

# living planet symposium

BONN  
23–27 May  
2022

TAKING THE PULSE  
OF OUR PLANET FROM SPACE



## Improving the Radiometric Calibration of the Heterogeneous Planet Dove Fleet

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23.05.2022





# Overview

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02 | Calibration Methodology

03 | Lunar Campaign

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05 | Summary





An aerial photograph of Singapore, showing a dense urban landscape with a grid of streets and numerous buildings. The city is situated along a coastline with a clear blue sea. In the bottom right corner, there is a small circular logo containing a lowercase letter 'p'.

# Introduction to Planet Doves

Singapore Strait, Singapore – July 29, 2016







## Agile Aerospace



# 100+

**Active calibrated satellites in SSO**

Keeping track of their radiometric calibration is an important task

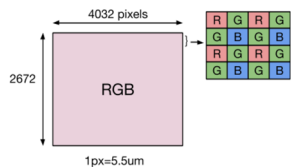




# Planet Payloads Over the Years

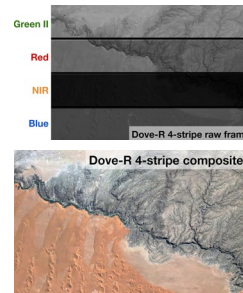
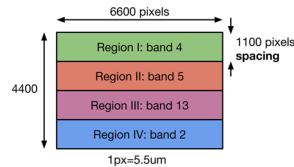
Dove Pilot (~50 satellites)

2016



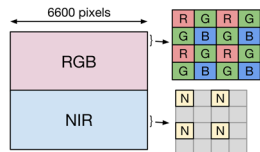
Dove-R (24 satellites)

2018



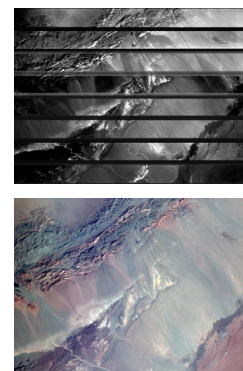
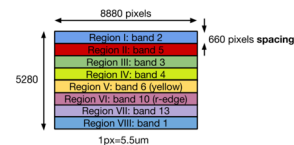
Dove (~150 satellites)

2017



SuperDove (~120 satellites)

