Recent advances in Satellite Imagery for Oil and Gas Exploration and Production.

DESK AND DERRICK APRIL 2016
PRESENTED BY GARY CREWS---RETIRED
 Agenda

- Brief review of state of the applications in 2010
- Basics on how satellites collect imagery
- How things have changed with the five new satellites of interest
- New Applications and improvements to older uses
- Radar satellites and their special use
- A look at the future with UAS (drones) and micro satellites.
Asset Identification & Correction

Database Well Locations: LL NAD27

108 Feet Error

Power Lines
Well Locations
Seismic Line
Access Road
Power Lines
Construction monitoring

Imagery Solutions for Energy Companies

Compare Actual To Plan
Operations Monitoring---Gulf of Mexico Platform
Use of NIR for vegetation health
How Optical Earth Observation satellites work
Basic Satellite Operations
Pushbroom Scanning

- It takes roughly 4 seconds to collect a 16.5 km x 16.5 km image
- The sensor collects:
  - Panchromatic (Black & White)
  - Multispectral
    - Blue
    - Green
    - Red
    - Near-infrared
Store and download

GeoEye ground stations for Ikonos
Command and data link
Orbit: Sun-synchronous-Polar Orbit

10:30 am sun-synchronous orbit

• Satellites collect imagery in the descending pass
• Approximately 95 minute orbit

Benefits
• Provides shorter shadows
• Morning less likely to be cloudy
• Provides most consistency
Walking Orbit
Orbit Height

Low Orbit
- Improved resolution
- Lower time on target
- Longer revisit time

High Orbit
- More time on target
- Larger area seen
- Shorter revisit

Orbit Heights:
- 450 km
- 600 km
- 16.5 km
Stereo Collection

- Same Pass Collection of Large Areas
  - 3-D feature extraction
  - DEM Creation
  - Worldwide Ortho
  - Reference Stereo (25m CE90)
  - Precision Stereo (4m CE90)
Some real rocket science

• How do you point satellite
• Reaction Wheels or Control Moment Gyro

1) Change the speed of a spinning wheel
2) Change the orientation of wheel
• GEN II Satellites
  – GeoEye -1  50 cm, 4 band, some agility, stereo
  – WV 1  50cm, black and white, high agility, stereo
  – WV 2  50 cm, 8 band, high agility, stereo
  – Pleiades 1 (a and b)  50 cm, 4 band, high agility, daily revisit, direct tasking
  – Spot 6/7  150 cm, 4 band, high agility, daily revisit, direct tasking, very large foot print.

• Gen III Satellite
  – WV 3  30 cm, 16 band, high agility, stereo
Increased collection with WV-1agility
WV-1 Agility

Single pass

Month’s data in one day!

WorldView 1 collect 10/18/07. The total area collected was about 7700 km². In comparison, Quickbird can only collect one of the green strip per pass.
WorldView-2

Assembled WV2 spacecraft

4-Band

8-Band

Improved Feature Classification ....
Extending Technology Leadership

Introducing the 1st multi-payload, super-spectral, high-resolution commercial satellite.

WorldView-3®
WorldView bus: High-agility platform
Main instrument: Panchromatic + 8 multispectral bands
Secondary instruments: 8 SWIR bands + 12 atmospheric correction bands
Resolution: .31 meter, <3.5 m CE90
WV-3 and SWIR
(Short Wave Infrared)

Visible (V)  Near Infrared (NIR)  Short Wave Infrared (SWIR)

<table>
<thead>
<tr>
<th>Picture</th>
<th>Veg</th>
<th>Iron</th>
<th>Man made</th>
<th>Rocks</th>
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Landsat 8
(30 m)

ASTER
(15/30 m)

WV 2 - 3
(1.2 / 3.7)

WV 3 only

300  500  700  900  1100  1300  1500  1700  1900  2100  2300  2500
New and extended applications
Imagery Solutions for Energy Companies

Precision Shallow water bathymetry

- 4-5m depth posting, 0.5 m vertical (shallow)
- Based on 8 band WV-2 mono imagery
- Color calibration
- Needs some calibration control
- Raster maps and contours
- Limited to about 30m depth
- Cost range $120-$150/ sq km
WorldView-2
RE, NIR1, NIR2
2m Image

Aitutaki Lagoon

wave refraction patterns and submerged aquatic vegetation

linear reefs
WorldView-2
C, B, G
2m Image

Aitutaki Lagoon
Qatar Bathymetry with close-up; GRAS sample, 2011
Geologic Mapping
Does resolution make a difference?
WV-3 vs ASTER

WV-3 simulation 3.5 m
False Color IR

ASTER resampled 30 m
False Color IR
Spectral geology

- Surface reflectance and texture
Mutulla Block – QB/WV satellite imagery (50cm)
Mutulla Block – updated geological mapping
Original input data of DEM and satellite imagery
Current outcrop model projected to depth
ASTER: mineral alteration near oil seeps
30 meter, 10-band

