat International

- Launched in 1995
- Day/Night, all weather capability
- Single frequency - C-band
- 10-100 meter resolution
- First operational commercial satellite radar
- Sun-synchronous
- www.rsi.ca

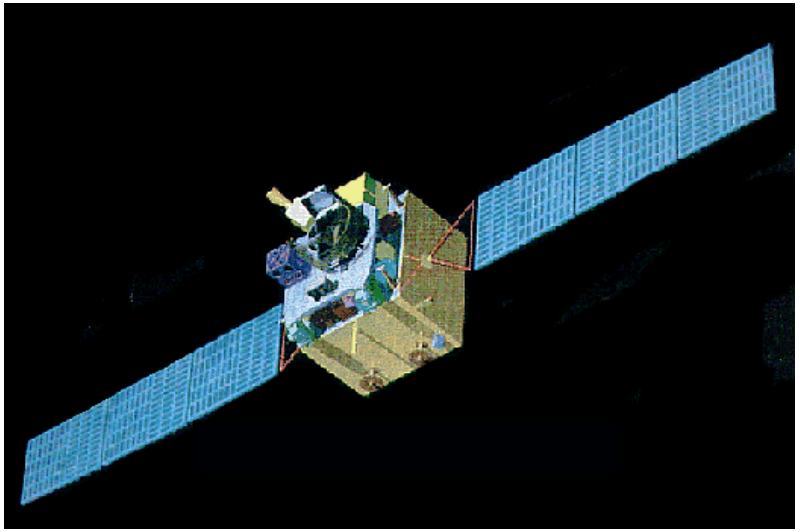


Radarsat Image - 50 x 50 km



(Radarsat International)

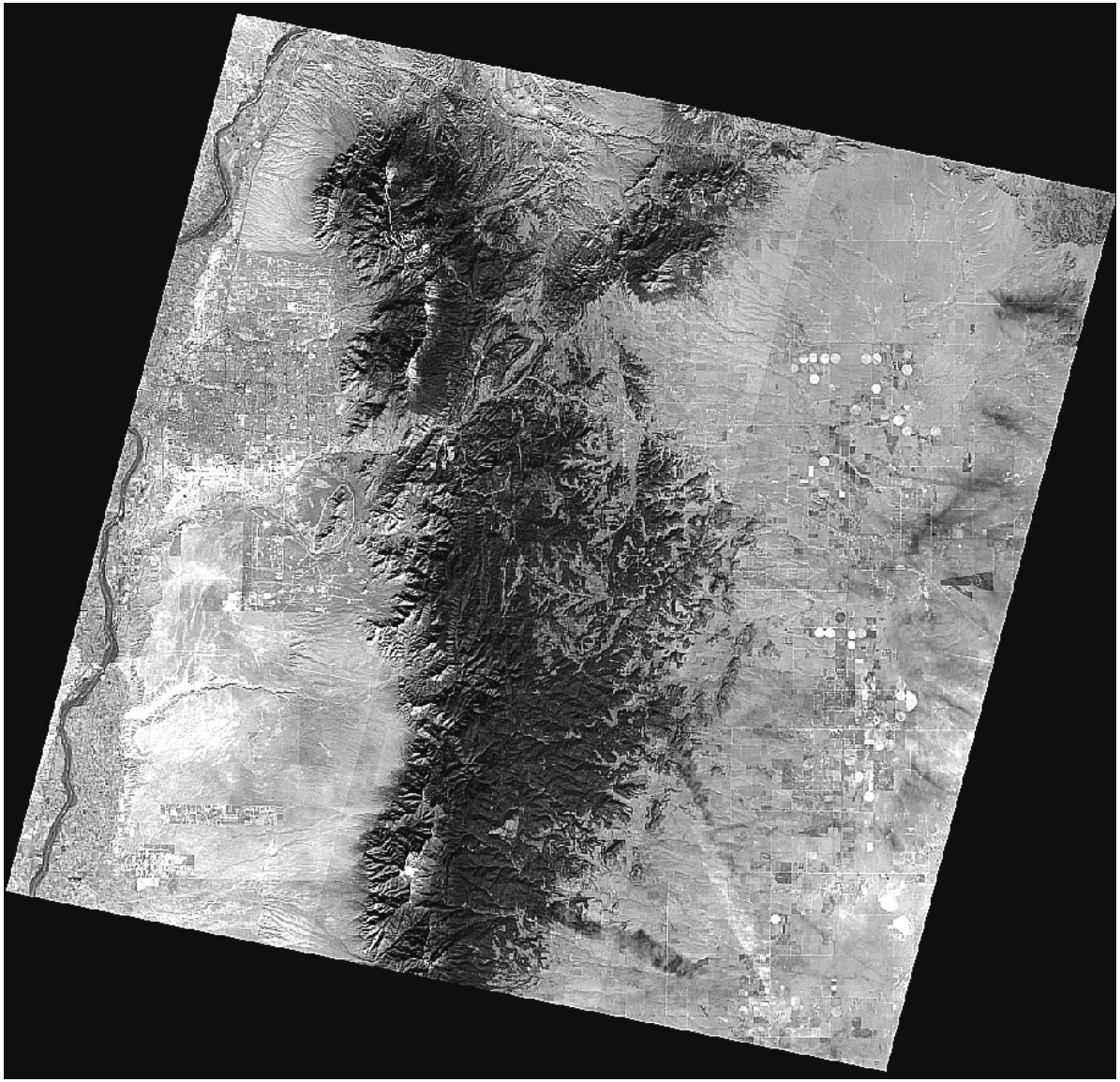
IRS Series (India) - Space Imaging



- 5.8 meter panchromatic
- 20 meter multispectral -

  two visible, one near IR
- Sun-synchronous
- 6 bit data expanded to 8 bit
- Several satellites in the series since 1995
- Distributed in US by GeoEye (formerly, Space Imaging)
- www.geoeye.com

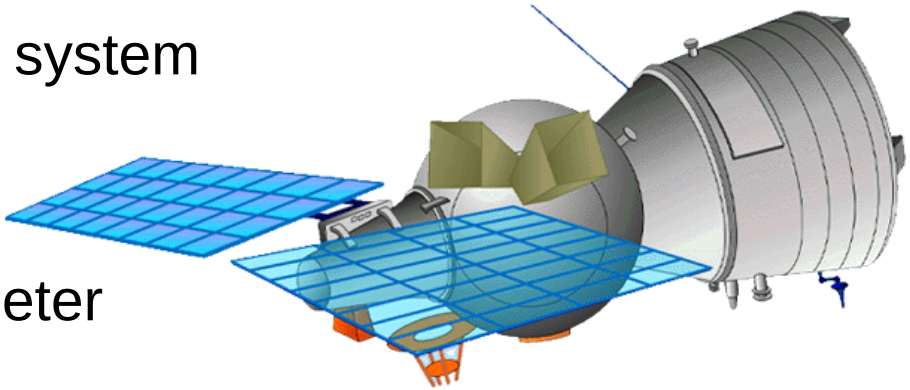
IRS Image - 70 x 70 km



(Space Imaging)

KVR-1000 (US/Russia) - Spin-2

- Jointly owned by US and Russian companies
- Former Soviet spy satellite system
- Film return system
- 1 meter pixel, formerly 2 meter
- Irregular launches and coverage
- Not sun-synchronous (overpasses at different times)
- TerraServer – online internet download of images
- www.spin-2.com, www.terraserver.com



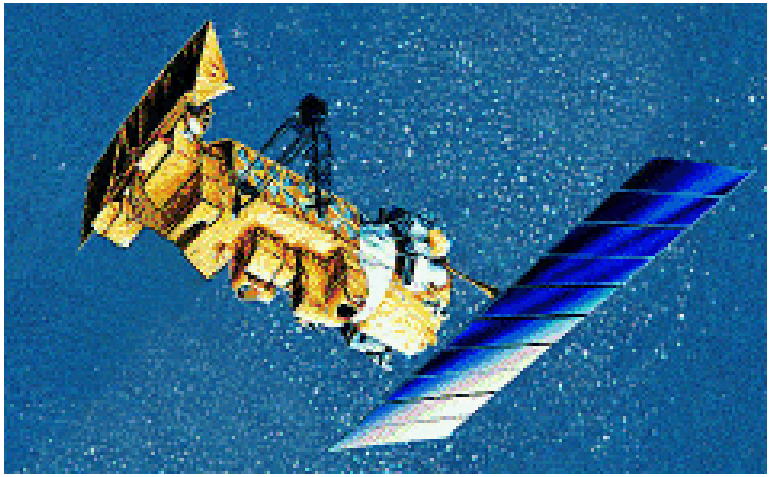
(Sovinformsputnik)

KVR-1000 (US/Russia) - Spin-2

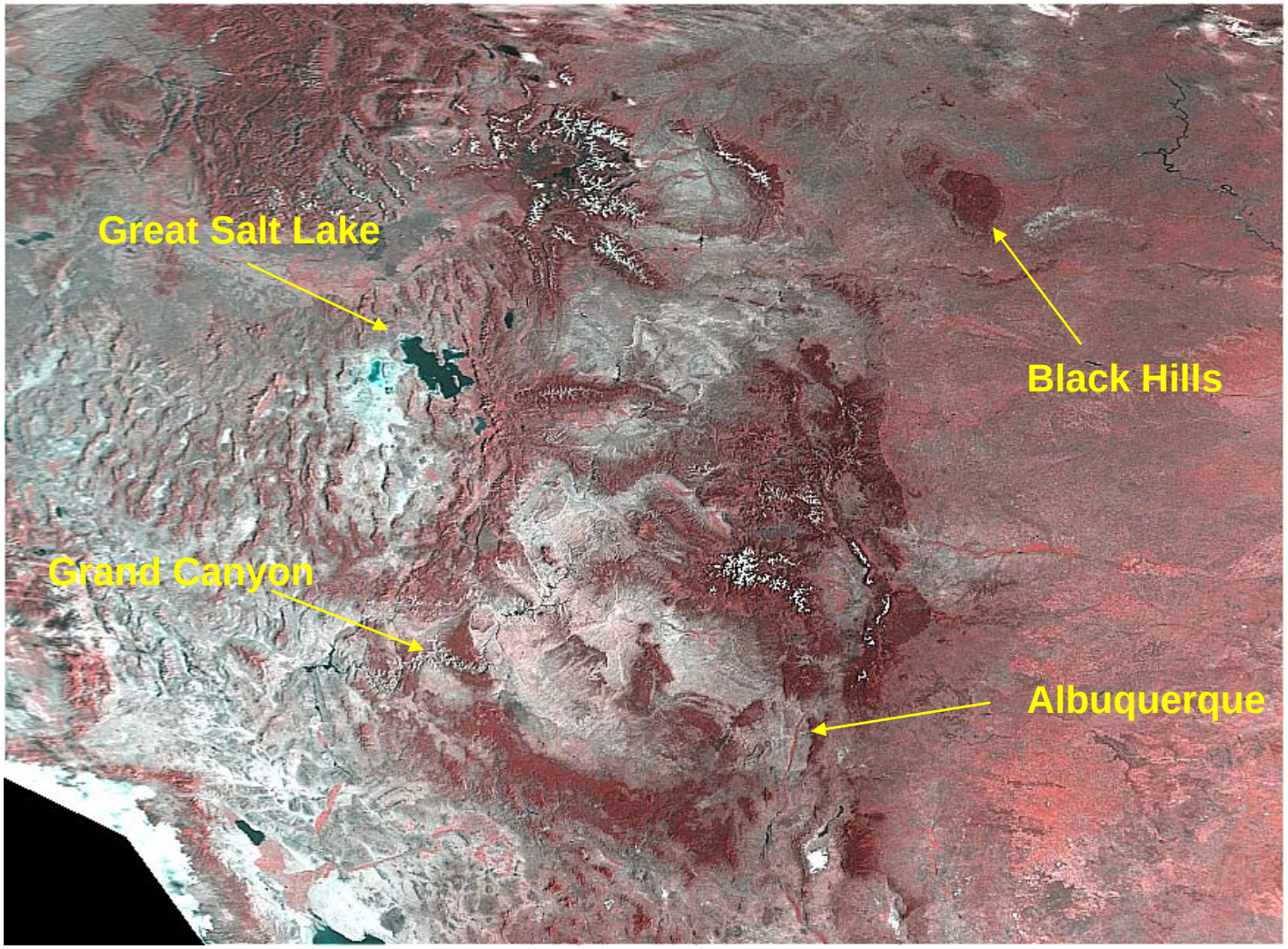
(Spin-2)

