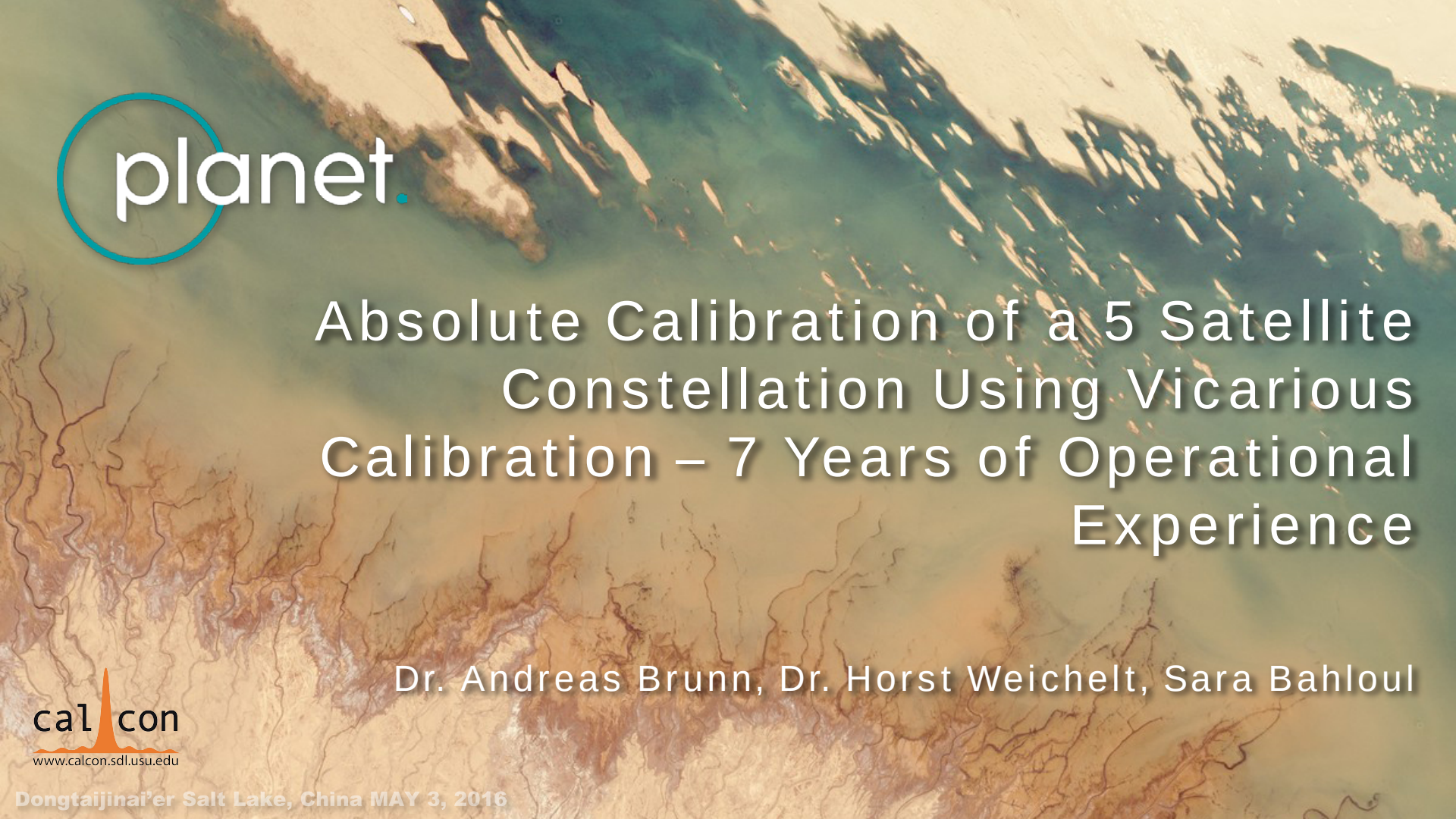


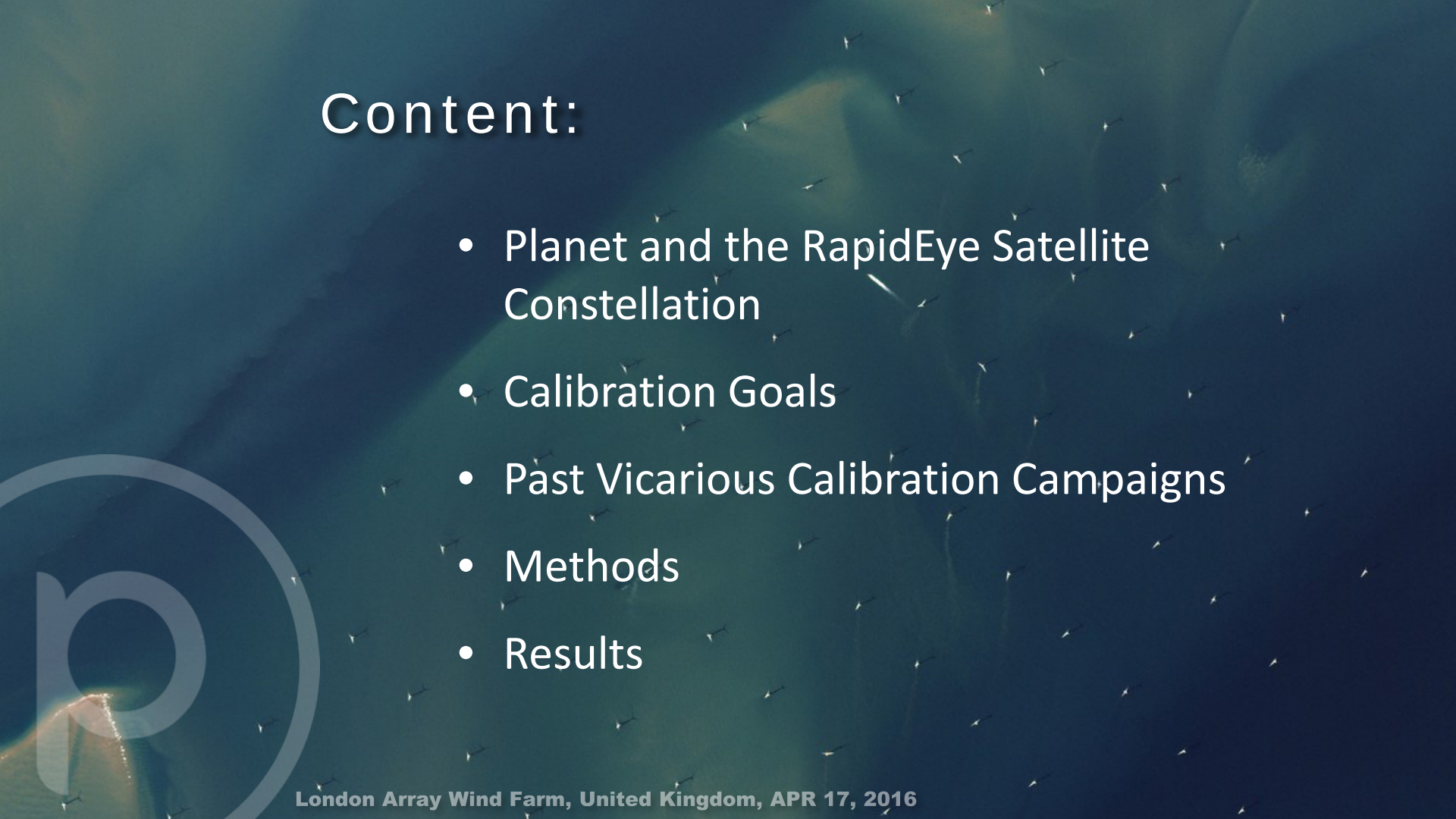
Absolute Calibration of a 5 Satellite Constellation Using Vicarious Calibration – 7 Years of Operational Experience

Dr. Andreas Brunn, Dr. Horst Weichelt, Sara Bahloul

calcon
www.calcon.sdl.usu.edu

Content:

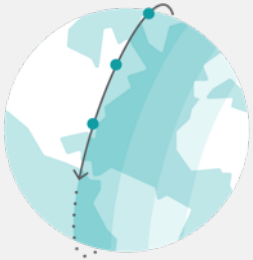
- Planet and the RapidEye Satellite Constellation
- Calibration Goals
- Past Vicarious Calibration Campaigns
- Methods
- Results



OUR PRODUCTS

Monitoring Programs

Our subscription program of continuous imaging of places you care about.

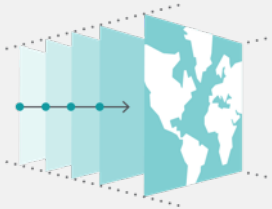


Imagery à la Carte

À la carte imagery that is tailored for one-time purchase of satellite data.

Global Basemaps

Seamless, color-balanced, cloud-free mosaics – ready for immediate use.



Imagery Archive

Explore one of the largest archives online today – dating back to 2009.

