planet

CALCON Technical Meeting - August 31, 2021

Evaluating Radiometry within a Heterogenous Satellite Fleet

via Continuous Moon Monitoring

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Introduction

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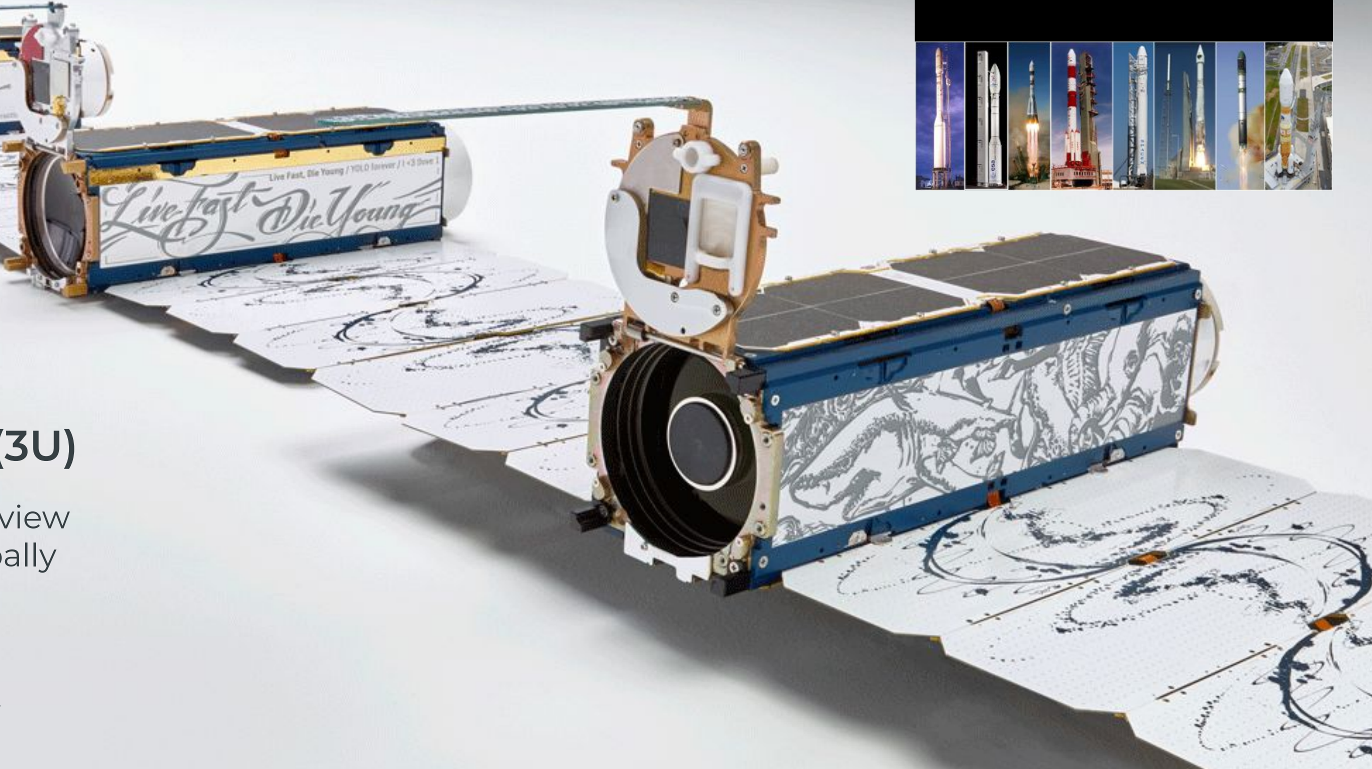
Agenda

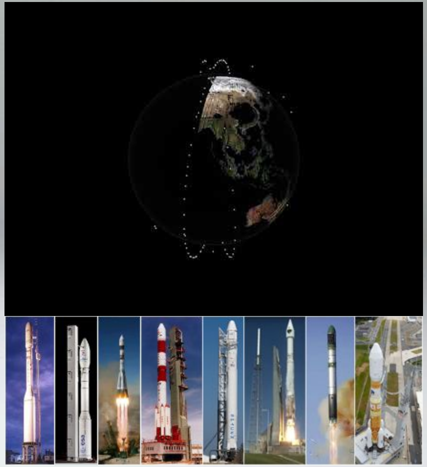
01 | Moon Observations on Planet Platform

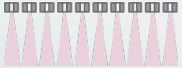
02 | Challenges on SuperDove Architecture