AVHRR Environmental Sensor (US) - NOAA

- Polar Orbiting Environmental Satellites (POES)
- Four or five bands (depending on satellite)
- One visible, one near IR, two or three thermal
- 1.1 kilometer resolution
- Daily global coverage
- In orbit on a series of satellites since 1978
- http://edcwww.cr.usgs.gov



AVHRR Image - Continental in Size



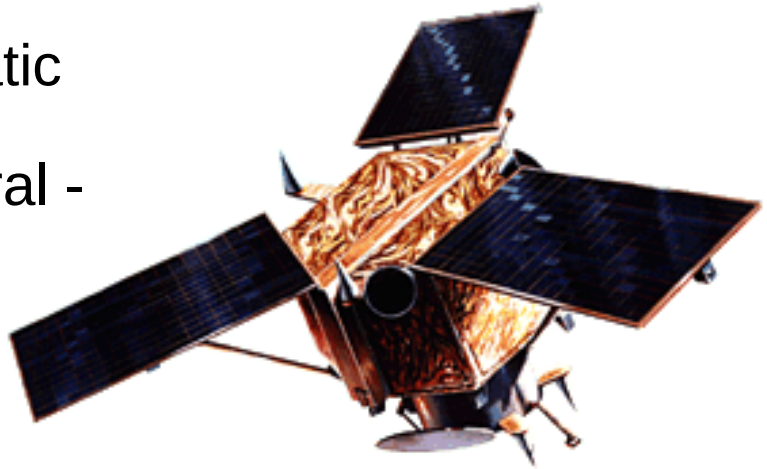
(NOAA)

Characteristics of New and Future Systems

- **Operations**
  - **High flexibility in sensor pointing**
  - **Ability for short-term tasking of imaging**
  - **Short revisit times**
  - **High location accuracy**
- **Images**
  - **High resolution (~ 1 m)**
  - **Small image footprint**
  - **11 bit, 2048 gray levels**
  - **Limited spectral range**
  - **Forward and backward viewing (same day stereo)**
  - **Many product options and formats**

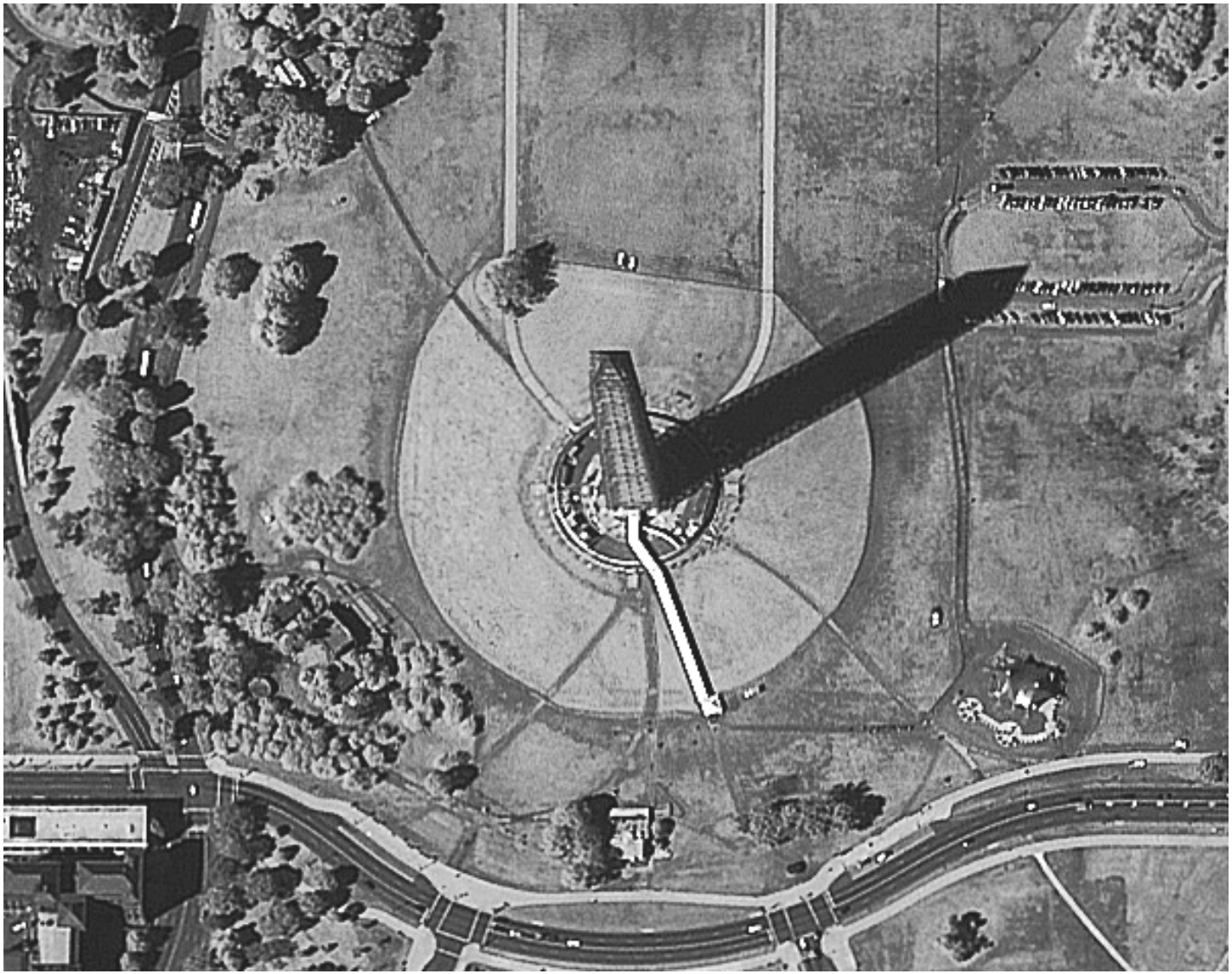
IKONOS (US) - GeoEye (formerly, Space Imaging)

- Launched in September of 1999
- One meter resolution in panchromatic
- Four meter resolution in multispectral - three visible, one near IR
- 11 bit data (2048 gray shades)
- Sun-synchronous orbit (same time every overpass)
- www.geoeye.com (formerly, www.spaceimaging.com)



(GeoEye/Space Imaging)

IKONOS Example – Washington, D.C. - 1 meter

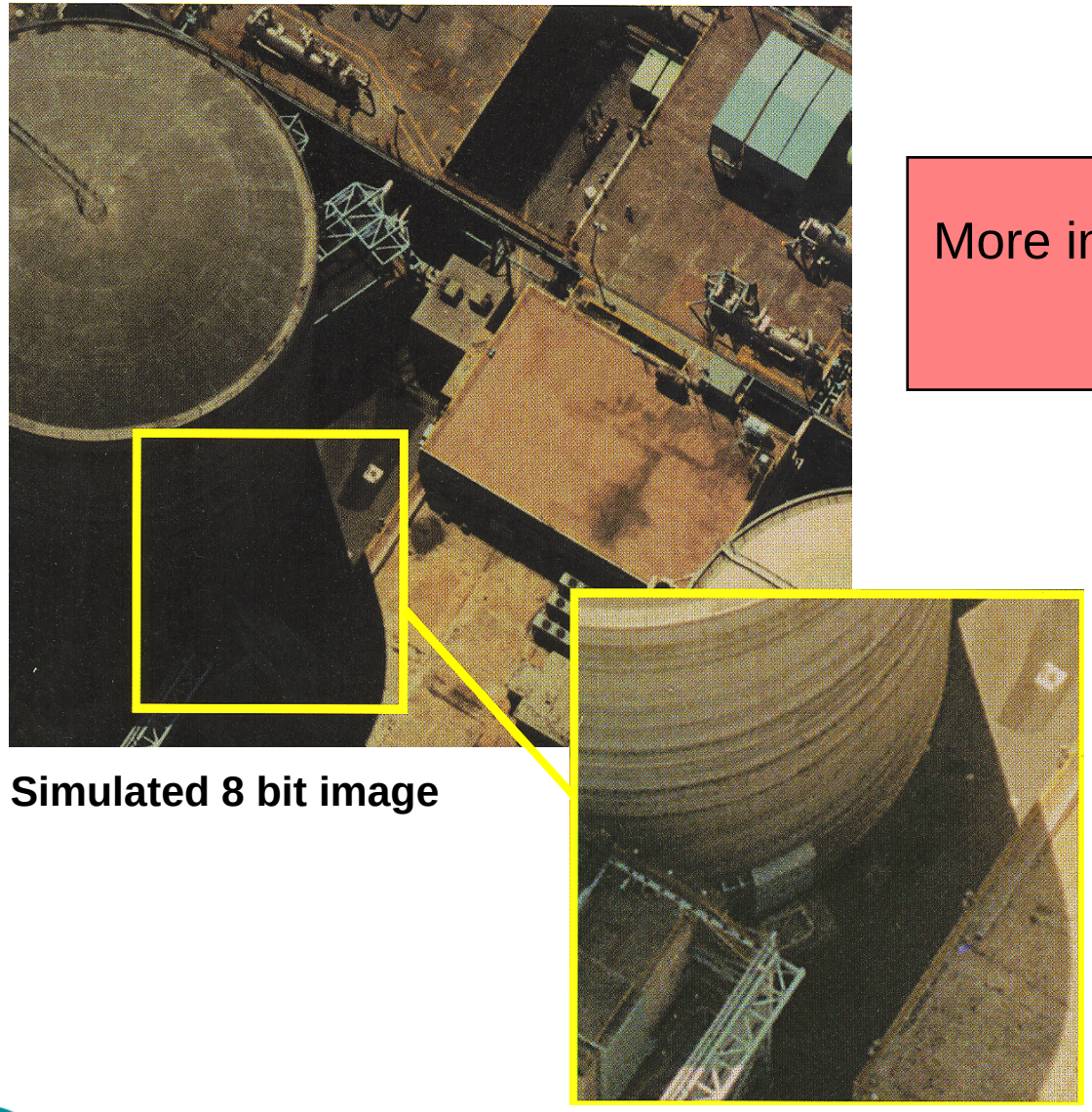


(GeoEye/Space Imaging)

IKONOS Example – Sea of Tranquility

(GeoEye/Space Imaging)