Planet operates the largest fleet of earth observation satellites available

- 5 Satellite RapidEye constellation (launched 2008, expected live at least until 2020 and beyond)
- Fast growing number of cubesats (doves in flocks)

The Satellite Constellation

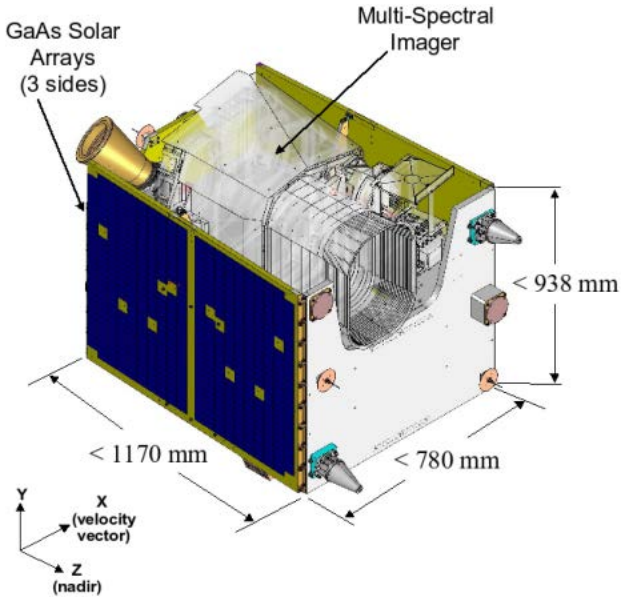
Launch date:	August 29, 2008
No. of satellites:	5
Orbit:	Sun synchronous
Equator crossing time:	11:00
Orbits per day:	14.8 per satellite
Nominal altitude:	630 km
Swath width:	77 km
Imaging capacity:	max. 1,500 km /orbit
System image capture capacity:	Up to 6 million km^2/day

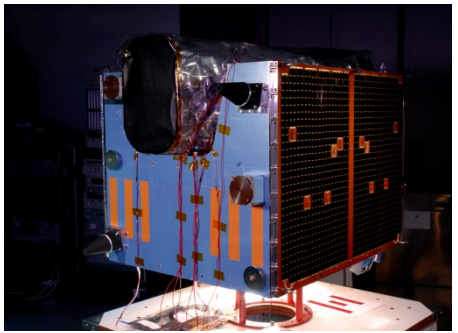
The Spacecraft

Weight:	156.4 kg
Bus:	112.9 kg
Payload:	43.5 kg

Bus built by: SSTL (UK)

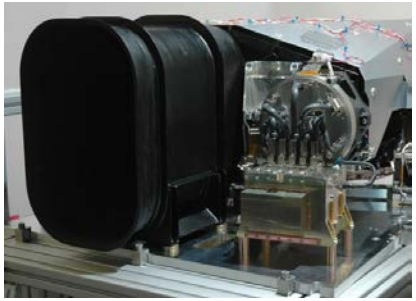
Payload built by: Jena Optronik (Germany)

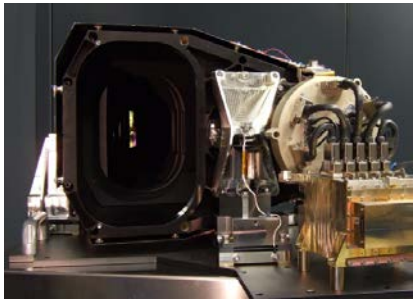




Sensors Onboard the Satellites

Manufacturer:	Jena Optronik, Germany
Model:	JSS56 Spaceborne Scanner
Design:	TMA (Al mirror)
Eff. focal length:	633 mm
Entrance Pupil Ø:	147 mm
f-number:	4.3
CCD:	Atmel (AT71544)
Pixel Size:	6.5 m
Pixels per line:	12,000
Camera dynamic range:	12-bit





Satellite Orbit Characteristics

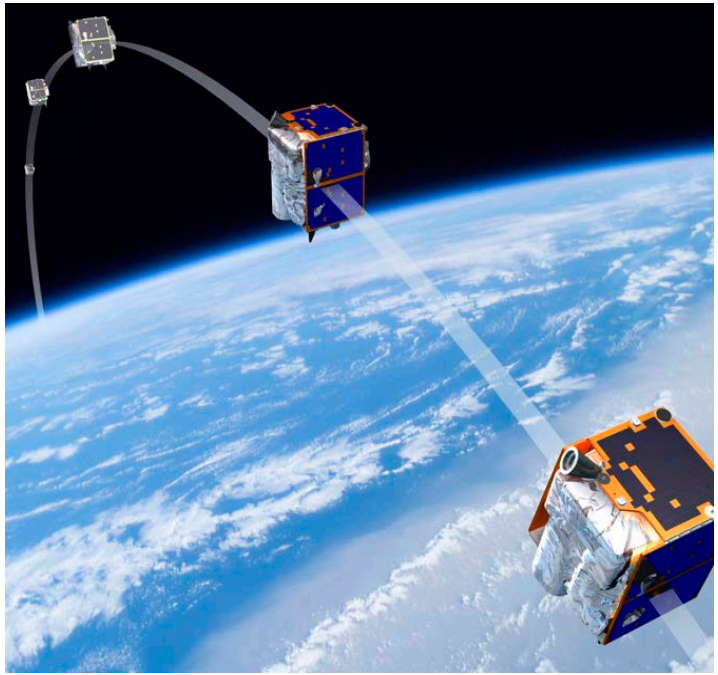
All 5 RapidEye satellites in the same orbit