03 | Radiometric Analysis via Moon Imagery

Rapidly innovating nano-satellite platform







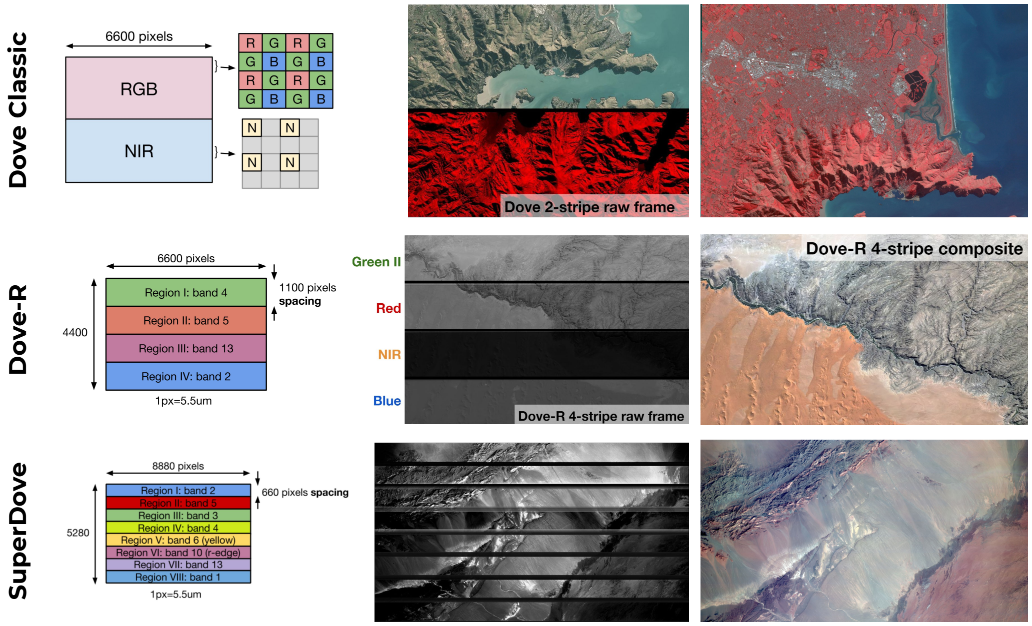
100+

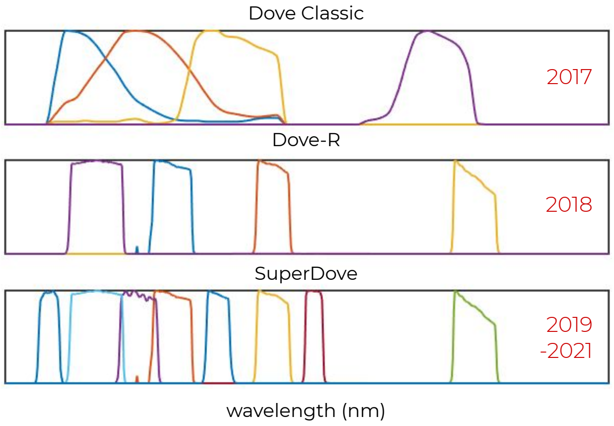
Nano-satellites (3U)

- Near-nadir field of view
- ~ Daily revisits globally
- 3 m resolution
- 4 bands (VIS + NIR)

