ABSOLUTE CALIBRATION OF THE RAPIDEYE CONSTELLATION - PROGRESS AND PLANS

- Andreas Brunn | BlackBridge CalVal
Outline

- BlackBridge and the RapidEye System
- Absolute Calibration Campaigns
  - Past and Current Campaigns
  - Integrating results
- Outlook
  - Integrating MOBY Buoy
  - First results
BLACKBRIDGE AND THE RAPIDEYE SYSTEM
RapidEye Capacity Overview

**Five-Satellite Constellation**
Enables daily target revisit

**Broad Area Collection**
77-km-wide sensor swath, ideal for large-area monitoring and mapping

**Large Collection Capacity**
More than 5 million km² collected daily

**High Resolution Imaging**
5-meter resolution imagery

**Multispectral Imaging**
5 spectral bands for improved feature discrimination

**Extensive Imagery Archive**
More than 6 billion km² of archived imagery
## The Satellite Constellation

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Launch date:</strong></td>
<td>August 29, 2008</td>
</tr>
<tr>
<td><strong>No. of satellites:</strong></td>
<td>5</td>
</tr>
<tr>
<td><strong>Orbit:</strong></td>
<td>Sun synchronous</td>
</tr>
<tr>
<td><strong>Equator crossing time:</strong></td>
<td>11:00</td>
</tr>
<tr>
<td><strong>Orbits per day:</strong></td>
<td>14.8 per satellite</td>
</tr>
<tr>
<td><strong>Nominal altitude:</strong></td>
<td>630 km</td>
</tr>
<tr>
<td><strong>Swath width:</strong></td>
<td>77 km</td>
</tr>
<tr>
<td><strong>Imaging capacity:</strong></td>
<td>max. 1,500 km /orbit</td>
</tr>
<tr>
<td><strong>System image capture capacity:</strong></td>
<td>more than 5 million km²/day</td>
</tr>
</tbody>
</table>
The Spacecraft

Weight: 156.4 kg

Bus: 112.9 kg

Payload: 43.5 kg

Bus built by: SSTL (UK)

Payload built by: Jena Optronik (Germany)
## Sensors Onboard the Satellites

<table>
<thead>
<tr>
<th>Manufacturer:</th>
<th>Jena Optronik, Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model:</td>
<td>JSS56 Spaceborne Scanner</td>
</tr>
<tr>
<td>Design:</td>
<td>TMA (Al mirror)</td>
</tr>
<tr>
<td>Eff. focal length:</td>
<td>633 mm</td>
</tr>
<tr>
<td>Entrance Pupil Ø:</td>
<td>147 mm</td>
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<tr>
<td>f-number:</td>
<td>4.3</td>
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<tr>
<td>CCD:</td>
<td>Atmel (AT71544)</td>
</tr>
<tr>
<td>Pixel Size:</td>
<td>6.5 m</td>
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<tr>
<td>Pixels per line:</td>
<td>12,000</td>
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<tr>
<td>Camera dynamic range:</td>
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System Overview

Blocks:
- Products
  - GeoCloud
- Business operations
  - Order
- Ground segment
  - Raw image data
  - Acquisition plan
- 5-spacecraft Constellation
- Customer DDL
  - Reception schedule
- Customer
  - Raw image data
  - Order

Flow:
- S/X-Band data Up-/ Downlink
- Imagery product processing
  - Level 1B
  - Level 3A
  - Level 3B
- Mosaic product processing
- Mosaics
- Dissemination system
ABSOLUTE CALIBRATION
Field Campaigns

- Field Equipment
  - Sun Photometer
  - Line-of-Sight Photometer
  - Wide Angle Photometer
  - Field Spectrometer
Field Locations

- Railroad Valley
  - Dry Lake Bed
  - Bright
  - Homogeneous
  - High Elevation
Field Locations

- Brookings
  - Prairie
  - Dark
  - Easily Accessible
Previous Vicarious Campaigns

