

From Science to Operational Information: Earth Observation and Software Development Trends

Arnold Hougham

Vice President, Sales and Marketing

PCI Geomatics

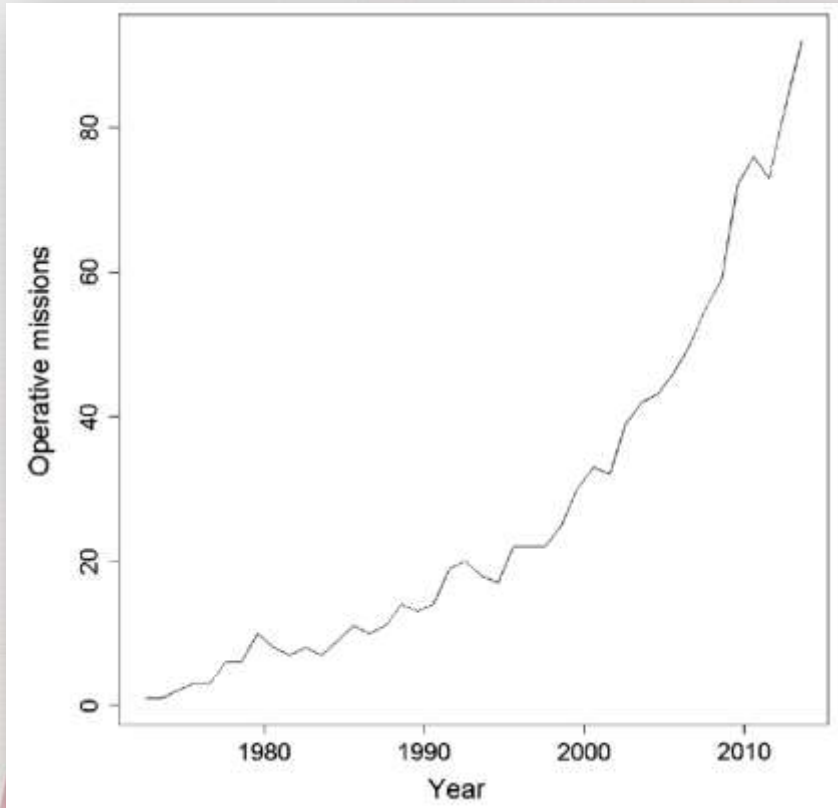
August 24, 2017





Important trends: Earth Observation Imagery

More EO Missions



197 missions since 1972

Launches per year/per decade:

1970-80: 2

1980-90: 3

1990-00: 5.5

2000-10: 8

2010-14: 12 (**6 x first decade**)

EARTH OBSERVATION SATELLITE LAUNCHES



1970
2 countries



2017
35 countries

197 EO satellites

178 Optical, 19 SAR

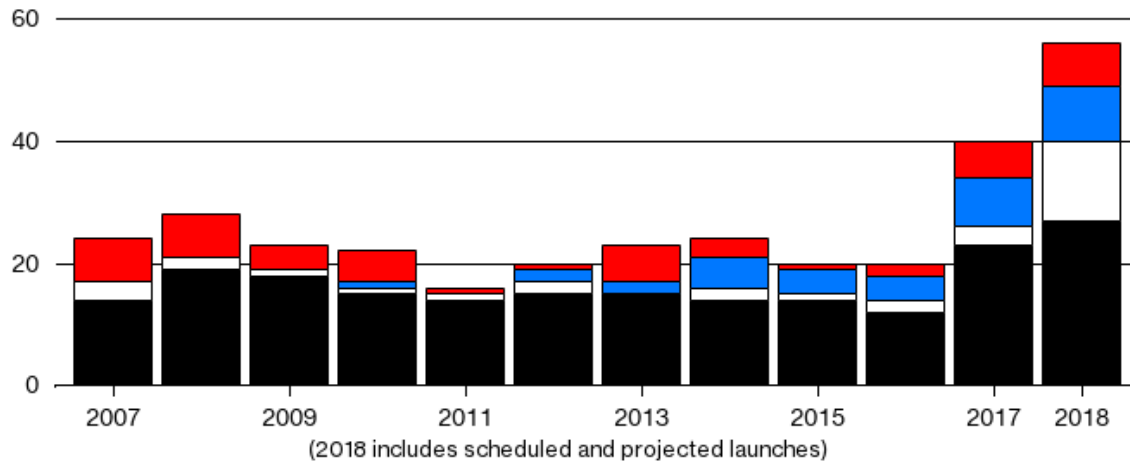
Source: EC, JRC, Ispra (2014):

<http://www.sciencedirect.com/science/article/pii/S0924271614000720>

Worldwide commercial satellite launches

Worldwide commercial orbital launches by type

■ Communications satellite □ Imaging satellite ■ Cargo, astronaut delivery
■ Other commercial satellites, technology demonstrations



Data: FAA Office of Commercial Space Transportation; graphic by Bloomberg Businessweek.

Chart pre-dates latest launch by Planet (88 satellites on February 14 2017)

More Accessibility (“free”)

“Imagery for Everyone”



Technical Announcement

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

Address:
Office of Communication
119 National Center
Reston, VA 20192

Release
April 21, 2008

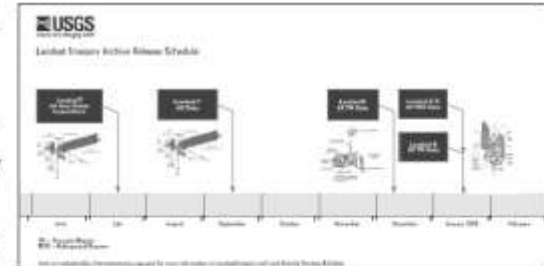
Contact
Ron Beck
Rachel Headley

Phone
605-594-6550
605-594-6118

Imagery for Everyone...

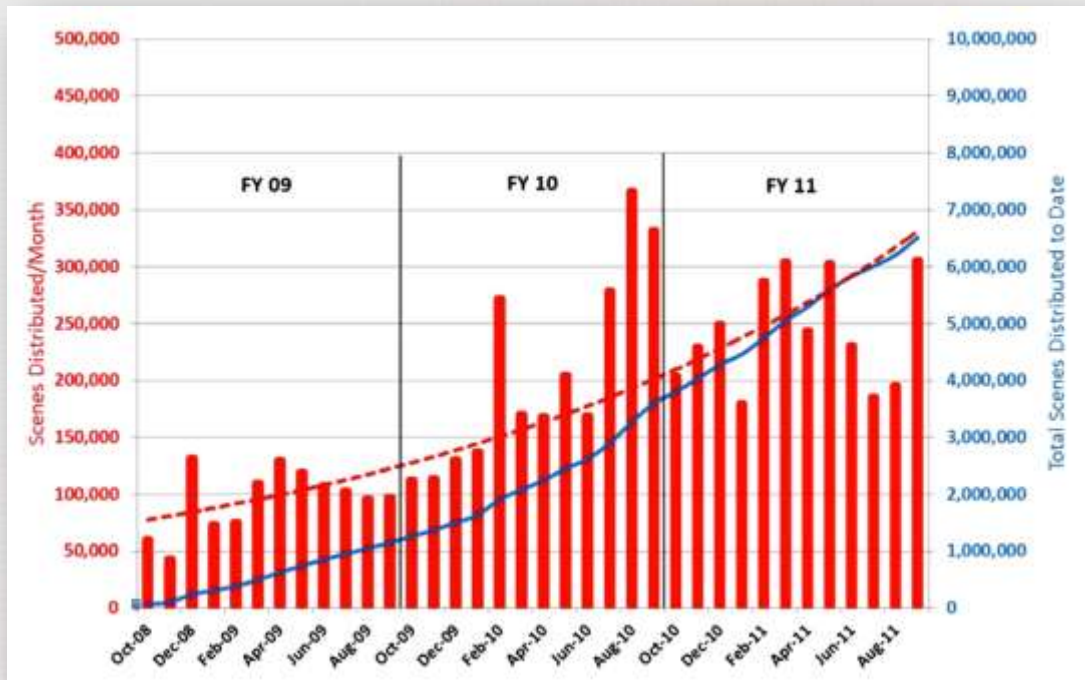
Timeline Set to Release Entire USGS Landsat Archive at No Charge.