“Flying” from north to south

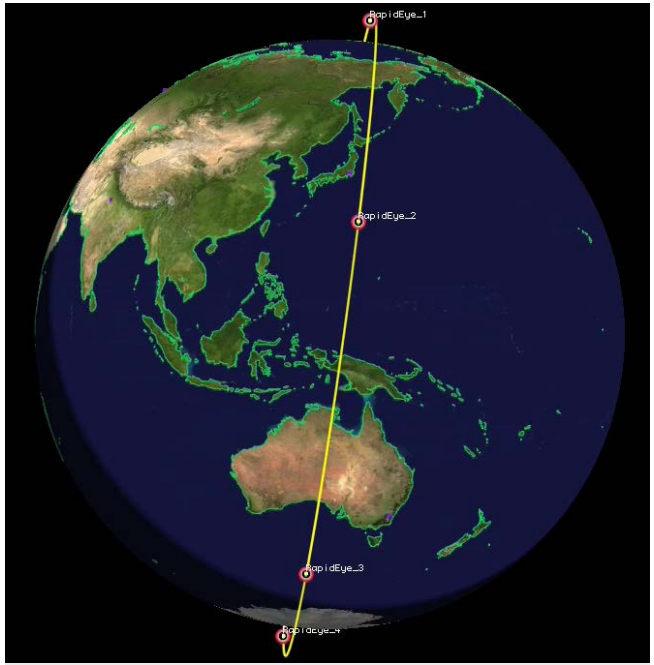
Image take(s): up to 40-50 per satellite, per day

