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Medium Spatial Resolution Satellite Characterization

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Remote Sensing Technologies

U.S. Department of the Interior
U.S. Geological Survey

Project Introduction

- **USGS Remote Sensing Technologies (RST) Project**
  - **calval.cr.usgs.gov**
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- Project provides:
  - characterization and calibration of *aerial and satellite systems* in support of quality acquisition and understanding of remote sensing data,
  - and verifies and validates the associated data products with respect to ground and atmospheric truth so that accurate value- added science can be performed.
  - assessment of new remote sensing technologies

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System/Product Characterization

- **System Characterization is related to understanding the sensor system, how it produces data, and the quality of the produced data**
- **Imagery attempts to accurately report the conditions of the Earth's surface at a given the time.**
  - Assessed by *product characterization* categories:
    - **Geometric/Geodetic:** The positional accuracy with which the image represents the surface (pixel coordinates vs. known ground points)
    - **Spatial:** The accuracy with which each pixel represents the image within its precise portion of the surface and no other portion
    - **Spectral:** The wavelengths of light measured in each spectral "band" of the image
    - **Radiometric:** The accuracy of the spectral data in representing the actual reflectance from the surface
    - **Dataset Usability:** The image data and understanding of the data is easily usable for science application

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Medium Resolution Characterization

- **DCWG "Data Characterization Working Group" feeds Tech Group**
  - GSFC Team led by Brian Markham
  - SSC Team led by Tom Stanley
  - USGS Team led by Greg Stensaas
- **Using JACIE methods**