Potential Advantage of 11-bit Imagery



Simulated 8 bit image

Simulated 11 bit image

More information on the “low end” of the histogram

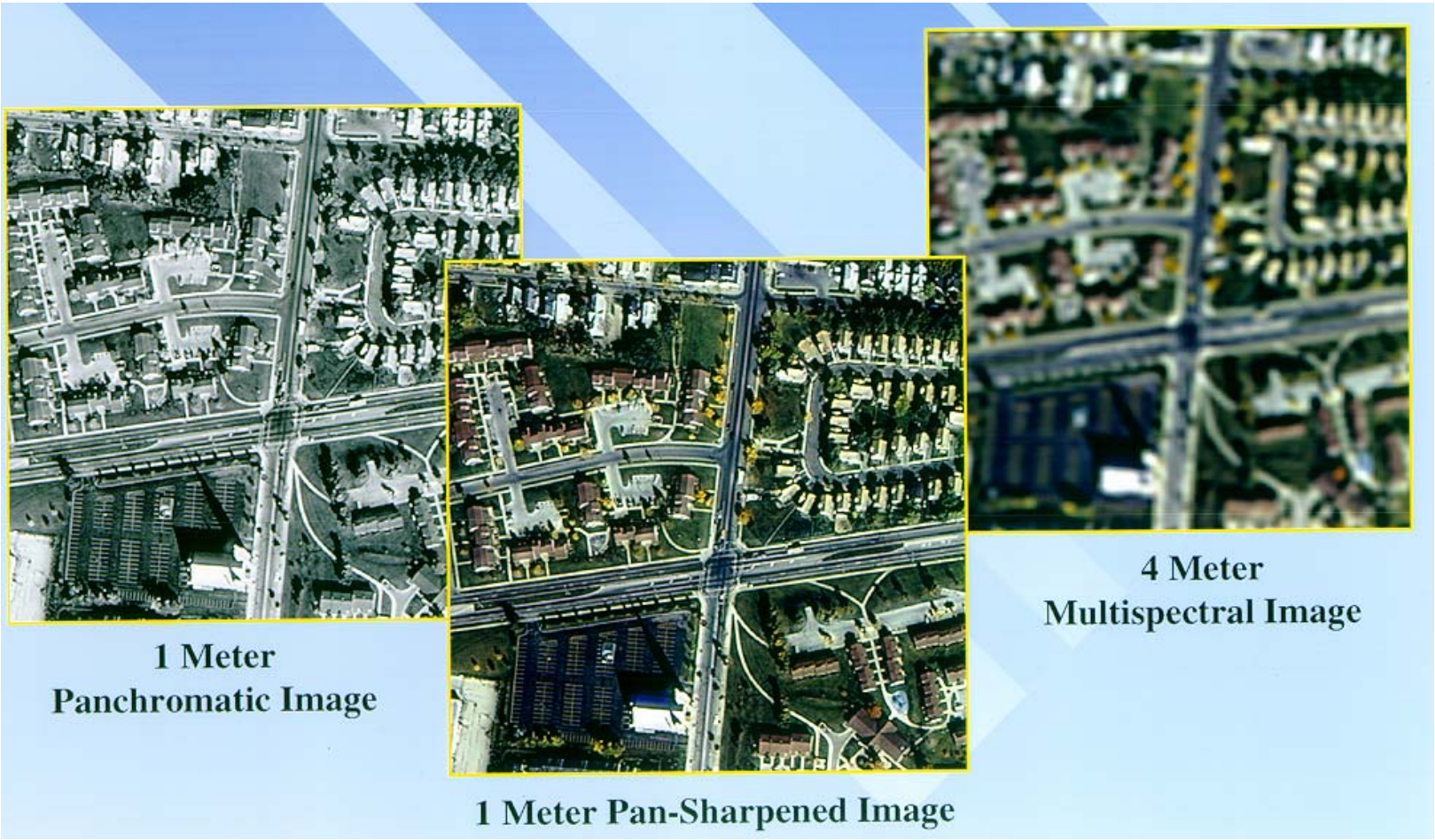
Potential Advantage of 11-bit Imagery

More information on the “high end” of the histogram

Simulated 8 bit image

Simulated 11 bit image

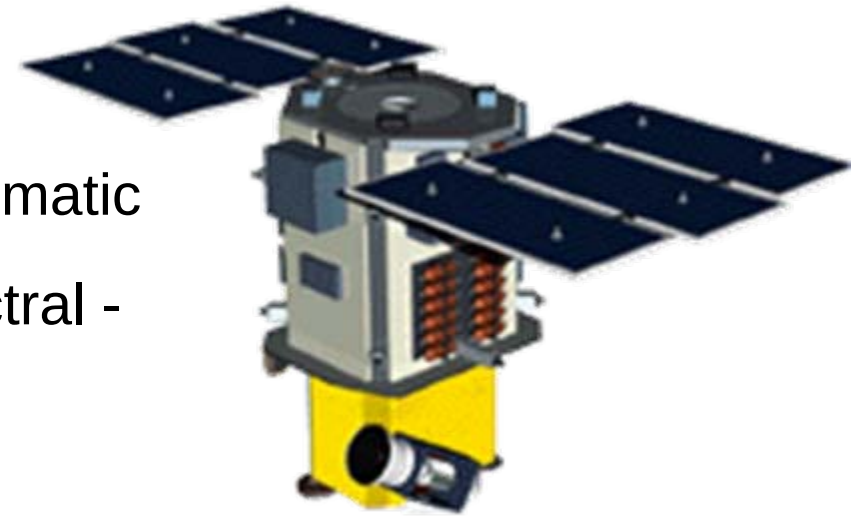
Panchromatic Sharpening



(GeoEye/Space Imaging)

QuickBird (US) - EarthWatch

- Launch failed on Nov. 20, 2000.
  Next launch late 2001?
- 0.61 meter resolution in panchromatic
- 2.5 meter resolution in multispectral - three visible, one near IR
- 11 bit data (2048 gray shades)
- Not sun-synchronous orbit (overpasses at different times)
- www.digitalglobe.com



(EarthWatch)

EROS – A1 (Israel/U.S.) - ImageSat International

- Launched on December 5, 2000
- 1.8 meter panchromatic resolution
- 11 bit data (2048 gray shades)
- No multispectral capability
- Sun-synchronous orbit (same time every overpass)
- First of up to 8 satellites in the next five years
- www.imagesatintl.com

(Imagesat International)

EROS – A1 Example - Izmir, Turkey - 1.8 meter

(Imagesat International)

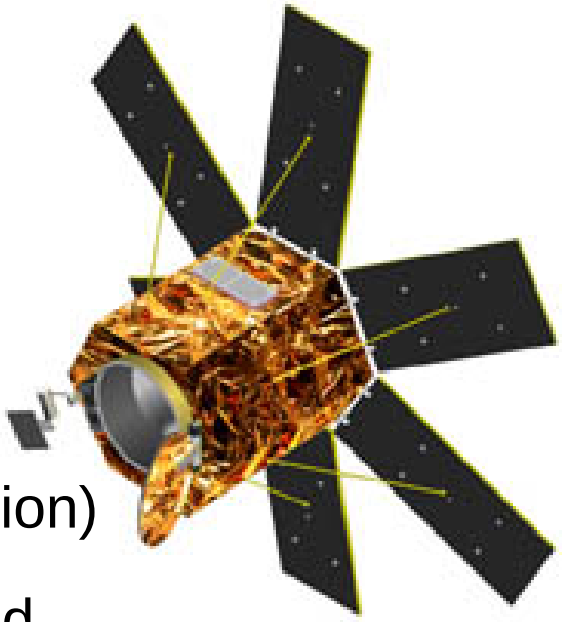
OrbView - 3 (US) - ORBIMAGE

- Launch proposed for 2001
- One meter resolution in panchromatic
- Four meter resolution in multispectral -

  three visible, one near IR
- 11 bit data (2048 gray shades)
- Not sun-synchronous orbit (overpasses at different times)
- www.orbimage.com

(ORBIMAGE)

Orbview - 4 (US) – ORBIMAGE



- Launch proposed for 2001
- One meter resolution in panchromatic
- Four meter resolution in multispectral -

  three visible, one near IR
- 200 band hyperspectral (8 meter resolution)

  US military sensor - mostly classified
- 11 bit data (2048 gray shades)
- Not sun-synchronous orbit (overpasses at different times)
- www.orbimage.com

(ORBIMAGE)

IKONOS Example – 1 meter

Space Imaging Ikonos Panchromatic - 1 meter resolution

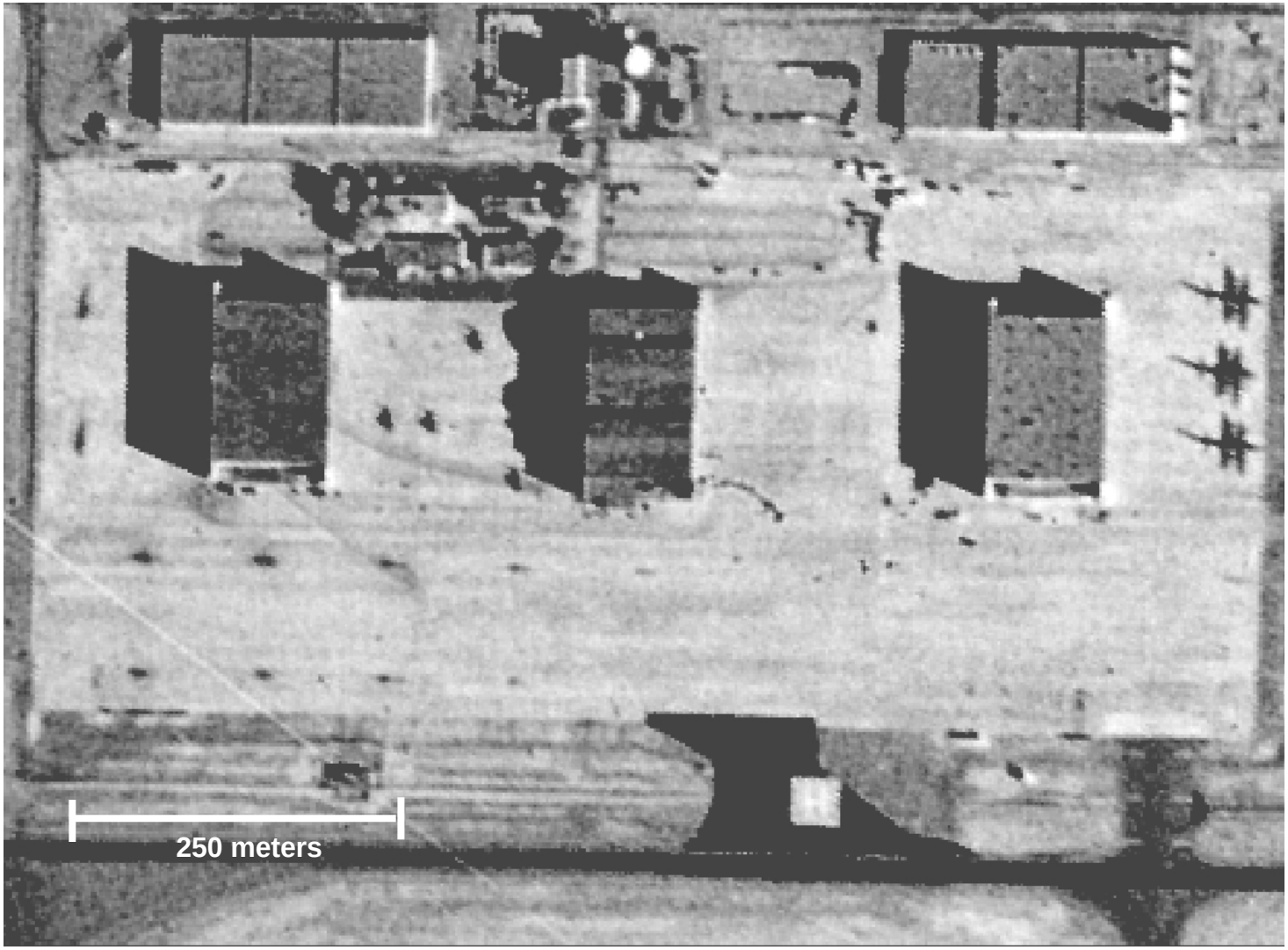
(GeoEye/Space Imaging)

