THE CALIBRATION AND VALIDATION ACTIVITIES PERFORMED AT RAPIDEYE DURING THE LAST YEAR

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CONTENT

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- Short System Overview and Calibration Concept
- Relative Radiometric Calibration
- Absolute Calibration
  - History of Absolute Calibration at RapidEye
  - Results of the 2012 Campaign
- Response Evaluation using Near Simultaneous Collects
- Spatial Resolution Evaluations

SYSTEM OVERVIEW

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- Commercial Earth Observation System
  - Constellation of 5 EO satellites
  - Image acquisition at 11:00 local, sun sync orbit
  - Global coverage and daily re-visit capability
  - 6.5 m GSD
  - 5 bands in VIS and NIR wavelength
  - Designed for applications in agriculture, forestry, infrastructure, security, emergency monitoring …

SYSTEM OVERVIEW

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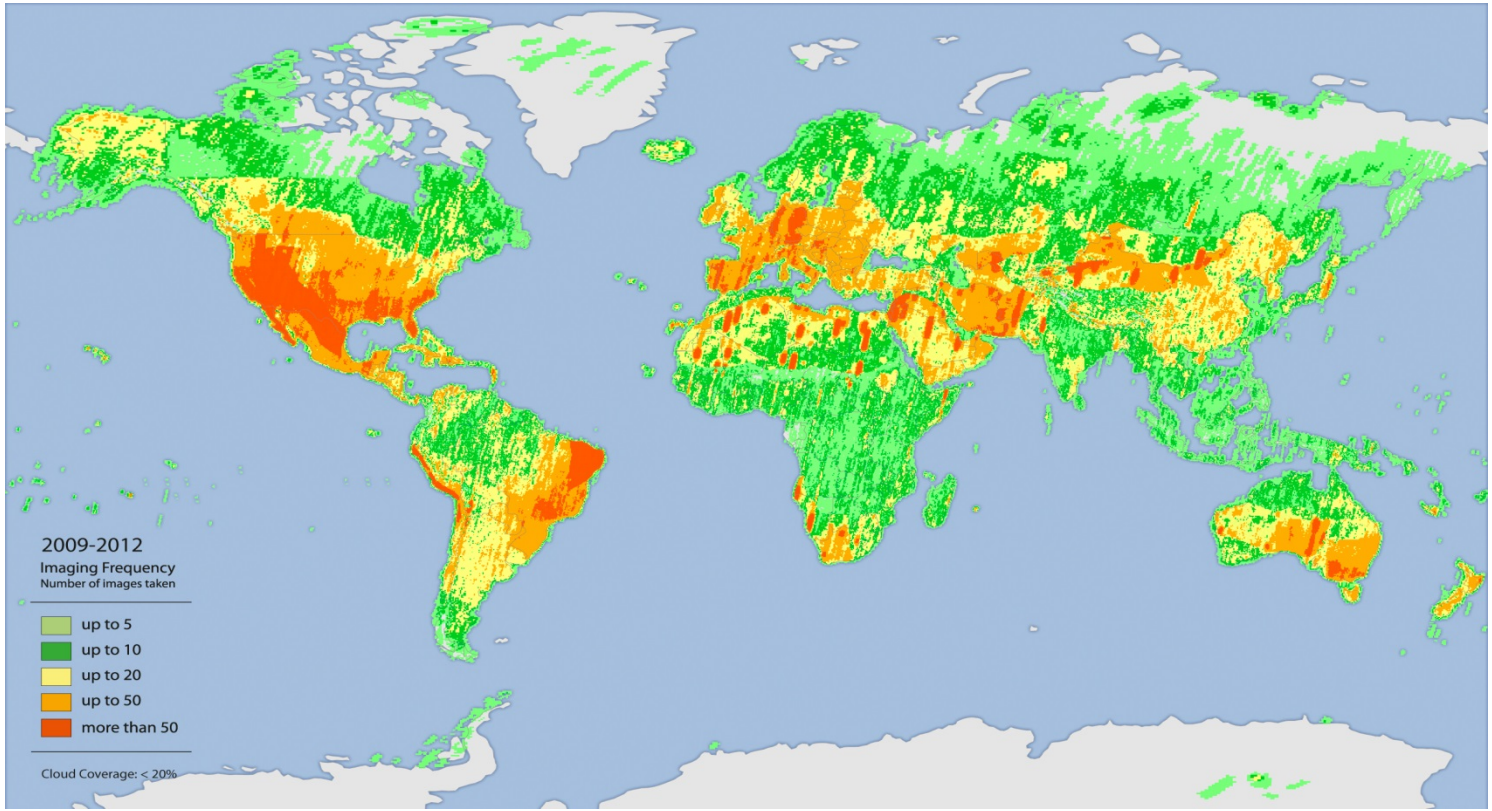