Color-coded altered exposures on ASTER imagery
a top Baba Dome

“orange” class reflects smectite, altered w/Fe loss

“blue” class reflects illite, chlorite/epidote, and Mg silicate
WV-2: mineral alteration near oil seeps
2.0 meter, 8-band

Mineral Spectral Profiles

Value (Offset for clarity)

Wavelength Range of WV-2

chlorite
jarosite_2
jarosite_1
goethite

chlorite
goethite
jarosite_1
jarosite_2

image width ~4 km
Ready for Field Checking using GPS
Monitoring
Daily revisit
Classification
Change detection

PLEIADES AND SPOT 6 HAVE DAILY REVISIT
DG CONSTELLATION CHANGING TO COMPLEMENTARY ORBITS
DAILY REVISITS HELPS FOR MONITORING IN POOR WEATHER AREAS.
Monthly – weekly monitoring
Even daily is possible
Acquisitions and divestitures
Leak from drilling fluids, plant damage
Determination whether a well is identifiable

YES

NO
Typical Offsets

157 Feet

235 Feet
Offset Distance (Feet) - Panola

- 0 – 25: 19%
- 26 – 50: 16%
- 51 – 75: 11%
- 76 – 100: 10%
- 101 – 200: 21%
- 201 – 300: 11%
- 301 – 400: 8%
- 401 & Greater: 4%
Louisiana Oil Spill 2010
Oil in the Marshes
Louisiana Oil Spill 2010: Mapping marsh oil using simulated WV-3 SWIR data.

Marsh oil mapped by spectral matching of simulated WV3 data.
Boats

Hollow body boats are used to transport pirated crude and refined oil to and from various locations along the river system.

DigitalGlobe Color Infrared Imagery, October 7, 2013

DigitalGlobe Panchromatic Imagery, October 7, 2013
Identification of Bush Refineries

Due to the refining process employed by the thieves, much of the vegetation in and around the immediate area tends to be destroyed by fire.

In color infrared imagery, healthy vegetation is presented in various shades of red. Conversely, vegetation that has been burned or otherwise damaged by oil in the water appears black.
Development of Illicit Refineries

Imagery analysts leverage DigitalGlobe’s vast archive of imagery to determine the time frame in which new refineries are established.
Multiple resolution of DEM
.5m to 20m spacing  .25m – 5m vertical

- High revisit stereo has made timing practical
- Wide area collections with SPOT 6/7 for mid resolution
- New methods that exploit existing mono imagery
Spot 20 m DSM converted to slope
Green is < than 10°, Yellow is 10-20° and red is >20°
Pleiades/Airbus 1m DSM converted to slope
Feature with about 2m of relief with 20m DEM
Same feature with 1m DEM
While only 2m elevation change the abrupt nature makes a substantial obstacle.
Satellite Imagery ➔ Vricon 3D model ➔ Vricon Rapid DSM

Multiple overlapping satellite images from archives ➔ The Vricon 3D terrain model is produced from:
- Multiple overlapping images
- A unique stereo algorithm

The Vricon Rapid DSM is produced by sampling the elevation from the Vricon 3D terrain model
Radar Satellite

- Active source
- Day and Night Pictures
- Two collection windows per day
- Penetrates clouds
- High probability to collect
- Variable resolution and beam pattern to meet requirements
- Penetrates vegetation with some wavelengths.
Ice picture
Natural Oil Seeps
Landsat over Terrain
Palsar over terrain
Pipeline Startup
Radar—Forties Field Dec 24
Radar—Forties Field Dec 27
GOM Spill
GOM Spill
Surface Movement Monitoring

Differential SAR Interferometry

Sample – Oil Production 1

BAFA Rel. 424-12.00-1101454 bis
BAFA Rel. 424-12.00-1101457
Surface Movement Monitoring

New Developments – Oilfield Infrastructure Monitoring

Water Flooding: Well casing failure results in leakage into shallow layers and resulting uplift

Oilfield Infrastructure Monitoring: Surface Movements for Oman Oilfield derived from TerraSAR-X data between 27/01/2008 and 14/05/2009
Pipeline Applications
Alignment sheet are the bible of pipelines
Pipeline Monitoring-Optical
Revegetation change

Green is good, red is bad
Some things to come

- UAS (Drones)
  - Small Quadcopters---applications to inspection and monitoring
    - Have been approved for commercial operations with limitations
  - Long range –larger units—pipeline monitoring, wild life monitoring
    - Approval further away, must figure out avoidance

- Micro earth observation satellites
  - Low resolution 1-5m Very high revisit to multiple daily
A short review of things that are going on in satellite earth observation

THANK YOU