2019  
2020  
2021  
2022

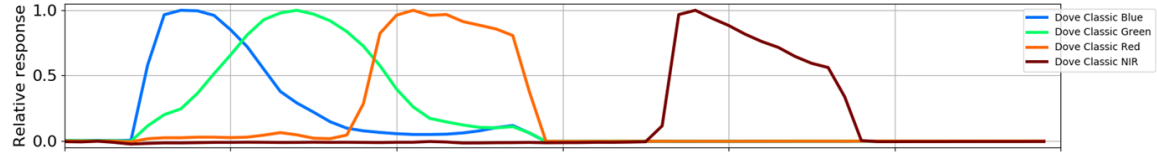




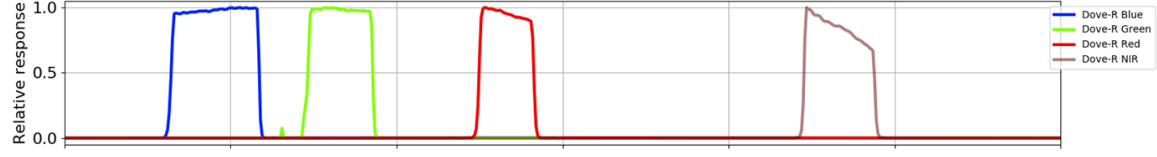
# Planet Payloads

## Over the Years

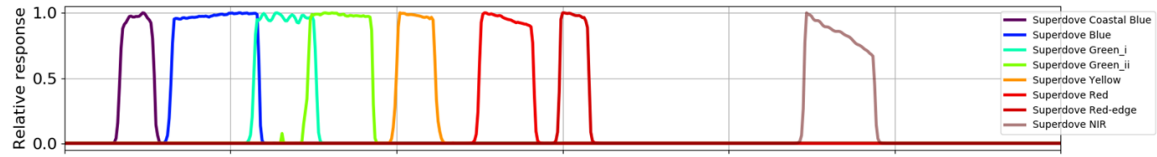
**Dove Classic**



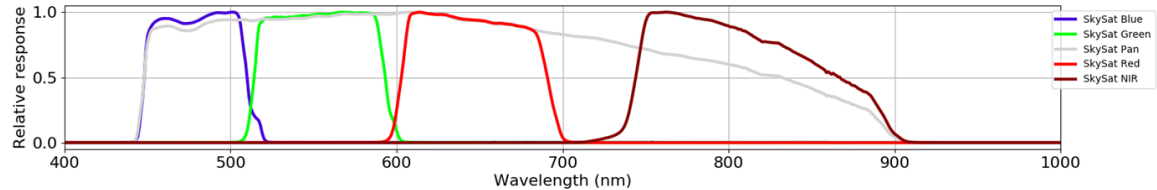
**Dove-R**



**SuperDove**



**SkySat**

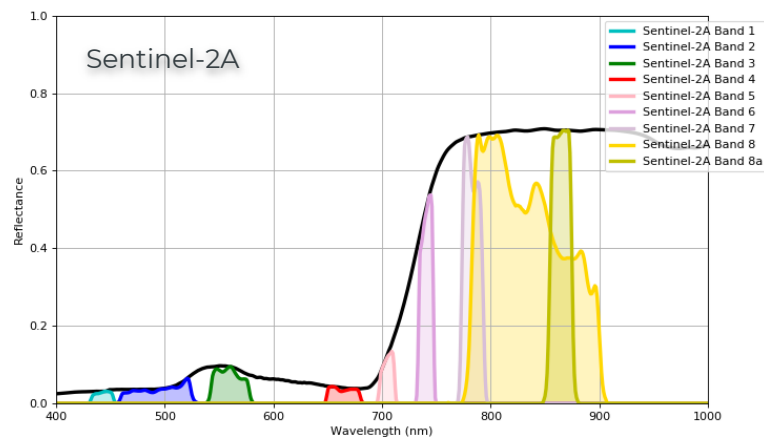
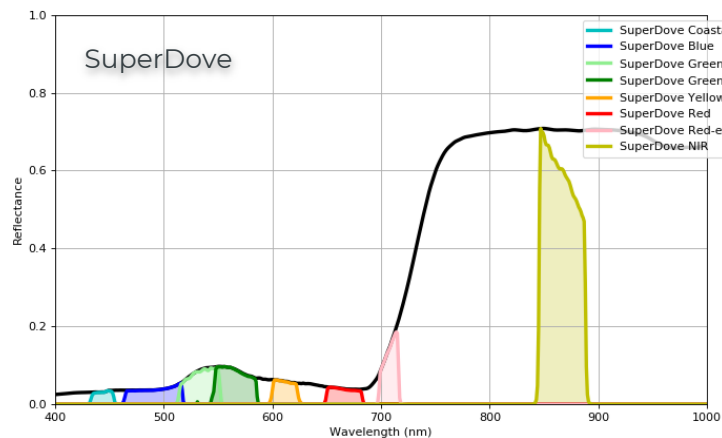




# Effects of Differing Responses

## SuperDove

### A lawn grass spectrum from a spectral library



SBAF Corrections <i>SuperDove</i> → <i>Sentinel-2</i>	Coastal Blue to Band 1	Blue to Band 2	Green_ii to Band 3	Red to Band 4	Red-edge to Band 5	NIR to Band 8a
	0.992	1.019	1.053	0.9524	0.846	1.000







# Calibration Methodology

Lake Tuborg, Canada – May 30, 2015



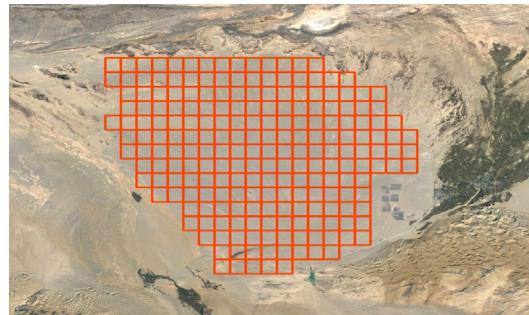




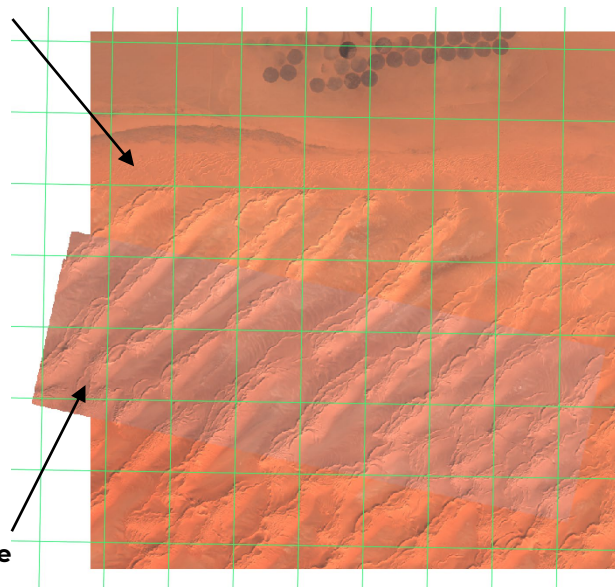
# Overview

## Dove Classic Methodology

- Calibrations are based on near simultaneous crossovers with **Sentinel-2**
- **Calibration Sites**
  - Limited to standard set of calibration sites, “homogeneous” sample regions
  - **Hyperion spectra** for characterizing the surface reflectance to calculate SBAFs
- **Lunar collects used for:**
  - per-satellite trending of calibration gains to check satellite health
  - Intra-flock consistency adjustments
- **6-month update interval chosen**
  - Long enough to allow sufficient crossovers
  - Short enough to allow needed updates
  - Updates apply to new collects - **not retroactive**