RESTON, VA – The USGS Landsat archive is an unequalled 35-year record of the Earth’s surface that is valuable for a broad range of uses, ranging from climate change science to forest management to emergency response, plus countless other user applications. Under a transition toward a National Land Imaging Program sponsored by the Secretary of the Interior, the USGS is pursuing an aggressive schedule to provide users with electronic access to any Landsat scene held in the USGS-managed national archive of global scenes dating back to Landsat 1, launched in 1972. By February 2009, any archive scene selected by a user – with no restriction on cloud cover – will be processed automatically to a standard product recipe, using such parameters as the Universal Transverse Mercator projection, and staged for electronic retrieval. In addition, newly acquired scenes meeting a cloud cover threshold of 10% or below will be processed in the standard recipe and placed on line for at least three months, after which they will remain available for selection from the archive.



Data	Available over the Internet
Landsat 7 – all new global acquisitions	July 2008
Landsat 7 – all data	September 2008
Landsat 5 – all TM data	December 2008
Landsat 4 – all TM data	January 2009
Landsat 1-3 – all MSS data	January 2009

More usage of EO imagery



Source: Opening the archive: How free data has enabled the science and monitoring promise of Landsat, Wulder et al, 2012

Global Land Cover Facility, at the University of Maryland was the key catalyst for open data policy (copying / sharing data once purchased)

www.glovis.usgs.gov

EROS Data Centre provided approximately 25,000 Landsat images in 2001 (total) vs 250,000 images (per month) in 2010!

25,000 vs 3,000,000 / year
Increased by factor of 120!!



More Accessibility (“free”)

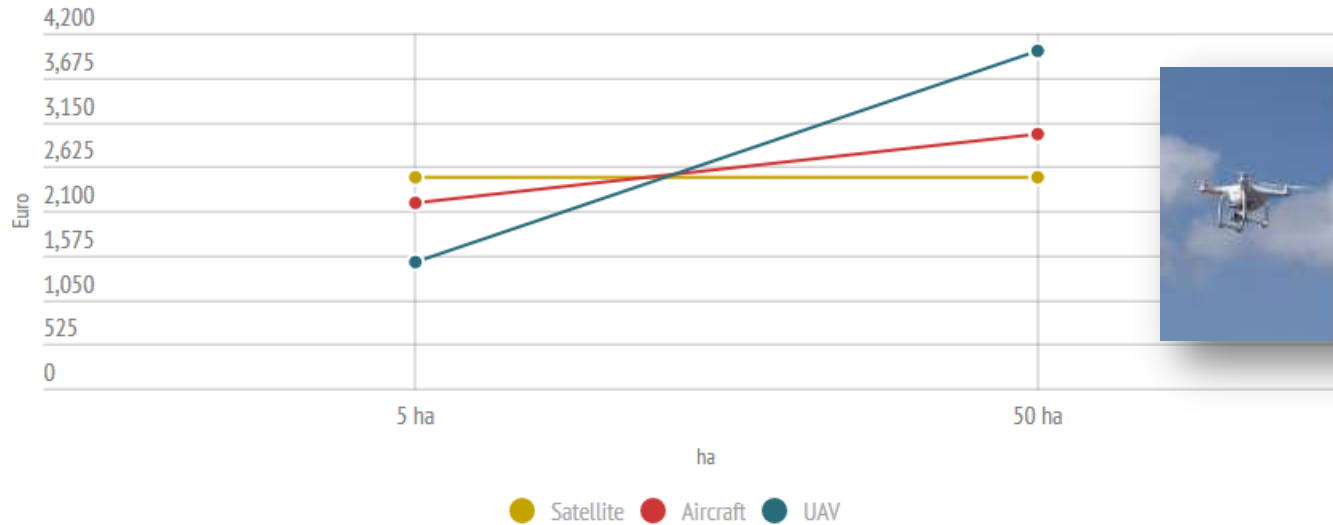


The image shows a screenshot of the Copernicus Sentinel Online website. At the top left is the Copernicus logo with the tagline "Europe's eyes on Earth". To the right are several icons representing different Copernicus services: a globe, a fish, a plant, a person, a tree, and a shield. Further right are social media icons for RSS, YouTube, Facebook, and Twitter, along with a search bar. Below the header is a navigation menu with a sidebar on the left containing links like "What is Copernicus", "Copernicus Services", "Infos & Opportunities", "Tenders and Grants", "Documentation", "Research", "News", "Events", and "Media". The main content area features the ESA logo and "Sentinel Online" text, followed by icons of various satellites and the European Commission logo. A navigation bar includes links for "Need Help?", "FAQ", "Contact Us", and "About Sentinel Online". A search bar labeled "Google Custom Search" is present. A main navigation menu has dropdowns for "Missions", "User Guides", "Technical Guides", "Thematic Areas", "Data Access", and "Toolboxes". The "Data Access" dropdown is open, showing options: "Sentinel Data Access Description", "Use Typologies and available Services", "Available Data Collections", and "Access to Sentinel Data". Below this, a breadcrumb trail reads "You are here Home > Missions". A large dark blue banner reads "- SENTINEL Overview". Below the banner, text states: "ESA is developing a series of next-generation Earth observation missions, on behalf of the joint ESA/European Commission. The Programme is coordinated and managed by the European Commission. It is implemented in partnership with the Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Océan. Vast amounts of global data from satellites and from ground-based, airborne and seaborne measurement systems are being used to provide information to help service providers, public authorities and other international organisations improve the quality of life for the citizens of Europe. The information services provided are **freely and openly** accessible to its users."



Price Pressure on imagery (more options)

Category costs (Euro) for satellite, aircraft and UAV mapping

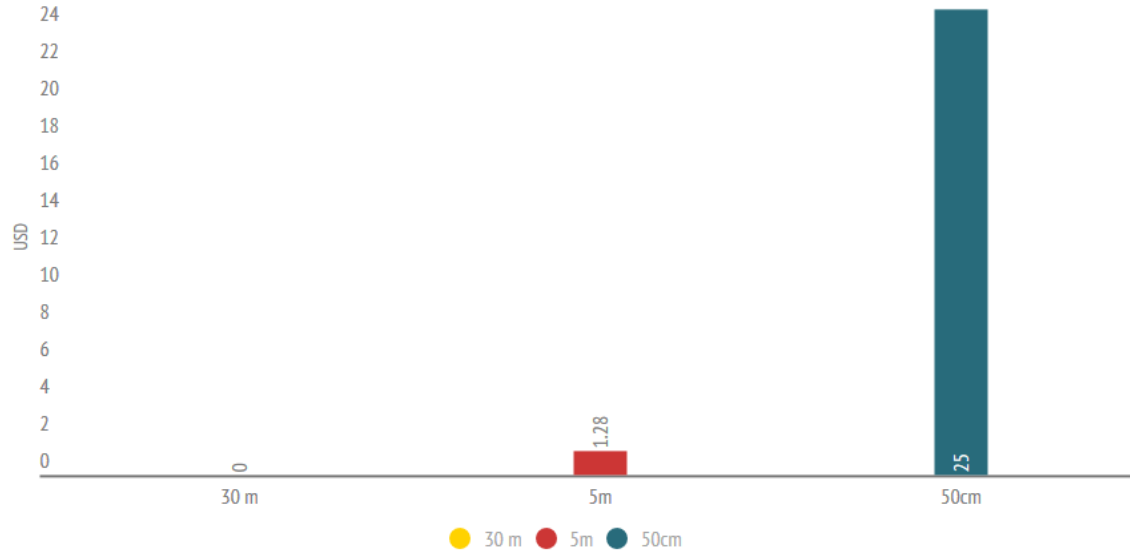


Source: <https://droneapps.co/price-wars-the-cost-of-drones-planes-and-satellites/>



