High resolution sensors

corporate ventures authorised by Bill Clinton, 1993

.. And yet Radarsat 2 launch was delayed till 2007 ?

Costa Concordia
Jan 13, 2012

Worldview 1

Hunga-Tonga
Jan 7, 2022

Skysat, Planet Labs

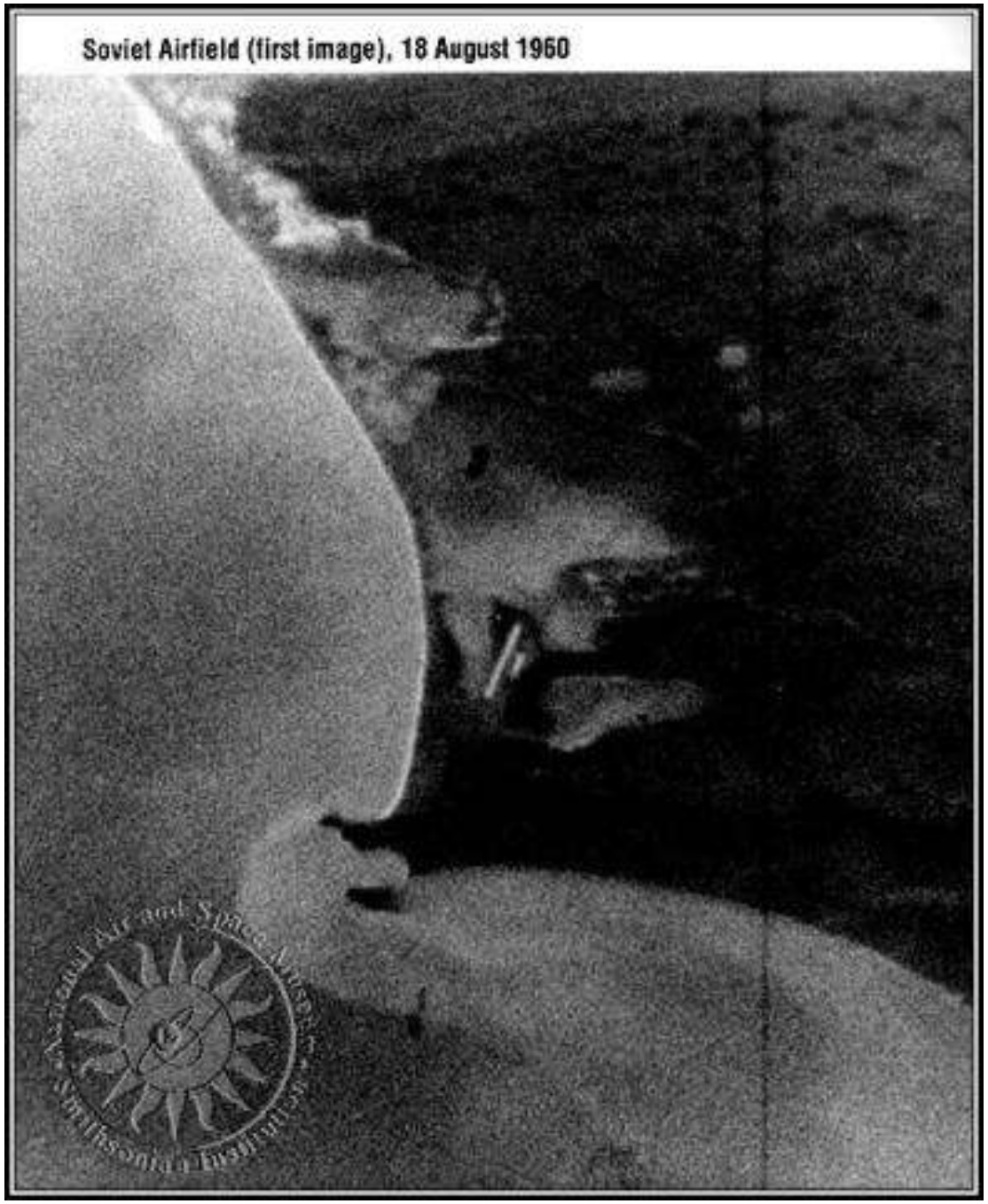
First US satellite spy photo – Soviet airfield in Siberia

Resolution 14m

Orbit altitude – 100 miles

Discover-14

1960



Spy satellites and movies

Movie

a. How satellites figure in the plot.

b. What it got right.

c. What it got wrong.

ICE STATION ZEBRA (1968)

a. A 16mm film capsule from a satellite falls in the Arctic and superpowers race to find it (based on a true story)

b. Early satellites did drop their film to Earth

c. The resolution of 16mm film isn't good enough to see anything

THE WORLD IS NOT ENOUGH (1999)

a. British spy satellite photographs James Bond in the sack with beautiful scientist

b. Not much

c. When did the British get a spy satellite?