DOQ Example – 1 meter

USGS Digital Orthophoto Quadrangle (DOQ) Panchromatic - 1 meter resolution

(USGS)

KVR-1000 Example – 2 meter



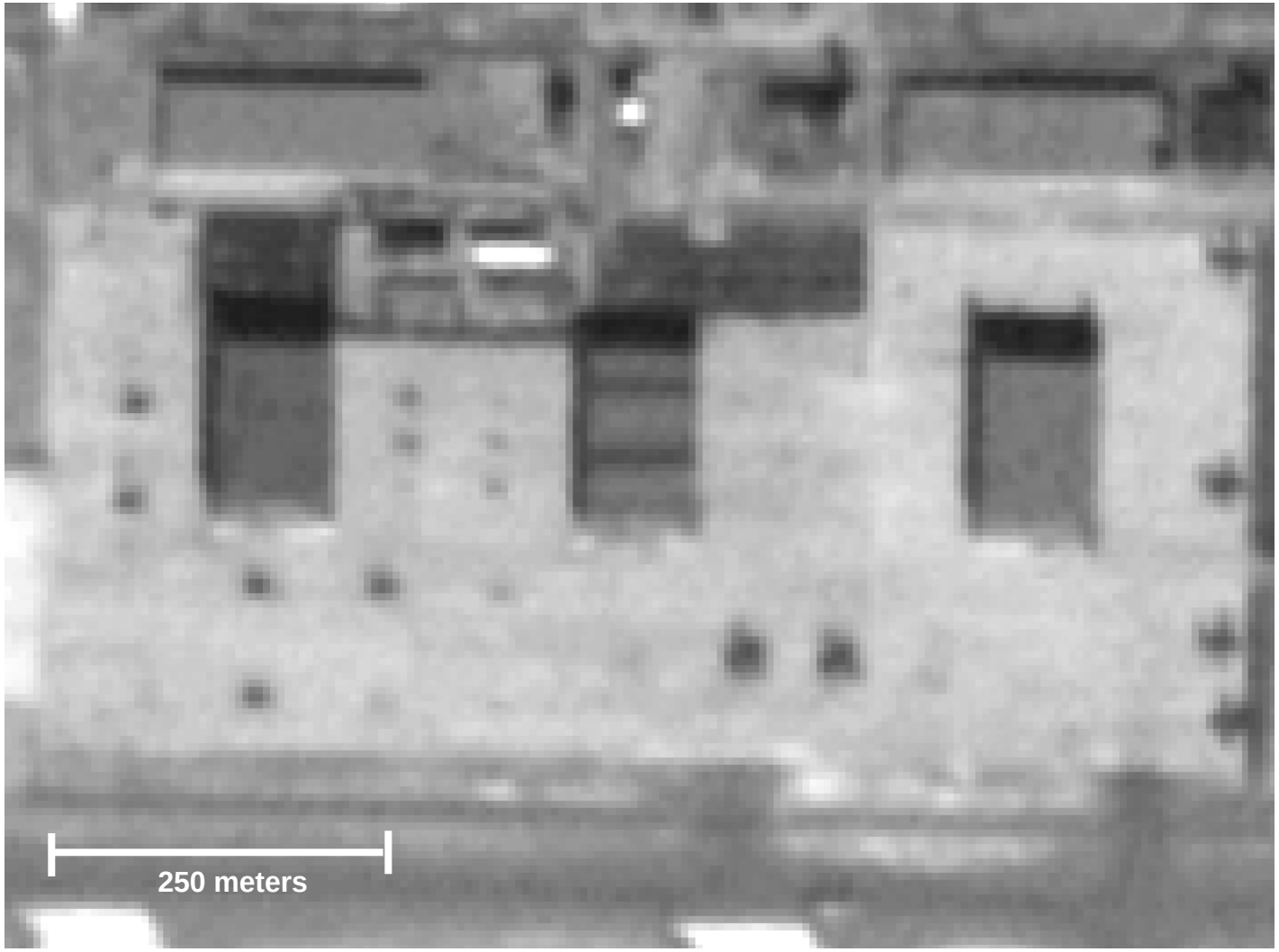
Russian KVR-1000 Panchromatic - 2 meter resolution

DRG Example – 2.4 meter

USGS Digital Raster Graphic (DRG) - 2.43 meter resolution

(USGS)

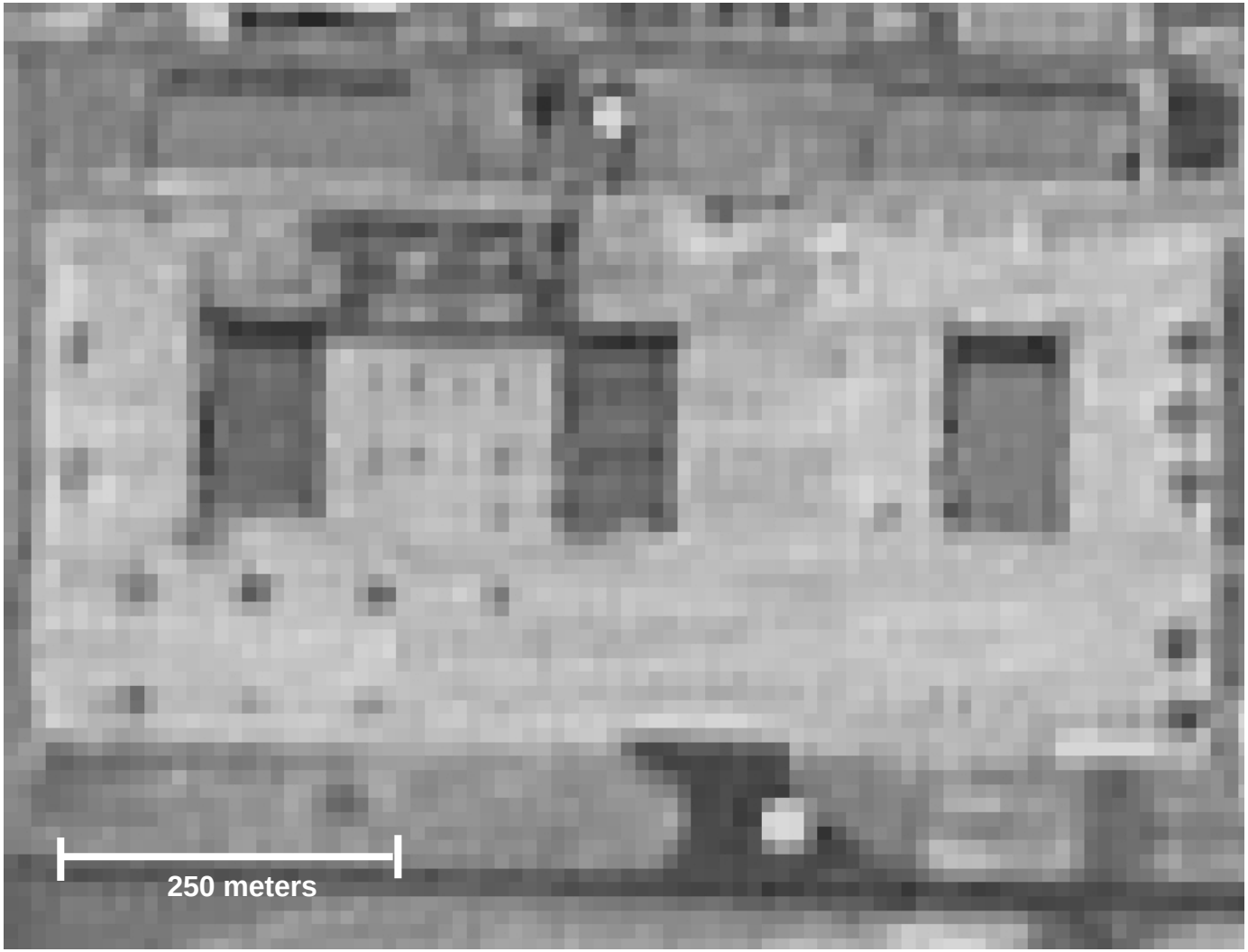
IRS Example – 5.8 meter



Indian Remote Sensing Satellite (IRS) Panchromatic - 5.8 meter resolution

(GeoEye/Space Imaging)

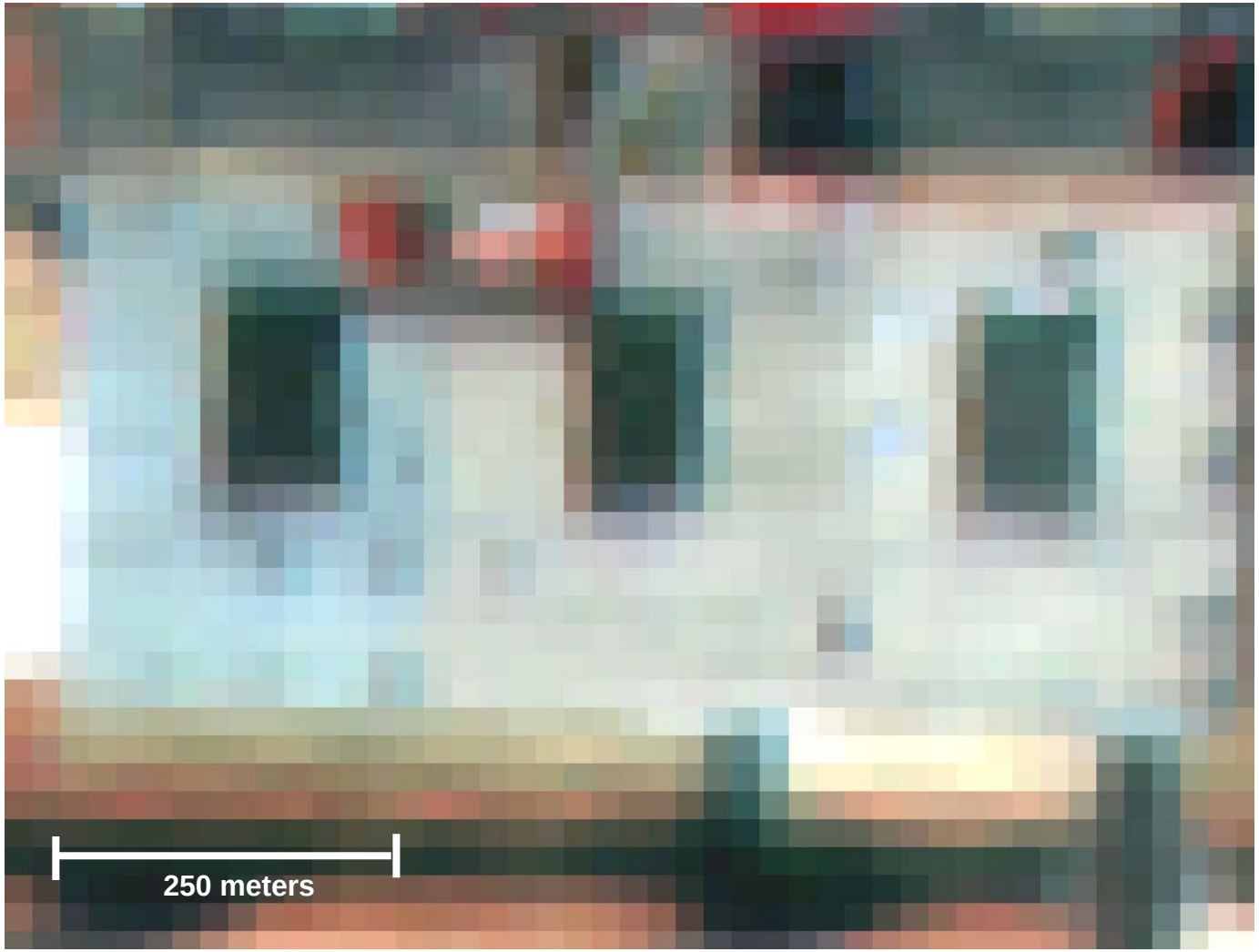
SPOT Panchromatic Example – 10 meter



French SPOT Panchromatic - 10 meter resolution

(Spot Image)