CALIBRATION CONCEPT (RADIOMETRY)

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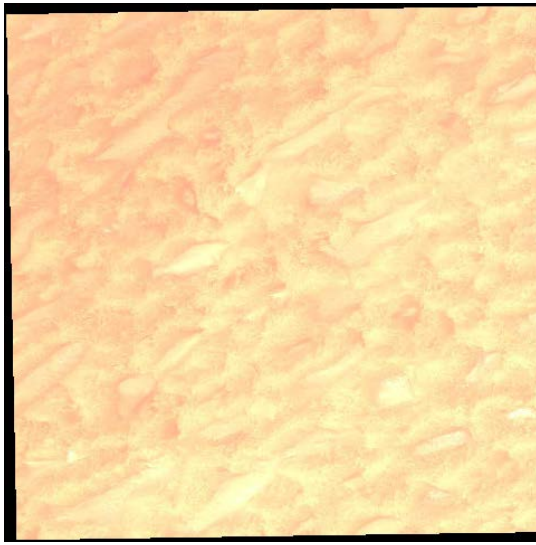
- System Requirements:
  - Each detector of one band delivers the same DN when excited to the same radiance (PRNU).
  - The individual cameras are cross calibrated to within 5 %.
  - The response is stable over the full mission lifetime.
  - The cameras are absolutely calibrated to radiance.

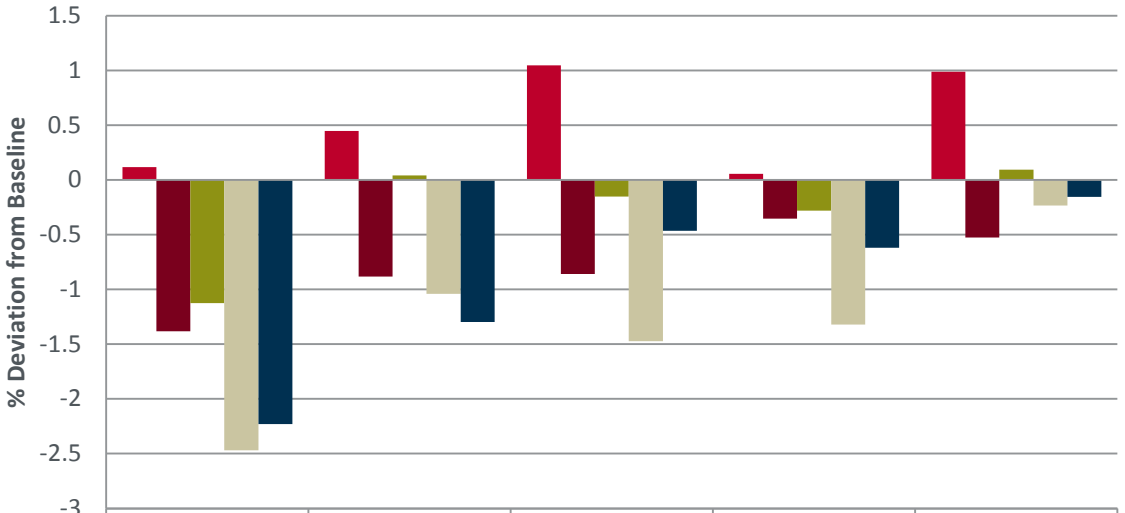
RELATIVE RADIOMETRIC CALIBRATION

- Cross calibration between the satellites of the constellation.
  - 26 calibration sites are imaged on a twice a month basis.
  - Medium – high radiance homogeneous desert sites are used as calibration sites.
  - Site means are used to compare the actual sensor response against a pre-defined response baseline



RELATIVE RADIOMETRIC CALIBRATION

Percent Deviation from radiometric Baseline. (Feb ’13)



