DigitalGlobe Geometric Calibration

Chris Comp

Remote Sensing Sciences Team
DigitalGlobe Current Constellation

1999
IKONOS®
681 km orbit
0.82 m GSD
408 M sqkm mission

2001
QuickBird®
450 km orbit
0.65 m GSD
636 M sqkm mission

2007
WorldView-1®
496 km orbit
0.50 m GSD
1.3 M sqkm/day

2008
GeoEye-1®
681 km orbit
0.41 m GSD
0.35 M sqkm/day

2009
WorldView-2®
770 km orbit
0.46 m GSD
1.0 M sqkm/day

2014
WorldView-3®
617 km orbit
0.31 m GSD
0.68 M sqkm/day

2016
WorldView-4®
617 km orbit
0.31 m GSD
0.68 M sqkm/day

AVAILABLE VIA DIGITALGLOBE ARCHIVE
CURRENTLY IMAGING IN ORBIT

The DigitalGlobe active constellation collects ~4 Million sq.km. of imagery.
Equivalent to 13.2 Terra pixels. EVERY DAY!
Anatomy of a DigitalGlobe Satellite: WorldView-3

- **Orbit**
  - 617 km sun-synchronous orbit
  - Local time descending node 10:30am

- **Satellite**
  - 2800 kg mass
  - 5.7 m tall x 2.5 m across (7.1 m including solar arrays)
  - CMG momentum actuators
  - General Dynamics Viceroy GPS Receiver
  - Ball Aerospace CT-602 star trackers
  - Northrop Grumman SSIRU gyro

- **3 Imaging Sub-Systems**
  - Visual 0.31 m Panchromatic + 8 1.24 m Multispectral bands
  - SWIR, 8 bands, 3.7 m GSD
  - CAVIS (cloud, aerosol, water-vapor, ice, snow, atmospheric calibration instrument)
DigitalGlobe Future Constellation: WorldView Legion

- Multi-satellite constellation
- 2X 30cm collection capacity
- Built by Maxar partner Space Systems Loral
What is geometric calibration?

*Exterior*: observing alignments of star trackers and gyroscope sensors relative to telescope boresight.

*Interior*: observing distortion in telescope optics and focal-plane (CCD that collects light to make pixels in an image)
Exterior Geometric Calibration – How do we do it?

• Align star tracker and gyroscope attitude sensors to telescope to about 60-millionths of a degree

• Observe alignment errors using images of ground-control points, and also images of stars

• Critical driver to geolocation accuracy of image products
WorldView-3 Instrument Alignment: First 6 weeks

Launch: Aug 13, 2014
Fully Calibrated: Oct 1, 2014

Each dot is the mean in-scan or cross-scan accuracy of a calibration image measured in the camera frame (converted to meters)
WorldView-3 Accuracy Trend: First 9 months of mission

Each green dot is the mean radial accuracy of a calibration image measured in a horizontal geodetic coordinate system.

Each black dot is the CE90 accuracy of the month as shown.
WorldView-3 Interior Geometric Calibration

• Collected 15 calibration images over Las Vegas calibration range

• Register calibration images to ground-control features from reference imagery: this generates observations of interior geometry

• Fit observations to mathematical models of optical distortion and focal-plane detector locations: this generates the calibration parameters

• Validate calibration using an additional 66 images over calibration range

• This is all done using custom software built by DG calibration team
Las Vegas Test Range

50x50 km Of Reference Image Tiles with GCPs

Calibration images overlaid with GCPs
Geometric Distortion Before Calibration: Pan Band

In-scan Geometric Errors (pan pixels)

Cross-scan Geometric Errors (pan pixels)
Geometric Distortion After Calibration: Pan Band

In-scan Geometric Errors (pan pixels)

Cross-scan Geometric Errors (pan pixels)
WorldView-3 Multi-spectral Band-to-Band Registration

<table>
<thead>
<tr>
<th></th>
<th>Coastal</th>
<th>Blue</th>
<th>Green</th>
<th>Yellow</th>
<th>Red</th>
<th>RedEdge</th>
<th>NIR1</th>
<th>NIR2</th>
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Units are 90-percentile of MS pixels.
For example, band pair Blue-Green registration = 0.10 pixel 90%
High-resolution pan-sharpened color
Stereo-image Derived Elevation/Topography*

*Images Courtesy of PhotoSat, Ltd
## Remote Sensing Sciences (Calibration) Team

### Remote Sensing Sciences Team

<table>
<thead>
<tr>
<th>Geometric Calibration</th>
<th>Radiometric Calibration</th>
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<tbody>
<tr>
<td>David Mulawa (5)</td>
<td>Nancy Podger (3)</td>
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<tr>
<td>Brendan Clarke (4)</td>
<td>Todd Updike (8)</td>
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<td>Ryder Whitmire (2)</td>
<td>Michele Kuester (3)</td>
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<td>Woodson Bercaw (12)</td>
<td>Tina Ochoa (1)</td>
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<td>Chris Comp (4)</td>
<td>Summer interns</td>
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(Number of satellite launches supported)

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<thead>
<tr>
<th>Satellite &amp; Instrument Expertise</th>
<th>R&amp;D Geometric Expertise</th>
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<tr>
<td>John McKune (54 incl Shuttle)</td>
<td>James Balasalle (1)</td>
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