Swath: 77 km

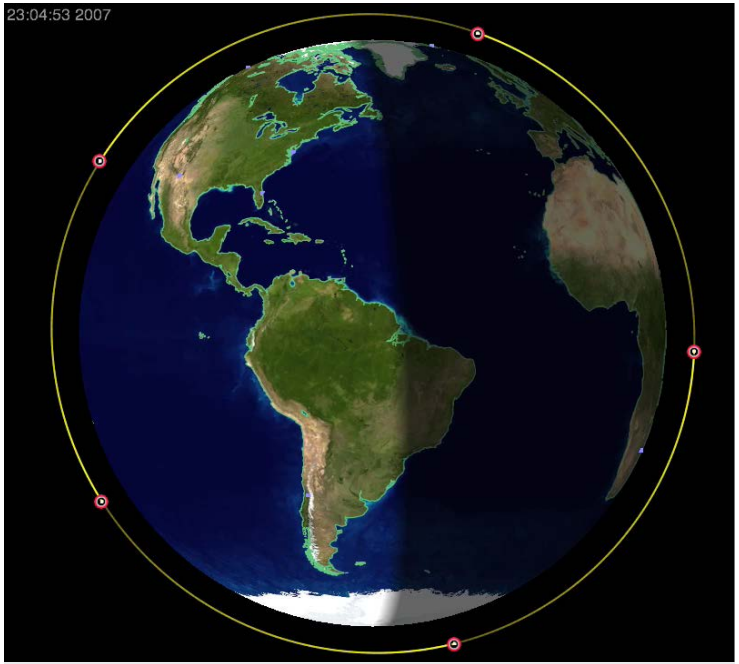
Path Length: ~1200 km



Satellite Orbit Characteristics



Sun-synchronous orbit



Equally spaced in one orbital plane

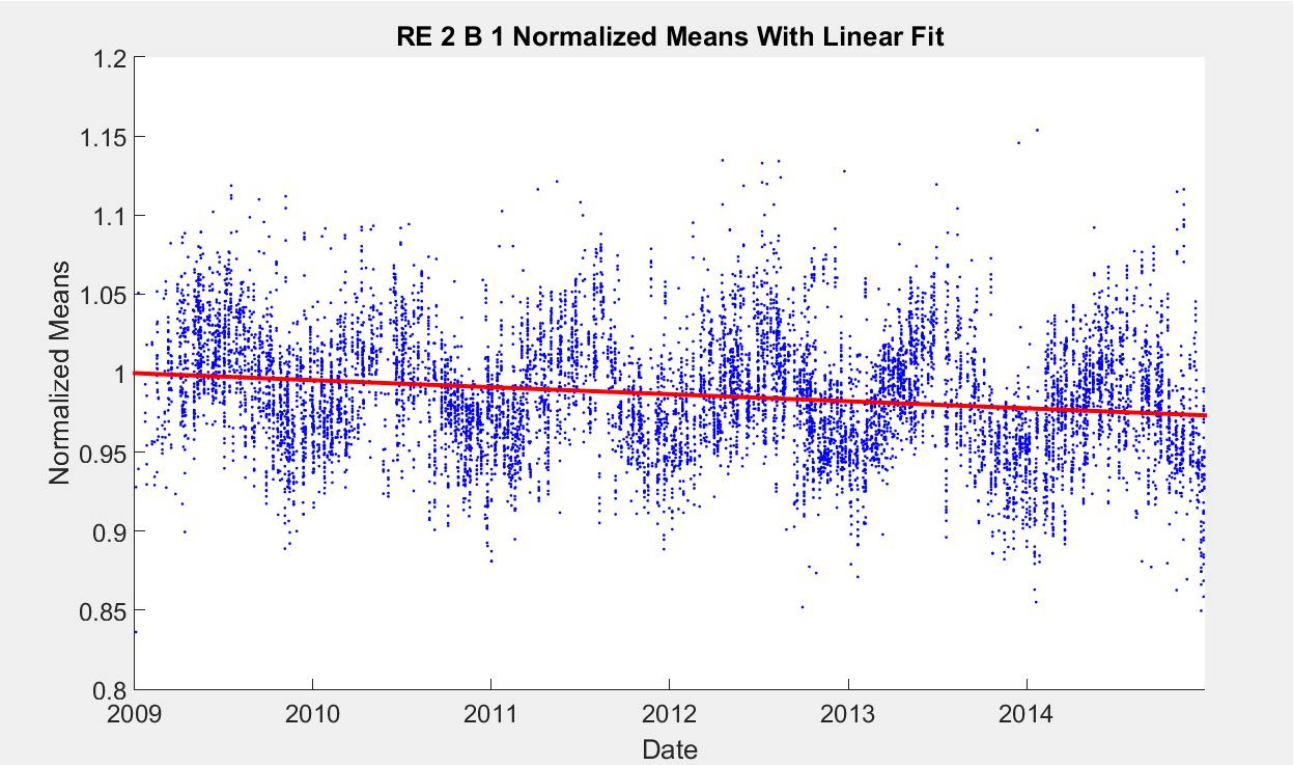
Calibration Goals

- Cross calibrate the satellites and deliver stable response over time
- Transfer the relative response to absolute radiance units

Temporal Calibration Approach

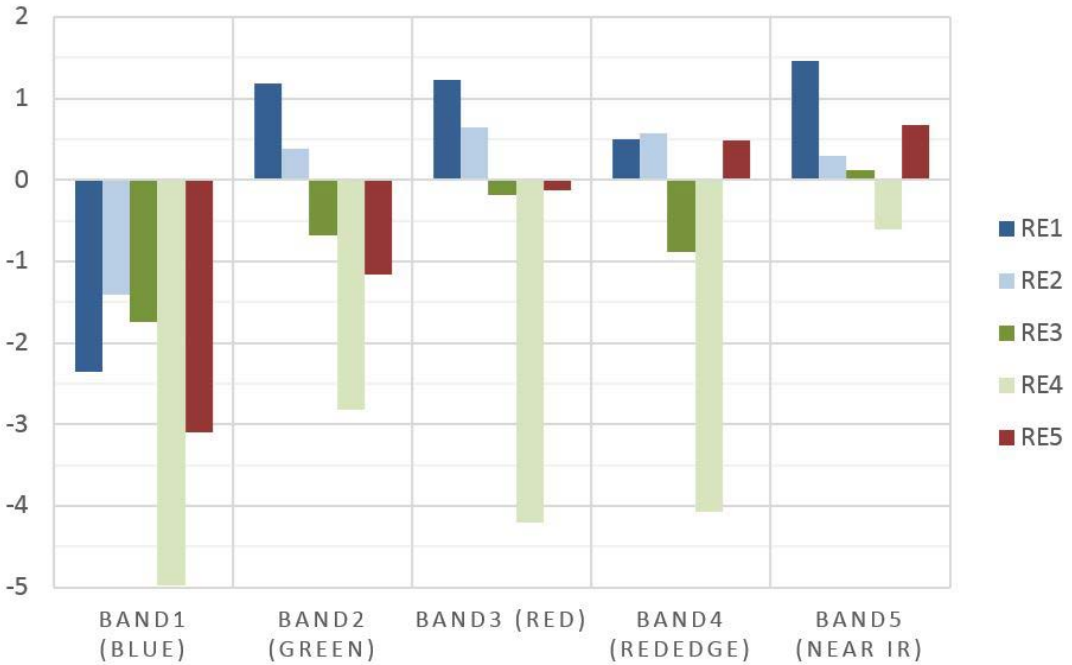
26 Calibration Sites, imaged every 2 Weeks with all Satellites