Sentinel





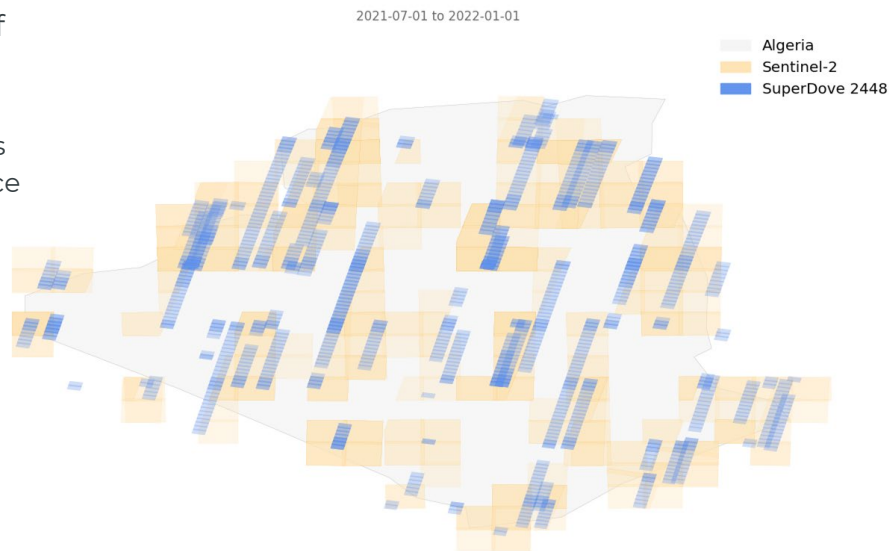
# Overview

## SuperDove / Dove-R Methodology

- Calibrations are based on gathering a dataset of **global** near simultaneous crossovers with **Sentinel-2**
  - A simultaneous crossover is when there is less than two hours difference between a reference image and a Planet image for the same point on the ground
- **Lunar collects used for\*:**
  - per-satellite trending of calibration gains to check satellite health
  - Intra-flock consistency adjustments
- **6-month update interval chosen**
  - Long enough to allow sufficient crossovers
  - Short enough to allow needed updates
  - Updates apply to new collects - **not retroactive**

\* planned

### Algeria Crossovers between 2448 and Sentinel-2







## Details

### SuperDove / Dove-R

- **No SBAF corrections** are applied.
- No radiometric offset for these satellites.
- Direct comparisons are made between ortho tile products **resampled to 20m GSD**
  - No predefined sample areas needed
  - Helps reduce effects from registration differences
- Simultaneous crossovers are randomly divided into calibration and validation datasets
  - Up to ~10,000 ortho tiles for each, fewer for initial commissioning





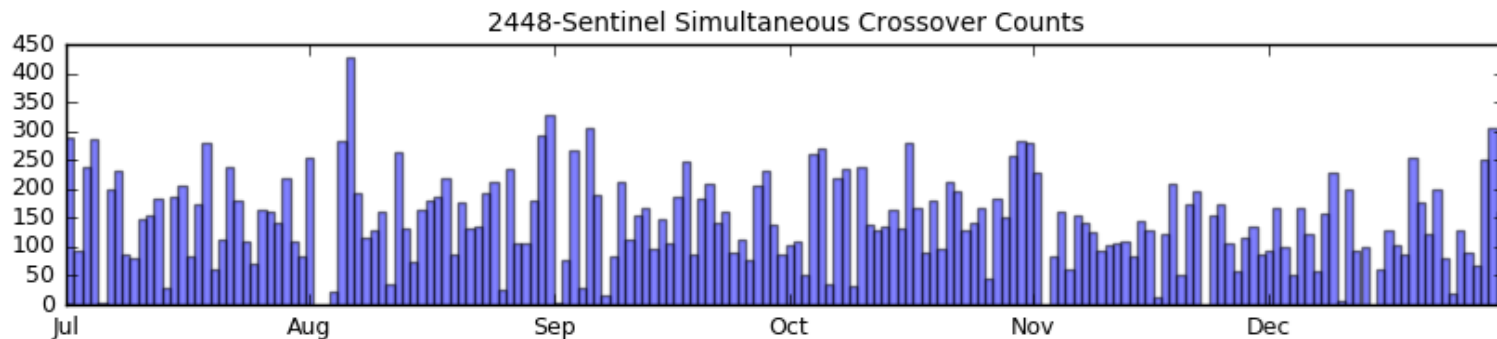
# SuperDove 2448 Crossovers

2021-07-01 to 2022-01-01

Simultaneous crossovers with Sentinel-2 are searched for each satellite over the entire calibration time period.

Simultaneous crossovers are collected roughly uniformly over time with the goal of reaching a targeted total number of image collects.

Crossover searches are fully automated and triggered every two weeks.