	Blue	Green	Red	Red-Edge	NIR
RE1	0.1171	0.447	1.0459	0.0563	0.9861
RE2	-1.3831	-0.8826	-0.8592	-0.3547	-0.5255
RE3	-1.1268	0.0392	-0.1536	-0.2801	0.0931
RE4	-2.4705	-1.0394	-1.4739	-1.3201	-0.2355
RE5	-2.23	-1.2979	-0.4638	-0.6199	-0.1553

ABSOLUTE CALIBRATION

- History of absolute Calibration at RapidEye
  - Pre-Launch, On Ground absolute Radiometric Calibration (2007)
  - Vicarious Calibration
    - 2009 / 2010 Ivanpah Playa and Railroad Valley Playa, 10 field events with 2 satellites (5 per spacecraft), UoA
    - 2011 Railroad Valley Playa, 5 field events (1 with each satellite, verification), UoA
    - …

ABSOLUTE CALIBRATION

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- Contd.
  - 2012 Railroad Valley Playa, 20 field events (4 per satellite), UoA
  - 2012 Brookings Site, 9 field events, SDSU (final results under evaluation)
  - 2013 Railroad Valley Playa, one field event with each of the spacecraft for verification, UoA
  - Potentially more field collects over the Brookings Site in 2013

ABSOLUTE CALIBRATION

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- 2009 absolute calibration campaign showed deviations between modeled and measured at sensor radiance of up to +/- 7.5%
- Absolute calibration of RE3 and RE4 combined with relative radiometric calibration of the constellation allows the transfer of the results to all satellites.

Naughton et all, JACIE 2011

ABSOLUTE CALIBRATION

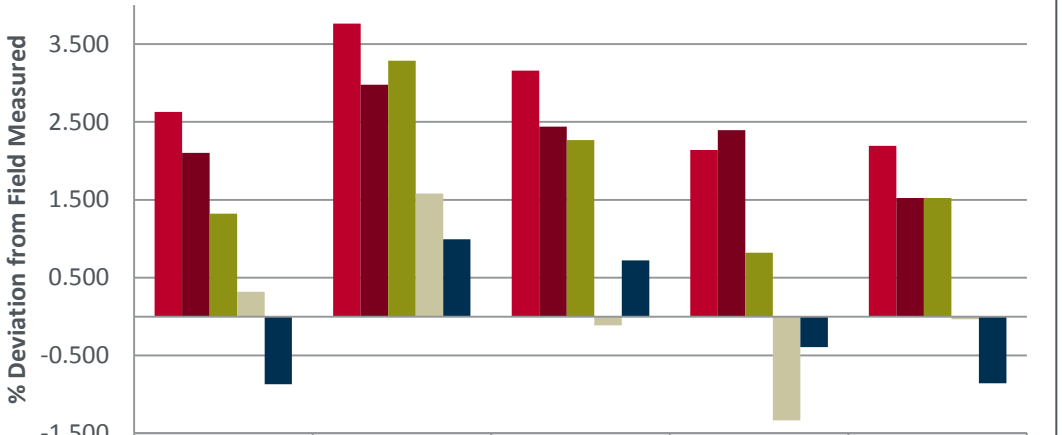
- Jan 2010: Absolute calibration results have been used to adjust RapidEye calibration and correction settings.

- Verification campaign in spring 2010 showed that satellite at sensor radiance matches ground measurement based prediction to better than 4%

Naughton, JACIE 2010

ABSOLUTE CALIBRATION

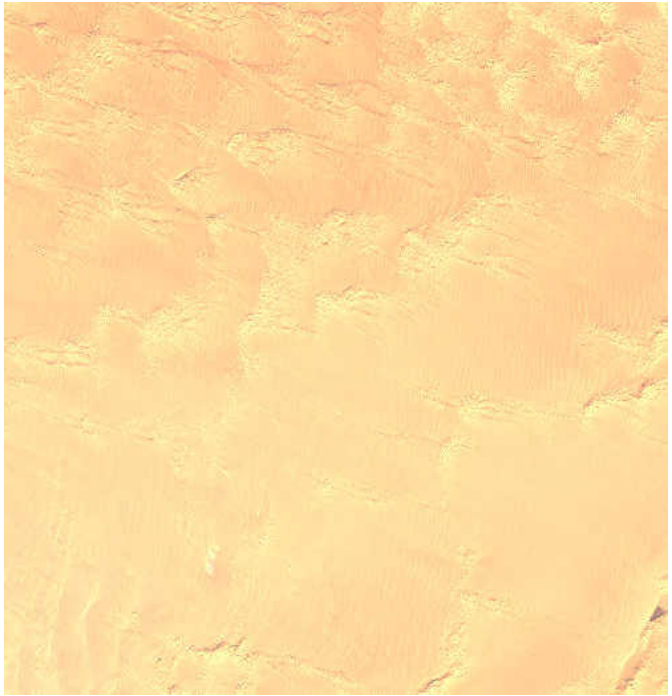
- Results 2011 + 2012 Absolute Calibration Campaign
- All deviations are well within 4% of the field measured reference