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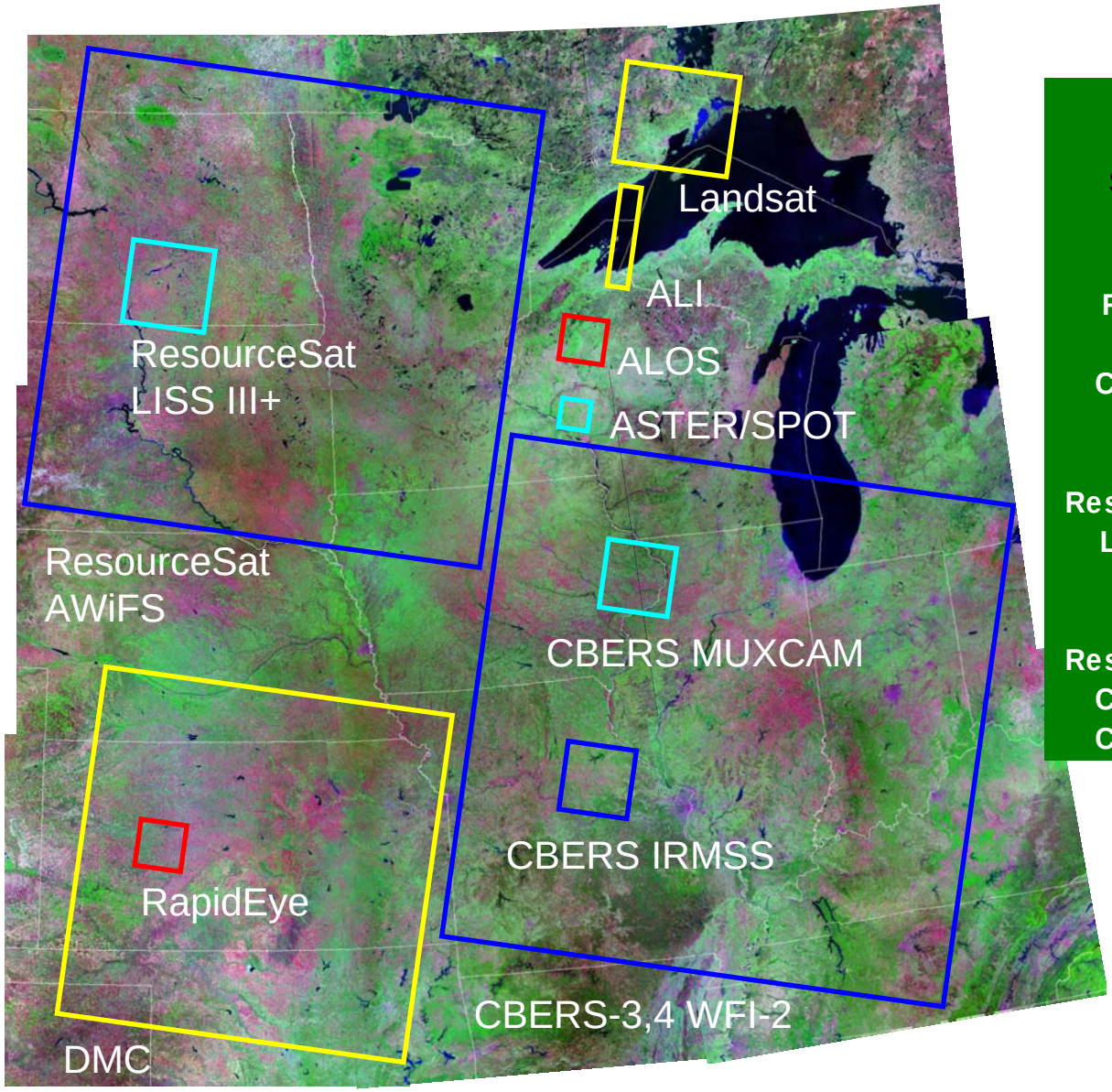
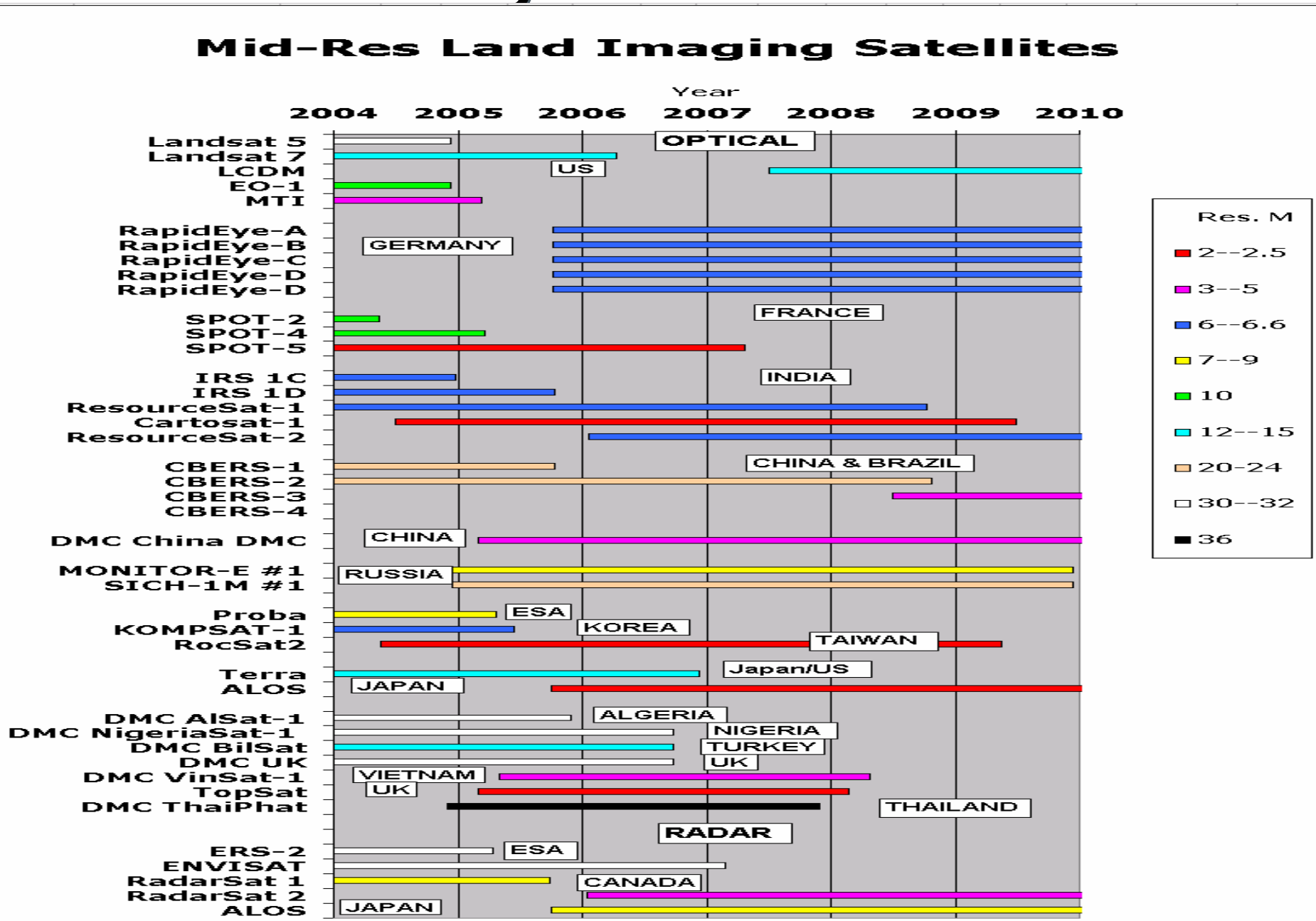
Data Scene Characteristics