CORONA satellite photography 1960-72

- America's first reconnaissance satellite program designed to take photos of the Soviet bloc countries
- Corona missions were officially top secret until 1992
- Photos became declassified on February 22nd, 1995

- 144 Corona satellites w launched and 102 returned usable photos
- 860,000 images of the earth's surface collected 1960 -1972

http://www.bukisa.com/topics/reconnaissance-satellites-of-the-united-states

Himalayas - glaciers

The Israeli Dimona nuclear reactor complex. Photographed by Corona satellite on November 11th, 1968.

A JC-130 recovery aircraft of the U.S. Air Force retrieves a Corona satellite film-return capsule, also known as a "bucket," over the Pacific Ocean. Photo credit: CSNR collection.

Images can be ordered from EROS Data Center:
http://edc.usgs.gov/products/satellite/corona.htm

EarthExplorer from USGS:
http://edcsns17.cr.usgs.gov/NewEarthExplorer/

This 1961 satellite photo shows Tell Rifaat in northwest Syria; it's now completely surrounded by a modern town.

Past, Current and Future Uses of Corona Photos

- Military purposes
- Photo-geologic mapping
- Identification of natural resources
- Agricultural land-cover classification
- Archaeological studies

A repository of earth resource information – CORONA satellite programme
Dashora, A., et al. 2007.

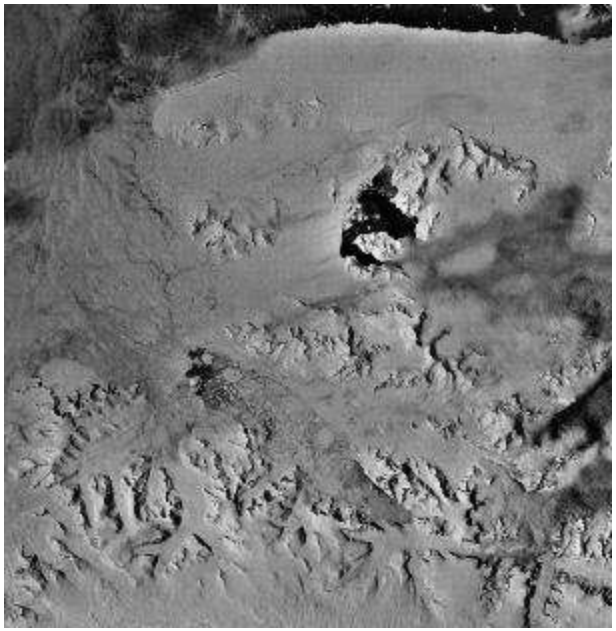
Digital surface model generation from CORONA satellite images
Altmaier, A. and C. Kany. 2002.

Satellite imagery and archaeology: the example of CORONA in the Altai Mountains
Goossens, R., et al. 2006.

Detection of archaeological crop marks on declassified CORONA KH-4B intelligence satellite photography of southern England
Fowler, M.J.F and Y.M. Fowler. 2005.

First Soviet 'high-res' spy satellite ~1960
Zenit 2 (-8)
camera ports visible
resolution 10m
>500 launched 1961-94

Antarctica 1973, Zenit 4, 15m res.



https://gis.stackexchange.com/questions/267711/is-there-an-online-catalog-for-declassified-soviet-union-spy-satellite-images-z

High resolution corporate satellites

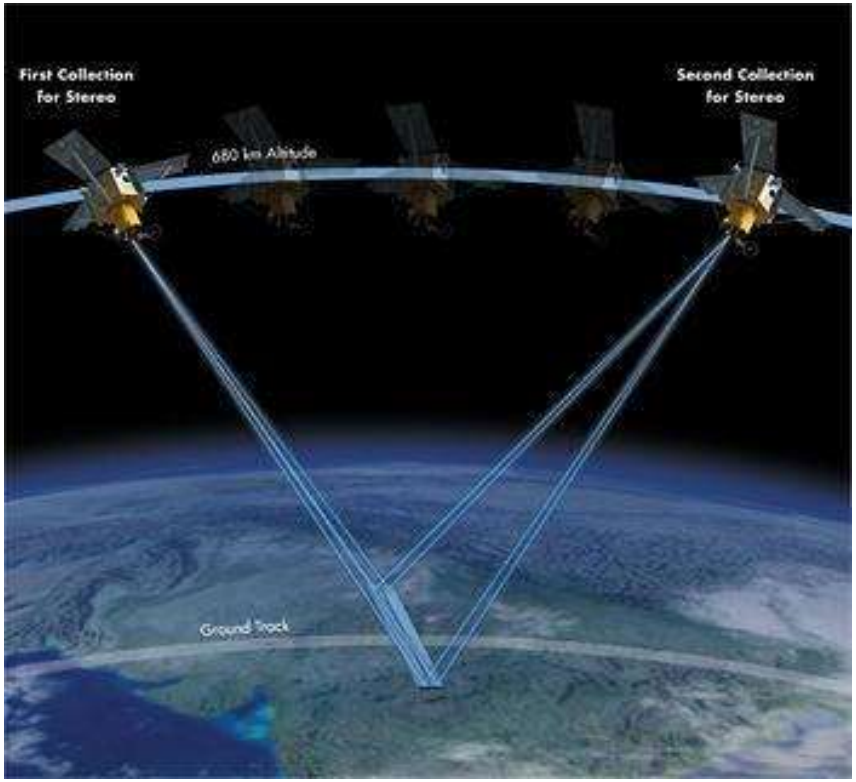
Ikonos: launched 1999; first data sold Jan 1, 2000 -> 2015