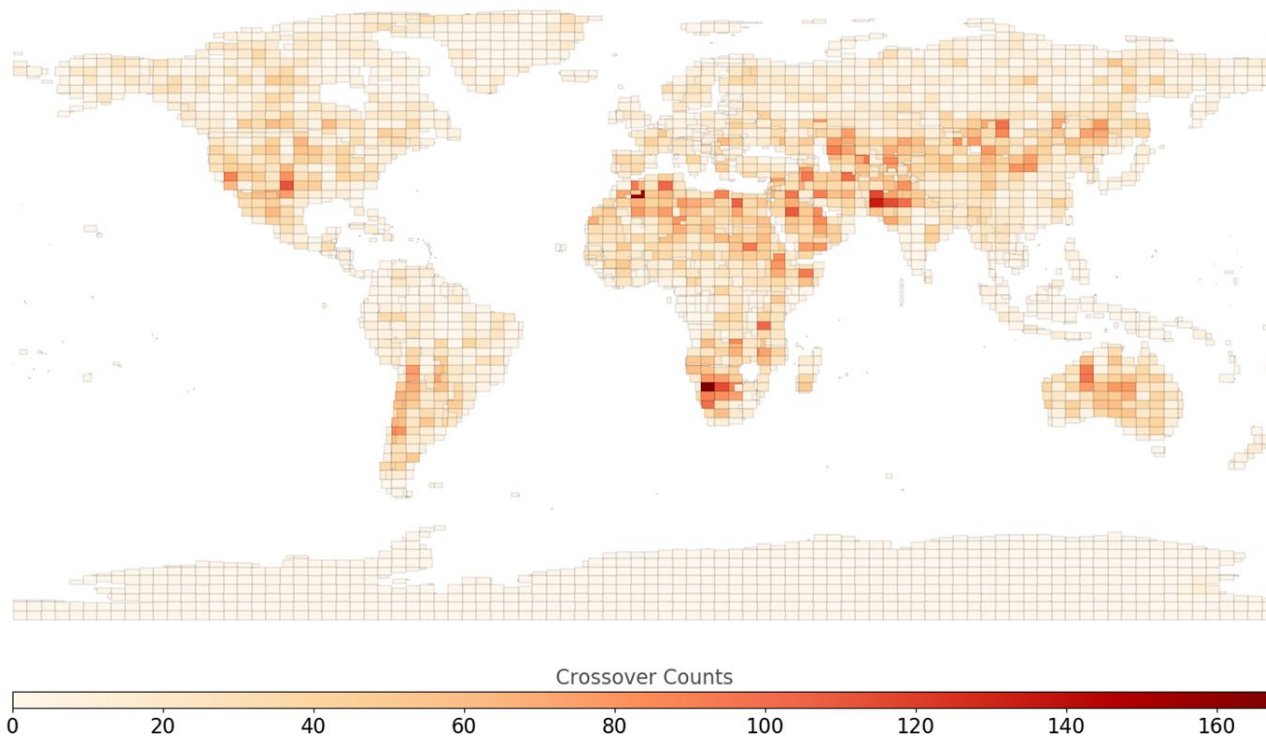






# SuperDove 2448 Crossovers

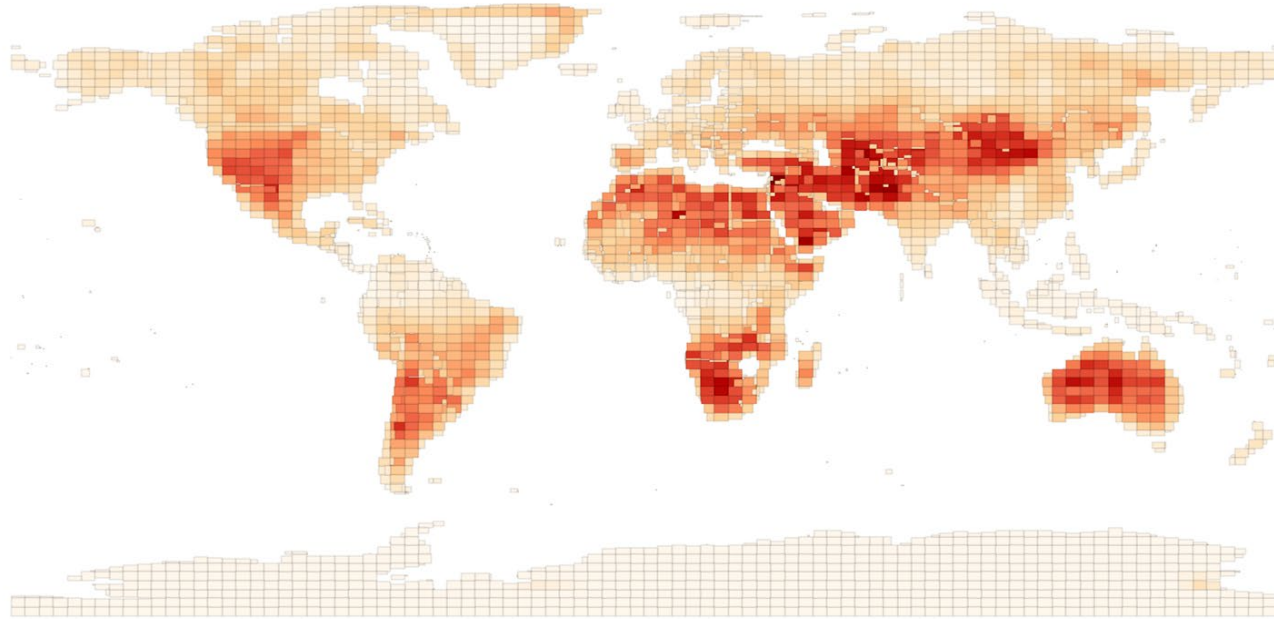
2021-07-01 to 2022-01-01





# All SuperDove Crossovers

2021-07-01 to 2022-01-01







# SuperDove 2448 Calibration

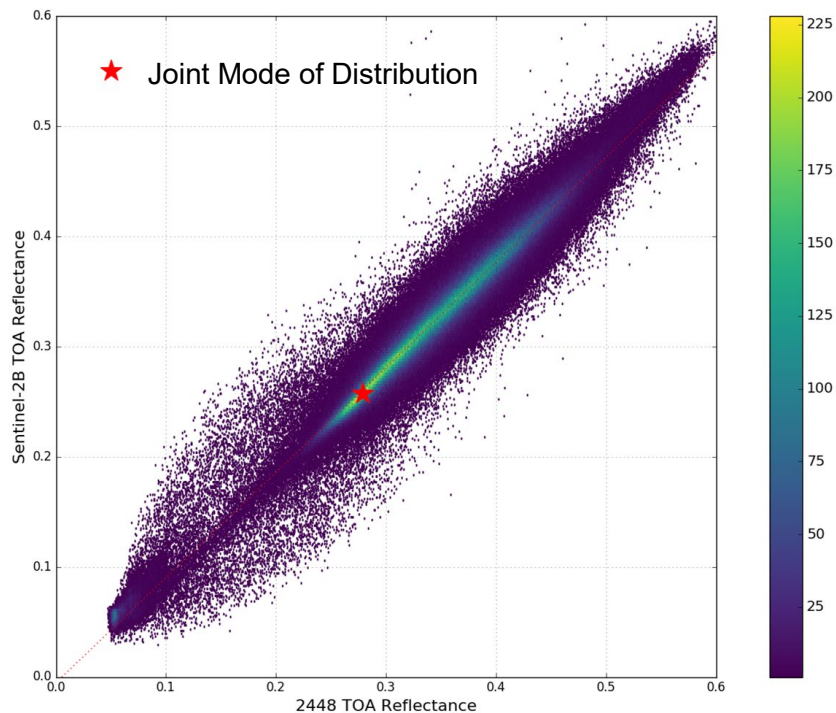
## Analyzing Individual Crossover Pairs

Individual Dove-Sentinel crossover pairs are compared pixel-by-pixel.