Satellite	Sensor	Ground Sample Distance (m)
RapidEye	REIS	6.5
ALOS	AVNIR	10
CBERS-3,4	MUXCAM	20
SPOT 5	HRG	10/20
Terra	ASTER	15/30/90
ResourceSat-1	LISS III+	23.5
Landsat 7	ETM+	15/30/60
EO-1	ALI	30
DMC	MSDMC	32
ResourceSat-1	AWiFS*	56
CBERS-3,4	WFI-2	73
CBERS-3,4	IRMSS	40/80

Note: For purposes of scene size comparison only. Locations do not represent actual orbital paths or operational acquisitions.

ASPRS Study


Mid-Res Land Imaging Satellites
Year
2004
2005
2006
2007
2008
2009
2010
Landsat 5
Landsat 7
LCDM
EO-1
MTI
OPTICAL
US
RapidEye-A
RapidEye-B
RapidEye-C
RapidEye-D
RapidEye-D
GERMANY
SPOT-2
SPOT-4
SPOT-5
FRANCE
IRS 1C
IRS 1D
ResourceSat-1
Cartosat-1
ResourceSat-2
INDIA
CBERS-1
CBERS-2
CBERS-3
CBERS-4
CHINA & BRAZIL
DMC China DMC
CHINA
MONITOR-E #1
SICH-1M #1
RUSSIA
Proba
KOMPSAT-1
RocSat2
ESA
KOREA
TAIWAN
Terra
ALOS
Japan/US
JAPAN
DMC AlSat-1
DMC NigeriaSat-1
DMC BilSat
DMC UK
DMC VinSat-1
TopSat
DMC ThaiPhat
ALGERIA
NIGERIA
TURKEY
UK
VIETNAM
UK
THAILAND
RADAR
ERS-2
ENVISAT
RadarSat 1
RadarSat 2
ALOS
ESA
CANADA
JAPAN
Res. M
2--2.5
3--5
6--6.6
7--9
10
12--15
20-24
30--32
36

Systems Considered

- IRS ResourceSat – 1, 2 (India)
- CBERS – 2, 2A, 3, 4 (China & Brazil)
- RapidEye – 1, 2, 3, 4, 5 (Germany)
- DMC (Algeria, Nigeria, UK, China)
- Terra/ASTER (US & Japan)
- High-resolution U.S. commercial systems
- SPOT – 4, 5 (France)
- ALOS (Japan)
- EO-1/ALI (US)

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Advanced Land Observing Satellite (ALOS)

- ALOS to be launched in 2005 by Japan Aerospace EXploration Agency (JAXA)
- Revisit time is 46 days, but it can observe any area within 2 days
- Orbital altitude/inclination: 692 km/~98 degrees
- Nodal crossing: 10:30 a.m.
- System life: 3 - 5 years
- Three instruments devoted to land imaging
  - **Panchromatic Remote Sensing Instruments for Stereo Mapping (PRISM)**
  - **Advanced Visible and Near Infrared Radiometer (AVNIR-2)**
  - **Phased Array L-band Synthetic Aperture Radar (PALSAR)**
- Availability of data and products, data policy, and pricing is TBD
- Website: http://alos.nasda.go.jp/

	PRISM	AVNIR-2	PALSAR
Sprectral bands	0.52-0.77um	0.42-0.50um 0.52-0.60um 0.61-0.69um 0.76-0.89um	1.27GHz (L-ba
Resolution	2.5m	10m	10m/100m
Swath width	35km/70km	70km	70km/350km
Pointing (+-)	1.5 degrees	44 degrees	10-51 degree
Revisit	-	2 days	2 days
Actual revisit	46 days	46 days	46 days