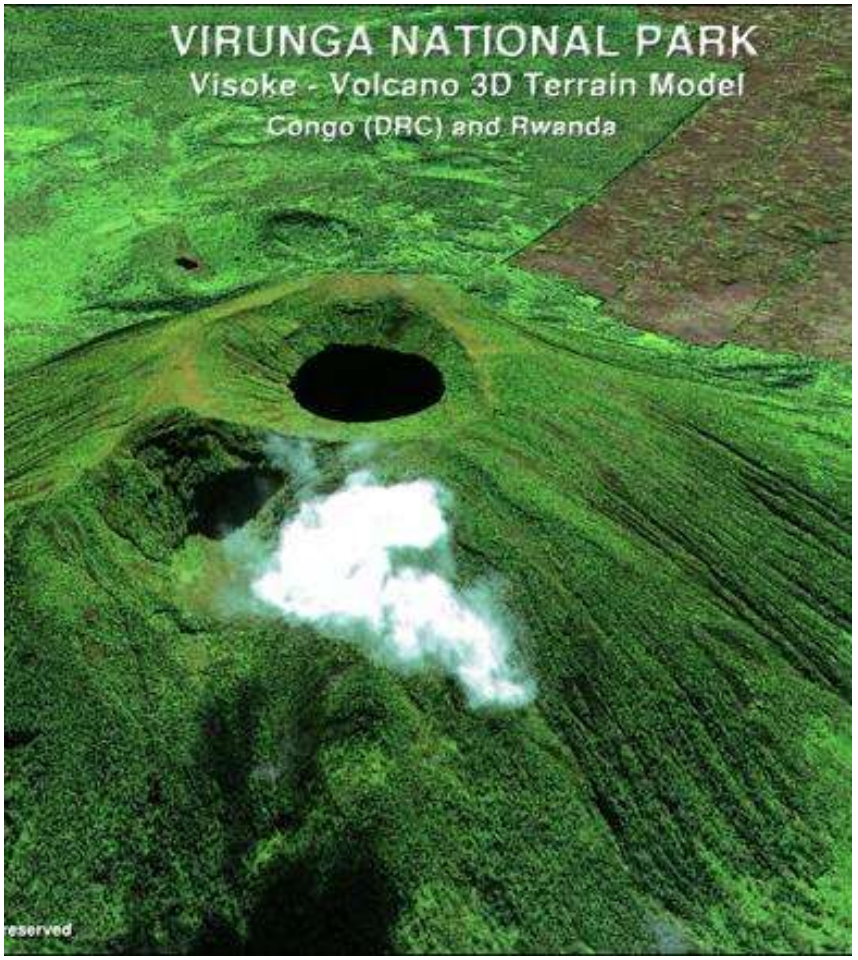
Resolution: Pan 1m Multispectral (BGRN) 4m;

Ikonos (from Greek *eikōn* → *image)*

Owner	GeoEye → now part of DigitalGlobe
Resolutions	4m multispectral 1 panchromatic
Bands	Blue (445-516nm) Green (506-595nm) Red (632-698nm) NIR (770-888nm) PAN (450-900nm)
Operational Dates	Jan 2000 to 2015
Data Cost	\$10 to \$45 per km^2 (from landinfo.com)
equatorial time	10:30 am
Revisit time	11 days but can be as little as 3 days with 45 degree viewing angle
Viewing angle	Can be rotated up to 45 degrees off nadir
Individual Image coverage	11km x 11km = $121km^2$
Altitude	681 km sun synchronous

Ikonos imagery is available in stereo due to maneuverability of viewing angle. Stereo pair are captured on same swath, moments apart to create DEM





Interesting applications/literature

- There was some excitement concerning the use of high resolution Ikonos imagery for forestry classifications.
- Ikonos facilitated shift in thinking. Rather than pixels as the medium of analysis, object oriented classification could be possible, such as individual tree crown analysis (ITC).

Carleer and Wolff. 2004. Exploitation of very high resolution satellite data for tree species identification. Photogrammetric Engineering & Remote Sensing. 70: 135-140.

Franklin et al. 2001. Texture analysis of IKONOS panchromatic data for Douglas-fir forest age class separability in British Columbia. International Journal of Remote Sensing. 22: 2627-2632.

Gougeon and Leckie. 2006. The individual tree crown approach applied to Ikonos images of a coniferous plantation area. Photogrammetric Engineering & Remote Sensing. 72: 1287-1297.