Price Pressure on imagery (resolution)

Cost of image acquisition in USD per km² vs Resolution, using satellites



Frequency of Acquisition

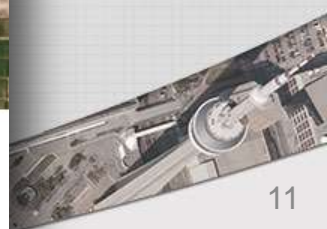


planet.

PLANET MONITORING

See everywhere, every day.

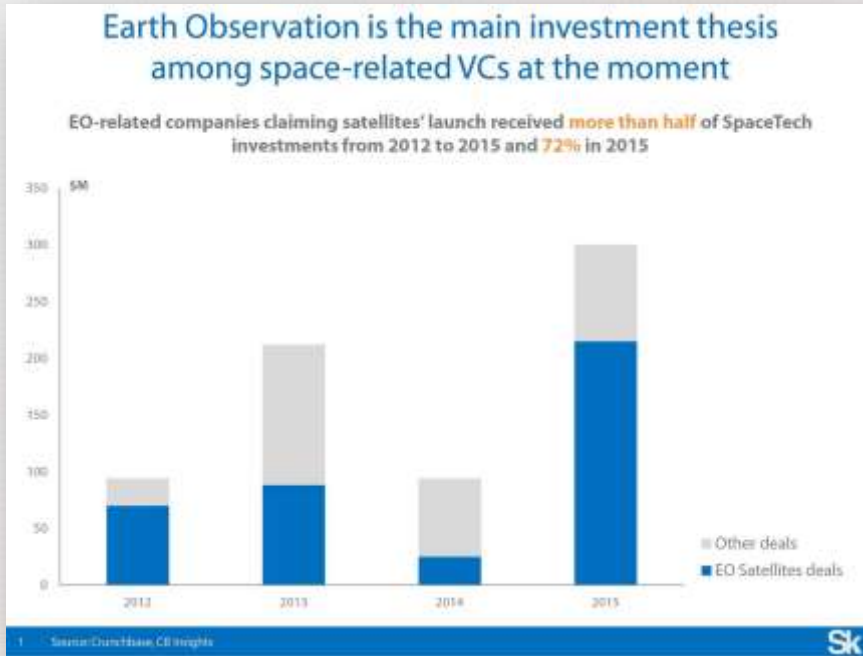
The image shows a satellite view of a landscape with a river on the left, a grid of agricultural fields in the center, and a road or canal running through them. The Planet logo is in the top left corner. A dark grey box at the bottom contains the text 'PLANET MONITORING' and 'See everywhere, every day.'.





Important trends: Funding

Private funding for commercial satellite programs



Source:

<https://venturebeat.com/2016/08/14/earth-observation-data-multibillion-dollar-opportunity-or-dud/>

- The funding model for new space based startups is changing
- Not only about cost recovery for big programs; it's also about profit opportunities that come with constellation / privately funded missions / companies

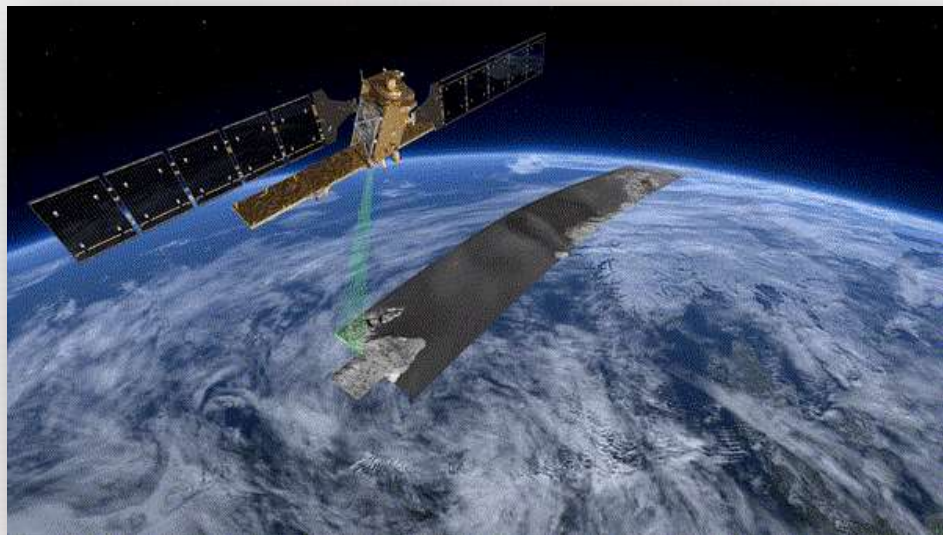




CREDIT TO DIGITALGLOBE

Important trends: More data

Sentinel Data Volumes



“By the end of 2017, the operational Sentinel-1, -2 and -3 satellites alone will continuously collect a volume of 20 Terabytes per day.”

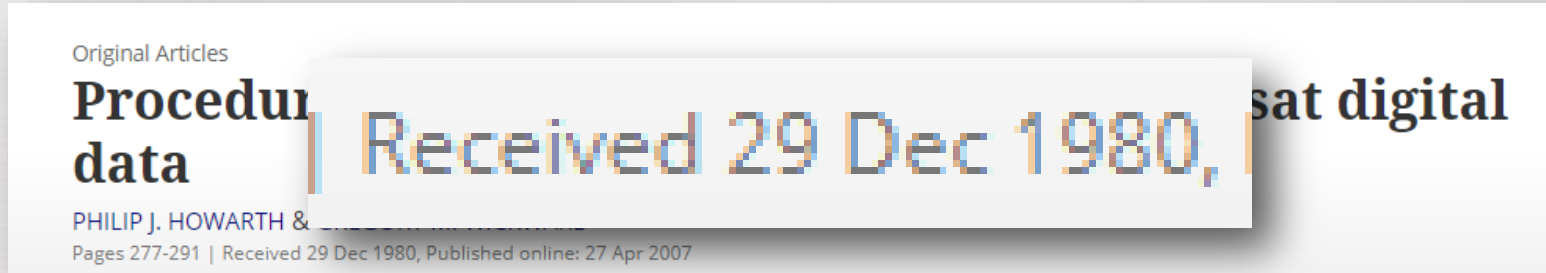
<https://medium.com/google-earth/a-golden-age-for-earth-observation-f8b281cec4b7>



EO Data Trends: Consequences and Opportunities

Multi-temporal methods possible

Change detection is not new...