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Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)

- ASTER was launched on December 18, 1999 on the Terra satellite
- Orbital altitude/inclination: 705 km/98.2 degrees
- Nodal crossing: 10:30 a.m.
- System life: 6 years
- Three instruments are
  - **Visible and Near-Infrared Radiometer(VNIR)**
  - **Short Wave Infrared Radiometer (SWIR)**
  - **Thermal Infrared Radiometer(TIR)**
- Archive data sets are available at $60/scene
- Website: http://asterweb.jpl.nasa.gov/

	VNIR	SWIR	TIR
Sprectral bands	0.52-0.60um 0.63-0.69um 0.76-0.86um	1.60-1.70um 2.14-2.18um 2.18-2.22um 2.23-2.28um 2.29-2.36um 2.36-2.43um	8.12-8.47um 8.47-8.82um 8.92-9.27um 10.25-10.95um 10.95-11.65um
Resolution	15m	30m	90m
Swath width	60km	60km	60km
Pointing (+-)	24 degrees	8.55 degrees	8.55 degrees
Revisit	-	-	-
Actual revisit	16 days	16 days	16 days

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China-Brazil Earth Resources Satellite (CBERS 1-2)

- CBERS-1 launched on October 14, 1999; CBERS-2 on October 21, 2003; CBERS-2B to be launched in 2006
- Revisit time is 26 days
- Orbital altitude/inclination: 778 km/98.5 degrees
- Nodal crossing: 10:30 a.m.
- System life: 2 years
- Data only downlinked to Brazil and China, may commercialize in future
- Each satellite has 3 cameras (see below)
- Availability of data and products, data policy, and pricing is TBD
- Website: http://www.cbers.inpe.br/en/

	CCD	IRMSS	WFI
Sprectral bands	0.51-0.73um 0.45-0.52um 0.52-0.59um 0.63-0.69um 0.77-0.89um	0.50-1.10um 1.55-1.75um 2.08-2.35um 10.4-12.5um	0.63-0.69um 0.77-0.89um
Resolution	20m	80m/160m	260m
Swath width	113km	120km	890km
Pointing (+-)	32 degrees	none	none
Revisit	3 days	-	-
Actual revisit	26 days	26 days	5 days

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China-Brazil Earth Resources Satellite (CBERS 3-4)

- CBERS-3 to be launched in 2007 or 2008; CBERS-4 after 2007
- Revisit time is 26 days
- Orbital altitude/inclination: 778 km/98.5 degrees
- Nodal crossing: 10:30 a.m.
- System life: 2 years
- Each satellite will have 4 cameras (see below)
- Availability of data and products, data policy, and pricing is TBD
- Website: http://www.cbers.inpe.br/en/

	MUXCAN	PANMUX	IRMSS	WFI
Sprectral bands	0.45-0.52um 1.55-1.75um 0.52-0.59um 0.63-0.69um 0.77-0.89um	0.51-0.75um 0.51-0.85um 0.52-0.59um 0.63-0.69um 0.77-0.89um	0.76-0.90um 0.76-1.10um 1.55-1.75um 2.08-2.35um 10.4-12.5um	0.52-0.59um 0.63-0.69um 0.77-0.89um 1.55-1.75um
Resolution	20m	5m/10m	40m/80m	73m
Swath width	120km	60km	120km	866km
Pointing (+-)	32 degrees	32 degrees	none	none
Revisit	3 days	5 days	-	-
Actual revisit	26 days	none	26 days	5 days

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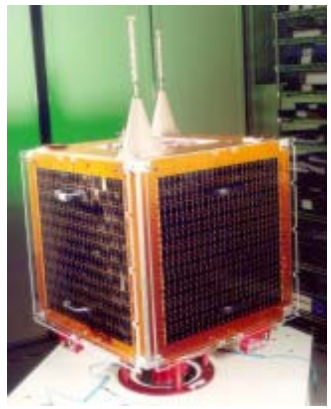
Disaster Monitoring Constellation (DMC)