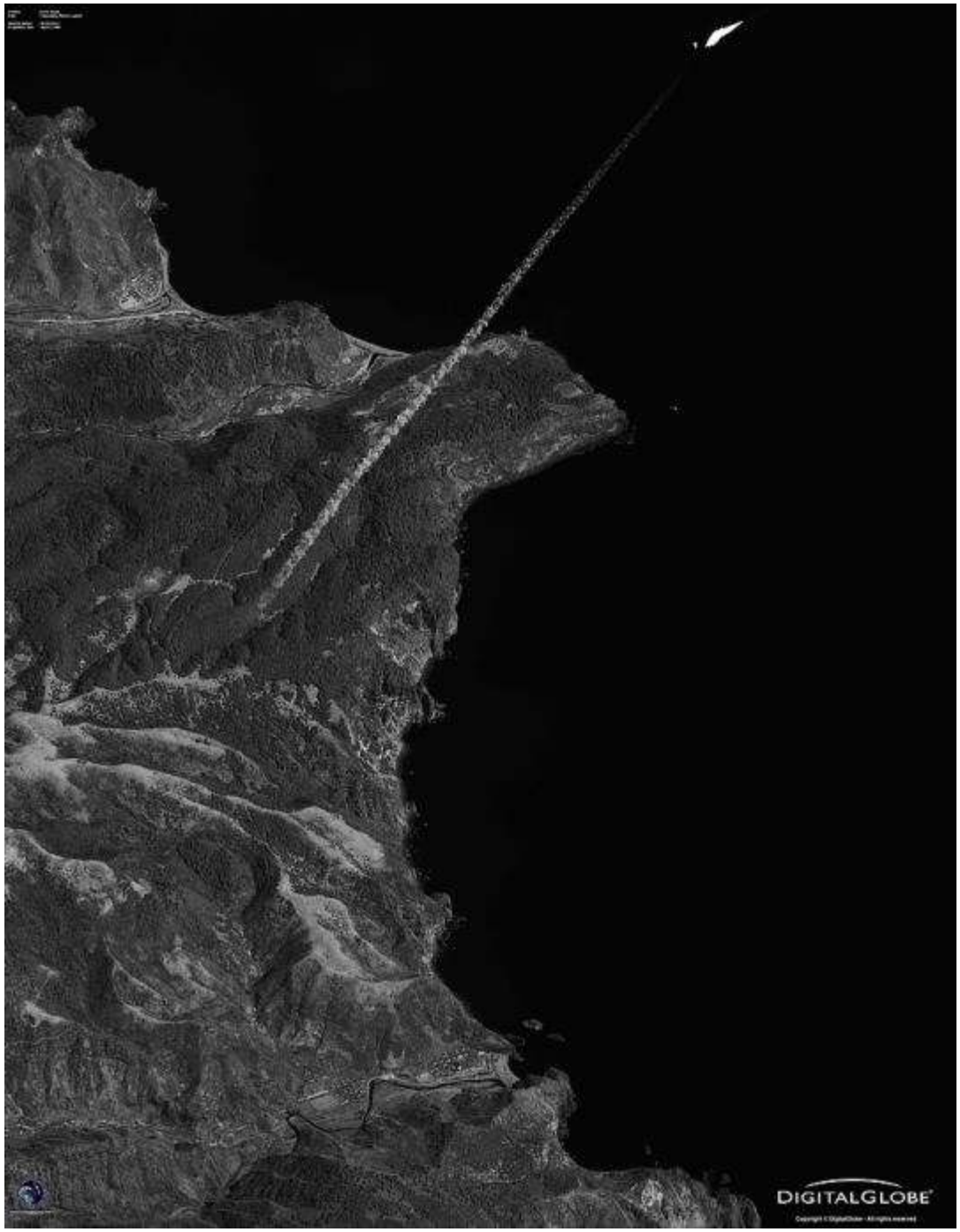
Imaging Olympic venues – including Vancouver 2010 ….

Quickbird (Oct) 2001 …. 2015

swath width :16.5km by 16.5km, Orbit 450km, 11 bit data
Multispectral resolution is 2.44m pan 61cm
Bands : PAN 405 -1053 nm
Blue: 430 – 545 nm
Green: 466 – 620 nm
Red: 590 – 710 nm
Near-IR: 715 – 918 nm

April 19, 2011, Quickbird was raised to an altitude of 482km to extend its life cycle. This has also changed the swath to 18km x 18km. Decayed 2015.