Temporal Calibration Approach



Per Band Normalized Image Mean Values

Temporal Calibration Approach



Detector Degradation since beginning of operations until July 2015

Degradations are corrected in image products

Absolute Calibration

- RapidEye Cameras do not have on board calibration means (no shutter door, no light, no diffusors, ...)
- Absolute Calibration is done using vicarious calibration approaches
  - Since 2009 using Railroad Valley and Ivanpah desert site

Railroad Valley

Ivanpah Playa

Absolute Calibration

- Since 2013 Brookings (South Dakota) Grass Site

- Less stable atmosphere
- easier accessible
- Darker site (except NIR)

Absolute Calibration Reference Sets

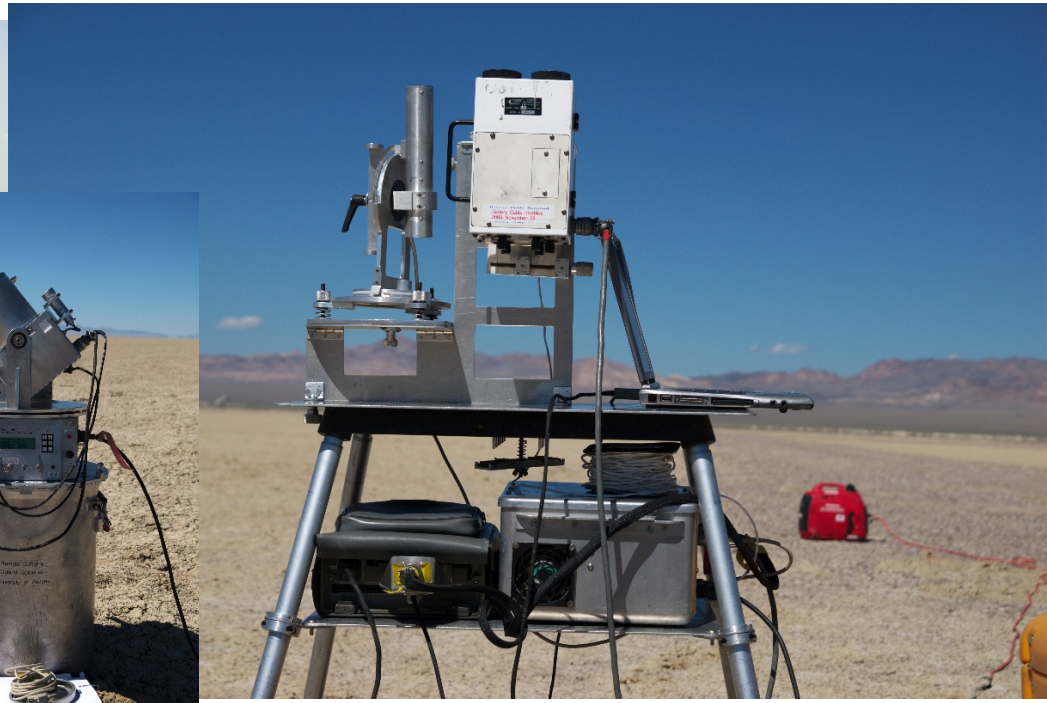
	U o Arizona	South Dakota SU
2009 - 2010	10	-
2011	5	-
2012	25	-
2013	5	9
2014	10	12
2015	35 (incl. RadCats)	10

Number of collects per site and year

Data Acquisition

Field Spectrometer

Sun Photometer



LOSR, wide angle photometer, sky camera, etc

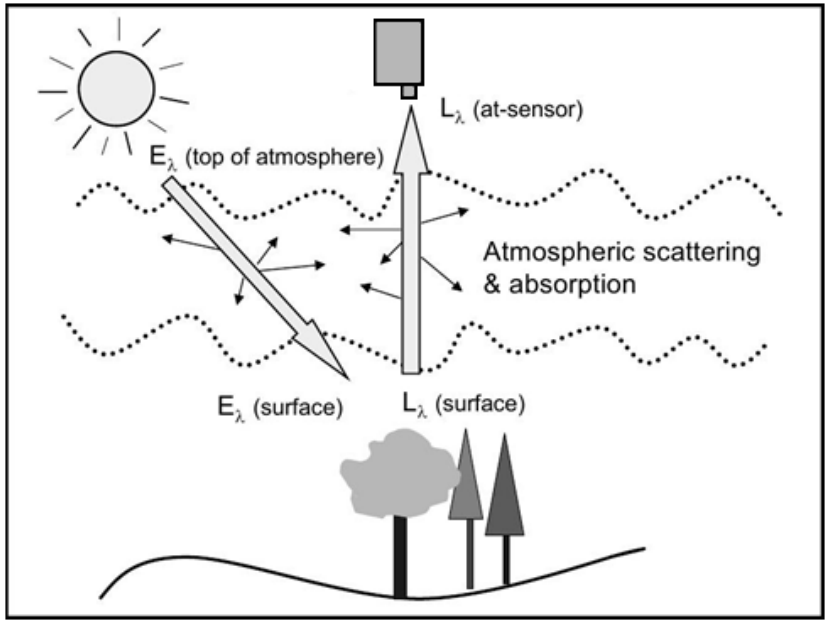
Establish the Known Radiance

On-site: Measure the surface reflectance of the target area.