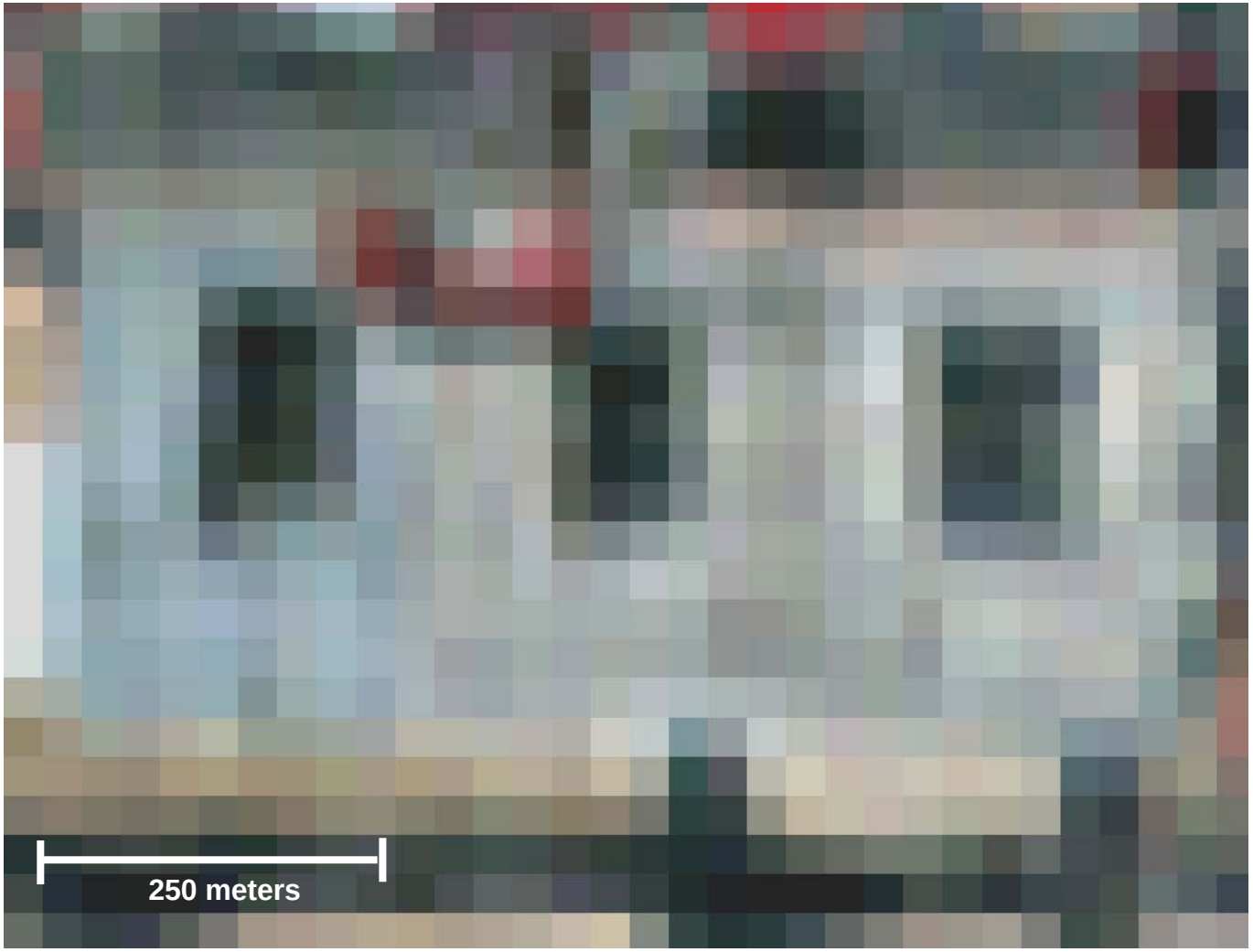
SPOT MSS Example – 20 meter



French SPOT Multispectral - 20 meter resolution

(Spot Image)

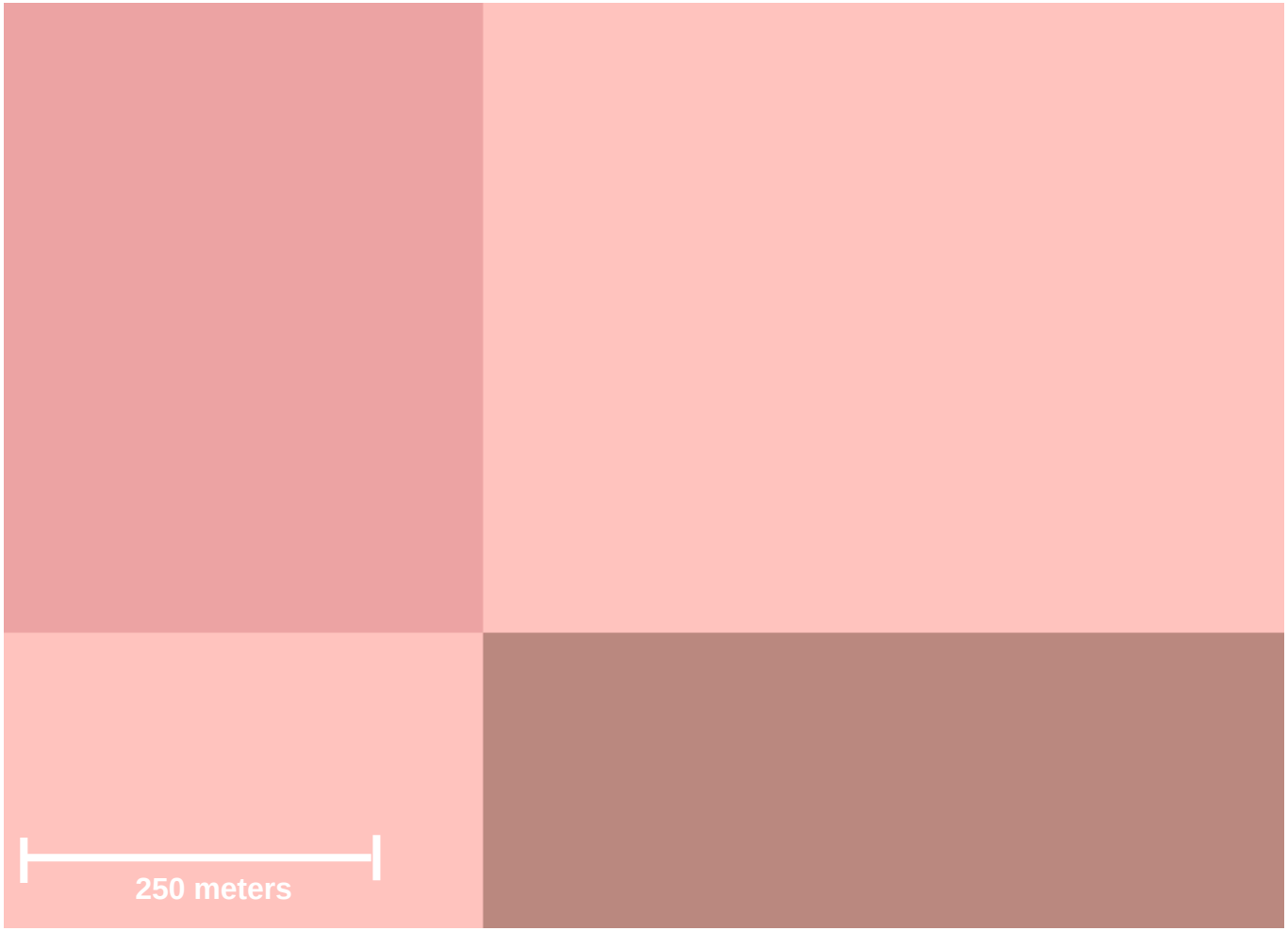
Landsat TM Example – 30 meter



Landsat Thematic Mapper (TM) - 30 meter resolution

(GeoEye/Space Imaging)

AVHRR Example – 1.1 kilometer



US AVHRR Weather/Environmental satellite sensor - 1.1 kilometer resolution

(NOAA)

Global Climate Observatories

- Long-term observations in climate, terrestrial and marine ecosystems
- Large, multi-sensor platforms
- Generally coarse resolution
- Multinational sensor systems
- Hyperspectral and large multispectral systems
- Large proportion of microwave sensors for aerosols, clouds, etc.
- Sensors carried on multiple missions

TERRA - (US) - Formerly EOS-AM

ASTER - Three radiometers, visible thru thermal, 15-90 meter resolution, surface temperature and composition

MODIS - Moderate resolution radiometer, 36 spectral bands, 250-1000 meter resolution, land, ocean, atmospheric mapping

CERES - Two scanning radiometers, 20 km resolution, thermal measurements of clouds and radiant energy