The scatter plot shows the intersection of a SuperDove tile product with a Sentinel-2 product.

The **Joint Mode** of this single distribution is used as the basis for deriving an overall calibration correction when combined with all other crossover pairs.

Product generation is fully automated with batches triggered every two weeks.





# SuperDove 2448 Calibration

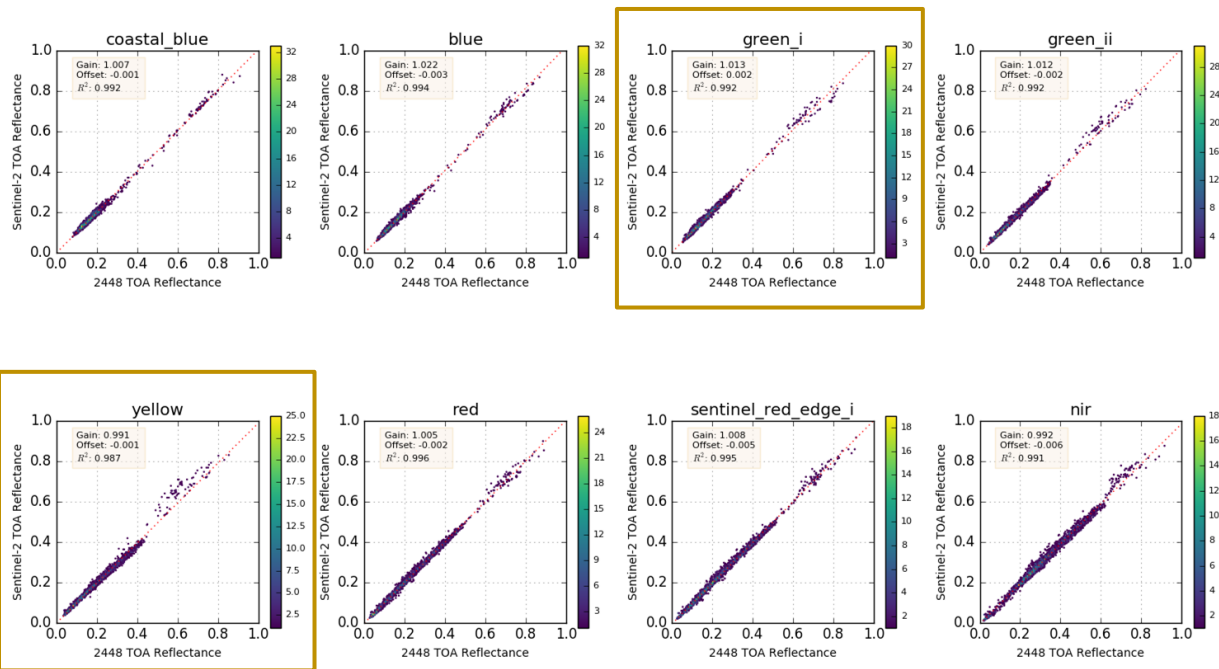
## Fitting the Distribution of Joint Modes

Each datapoint is the joint mode of a SuperDove-Sentinel-2 pair of intersecting tiles.

Crossover pairs are rejected if tile coverage is < 50% for either product or crossover time difference is > 2 hours.

Planet products must also pass standard quality conditions.

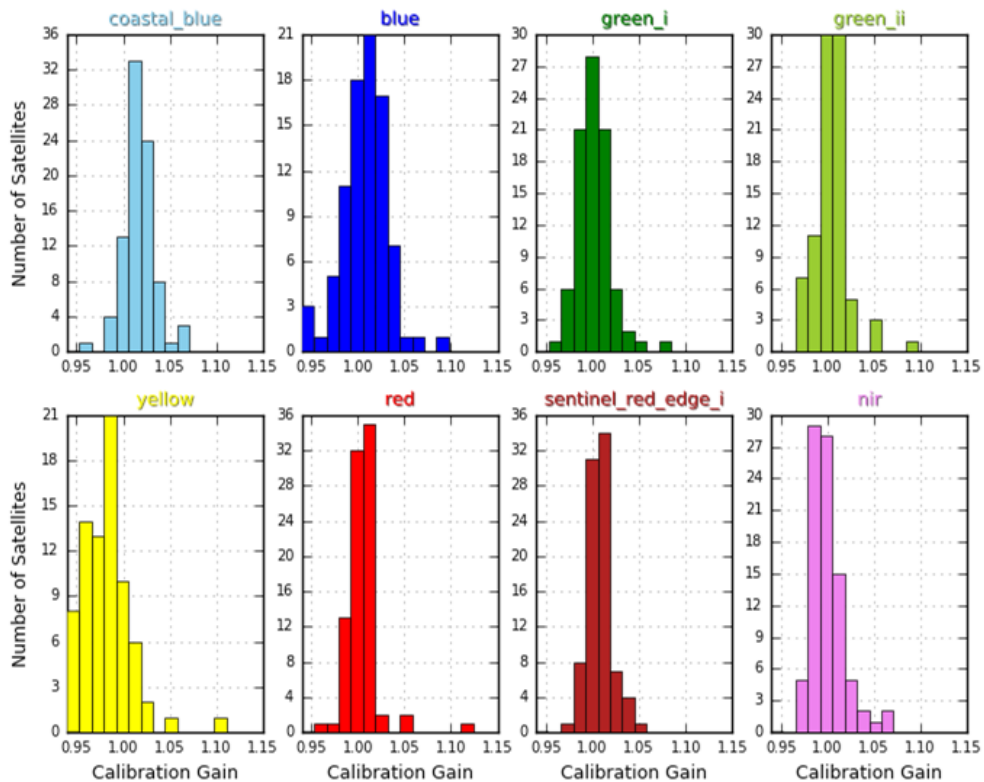
SuperDove **green\_i** and **yellow** bands are compared to the average values for the two closest Sentinel-2 bands.