Country : North Korea
Area : Taepodong Missile Complex
Satellite Sensor : QuickBird
Acquisition Date : March 26, 2009
Resolution (GSD) : 0.6m
Launch Pad with Rocket
www.satimagingcorp.com
Copyright © DigitalGlobe - All rights reserved



April 5, 2009 WorldView-1 Satellite Image of Missile Launch in North Korea

WorldView-1 2007

- Owned by: DigitalGlobe/USA
- Operational: October 18th, 2007
- Resolution: 0.5 m; Panchromatic
- Cost: $13 sq km

Hamid Karzai airport
August 21, 2021

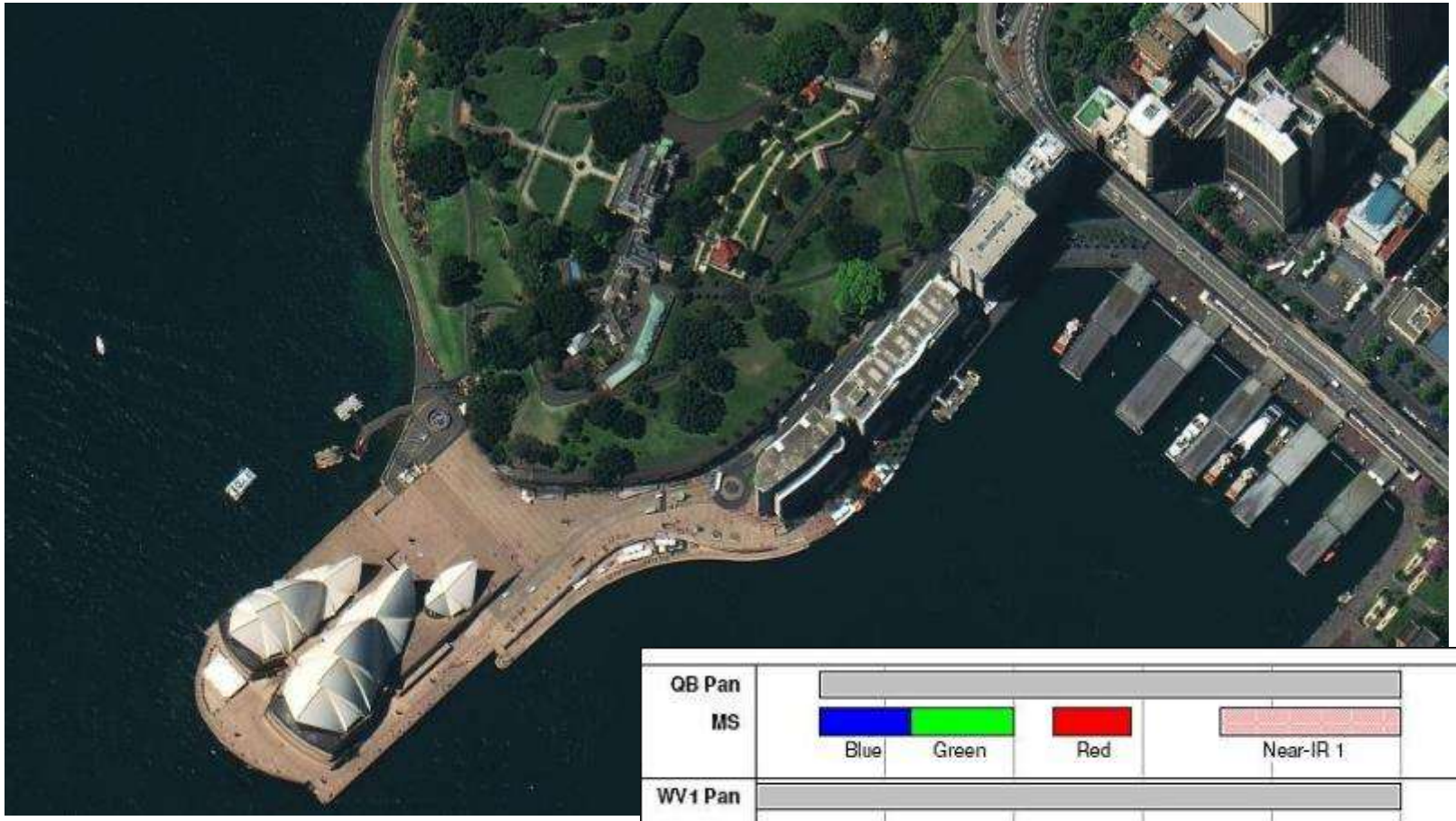
WorldView-1 and the Literature

- **Earthquake Damage Assessment of Buildings Using VHR Optical and SAR Imagery.**
  - QuickBird and **WorldView-1** (optical data), TerraSAR-X and COSMO-SkyMed (SAR data)
  - Uses a similarity threshold when comparing the images to detect damage on buildings after earthquakes.
  - Brunner, D., Lemoine, G., & Bruzzone, L. (2010). Earthquake Damage Assessment of Buildings Using VHR Optical and SAR Imagery. *IEEE Transactions On Geoscience & Remote Sensing*, *48*(5), 2403-2420. doi:10.1109/TGRS.2009.2038274