- Campaigns have been performed with the University of Arizona and South Dakota State University yearly since 2009.
  - 2009-2010 Railroad Valley and Ivanpah Playa (2 sats., 10 collects)
  - 2011 Railroad Valley (5 sats., 5 collects)
  - 2012 Railroad Valley (5 sats., 25 collects)
  - 2013 Brookings (5 sats., 9 collects)
  - 2013 Railroad Valley (5 sats., 5 collects)
  - 2014 Railroad Valley (5 sats., 10 collects)
  - 2014 Brookings (5 sats., 12 collects)
  - 2015 Continuing ...
INTEGRATION
Update Of Calibration Factors Early 2015

- Involves:
  - Absolute Calibration Results from all 2014 Collects
  - Temporal Calibration Results (incl. discontinuity correction)
  - Spatial Calibration Results from Side Slither and Dark Images
Discontinuity Correction

- Both sections are corrected with the same temporal correction gain.
- The second, smaller section is multiplied by a discontinuity correction gain.

Percent Difference 2.344%
Discontinuity Correction

Before Discontinuity Correction

Gaps are filled using mean values of the same time (months) of previous years adjusted using preliminary gains and offsets.
Discontinuity Correction

After Discontinuity Correction
Discontinuity Correction

Approx. 2% sensitivity loss over the mission lifetime
AbsCal Results

Blue Band Example

- Linear (2014)
  - 2014
  - R² = 0.9987
  - y = 16.674x - 3044.4

- Linear (ALL)
  - 2015
  - ALL
  - R² = 0.9955
  - y = 15.84x - 2311.8

Ground*100

Temp Adj Received Sensor DN

Brookings

0 200 400 600 800 1000 1200 1400

-1000

1000

3000

5000

7000

9000

11000

13000

15000

17000

19000
AbsCal Results

NIR Band Example

\[ y = 12.013x - 1564.9 \quad R^2 = 0.9977 \]

\[ y = 11.657x - 1264.7 \quad R^2 = 0.9979 \]
AbsCal Results
WHAT’S NEXT ...
2015 Absolute Calibration

- Railroad Valley Site
  - Collaboration with University of Arizona
  - 1 image and simultaneous field collect for each spacecraft in 2015
  - Up to 100 Image takes with all satellites and reference data from the automated calibration site between April 2015 and April 2016

- Brookings
  - Collaboration with South Dakota State University
  - Goal: 2 Image takes per SC with simultaneous field collects until End of October 2015
2015 Absolute Calibration

- MOBY Buoy
  - Method to use MOBY data for absolute calibration is currently under development

- Results of campaigns are evaluated as they come in

- Final combined implementation is expected to be done when all reference information is available
The MOBY Buoy

- Marine Optical Buoy
- Located 20 km west Lanai HI
- 1200 m water depth
The MOBY Buoy

- Marine Optical Buoy
  - Measures water leaving radiance (-1m)
  - Measures irradiance (+2.5m)
  - NIST calibrated response

Brown et.al., SPIE 2007
Integration of the MOBY Site

- **Goal:** Use MOBY bottom of atmosphere reflectance and irradiance data for validation of RapidEye imagery on the dark end of the brightness range.

- **Conditions:**
  - The station is moving
  - Water turbidity is large
  - Reflectance based method is limited by the wave registration on the satellite imagery
Reflectance Based Validation

1. Moby MOS Spectrum
   - Import spectra and metadata
     - Moby Metadata
       - MOS Spectrum
         - Reflectance based evaluation
2. Rapideye Imagery
   - Import imagery and metadata
     - ATCOR process / sun glint correction
       - Extract ROI at Moby location
         - Turbidity suppression
           - Image Spectrum/Stats
             - Reflectance based evaluation
First Results

- ATCOR processing with 10km visibility:
Aerosol Influence

- ATCOR processing with 15km visibility:

It is crucial to find the right atmospheric conditions for the right results.
MOBY Status and Outlook

- RGB bands may be processed to reasonable values using high aerosol contents
- NIR bands show consistently too high values
- water turbidity impede unlimited use of MOBY data for RapidEye validation and calibration

Further steps:
- implement at-sensor radiation based validation
- check sunglint correction approaches