	mean blue	mean green	mean red	mean red-edge	mean nir
RE1 (4)	2.630	3.763	3.157	2.141	2.192
RE2 (3)	2.101	2.978	2.439	2.395	1.524
RE3 (3)	1.322	3.285	2.265	0.822	1.522
RE4 (3)	0.317	1.580	-0.114	-1.336	-0.034
RE5 (2)	-0.869	0.991	0.721	-0.392	-0.856

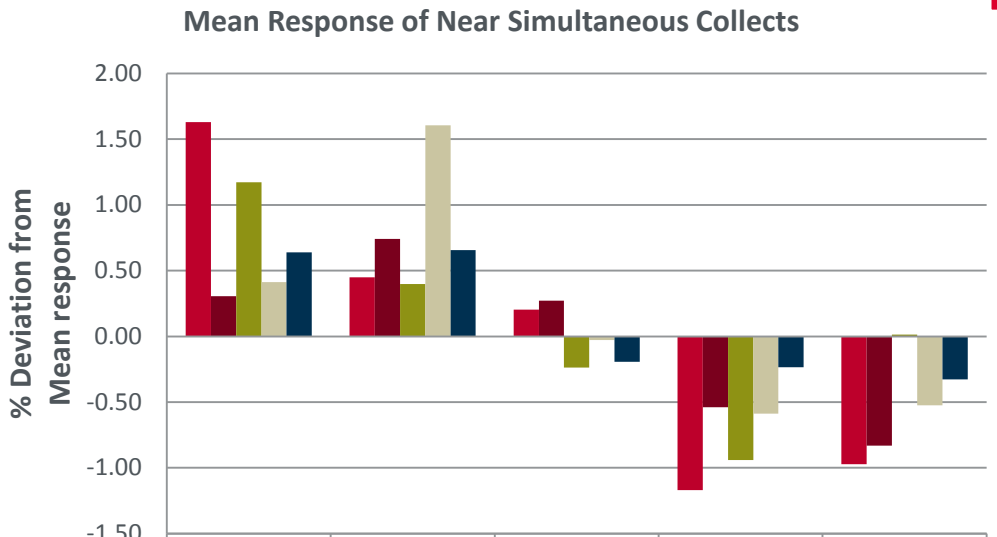
NEAR SIMULTANEOUS COLLECTS

- Near simultaneous collects over a desert site in Western Libya
  - 6 sets of subsequent images with all spacecraft have been evaluated (between April 2011 and Jan 2013)



NEAR SIMULTANEOUS COLLECTS

Mean per spacecraft and per band response of the near simultaneous collects relative to the band mean response of the constellation



	RE1	RE2	RE3	RE4	RE5
Blue	1.63	0.45	0.20	-1.17	-0.97
Green	0.30	0.74	0.27	-0.54	-0.83
Red	1.17	0.40	-0.24	-0.94	0.01
RedEdge	0.41	1.60	-0.03	-0.59	-0.52
NIR	0.64	0.66	-0.19	-0.23	-0.33

COMPARISON BETWEEN ABSOLUTE CALIBRATION AND NEAR SIMULTANEOUS COLLECTS

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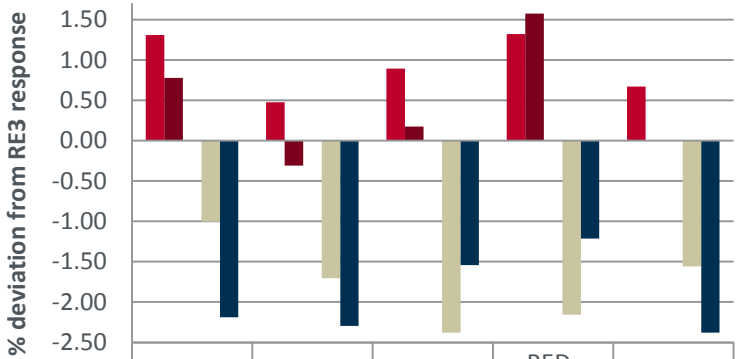
Absolute Calibration