A screenshot of a journal article snippet. The text includes "Original Articles", "Procedur", "data", "Received 29 Dec 1980,", "sat digital", "PHILIP J. HOWARTH &", and "Pages 277-291 | Received 29 Dec 1980, Published online: 27 Apr 2007".

Original Articles
Procedur
data | Received 29 Dec 1980, | sat digital
PHILIP J. HOWARTH &
Pages 277-291 | Received 29 Dec 1980, Published online: 27 Apr 2007

...but has not been practical due to data costs and access... until now.

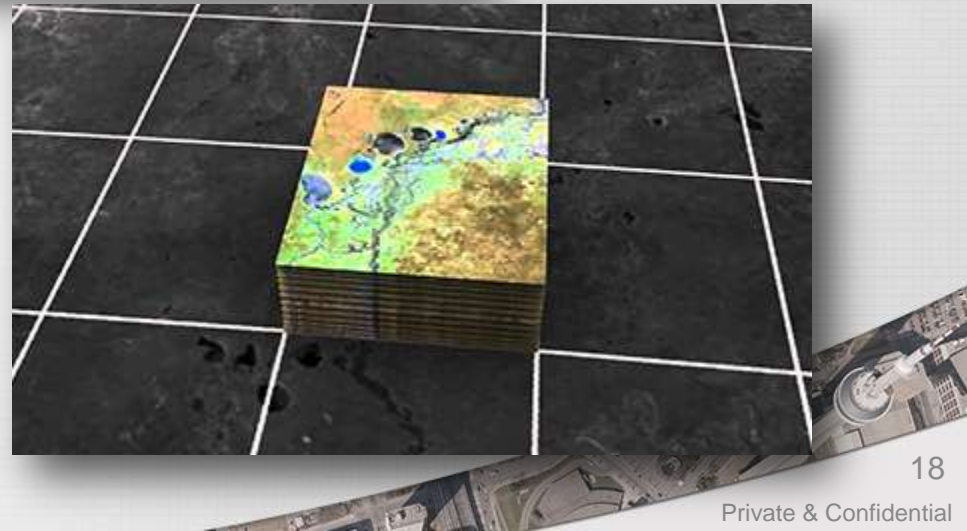
Australia Data Cube



Australian Geoscience

DATA CUBE

a world-leading data analysis environment
for satellite and other Earth Observations