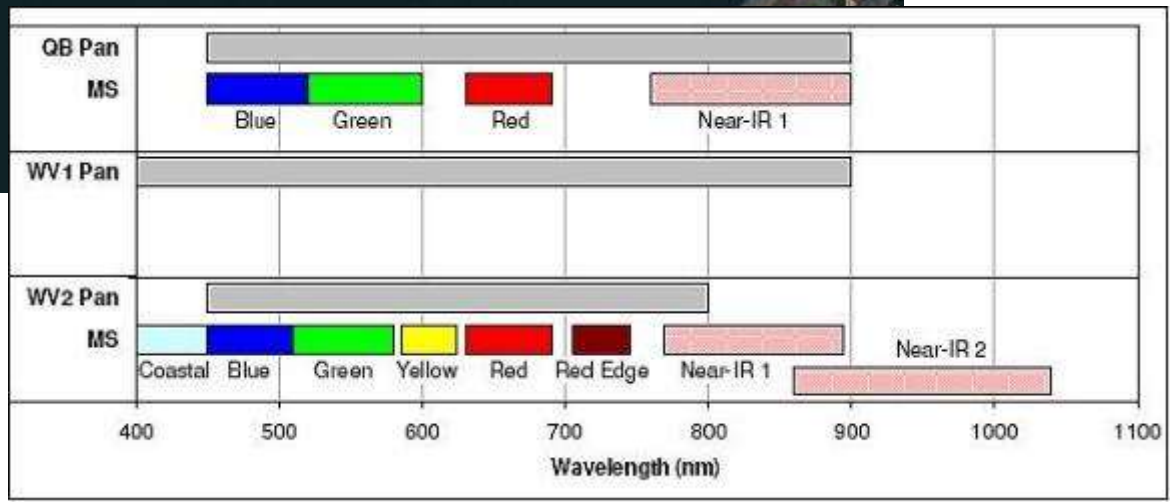
- **Modeling moulin distribution on Sermeq Avannarleq glacier using ASTER and WorldView imagery and fuzzy set theory.**
  - Uses a fuzzy set overlay to find spatial distributions of entry points of meltwater in to the ice
  - Phillips, T. T., Leyk, S. S., Rajaram, H. H., Colgan, W. W., Abdalati, W. W., McGrath, D. D., & Steffen, K. K. (2011). Modeling moulin distribution on Sermeq Avannarleq glacier using ASTER and WorldView imagery and fuzzy set theory. *Remote Sensing Of Environment*, *115*(9), 2292-2301. doi:10.1016/j.rse.2011.04.029

- **Satellite imagery can be used to detect variation in abundance of Weddell seals (Leptonychotes weddellii) in Erebus Bay, Antarctica.**
  - Compared ground counts of seals to counts from satellite imagery to see if the imagery provided an edge in research; authors think it “provides an accurate account” of the seal population
  - LaRue, M., Rotella, J., Garrott, R., Siniff, D., Ainley, D., Stauffer, G., & ... Morin, P. (2011). Satellite imagery can be used to detect variation in abundance of Weddell seals (Leptonychotes weddellii) in Erebus Bay, Antarctica. *Polar Biology*, *34*(11), 1727-1737. doi:10.1007/s00300-011-1023-0

Worldview 2: 2009, Pan 0.46m MS: 1.84m … first (very) high res. Red Edge



Sydney Opera house, Australia; captured October 20, 2009 (12 days after launch)



Worldview3 – ‘superspectral’ (10-50) 2014

PAN: 31cm VNIR: 1.24m – 8 bands **SWIR**: 3.72m – 8 bands

first (very) high res. Sensor With SWIR bands

Worldview 3 – SWIR bands

Multiband (8 bands) in SWIR (Shortwave Infrared) spectral range	SWIR-1	1195 - 1225 nm
	SWIR-2	1550 - 1590 nm
	SWIR-3	1640 - 1680 nm
	SWIR-4	1710 - 1750 nm
	SWIR-5	2145 - 2185 nm
	SWIR-6	2185 - 2225 nm
	SWIR-7	2235 - 2285 nm
	SWIR-8	2295 - 2365 nm

Band name	Spectral band
450 - 800 nm	
Coastal Blue	400 - 450 nm
Blue	450 - 510 nm
Green	510 - 580 nm
Yellow	585 - 625 nm
Red	630 - 690 nm
Red edge	705 - 745 nm
Near-IR1	770 - 895 nm
Near-IR2	860 - 1040 nm

April 26, 2015: In response to the devastating 7.8 magnitude earthquake that struck central Nepal on April 25, DigitalGlobe has made high resolution satellite imagery of the affected areas freely available online to all groups involved in the response and recovery effort. This imagery can be accessed: http://services.digitalglobe.com

Geomorphic and geologic controls of geohazards induced by Nepal's 2015 Gorkha earthquake