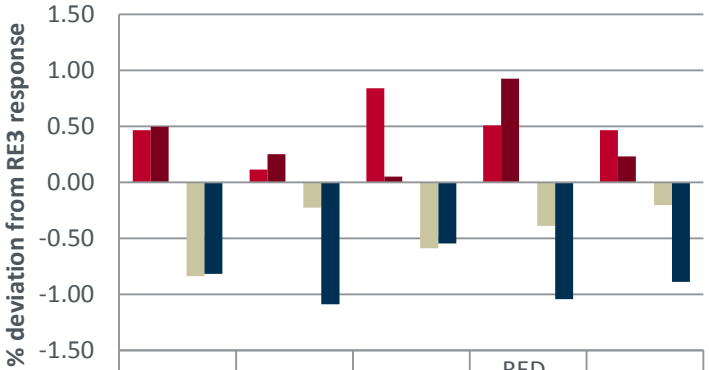
response relative to RE3



	BLUE	Green	RED	RED-EDGE	NIR
RE1 (4)	1.31	0.48	0.89	1.32	0.67
RE2 (3)	0.78	-0.31	0.17	1.57	0.00
RE3 (3)	0.00	0.00	0.00	0.00	0.00
RE4 (3)	-1.00	-1.71	-2.38	-2.16	-1.56
RE5 (2)	-2.19	-2.29	-1.54	-1.21	-2.38

Near-Simultaneous Collects

response relative to RE3

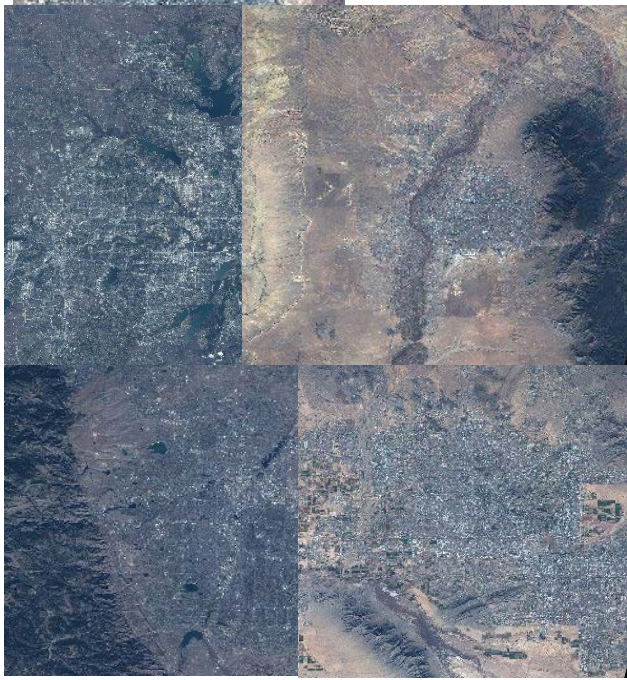


	BLUE	GREEN	RED	RED-EDGE	NIR
RE1	0.47	0.11	0.84	0.51	0.47
RE2	0.50	0.25	0.05	0.93	0.23
RE3	0.00	0.00	0.00	0.00	0.00
RE4	-0.84	-0.23	-0.59	-0.39	-0.20
RE5	-0.82	-1.09	-0.54	-1.04	-0.89

SPATIAL RESOLUTION ASSESSMENTS

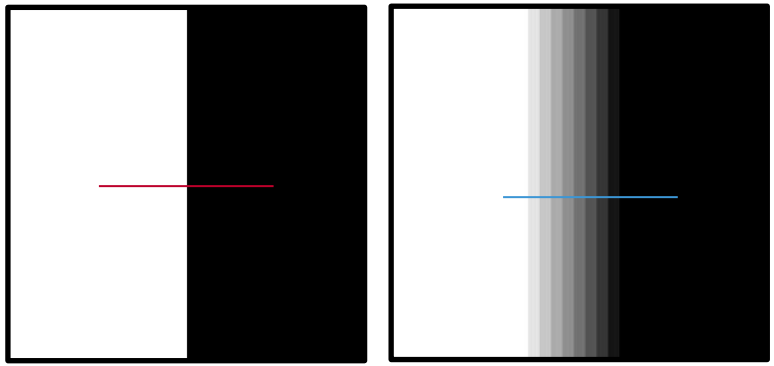
- Analysis of 25 images over urban areas (5 identical sites per Spacecraft)
  - Albuquerque, NM
  - Denver, CO
  - Dallas, TX
  - Las Vegas, NV
  - Tucson, AZ