# SuperDove Calibrations

2021-07-01 to 2022-01-01







# The Lunar campaign

Lake Tuborg, Canada – May 30, 2015





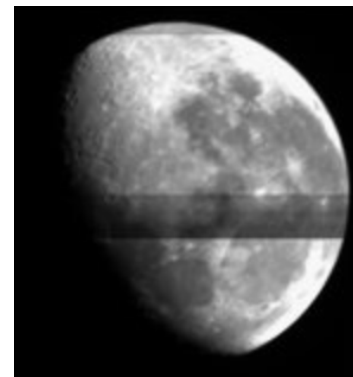
First successful **demo moon shot** using an ISS orbit satellite without a star camera



Start of the **Lunar campaign** - daily moon shots scheduled on the first SSO satellites



Start of the **multi-stripe moon shot** maneuver development



**Superdove** moon shots start

**55 satellites** taking daily moon shots

**130 satellites** taking moon shots

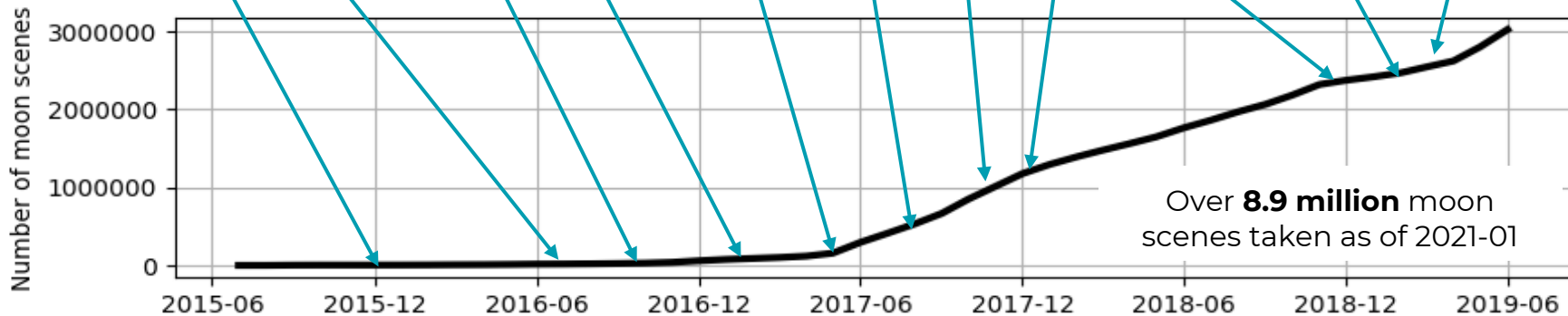
Flock 2p (12 satellites) **launched**

Flock 3p (88 satellites) **launched**

Flock 2k (47 satellites) **launched**

25 Dove-R satellites **launched**

**Dove-R** daily moon shots start







# Moon Monitoring

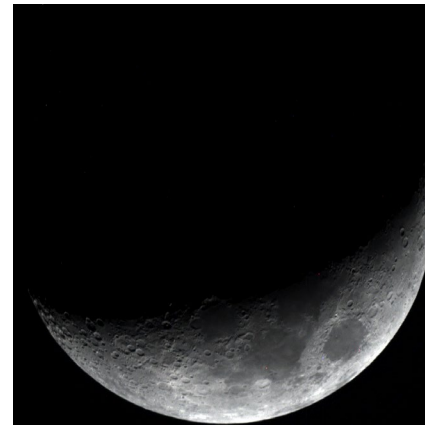
## For Radiometric Calibration

### Monitoring

- Full cycle of moon shots during the first full available lunar cycle after commissioning
- Subsequent maneuvers executed at low, medium and high moon phases for the life of the satellite
- Use of ROLO model of Moon's brightness at each phase can be used to monitor a satellite's spectral response.
- The model provides ~10% absolute accuracy, **< 1% relative accuracy**.
- We use changes in relative response over time to monitor a satellite's health and make relative calibration adjustments, as a group, over each 6-month time period.

### Calibration Adjustments

- The lunar data is used to make adjustments to calibrations to improve consistency.
- Adjustments are not made for satellites which had insufficient quality data for the selected timeframe.