Alignment and Calibration

The need for pixel-perfect alignment

Reference Image



Un-aligned Image

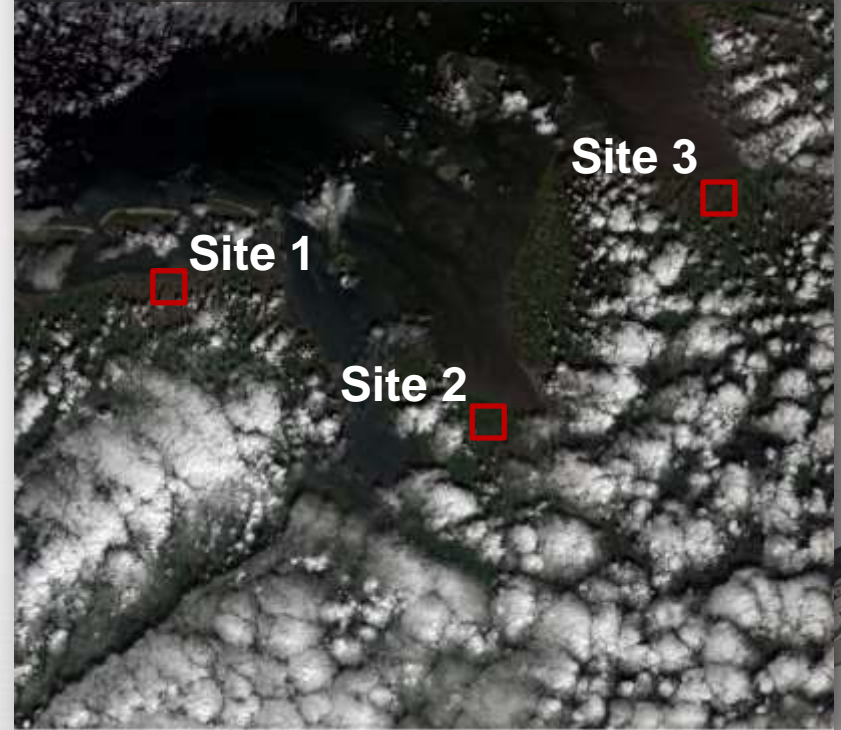


The need for pixel-perfect alignment

Reference Image



Misaligned Image



Multi-temporal not possible

Site 1



Site 2



Site 3



Multi-temporal possible

Site 1



Site 2



Site 3



Cross Sensor Calibration

PlanetScope
Dec 01/2016
3:05 PM
Local time



Cross Sensor Calibration

RapidEye
Dec 03/2016
11:36 AM
Local time



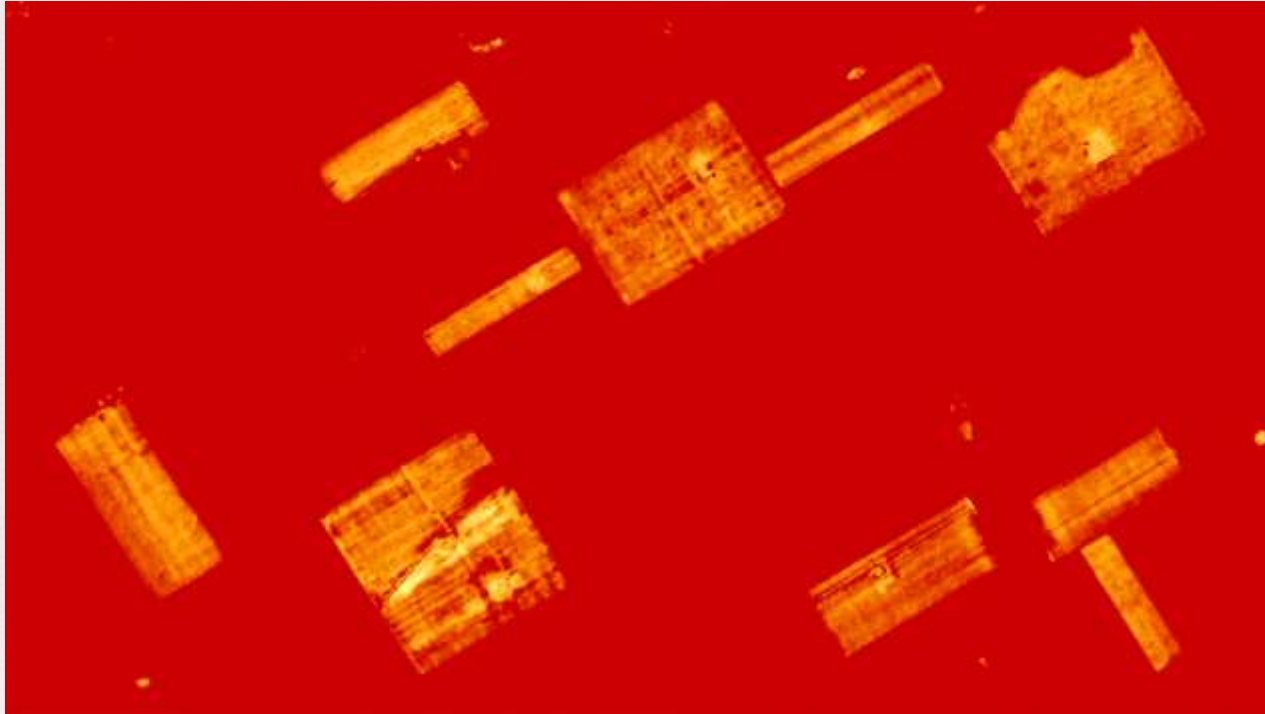
No Calibration NDVI

PlanetScope

Dec 01/2016

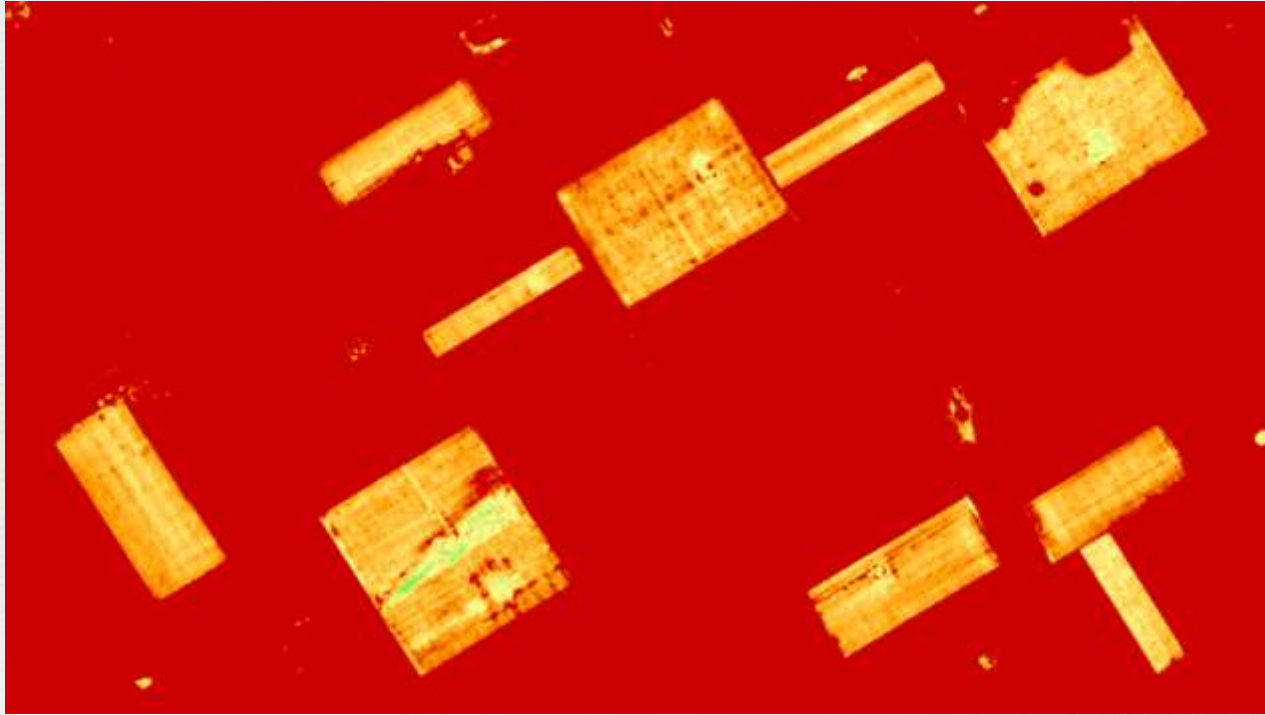
3:05 PM

Local time



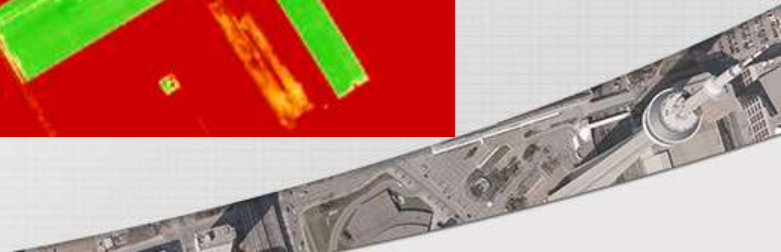
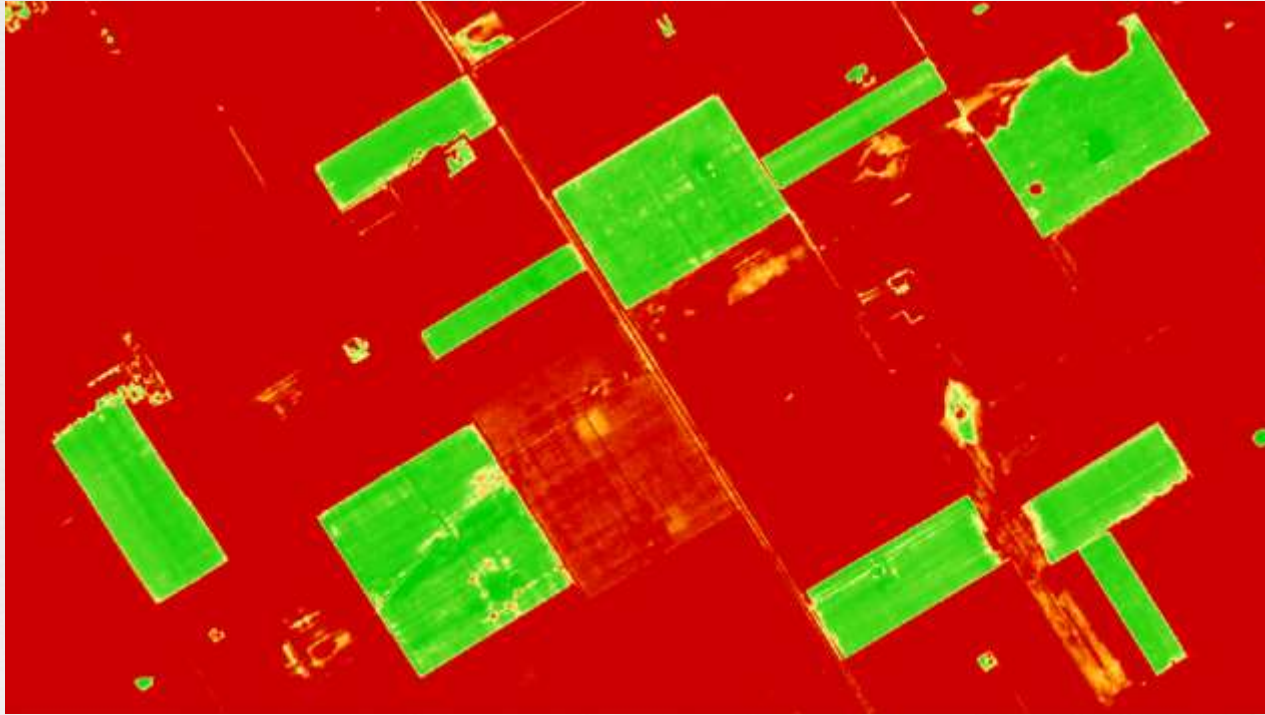
No Calibration NDVI