All Images collected in Nov. / Dec. 2012



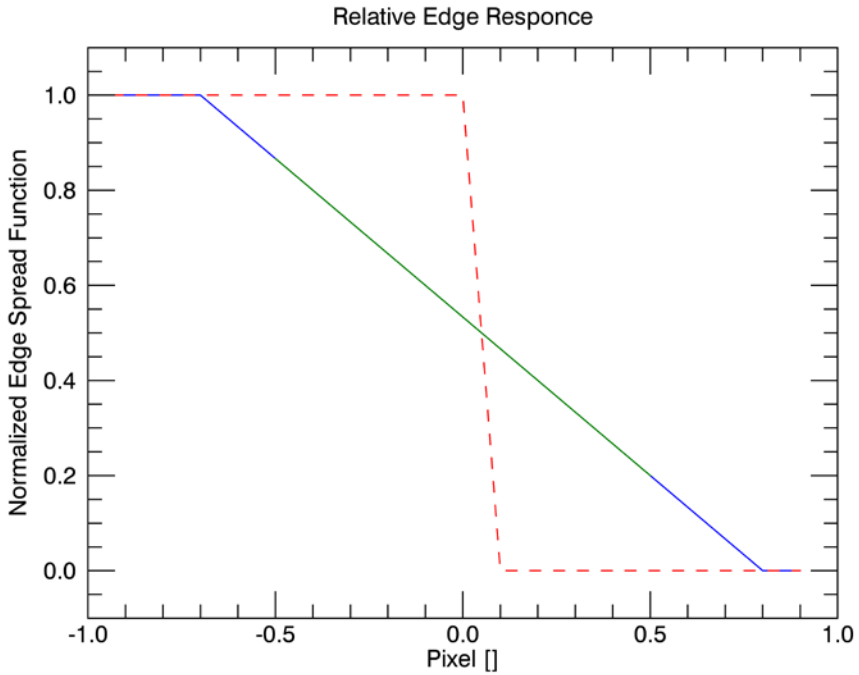
SPATIAL RESOLUTION ASSESSMENTS

- Relative Edge Response (RER) has been used to measure the Images Spatial Resolution



Ideal Response

Real Response



SPATIAL RESOLUTION ASSESSMENTS

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Relative edge response is defined as
the slope of the Edge Spread Function (ESF)

$$RER = \sqrt{\left[ESF_{(x+0.5)} - ESF_{(x-0.5)}\right] \cdot \left[ESF_{(y+0.5)} - ESF_{(y-0.5)}\right]}$$

Example:

$$RER = ER_{(0.5)} - ER_{(-0.5)} = 0.75 - 0.25 = 0.5$$

$RER^2 = 0.25$ means that 25% of information collected with the pixel PSF comes from the actual pixel area