- DMC is a constellation of microsatellites being developed by Surrey Satellite Technology Limited (SSTL) that would provide daily global coverage
- A five satellite constellation could collect 400-600 scenes/day
- Four satellites are currently operational; AlSAT-1 was launched on November 28, 2002; UK-DMC, NigeriaSat-1, and BILSAT-1 were launched on September 27, 2003
- An enhanced satellite for China will be launched in 2005
- Orbital altitude/inclination: 686 km/98 degrees
- Nodal crossing: 10:30 a.m.
- System life: 5 years
- Data characteristics are satellite dependent
- Availability of data and products, data policy, and pricing is TBD
- Website: http://www.sstl.co.uk/



	Standard	BILSAT-1	China DMC +4
	0.52-0.60um	0.52-0.60um	0.52-0.60um
	0.63-0.69um	0.63-0.69um	0.63-0.69um
Spectral bands	0.77-0.90um	0.77-0.90um	0.77-0.90um
		pan	pan
Resolution	32m	28m/ 12m	32m/ 4m
Swath width	600km	55km/ 24.5km	600km/
Pointing (+-)	-	30	-
Revisit	-	4-5 days	-
Actual revisit	4-5 days	16 days	4-5 days
Standard = AlSAT-1, NigeriaSat-1, UK-DMC			

Earth Observing-1 (EO-1)

- EO-1 was launched on November 21, 2000 by NASA, and continues today as the EO-1 Extended Mission operated by NASA and the USGS
- Revisit time is 16 days
- Cross track pointing: Three times in a 16 day cycle
- Orbital altitude/inclination: 705 km/98.2 degrees
- Nodal crossing: 10:15 a.m.
- System life: 1 year
- Two instruments devoted to land imaging
  - **Advanced Land Imager (ALI)**
  - **Hyperion**
- ALI, 9 multispectral bands at 30 m (0.43-0.45um, 0.45-0.51um, 0.52-0.60um, 0.63-0.69um, 0.77-0.80um, 0.84-0.89um, 1.20-1.30um, 1.55-1.75um, 2.08-2.35um) and 1 pan band at 10 m (0.48-0.69um)
- Swath width: 37 km by 42 km
- Capable of acquiring approximately 20 scenes/day on WRS-2 grid
- Archived data available at $250 or $500/scene; data acquisition requests are additional $1,500/scene
- Website: http://eo1.usgs.gov/ or http://eo1.gsfc.nasa.gov/

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RapidEye

- RapidEye to be launched in late 2007, a total of 5 satellites is proposed, all launched at once and 19 minutes apart on orbit
- Commercial effort focused on providing information to the agricultural and cartographic communities
- Revisit time is 1 day, average coverage repeat is < 5 days with all satellites operating
- Orbital altitude/inclination: 622 km/97.8 degrees
- Imaging area: +/- 75 degrees
- Cross track pointing: +/- 25 degrees
- Nodal crossing: 11:00 a.m.
- System life: 7 years
- Multi-Spectral Imager (push-broom scanner), 5 bands (0.44-0.51um, 0.52-0.59um, 0.63-0.685um, 0.69-0.73um, 0.76-0.85um)
- Ground resolution: 6.5 m
- Swath width: 78-80 km by 1,500 km
- Availability of data and products, data policy, and pricing is TBD
- Website: http://www.rapideye.de/

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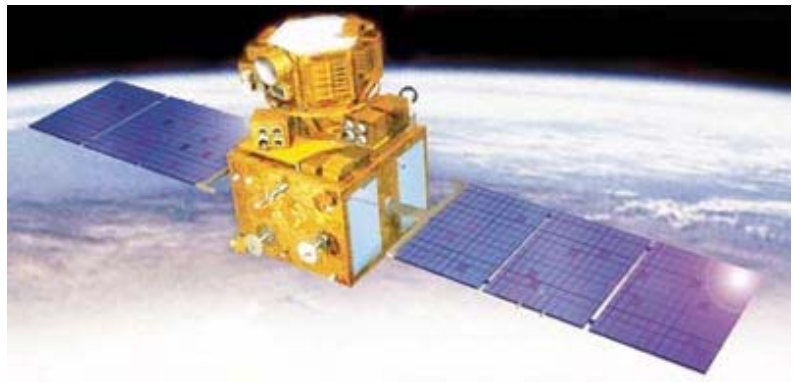
ResourceSat-1 (IRS-P6)