Dove Classic moon shot

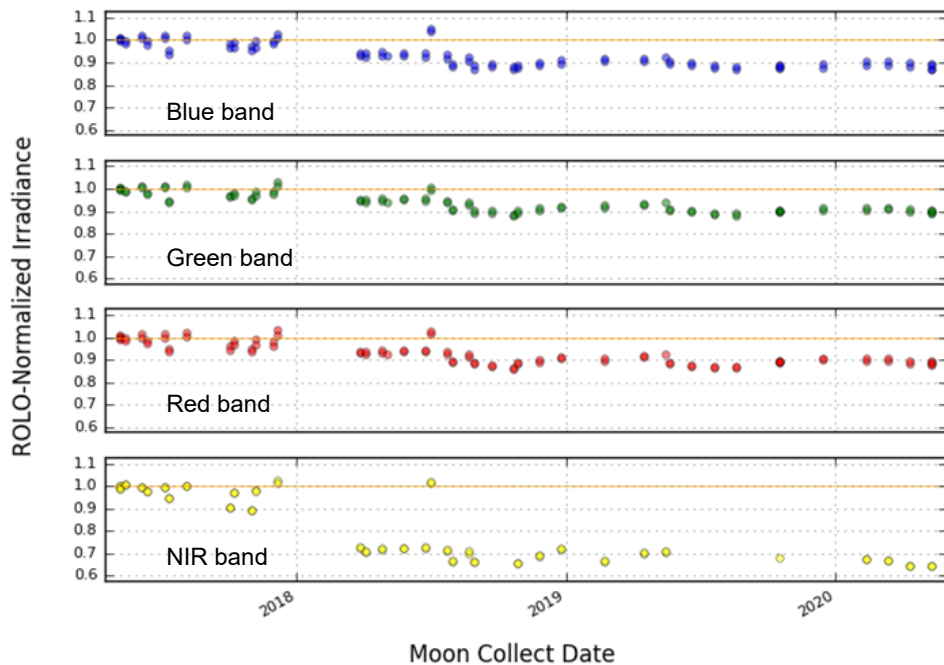




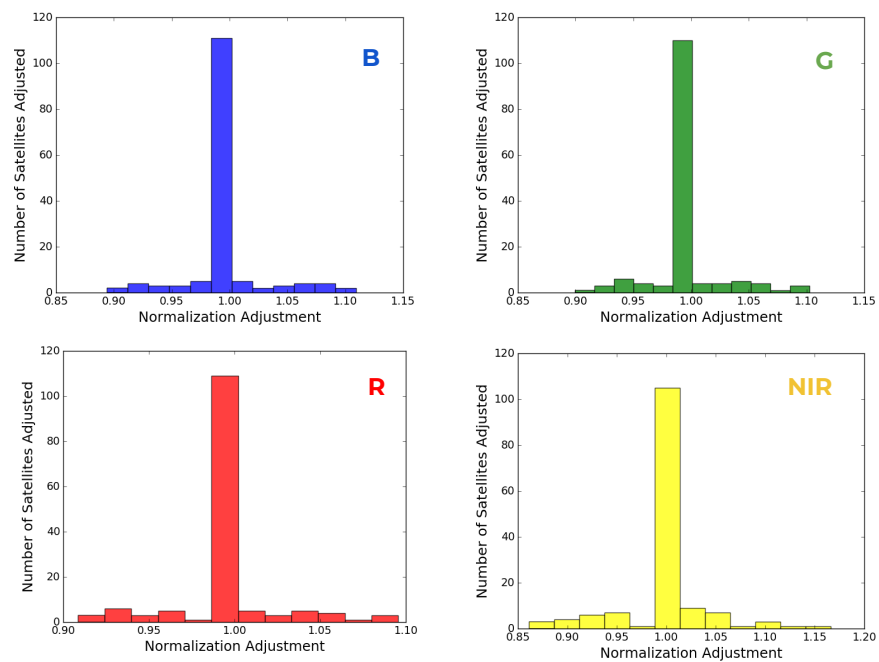


# Lunar Trending & Consistency

## Long Term Trends



## Calibration Adjustments





# Validation

Lake Tuborg, Canada – May 30, 2015





# SuperDove Validation

## Using Independent Crossovers Dataset

An independent validation dataset of simultaneous crossovers with Sentinel-2 and **SuperDove 2408** for the calibration period.

The data reflects the results with the calibration gain correction applied.

Band	Gain	Offset	Uncertainty (%)	R-squared Value
coastal_blue	1.0064	-0.0005	4.01	0.998
blue	1.0005	-0.0002	4.19	0.998
green_i	0.9999	-0.0052	4.09	0.998
green_ii	1.0007	-0.0025	4.18	0.998
yellow	1.0013	-0.0092	5.95	0.994
red	1.0001	-0.0043	5.64	0.998
sentinel_red_edge_i	1.0000	-0.0101	6.43	0.998
nir	1.0016	-0.0177	9.31	0.994