Science 08 Jan 2016: Vol. 351, Issue 6269, pp. DOI: 10.1126/science.aac8353

J. S. Kargel, G. J. Leonard, D. H. Shugar, U. K. Haritashya, A. Bevington, E. J. Fielding, K. Fujita, M.Geertsema, E. S. Miles, J. Steiner, E. Anderson, S.Bajracharya, G. W. Bawden, D. F. Breashears, A. Byers, B. Collins, M. R. Dhital, A. Donnellan, T. L. Evans, M. L. Geai, M. T. Glasscoe, D. Green, D. R. Gurung, R. Heijenk, A. Hilborn, K. Hudnut, C. Huyck, W. W. Immerzeel, Jiang Liming, R. Jibson, A. Kääb, N. R. Khanal, D. Kirschbaum, P. D. A.Kraaijenbrink, D. Lamsal, Liu Shiyin, Lv Mingyang, D. McKinney, N. K. Nahirnick, Nan Zhuotong, S. Ojha, J. Olsenholler, T. H. Painter, M. Pleasants, K. C. Pratima, Q. I. Yuan, B. H. Raup, D. Regmi, D. R. Rounce, A. Sakai, Shangguan Donghui, J. M. Shea, A. B. Shrestha, A. Shukla, D. Stumm, M. van der Kooij, K. Voss, Wang Xin, B. Weihs, D. Wolfe, Wu Lizong, Yao Xiaojun, M. R. Yoder, N. Young

GeoEye

Launched September 6, 2008

Imaging Mode	Panchromatic	Multispectral
Spatial Resolution	.41 meter GSD at Nadir	1.65 meter GSD at Nadir
Spectral Range	450-900 nm	450-520 nm (blue) 520-600 nm (green) 625-695 nm (red) 760-900 nm (near IR)
Swath Width	15.2 km	
Off-Nadir Imaging	Up to 60 degrees	
Dynamic Range	11 bit per pixel	
Mission Life	Expectation > 10 years	
Revisit Time	Less than 3 day	
Orbital Altitude	681 km	
Nodal Crossing	10:30 am	

Selected New millennium high resolution sensors Launched by corporations, not countries

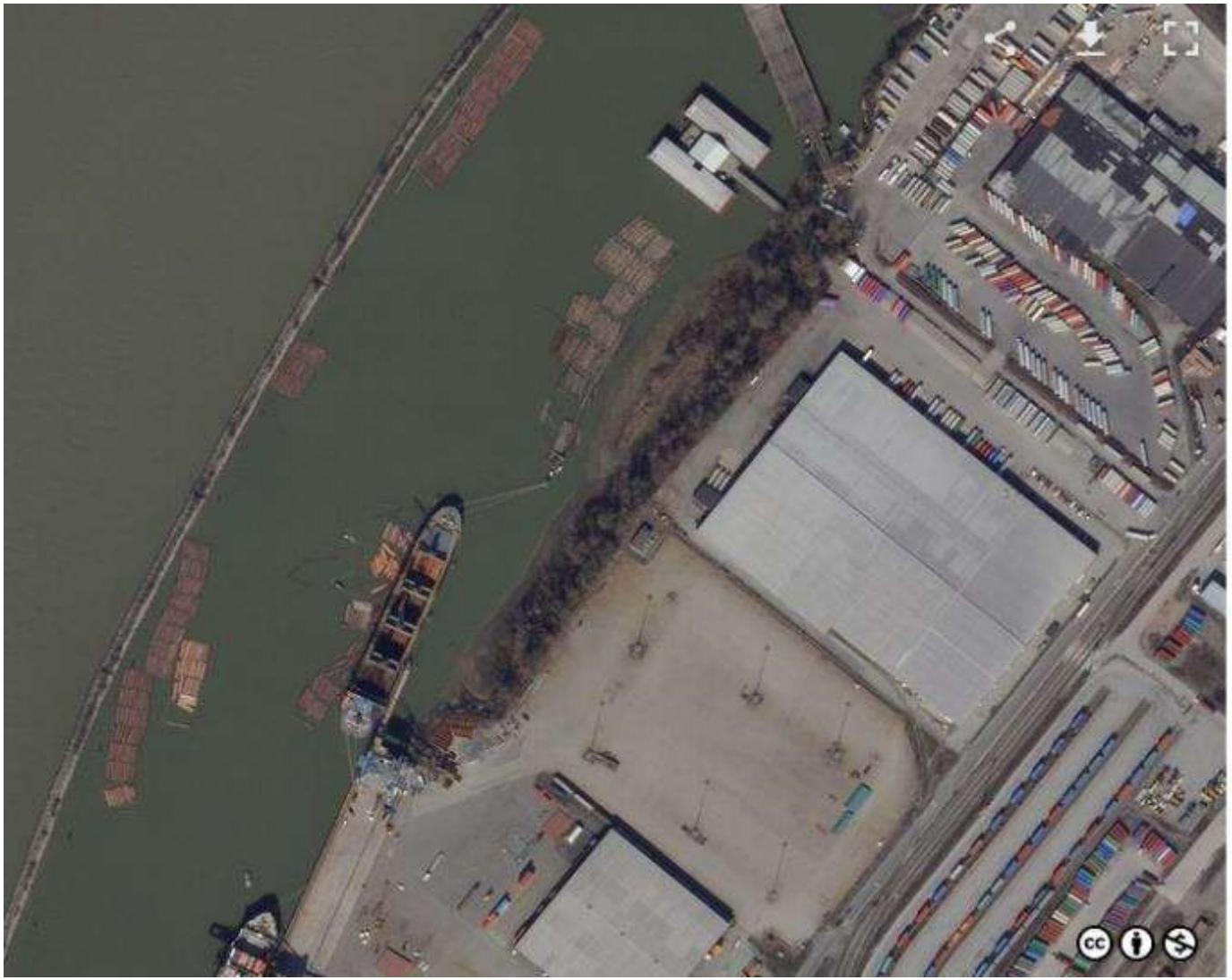
Date	Sensor	Bands	Pixel (m)	Swath (km)	Orbit (km)	Data
1999	Ikonos	RGBN	1 / 4	11.3	681	11 bit
2001	Quickbird	RGBN	0.6/2.4	16.5	450	11
2007	Worldview 1	PAN	.5 / 2	17.6	496	11
2008	GeoEye	RGBN	.41 /1.65	15	681	11
2009	Worldview2	RGBN	.46 / 1.84	16.4	770	11
2014	Worldview3	RGBN	.31 / 1.24	13.1	617	11