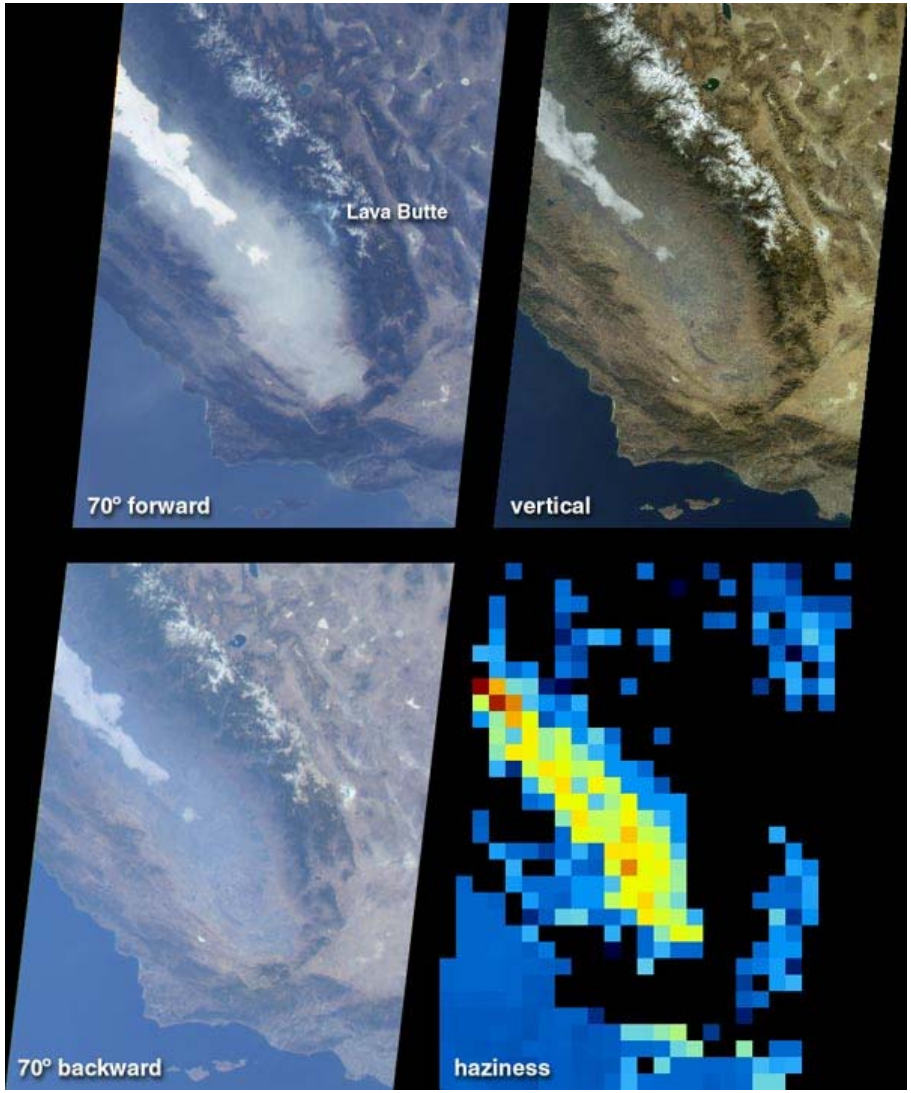
MISR - Nine cameras looking forward and backward, 275 meter to 1.1 km resolution, measurements of haze and aerosol properties

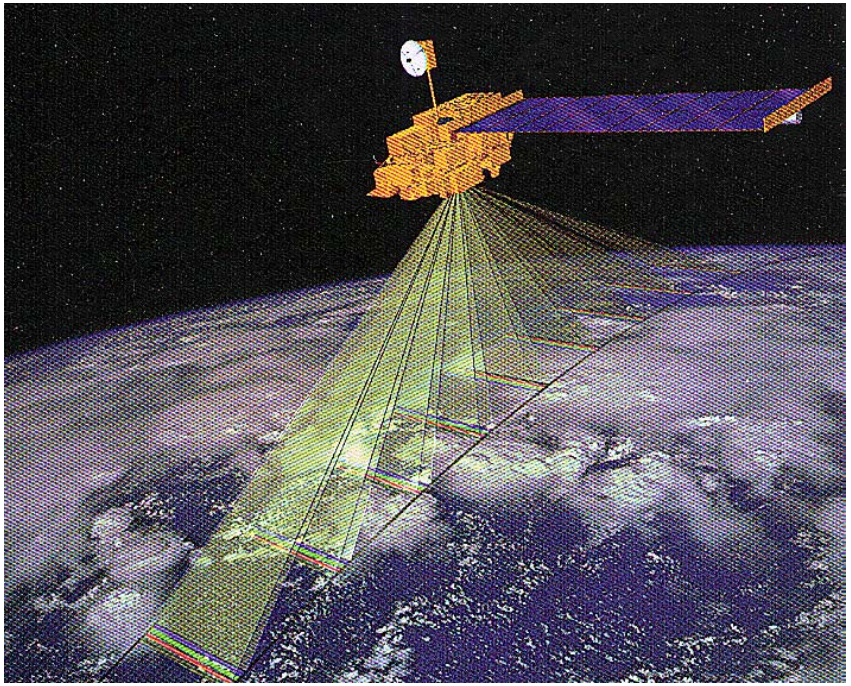
MOPITT - Radiometer operating in three regions of the near infrared, 22 km resolution, measures carbon dioxide and methane

Launched: Dec. 18, 1999

http://eos-am.gsfc.nasa.gov

MISR Image Example - Haze Measurement





AQUA - (US) - Formerly EOS-PM

AMSR - Advanced microwave radiometer, 4-75 kilometer resolution, clouds, precipitation, surface temperature, ice and snow

MODIS - Moderate resolution radiometer, 36 spectral bands, 250-1000 meter resolution, land, ocean, atmospheric mapping

CERES - Two scanning radiometers, 20 km resolution, thermal measurements of clouds and radiant energy

AMSU - Microwave sounder, atmospheric temperature and humidity

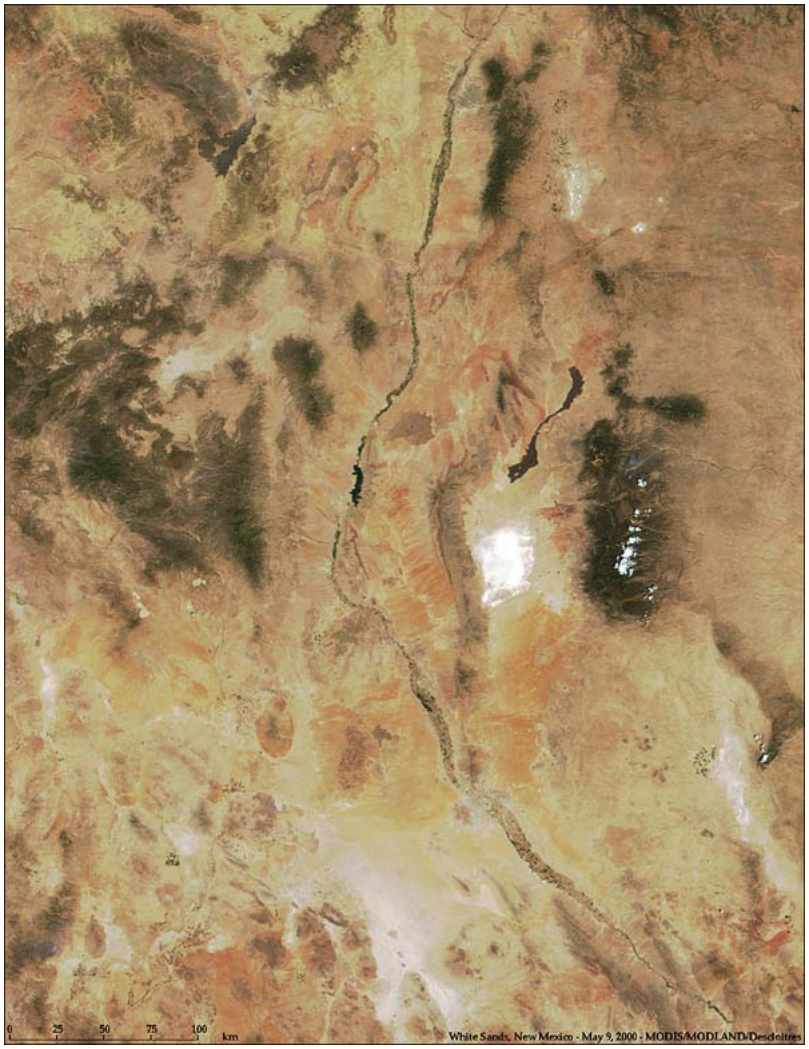
AIRS - Atmospheric infrared sounder, 2,300 channels, atmospheric temperature, humidity, surface temperature, clouds

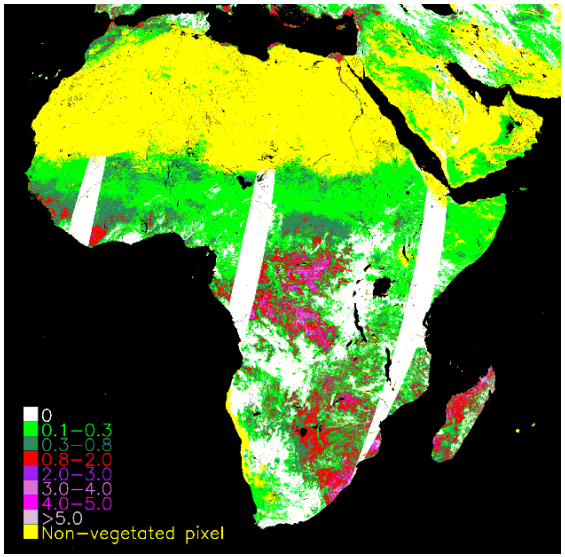
HSB - Humidity sounder for Brazil, measures atmospheric humidity

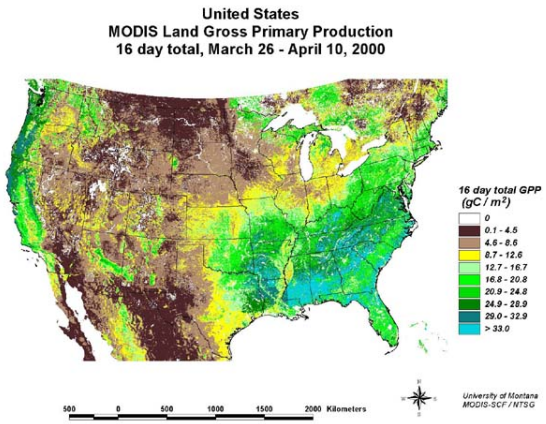
Launch: Last half of 2001

http://eos-pm.gsfc.nasa.gov

AQUA - Examples of MODIS Imagery Products







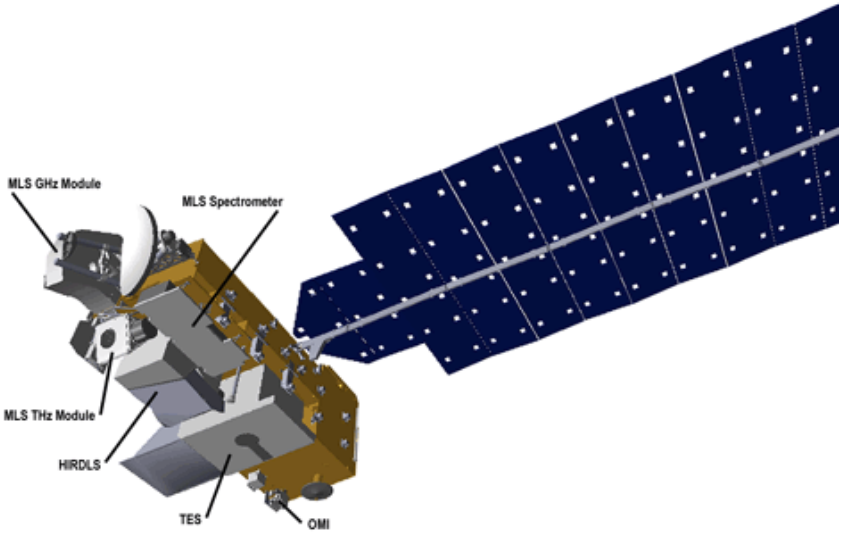
AURA – (US) – Formerly EOS-CHEM

HIRDLS – Infrared sounder for atmospheric gases, aerosols, cloud tops wind measurements

MLS - Microwave limb sounder, measures temperatures and gases in the lower atmosphere, ozone in the middle and upper atmosphere, and water in the troposphere, volcanic plumes