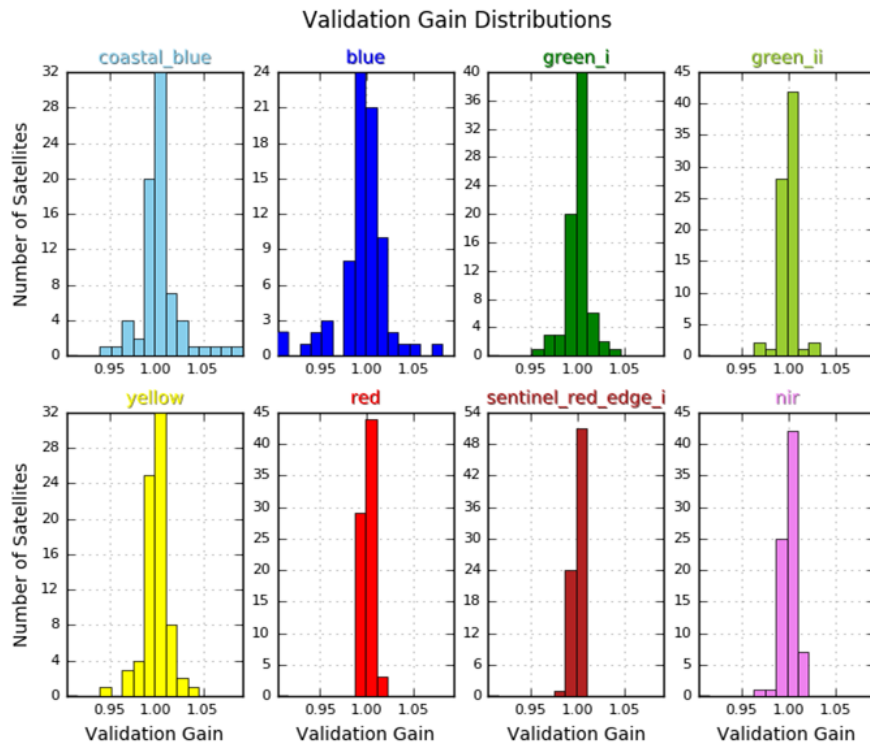


# SuperDove Validation

2021-07-01 to 2022-01-01

Distribution of validation gains for **all** SuperDoves updated during the July 2021 - December 2021 calibration period.

The validation dataset is comprised of  $\frac{1}{2}$  of the full collection of simultaneous crossovers with Sentinel-2, randomly selected.





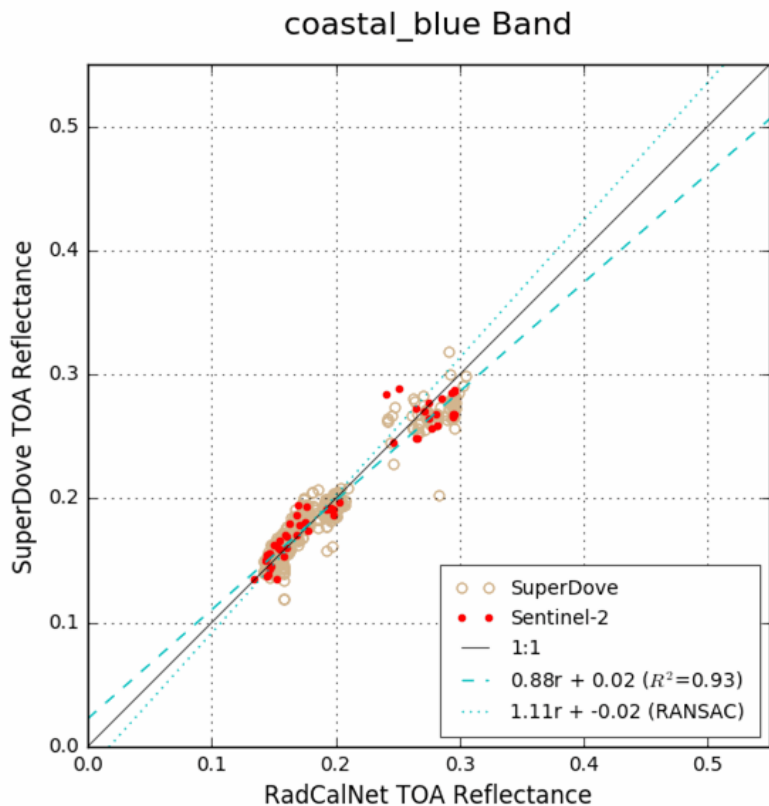
# SuperDove Validation

## RadCalNet Comparison

Collected all crossovers of the four **RadCalNet** sites for the July - December 2021 calibration period with both SuperDove and Sentinel-2 included.

Limited to scenes with < 10% clouds and a cloud free sample.

Generated TOA Reflectance products for all crossovers meeting the minimum requirements.





# Overview

## Current State of Planet Smallsat On-orbit Calibration

	Dove Classics*	Dove-Rs*	Superdoves	Skysats**
Simultaneous crossovers for on orbit calibration	With Sentinel-2 over calibration sites	With Sentinel-2 globally	With Sentinel-2 globally	With Sentinel-2 over calibration sites
Lunar monitoring	Since late 2016	Since late 2018	Since early 2019	None
Reported validation***	Comparison with RadCalNet data	Comparison with RadCalNet data	Comparison with RadCalNet data	Comparison with RadCalNet data

Full back catalog reprocessed to Sentinel-2 calibration reference

\* Satellites decommissioned

\*\* Updated radiometric calibration recently released

\*\*\* For L1 Image Quality reports from Q3 2021 onwards





# Summary

London Array Wind Farm, United Kingdom – April 17, 2016





# Current State of On-orbit Calibration

On-orbit calibration uses **simultaneous crossovers** with **Sentinel-2** across the entire fleet of satellites.

Because the spectral band responses for SuperDove and Sentinel-2 are so similar, we use **any** simultaneous crossovers, collected **globally**.

All Dove satellites image the moon six times **every lunar cycle** after commissioning has finished. Lunar calibration is used to provide the **relative calibration** within a flock and to **monitor the ongoing health** of all the Dove satellites.

**RadCalNet** is used to **validate** the radiometry of our satellites for public image quality reports.

## Future Improvements:

- Intra-fleet relative calibration via Dove-Dove crossovers
- Complete SuperDove lunar analysis
- Additional automation





# Thank You.

Engage with Planet's Science Programs and apply here for Planet Data via ESA Earthnet  
[go.planet.com/lps22](https://go.planet.com/lps22)



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