- ResourceSat-1 was launched on October 17, 2003 by Indian Remote Sensing (IRS)
- Orbital altitude/inclination: 817 km/98.69 degrees
- Nodal crossing: 10:30 a.m.
- System life: 5 years
- Three instruments devoted to land imaging
  - **Linear Imaging Self-Scanner (LISS-IV)**
  - **Linear Imaging Self-Scanner (LISS-III)**
  - **Advanced Wide Field Sensor (AWiFS)**
- Space Imaging has distribution rights outside of India
  - **LISS-III and LISS-IV are $2,750/scene; AWiFS is $850/scene**
- Website: http://www.spaceimaging.com/products/irs/



	LISS-IV	LISS-III	AWiFS
Sprectral bands	0.52-0.59um 0.62-0.68um 0.77-0.86um	0.52-0.59um 0.62-0.68um 0.77-0.86um 1.55-1.70um	0.52-0.59um 0.62-0.68um 0.77-0.86um 1.55-1.70um
Resolution	5.8m	23.5m	56m
Swath width	23.9km/70km	141km	740km
Pointing (+-)	26 degrees	-	-
Revisit	5 days	-	-
Actual revisit	24 days	24 days	5 days

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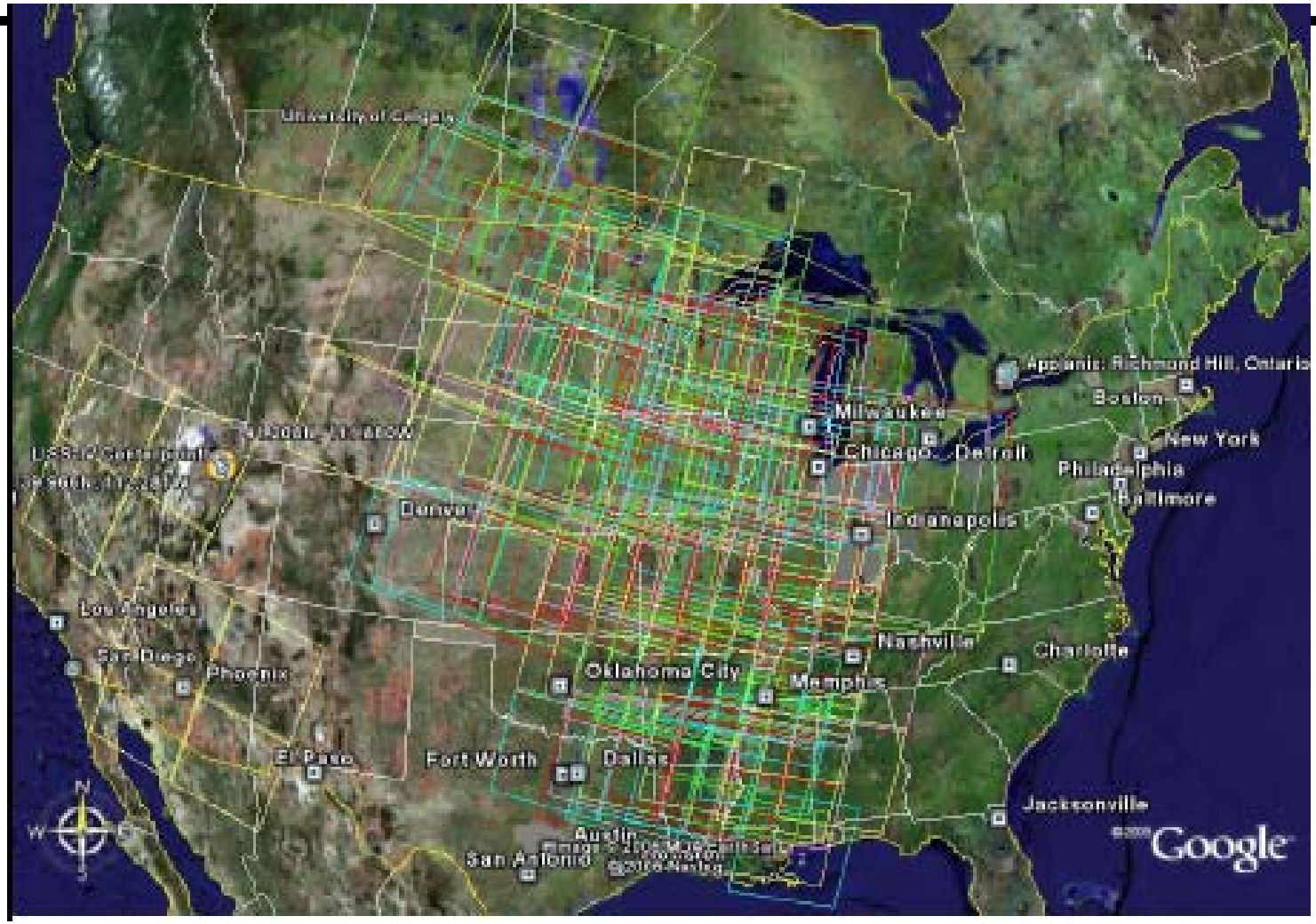
SPOT