RapidEye
Dec 03/2016
11:36 AM
Local time



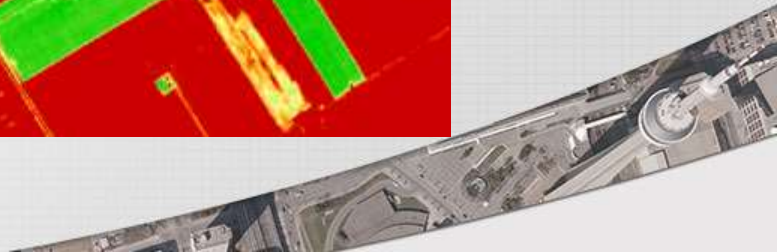
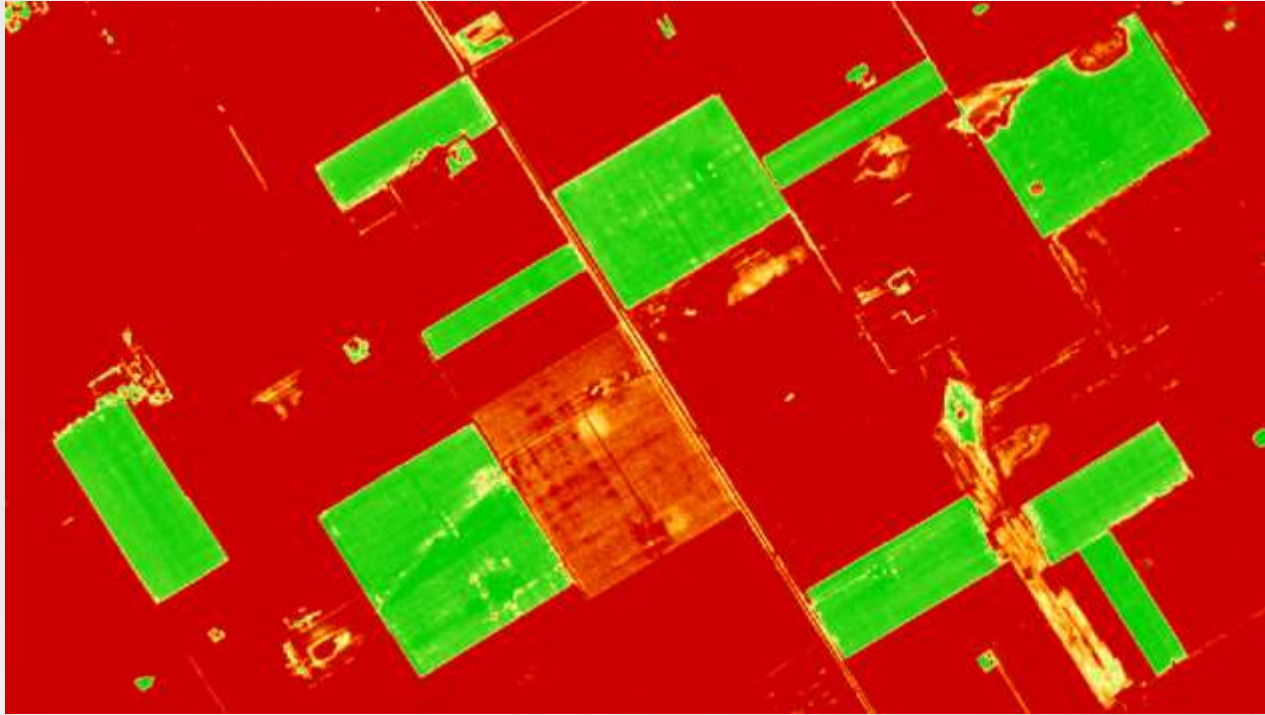
Calibrated NDVI

PlanetScope
Dec 01/2016
3:05 PM
Local time



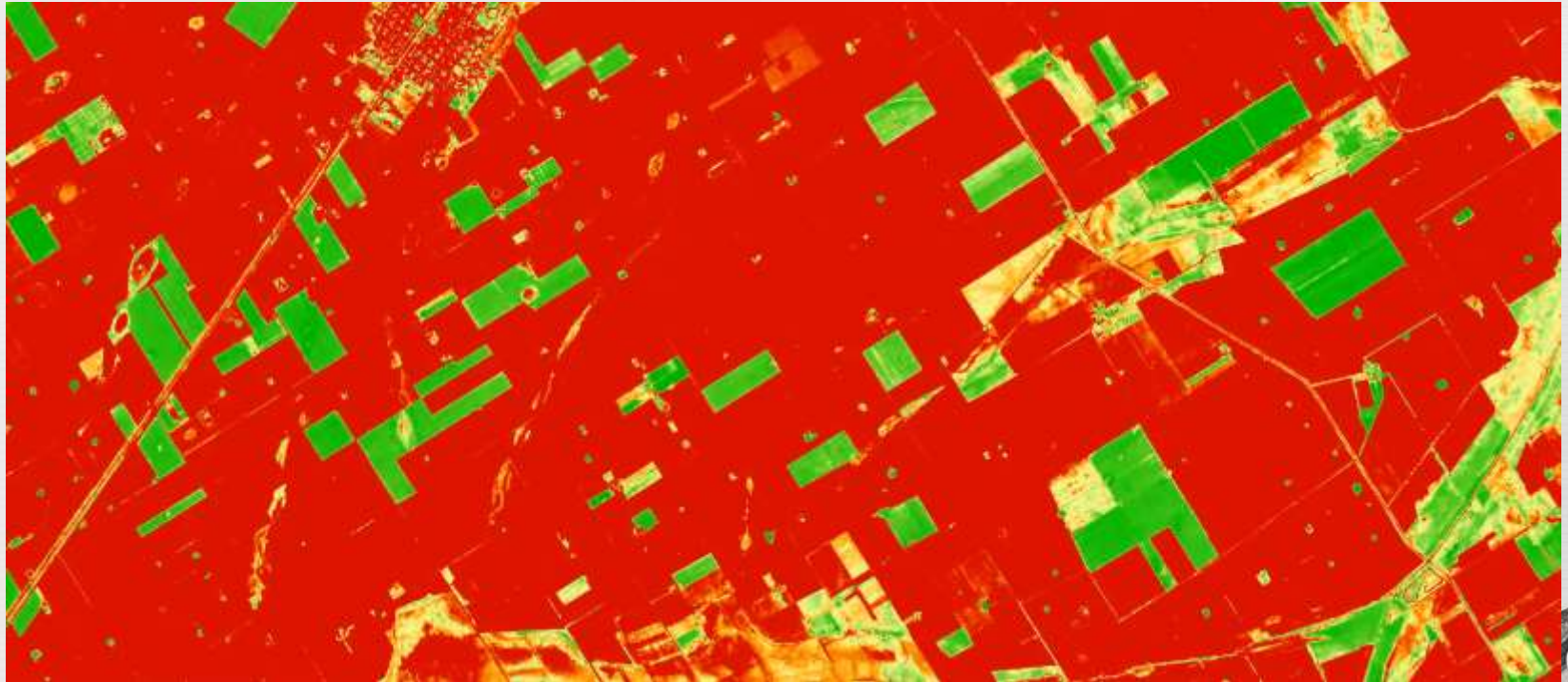
Calibrated NDVI

RapidEye
Dec 03/2016
11:36 AM
Local time




Calibration Makes Big Multi-temporal Analysis Possible

Dec 01/2016 (PS), Dec 03/2016 (RE), Dec 11/2016 (PS), Dec 20/2016 (RE), Dec 29/2016 (PS)