2016 GeoEye2 = Worldview4 …

Data cost ~ $10-25 per km

arrangements made with Universities and researchers for projects, humanitarian applications

Planet Labs – constellation of nanosatellites mapping the planet for better understanding



NORTHWEST TRADE

Surrey, British Columbia, Canada

Mar 31, 2021

Source: Skysat

Logs float on the Fraser River, waiting to be loaded onto waiting cargo ships in this SkySat image collected on March 31, 2021. Planet's latest SkySats—16–18 and 19–21 operate at an altitude of 400 kilometers (250 miles), providing an even higher-resolution look at global trade.

Are you a geospatial intelligence analyst?

Explore our imagery

https://www.planet.com/ ….. Map the planet every day at 1-5m resolution

India successfully launches 104 satellites

Launch sets a record for most satellites launched at once

The Associated Press Posted: Feb 15, 2017 9:18 AM ET | Last Updated: Feb 15, 2017 11:54 AM ET

This photograph released by Indian Space Research Organisation shows its polar satellite launch vehicle lifting off from a launch pad at the Satish Dhawan Space Centre in Sriharikota, India, Wednesday, Feb.15, 2017. (Indian Space Research Organization

Rocket Science !

The launcher started placing the satellites into polar Sun-synchronous orbits one after another after a flight of 16 minutes and 48 seconds.

The rocket launched Cartosat-2D and 103 nanosatellites: two from India, one each from Kazakhstan, Israel, the Netherlands, Switzerland, and the United Arab Emirates, along with 96 from the United States of America – 88 Dove satellites

Holding a dove in Winnipeg
Not a rocket scientist

Among the 96 satellites belonging to US companies, 88 CubeSats were owned by Planet Labs, a private Earth imaging company based in San Francisco, California.

High resolution sensor assignment for next Friday class – January 28, 12.30pm

Review one selected sensor (not shown in class) – resolution 5m or better

Create 3-4 slides showing:

1. Summary info

Launch date .. End of operation or till working, launcher (country or company)
Bands, wavelengths, pixel size, radiometric resolution e.g. 12 bit

2. 1 or 2 good examples of imagery (1-2 slides)

3. Brief summary of project examples completed e.g. disaster monitoring, relief work, research publications

4. Total length per talk = 3 minutes each

Send slides to me as pdf .. (recommended - more compact) by Thursday 27 January
Note that you can greatly reduce file size using picture compression in ppt and then choose 'minimum size' in save as … pdf

https://www.satimagingcorp.com/satellite-sensors

https://directory.eoportal.org/web/eoportal/satellite-missions/a

Sensors supported in Catalyst Focus: Tasseled Cap algorithm

Most are high resolution sensors

Deimos-1
DMC
Resourcesat-2 LISS-4
ALOS Avnir-2
CBERS-4 MUX
CBERS-4 WFI
Deimos-2
FASat Charlie
Formosat-2
Gaofen 1
Gaofen 2
GeoEye-1
Gokturk1
IRS-1A
IRS-2B
KazEOSat-2
Sentinel-2

KOMPSAT-2
KOMPSAT-3
OrbView-2
PeruSAT-1
Pleiades
RapidEye
SuperView-1
TripleSat
WorldView 2 to 4
ZY-3
ZY3-2
CBERS-4 P10
IRS-1C / D
IRS-P6
Resourcesat-2 AWiFS
Resourcesat-2 LISS-3
SAC-C

Most are suitable for review for next Friday's class talks

Sensors with red edge band(s)

❑ Rapideye	2008	5m
❑ Worldview 3	2014	1.24m
❑ Sentinel-2	2015	20m