OMI - Hyperspectral imager for ozone and climate parameters, 740 channels, 13 km resolution,

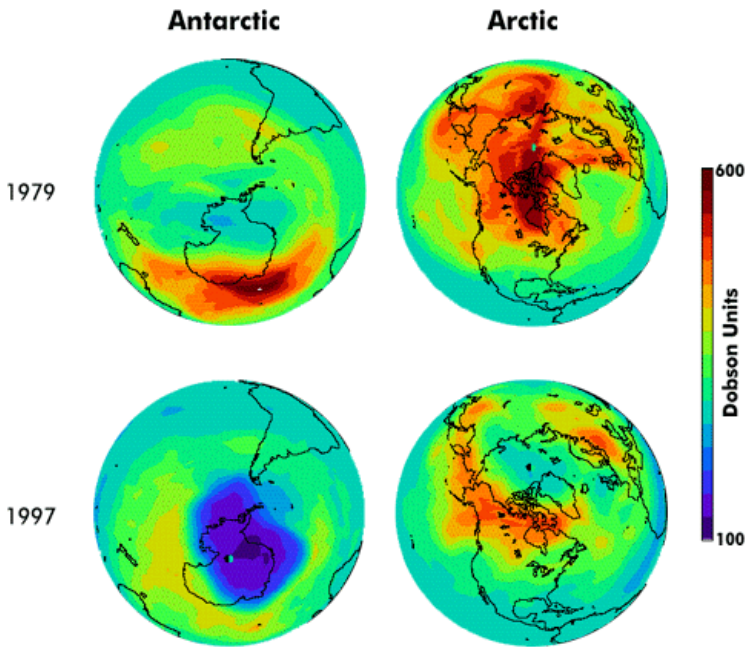
TES - Tropospheric emission spectrometer, thermal examination of atmospheric gases

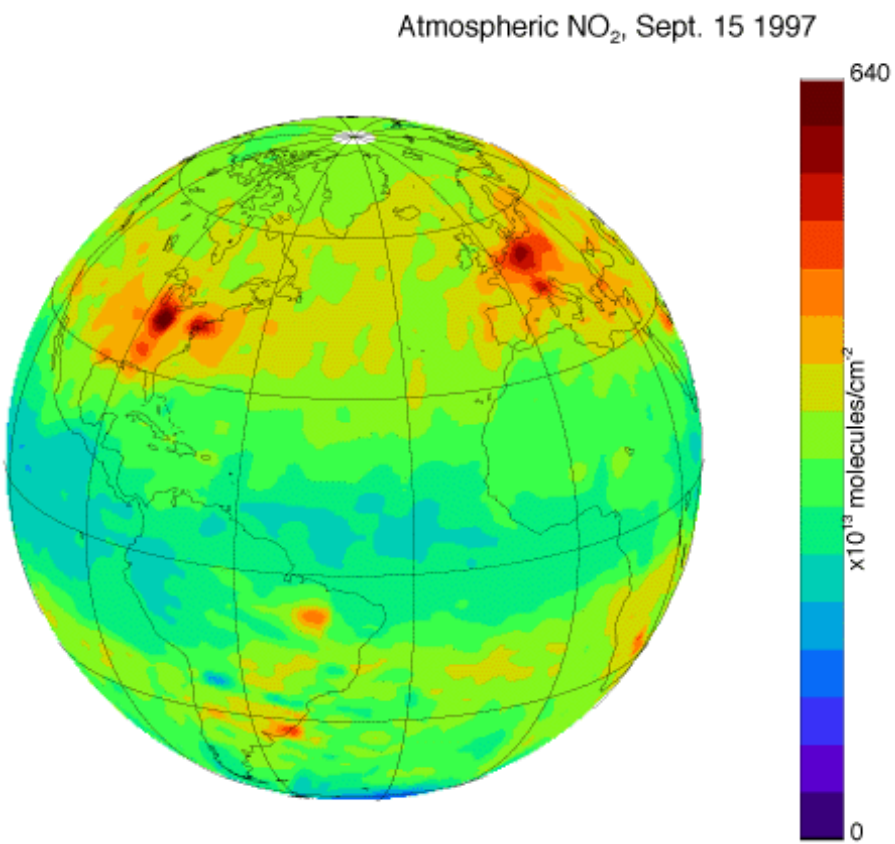


Launch: June 2003

http://eos-chem.gsfc.nasa.gov

AURA – (US) – Formerly EOS-CHEM





EO-1 - (US) – Earth Observing - 1

Launched: Nov. 21, 2000

Hyperion – Hyperspectral imager, 220 spectral bands, 30 meter resolution, image swath of 7.5 km x 100 km,

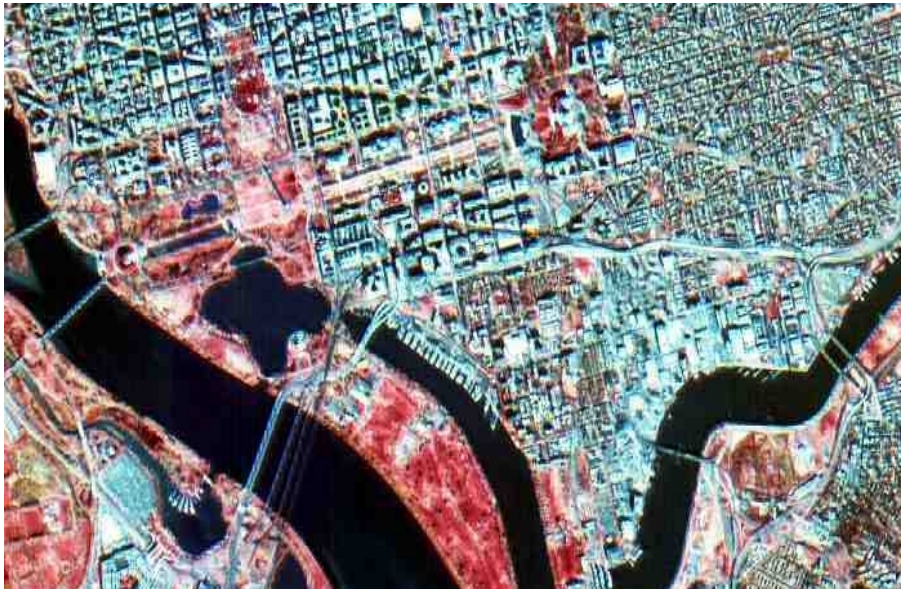
ALI - Advanced Land Imager. Basically a test bed copy of Landsat TM spectral bands but with substantial savings in mass, volume, and cost.

AC - Atmospheric Corrector. First space-based test of an atmospheric corrector to increase accuracy of surface reflectance estimates. High spectral resolution, moderate spatial resolution, correction primarily for water vapor.

Flying in formation one minute behind Landsat 7

http://eo1.gsfc.nasa.gov

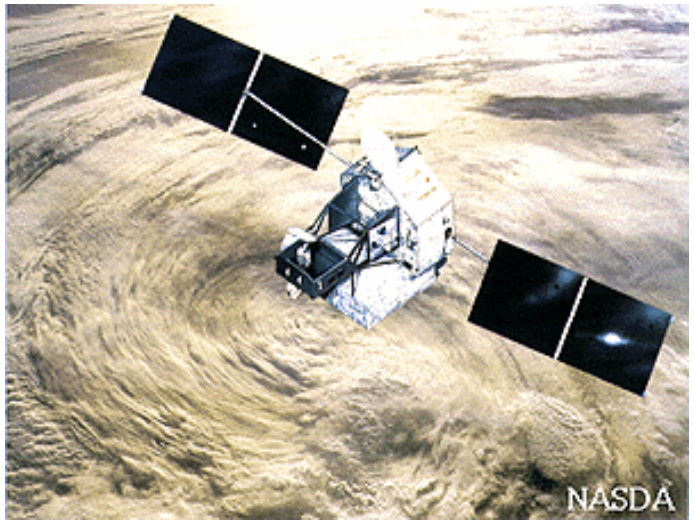
EO-1 - (US) – Earth Observing - 1



Advanced Land Imager - Washington D.C.

Hyperion hyperspectral image - Argentina

TRMM - (US/Japan) - Tropical Rainfall Measuring Mission



- Launched in 1997
- Cooperative program between US & Japan
- Rainfall measure 35 ° N & S of equator
- Aid in understanding water cycle and energy budget
- Current uncertainties in tropical rainfall up to 50%
- 5 sensors

Precipitation Radar

TRMM Microwave Imager

Visible Infrared Radiometer

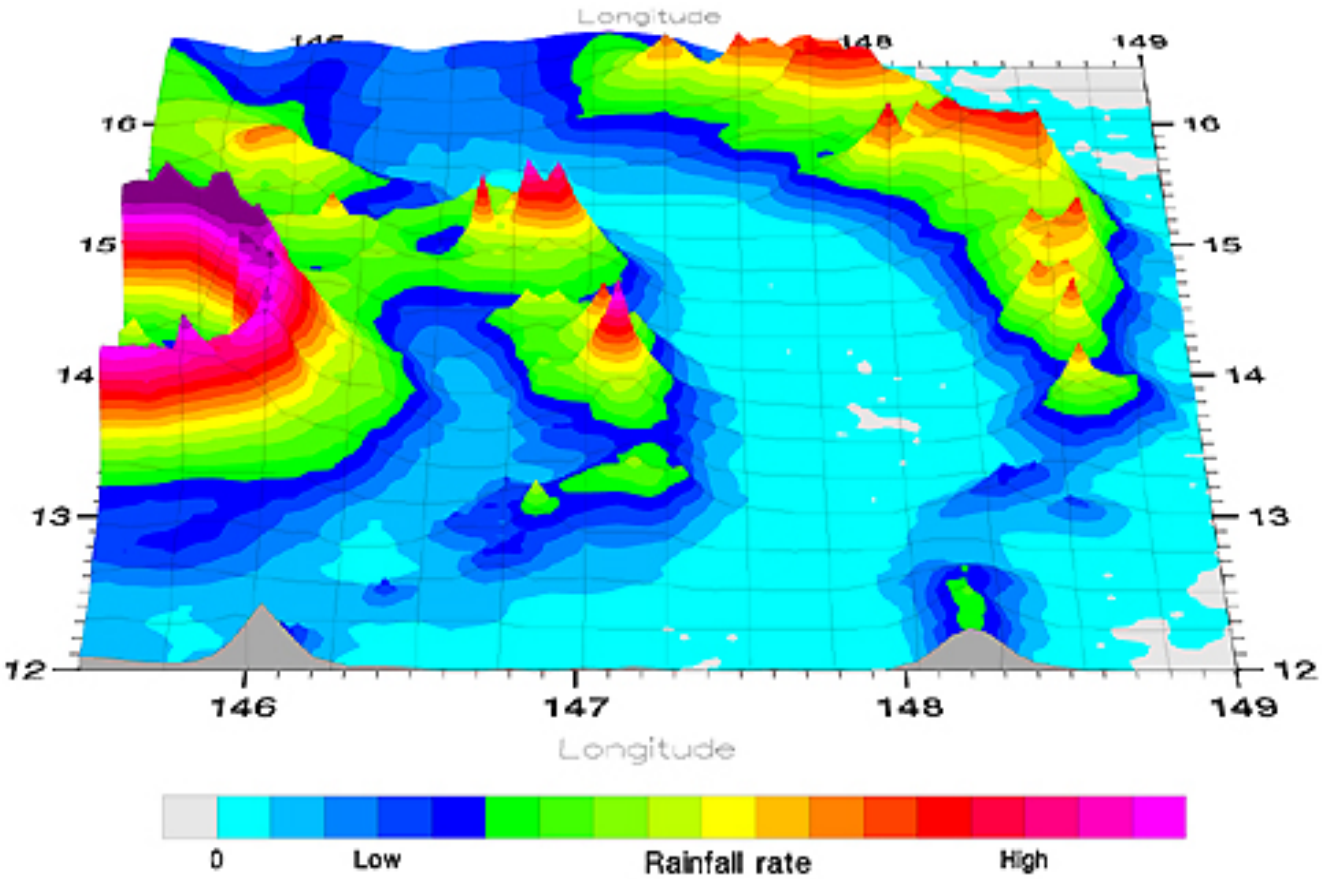
Cloud Sensor (CERES)