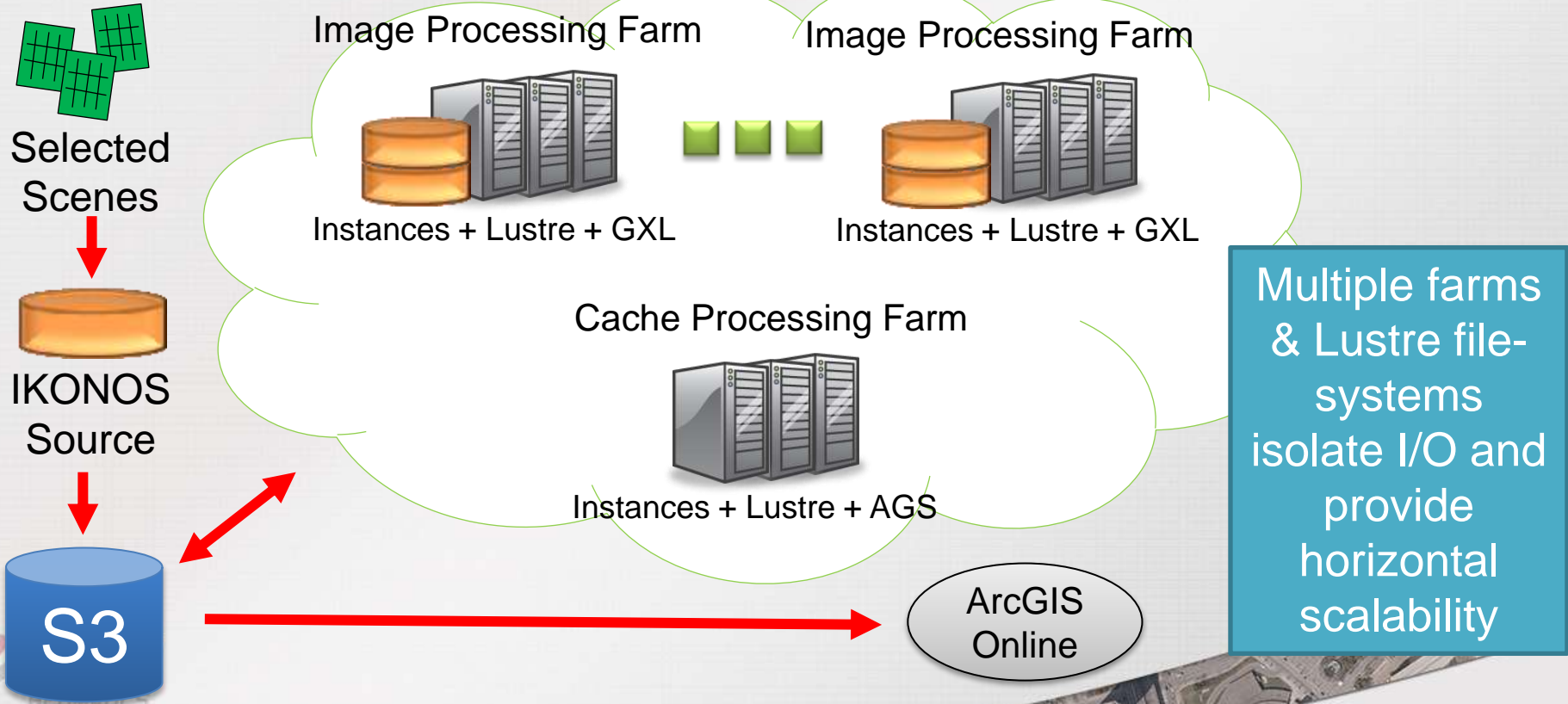


Big Data Analytics



Software needs to be scalable,
and easily integrated
Esri Cloud processing project

Massive Cloud Scalability (PCI/Esri 2011)



Node Configuration

“Standard”
compute node



- m1.xlarge
 - 15 GB memory
 - 8 EC2 compute units
 - 4 virtual cores, each with 2 x EC2
 - 1,690 GB ephemeral storage included “free”
 - 8 GB EC2 volume
 - 64-bit Linux OS
 - I/O performance level: High
- Designed to use minimal EC2 resources


Typical Task Provisioning

- Per farm, node requirements are typically as follows:
 - Ingest 25+ nodes
 - Tie-point collection 20+ nodes
 - Ortho w/Pansharpen 20+ nodes
 - Colour balancing 1 node
 - Mosaic Tiling 25+ nodes
 - Caching 8 nodes
- Tasks are pipelined on each farm
- Operational nodes per farm is 25+
- For 9 operational farms, potential is 225+ nodes

Cloud Geo-Processing Engine

Components for 10.0 & 10.1b GP Workflows



 PCI GXL /
Geomatica

 ArcGIS

Production Throughput

- Average based on current cloud compute configuration
- Component km²/node-hr
 - Ingest 7007 km²
 - Tie-point collection 2685 km²
 - Ortho w/Pansharpen 1773 km²
 - Colour balancing 39,925 km²
 - Mosaic Tiling 1899 km²
 - Caching 13,926 km²
- Total processing per area-of-interest ~681 node-hours
- Processing varies with sensor and size of area

VC Funding EO / Proliferation

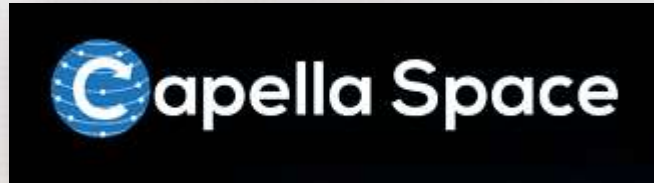
Company	Founded	Raised, \$M	Current # of satellites	Planned # of satellites	Full constellation deployment date
Terra Bella (ex. Skybox Imaging)	2009	91	2	24	2017
Planet (ex. Planet Labs)	2010	158,1	51	150	2017
Urthecast	2010	N/A	2	16	2020
Dauria Aerospace	2011	20	0	10	2020
Astro Digital (Aquila Space)	2014	N/A	2	30	2020+
BlackSky Global	2013	53,5	0	60	2019
Satelloptic	N/A	2	0	300	2020+
Omni Earth	2013	10,32	0	18	2018
Planetary Recourses	2010	22,5	0	10	2020+
AxelSpace	2008	16,05	0	50	2020+
Iceye	2012	2,8	0	40	2020+
Hera Systems	2013	4,2	0	48	2020
NorStar Data	N/A	N/A	0	40	2020+



Effect of VC Funding

Verticalization

- Examples: “8 Satellite Data Startups Doing Geospatial Analysis” (nanalyze.com article)



“Under Cover of Darkness”

Effect of VC Funding

Proliferation and verticalization

- Examples: “8 Satellite Data Startups Doing Geospatial Analysis” (nanalyze.com article)



“Reliable Economic Information”

Effect of VC Funding

Proliferation and verticalization

- Examples: “8 Satellite Data Startups Doing Geospatial Analysis” (nanalyze.com article)

A dark blue rectangular box containing the text "SPACEKNOW" in white, bold, sans-serif capital letters.