- SPOT 2 was launched on January 22, 1990; SPOT 4 was launched on March 24, 1998; and SPOT 5 was launched on May 4, 2002
- Orbital altitude/inclination: 822 km/98.7 degrees
- Nodal crossing: 10:30 a.m.
- System life: 3 and 5 years for SPOT 2, and SPOT 4 and 5, respectively
- Instruments on each satellite
  - **SPOT 2 - High Resolution Visible (HRV)**
  - **SPOT 4 - High Resolution Visible Infra Red (HRVIR)**
  - **SPOT 5 - High Geometric Resolution (HRG)**
- Single user price of geometrically (systematic) corrected archive scene (systematic) ranges from $2,400 (10m/20m) to over $10,000 (2.5m color)
- Website: http://www.spotimage.fr/

	HRV	HRVIR	HRG
Sprectral bands	0.50-0.73um	0.61-0.68um	0.48-0.71um
	0.50-0.59um	0.50-0.59um	0.50-0.59um
	0.61-0.68um	0.61-0.68um	0.61-0.68um
	0.78-0.89um	0.78-0.89um	0.78-0.89um
		1.58-1.75um	1.58-1.75um
Resolution	10m/20m	10m/20m	2.5m/5m/10m/2
Swath width	60km	60km	60km
Pointing (+-)	27 degrees	27 degrees	27 degrees
Revisit	2-3 days	2-3 days	2-3 days
Actual revisit	26 days	26 days	26 days