Lightning Imaging Sensor

- http://trmm.gsfc.nasa.gov

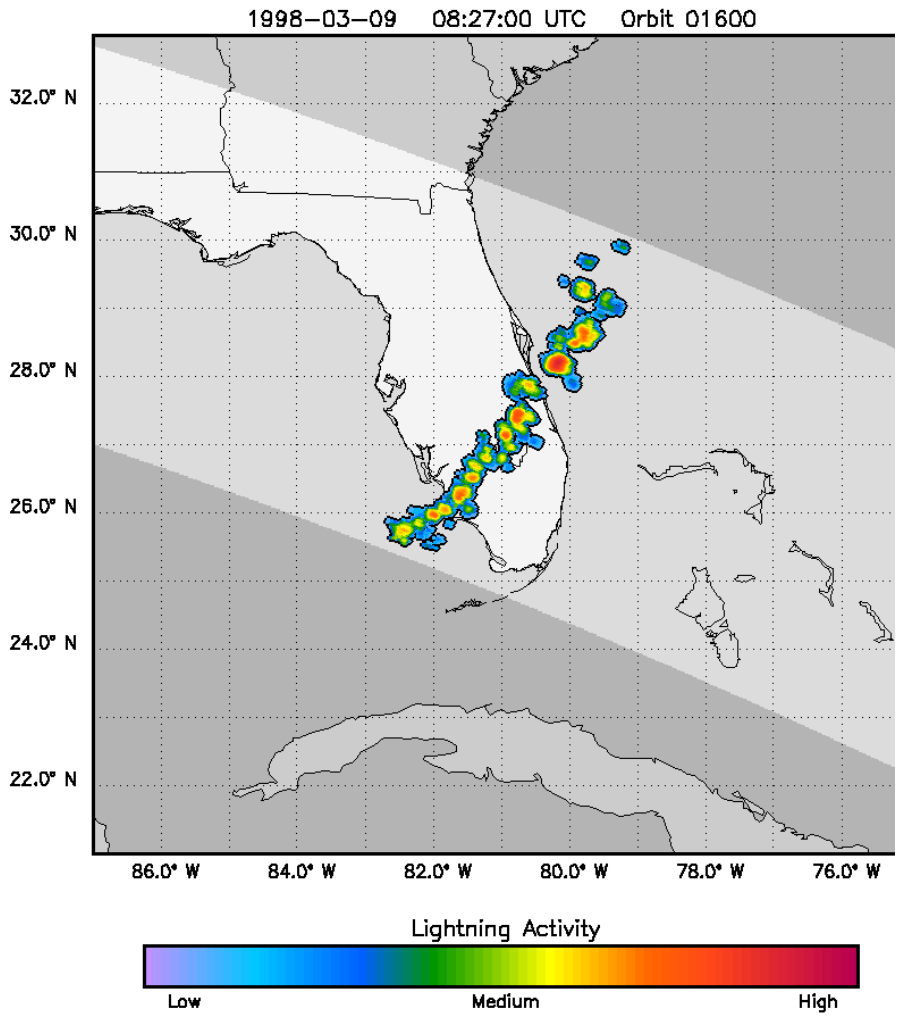
TRMM - (US/Japan) - Tropical Rainfall Measuring Mission

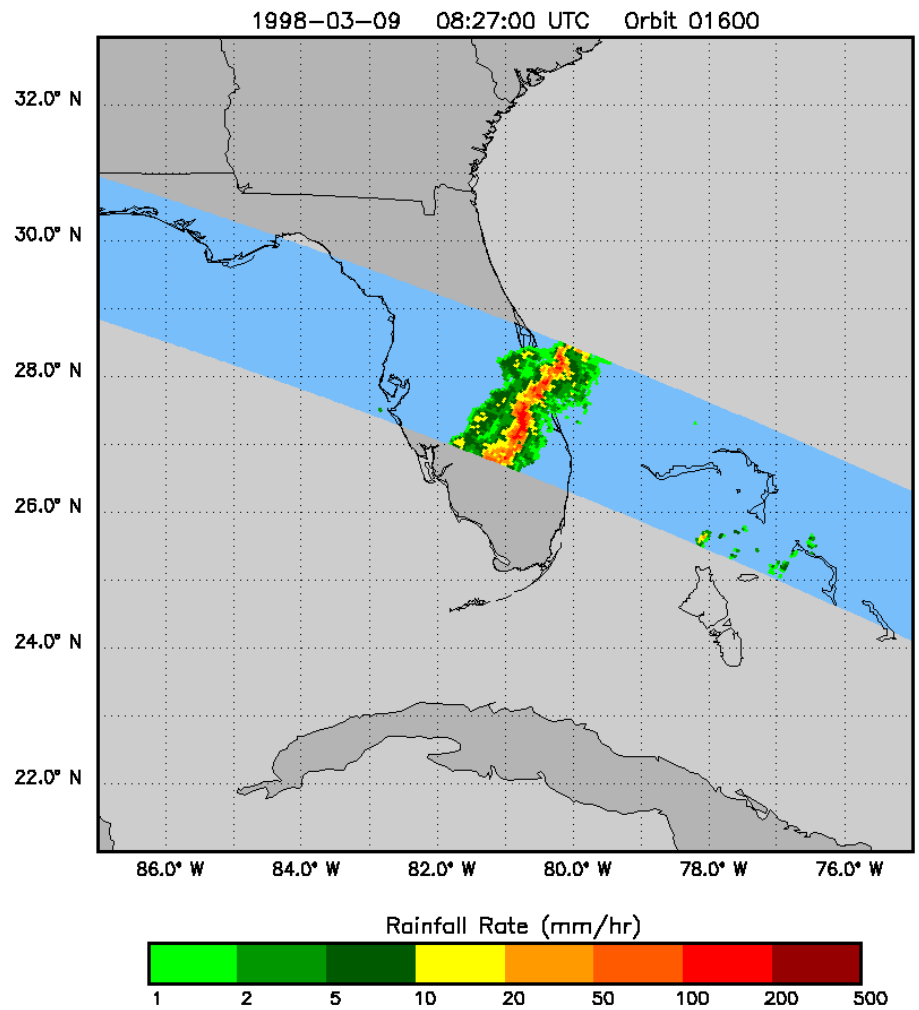
TRMM Microwave Imager Data (TMI)



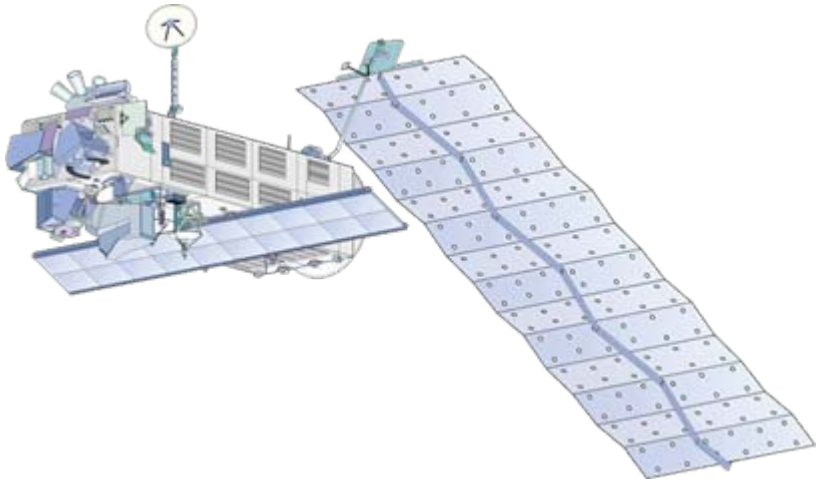
Section Through Typhoon Paka, 0443Z, 16th December 1997

TRMM - (US/Japan) - Tropical Rainfall Measuring Mission





ENVISAT - (European Space Agency)



- To be launched by ESA in July of 2001
- Designed as a follow-on to ERS series
- Will carry ten sensors

- **ASAR** - Synthetic Aperture Radar
- **GOMOS** - Global ozone monitor (1.7 km res.)
- **LRR** - Laser Retroreflector (altitude calibration)
- **MIPAS** - Michelson Interferometer (trace gases)
- **MERIS** - Medium resolution Imaging spectrometer (300 meter res., 15 bands)
- **MWR** - Microwave Radiometer (water vapor)
- **RA-2** - High precision radar altimeter
- **AATSR** - Scanning radiometer – sea temp.
- **DORIS** - Doppler tracking system
- **SCIAMACHY** - Absorption spectrometer

http://envisat.esa.int

Sensor Characteristics and Prices, as of April 2001

Satellite	Resolution (meters)	Spectral Bands	Footprint (km)	Revisit Time	Launched	Cost
Landsat 4,5	28.5 (120 TIR)	7	170 x 185	16 Days	1982, 1984	$600
Landsat 7	30 (60 TIR, 15 BW)	8	170 x 185	16 Days	Apr. 1999	$600
SPOT 1-3	20 MSS, 10 BW	3	60 x 60	26 Days *	1986, 1990, 1993	$750-$2,500
Spot 4	20 MSS, 10 BW, 1000 Mid-IR	4	60 x 60	26 Days *	Mar. 1998	$750-$2,500
Radarsat	10-100	1 (C-band)	50 x 50, 500 x 500	5-10 Days	1995	$1,500-$3,750
IRS	5.8 BW, 20 MSS	5	70 x 70, 140 x 140	24 Days *	1995	$900-$2,500
KVR-1000						
Old	1	1	40 x 40	Irregular	80s to early 90s	$25 sq. km.
New	1	1	40 x 40	Irregular	1998, 2000	$25 sq. km.
Ikonos	1 BW, 4 MSS	1, 4	11 x 11	1-3 Days	Sep. 1999	$18--$35 sq. km.
QuickBird	0.61 BW, 2.5 MSS	1, 4	22 x 22	1-5 Days	2001?	TBD
OrbView-3	1 BW, 4 MSS	1, 4	8 x 8	>3 Days	2001?	TBD
OrbView-4	1 BW, 4 MSS, 8 Hyper	1, 4, 8	8 x 8, 5 x 5	> 3 Days	2001?	TBD
EROS – A1	1.8	1	12.5	2 Days	Dec. 2000	$1,500

BW – Black & White
MSS – Multispectral Scanner
Mid-IR – Middle Infrared (reflective)

Hyper - Hyperspectral
TIR – Thermal Infrared

* More frequent coverage available using off-vertical viewing

Earth Data Analysis Center

Bandelier Hall West
University of New Mexico
Albuquerque, New Mexico 87131
505-277-3622, ext. 242
tbudge@edac.unm.edu