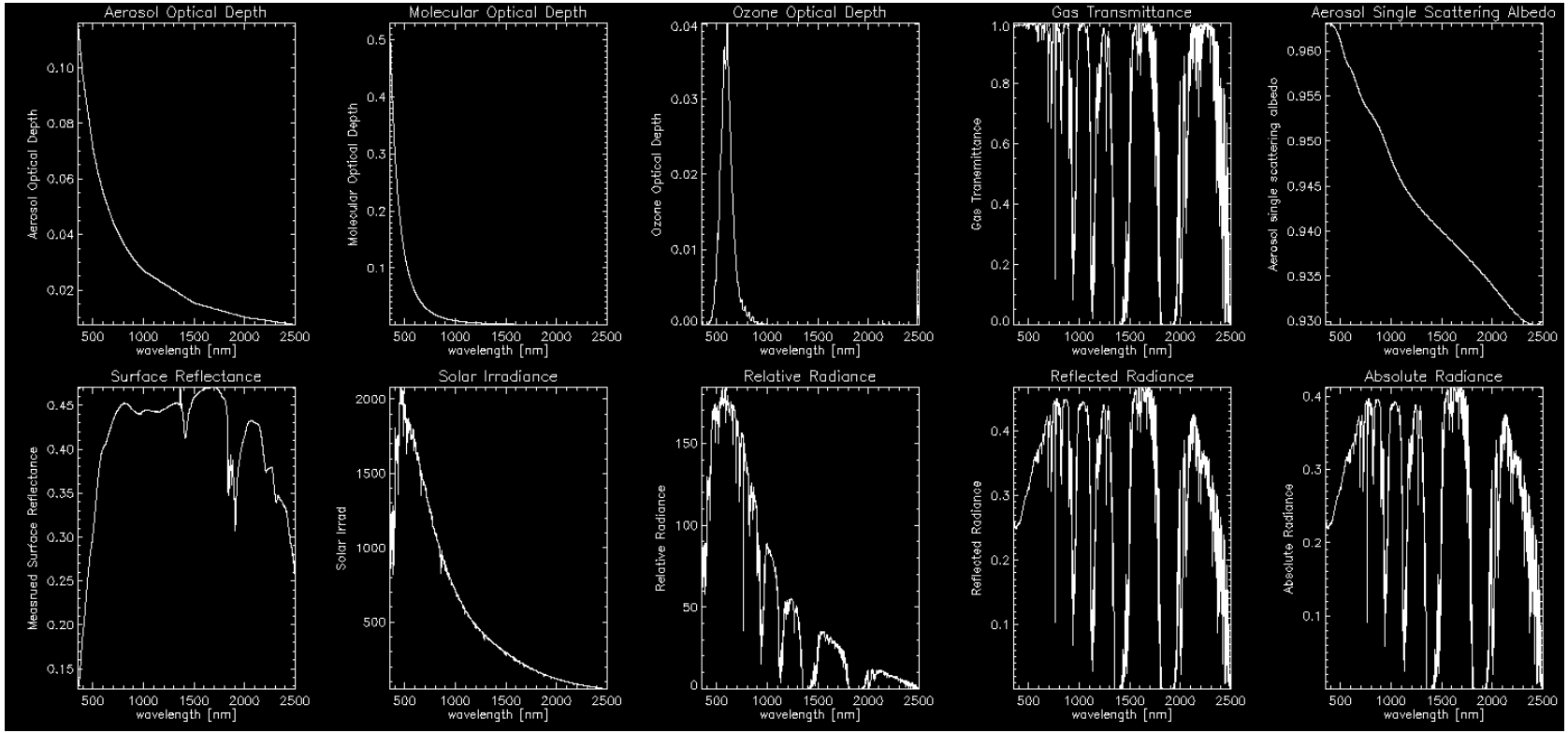
On-site: Measure the atmospheric conditions above the site

In-Lab: Use accepted values for the atmospheric scattering & absorption, and the sun-target geometry at the time of collection.

In-Lab: Ingest all of these into a radiative transfer algorithm and compute a predicted spectral radiance reaching the top of the atmosphere after reflection from the target.