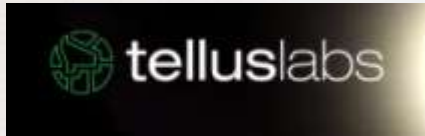
SPACEKNOW

“Parking Lot Economics”

Effect of VC Funding

Proliferation and verticalization

- Examples: “8 Satellite Data Startups Doing Geospatial Analysis” (nanalyze.com article)



“Old McDonald Had a Farm”

Effect of VC Funding

Proliferation and verticalization

- Examples: “8 Satellite Data Startups Doing Geospatial Analysis” (nanalyze.com article)



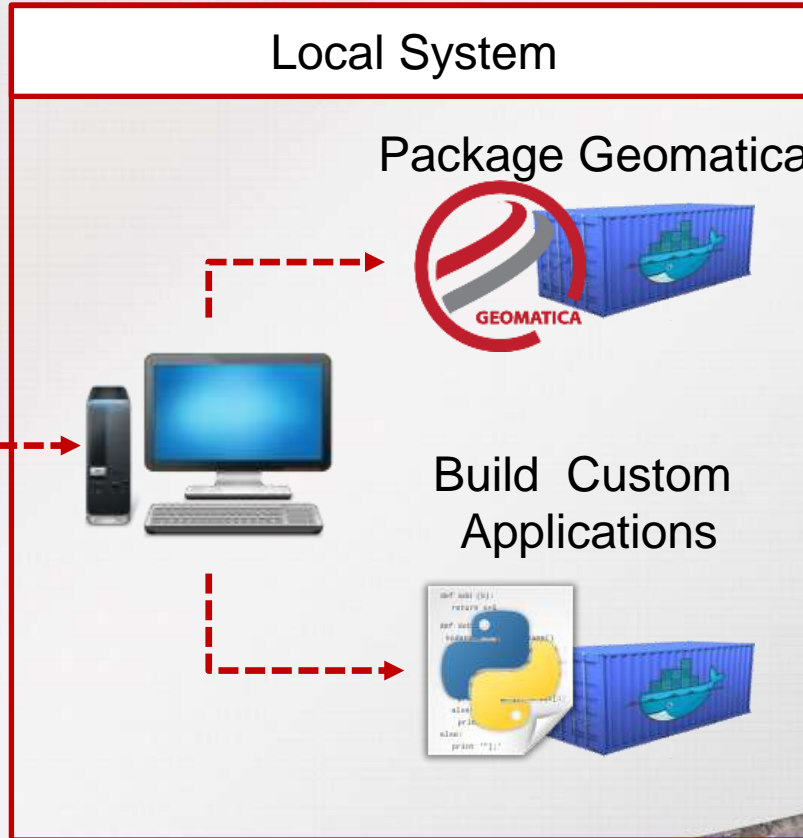
“Data access for DIY Intelligence”

Big Data Effects

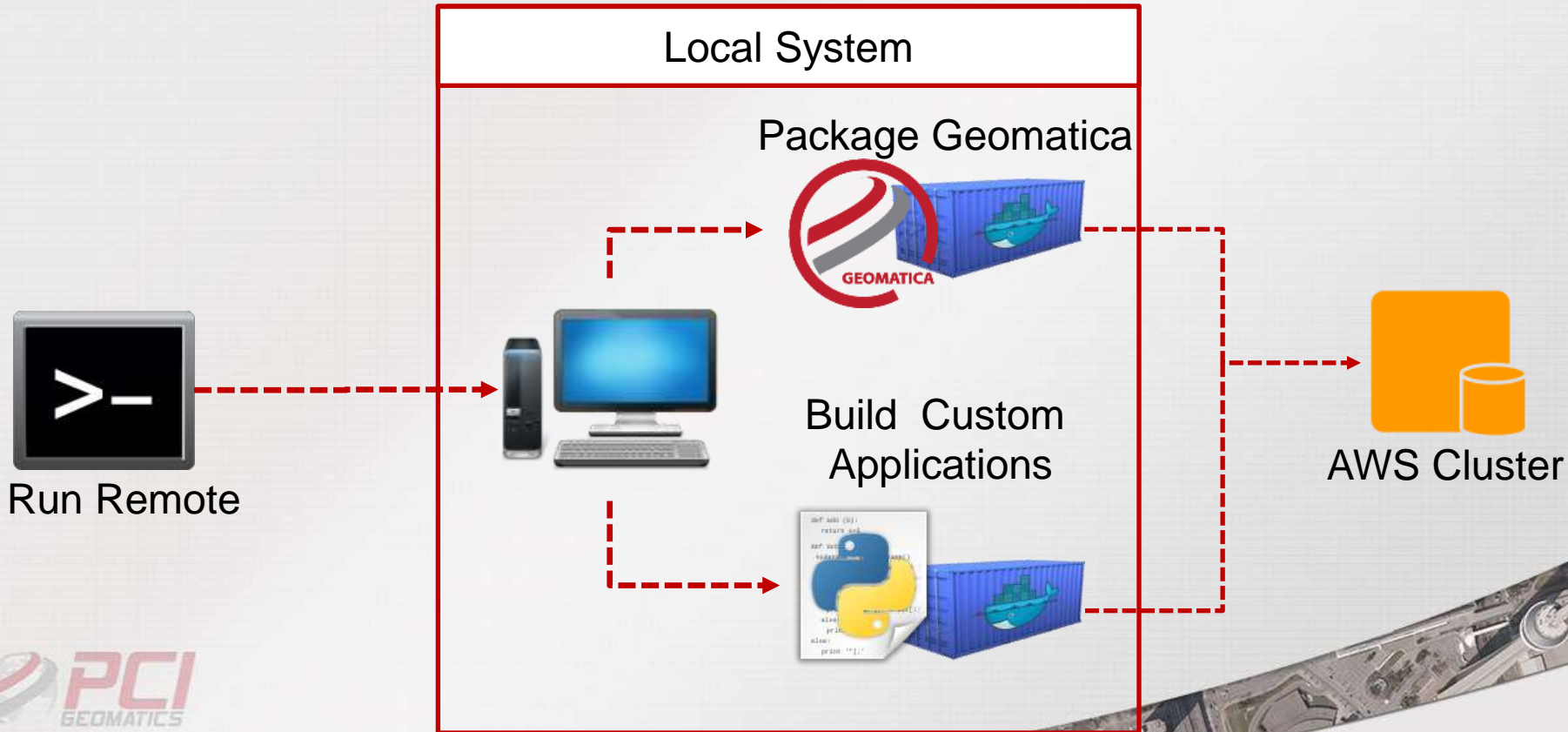
“I can’t wait for download delivery of data. I want to prototype my complex workflow on the desktop and migrate it to where the data are: in the “cloud.””



Local Deployment



Remote Deployment



Machine Learning

- Important technique given large datasets
- Support Vector Machine (SVM implemented in PCI OBIA s/w, Python integration→2018)

The screenshot displays the PCI OBIA software interface. On the left, the 'Object Analyst' window shows the 'Feature Extraction' process. The 'Source Channels' list includes 'L3_MSI_MS_010n_031E_32_240'. The 'Segmented Vector Layer' is 'S2A_MSI_MS_010n_030E_32_250_240'. The 'Feature Attributes' section is checked for 'Channel statistics' (Min, Max, Mean, Std Dev) and 'Geometrical' (Compactness, Elongation, Circularity, Rectangularity). The 'Process Canvas' shows a tree of operations: 'HCRG Segmentation', 'Feature Extract', and 'Statistics'. The 'Layer Selection' dialog box is open, showing a table of selected layers:

Layer Select	Band Alias	Description
1	<input checked="" type="checkbox"/> Bright	1 [16S] Brightness
2	<input checked="" type="checkbox"/> Green	2 [16S] Greenness
3	<input checked="" type="checkbox"/> Wet	3 [16S] Wetness
4	<input checked="" type="checkbox"/> NDVI	4 [16S] NDVI
5	<input checked="" type="checkbox"/> EVI	5 [16S] EVI

The main window shows a color-coded map of a field with various segments. The 'PCI GEOMATICS' logo is visible in the bottom left corner.

Summary

- EO proliferation = Big data
- Big data changes everything
 - Need for speed
 - Need for new deployment models and business models
 - Machine learning
- Science matters
 - Get the pixels in the right place (this is not easy)
 - Calibration and validation (this is not easy)
- Solutions are proliferating
 - Consumer beware
 - Experience matters