SPATIAL RESOLUTION ASSESSMENTS

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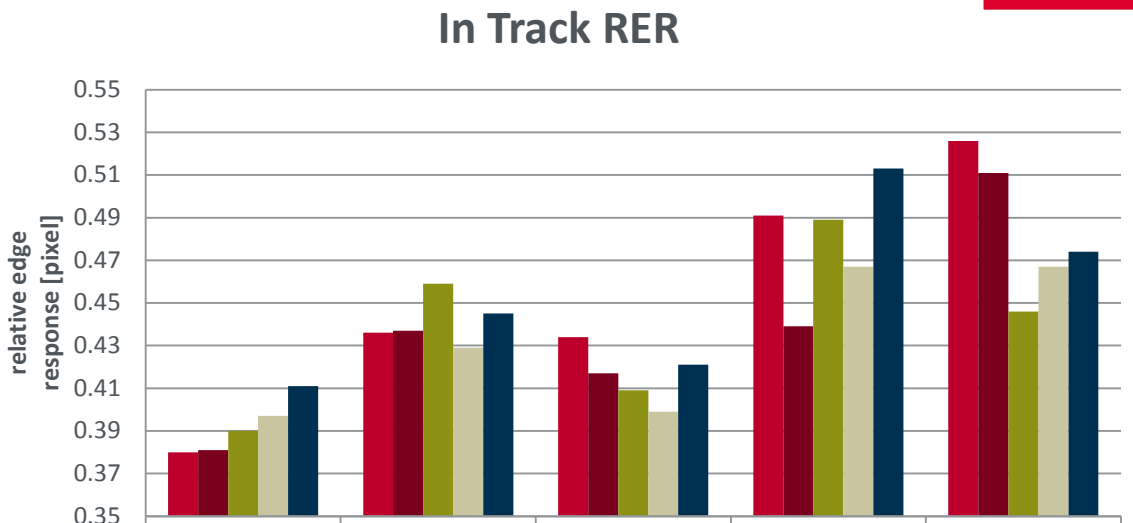
Results

In Tack

Direction

(Average = 0.45)



	RE-1	RE-2	RE-3	RE-4	RE-5
Band 1	0.38	0.436	0.434	0.491	0.526
Band 2	0.381	0.437	0.417	0.439	0.511
Band 3	0.39	0.459	0.409	0.489	0.446
Band 4	0.397	0.429	0.399	0.467	0.467
Band 5	0.411	0.445	0.421	0.513	0.474

SPATIAL RESOLUTION ASSESSMENTS

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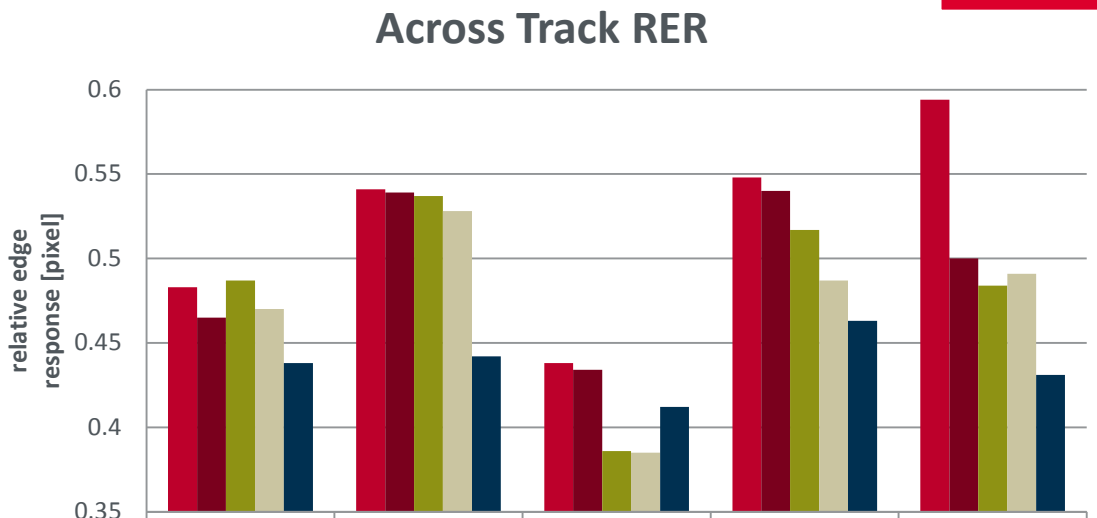
Results

Across Track

Direction

(average = 0.48)



	RE-1	RE-2	RE-3	RE-4	RE-5
Band 1	0.483	0.541	0.438	0.548	0.594
Band 2	0.465	0.539	0.434	0.54	0.5
Band 3	0.487	0.537	0.386	0.517	0.484
Band 4	0.47	0.528	0.385	0.487	0.491
Band 5	0.438	0.442	0.412	0.463	0.431

SPATIAL RESOLUTION ASSESSMENT

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Conclusion:

- analysis of Near Simultaneous collects deliver, in the range of uncertainty of the method, similar conclusions than the temporal calibration approach and the absolute calibration
- both Methods do not show significant degradation of the detectors over time
- average RER in horizontal and vertical direction nearly 0.5 pixel
- all bands in the constellation are on similar levels
- no significant changes in spatial resolution over the mission lifetime.

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