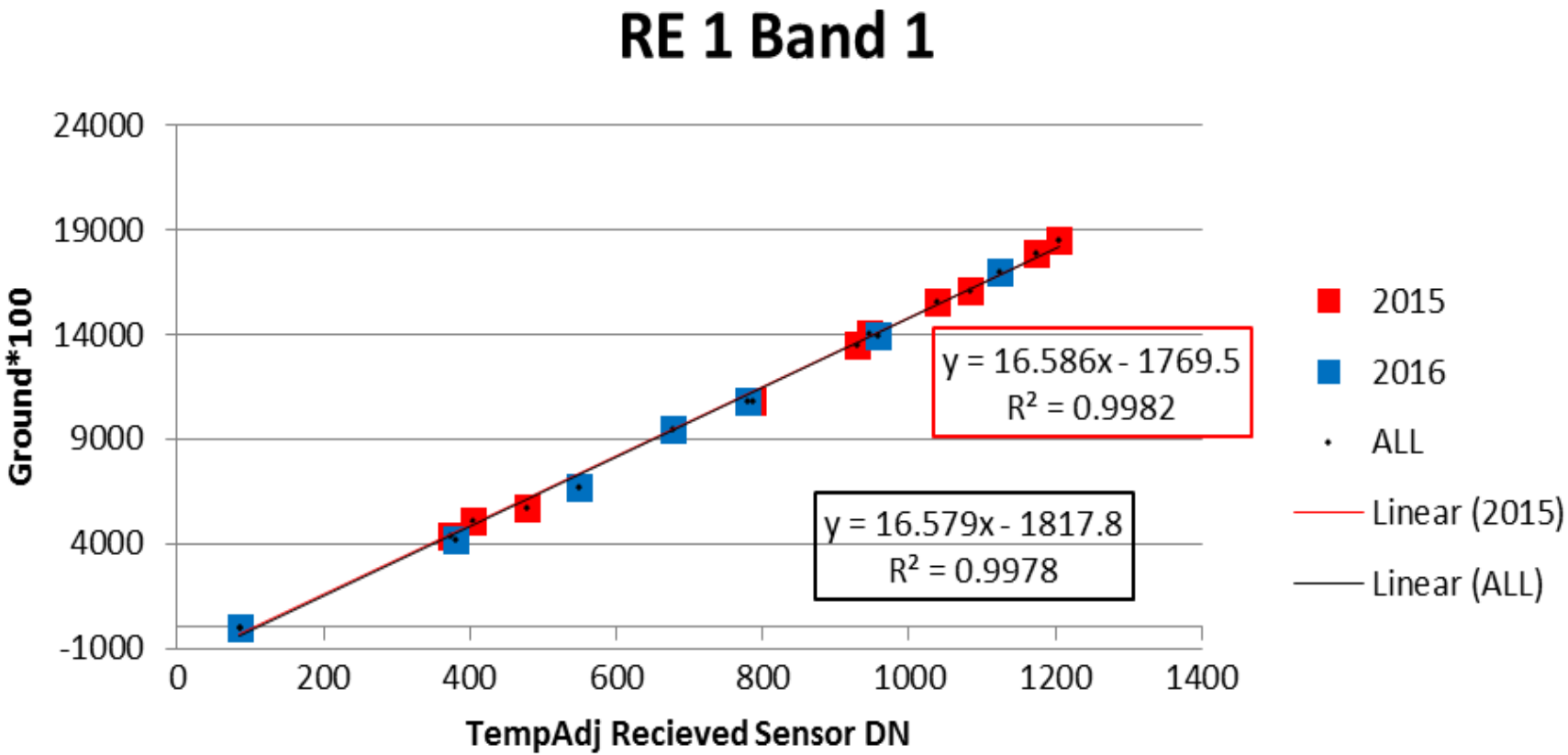
Derived from Ground measurements



Results

Muir Woods & Mt. Tamalpais, California, USA DEC 23, 2015

Linear Fit


RE 1 Band 1
24000
19000
14000
9000
4000
-1000
Ground*100
0
200
400
600
800
1000
1200
1400
TempAdj Recieved Sensor DN
y = 16.586x - 1769.5
R² = 0.9982
y = 16.579x - 1817.8
R² = 0.9978
2015
2016
ALL
Linear (2015)
Linear (ALL)

Calibration accuracies

All in all the temporal and absolute calibration approaches lead to these accuracies:

	RE1	RE2	RE3	RE4	RE5
Bd1	−2.52%	−1.34%	2.24%	3.04%	3.29%
Bd2	0.86%	−3.27%	−1.27%	−3.08%	0.50%
Bd3	2.41%	3.31%	1.12%	1.98%	1.23%
Bd4	0.42%	−0.10%	−0.18%	2.18%	−3.19%
Bd5	0.33%	−0.24%	1.56%	−0.35%	−1.95%

Lessons Learned

- Even with daily coverage possibilities and automated sites it is hard to get enough good reference points
- One calibration site is not enough: more than one sites on different brightness levels are required to correct gains

Thank You!
Questions?

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horst.weichelt@planet.com
sara.bahloul@planet.com