USDA AWiFS Data



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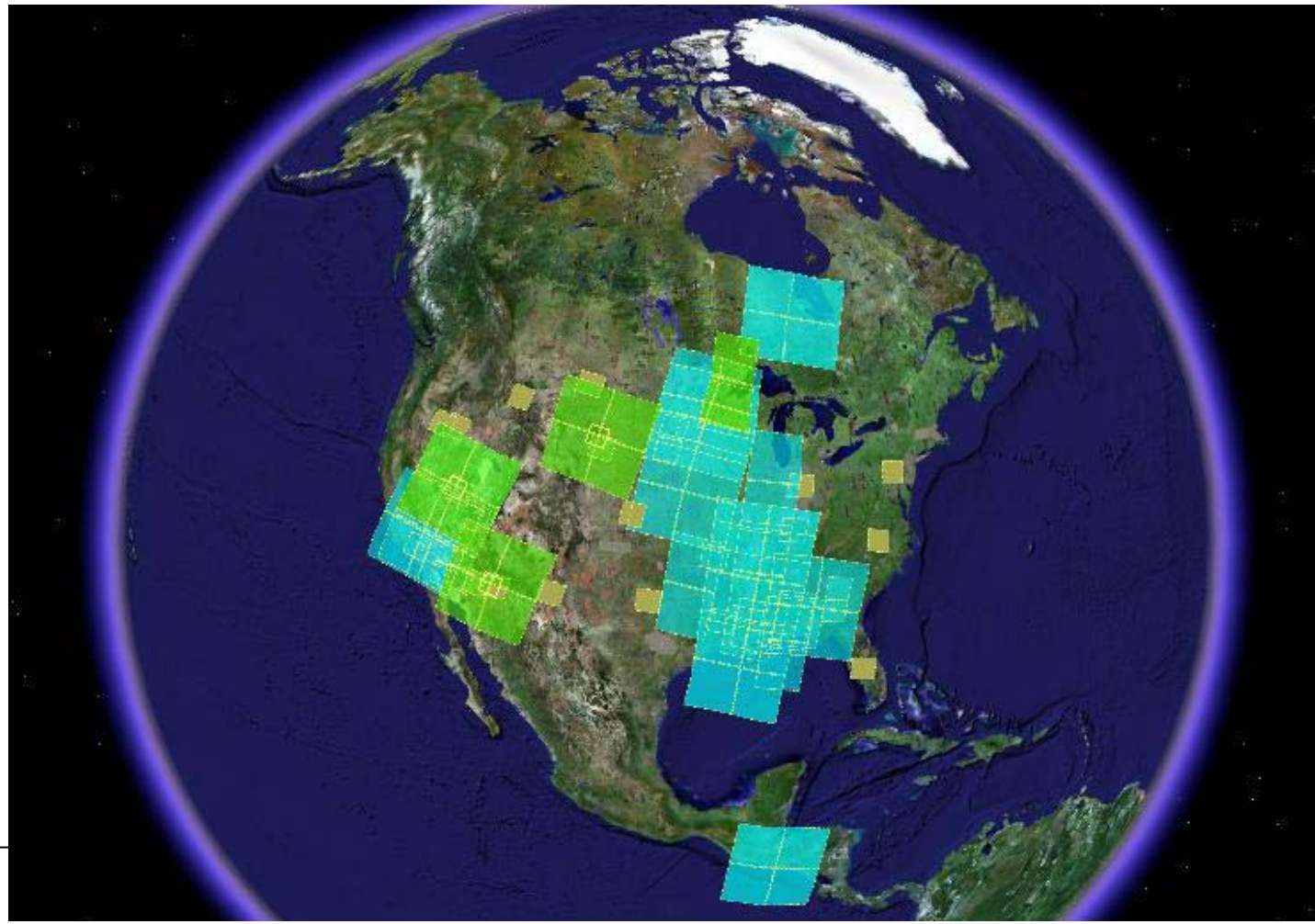
DCWG ResourceSat Holdings

- USGS Green, SSC Blue



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Satellite Characterization Summary (1)

- There are many instruments providing image data for civil science purposes
  - **Support of Global Earth Observing System of Systems**
- Some systems maybe available candidate sensing systems may be able to meet at least some of the needs of the Landsat user community.
- Technical advances have enabled the creation of many multi-spectral satellites
  - **14 -15 countries have mid to hi resolution satellites in orbit**
  - **By the end of the decade, there will be 20+ countries**
  - **66 Civil Land Imaging Satellites by 2010**
- All the data has value but it needs to be well understood
  - **System characterization and calibration needed**
    - **Cal parameter files and metadata important**
  - **Product verification and validation needed**
    - **Cross calibration and international test areas must be used**

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Satellite Characterization Summary (2)

- Assessing ResourceSat-1 (AWiFS, LISS-III LISS-IV), and SurreySat DMC, and working with INPE to access CBERS-2
- Technologies are becoming robust enough to fill niches and cheap enough to cover many areas; **<u>however, there are major issues to be address:</u>**
  - Resolution and required bands – SWIR bands?
  - Accuracy and stability
  - Calibration concerns/Cross calibration concerns
  - Data acquisition
  - Data availability
- Cross calibration requires a stable base with cross band coverage (GEOSS)
  - **Strong need for a base, long term mission (Landsat)**
- Precise high resolution data provides a great compliment to global assessment and is a must for ER

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Summary

- **JACIE teams moving forward in support of digital imagery processes and guidelines**
- **Satellite characterization efforts continue**
  - Future assessments – IRS-6, CBERS-2, DMC, TopSat, ChinaSat, ALOS, RapidEye, ….
- **Future is very bright – many new technologies – many new aerial and satellite products**
- **New systems and integrated products require characterization and calibration**
- **Strong position to support US GEO and GEOSS**
- **UAV and miniaturization technologies**
- **Real time products – what do we do with all the data?**
- **Forecasts available showing continued growth**

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Forecasts


10-Year Industry Forecast
Phases I-III – Study Documentation
GRAND PRIX FIRE
LAKE ARROWHEAD, CALIFORNIA
1-METER FALSE COLOR IKONOS® IMAGE


Survey and Analysis
of
Remote Sensing Market
Aerial and Spaceborne
Study Documentation 2005