Planet Payloads

over the years

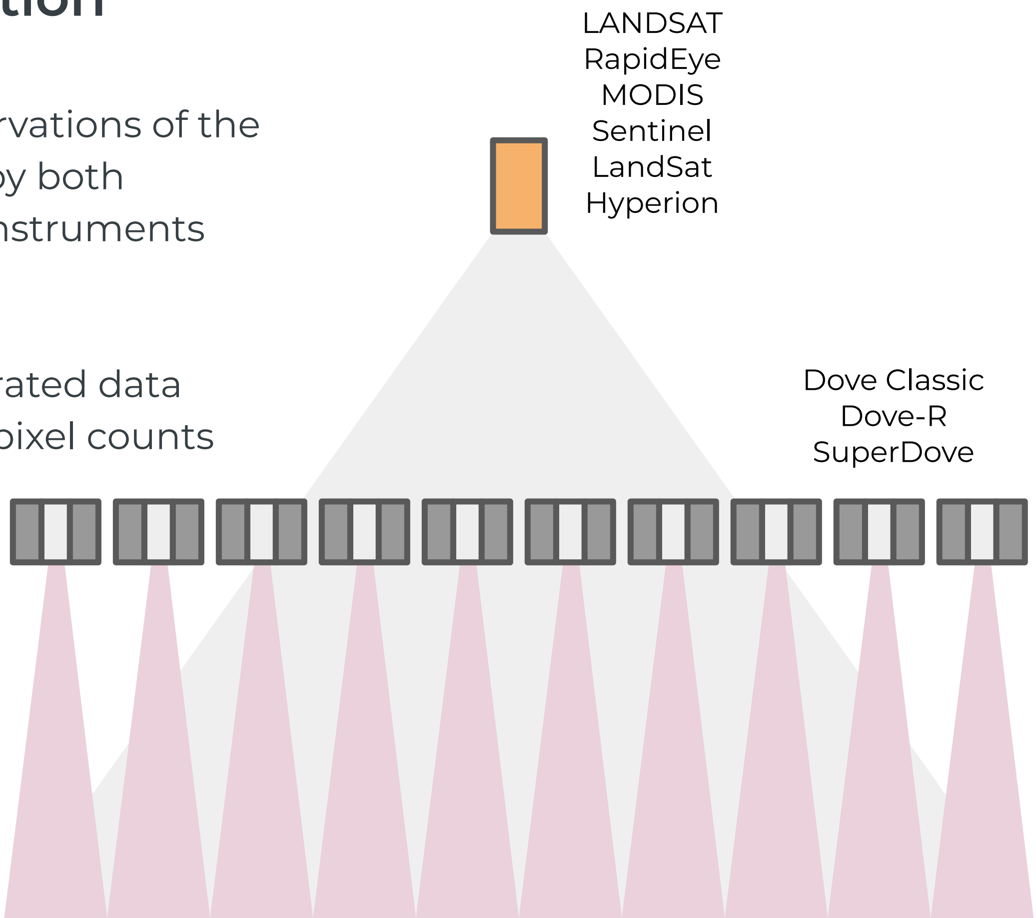




- Rapidly iterating satellite designs improves the quality and efficacy of date over time
- Heterogeneous dataset necessitates multiple approached to be developed in parallel

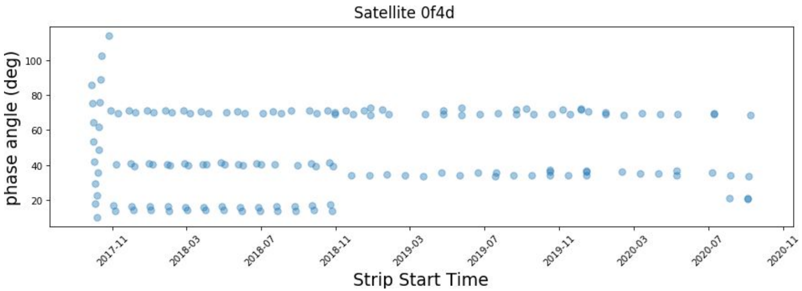
Radiometric Calibration

- Near-simultaneous observations of the same groundsite made by both PlanetScope and other instruments are collected
- Crossovers used to generated data products that make our pixel counts more in alignment with absolute truth
- Absolute references could take the place of relative calibration



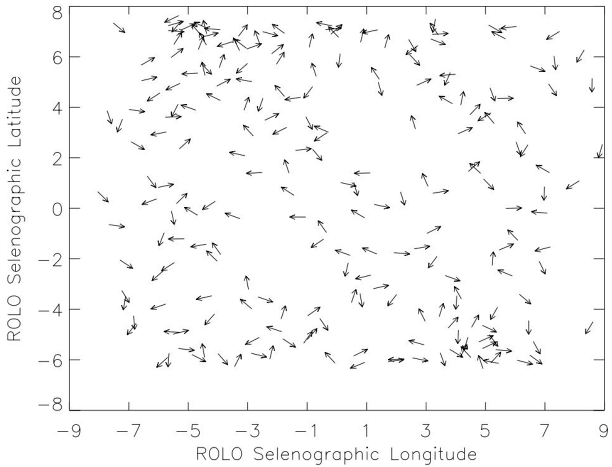
Moon Monitoring
for Radiometric Calibration

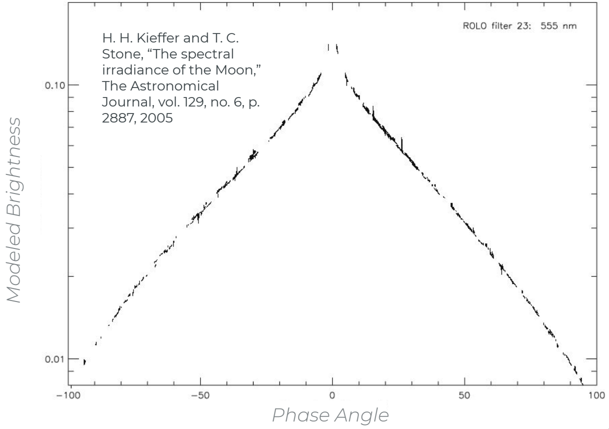
- Doves are maneuvered to point towards the moon through the range of the lunar cycle
- Allows for studies of different response ranges
- Full cycle of moon shots during the first full available lunar cycle after commissioning
  - Confirm normative operation
- Subsequent maneuvers executed at low, medium and high moon phases for the life of the satellite
  - Exposure to a ‘constant’ illumination source with no atmosphere useful for validation and calibration



ROLO Model Brightness
for Moon Phases

- Over 1000 images, each in 32 wavelengths, taken at a variety of selenographic longitude, latitude and phase angles
- ROLO model produces the moon's **full disc** brightness
    - 328 coefficients and position of the Earth, moon, and satellite yields a reflectance
    - Solar spectrum and satellite RSR yields a radiance
- Model is absolutely accurate to within ~10%, but relatively accurate to within sub-percent





H. H. Kieffer and T. C. Stone, "The spectral irradiance of the Moon," The Astronomical Journal, vol. 129, no. 6, p. 2887, 2005

Dove Classic

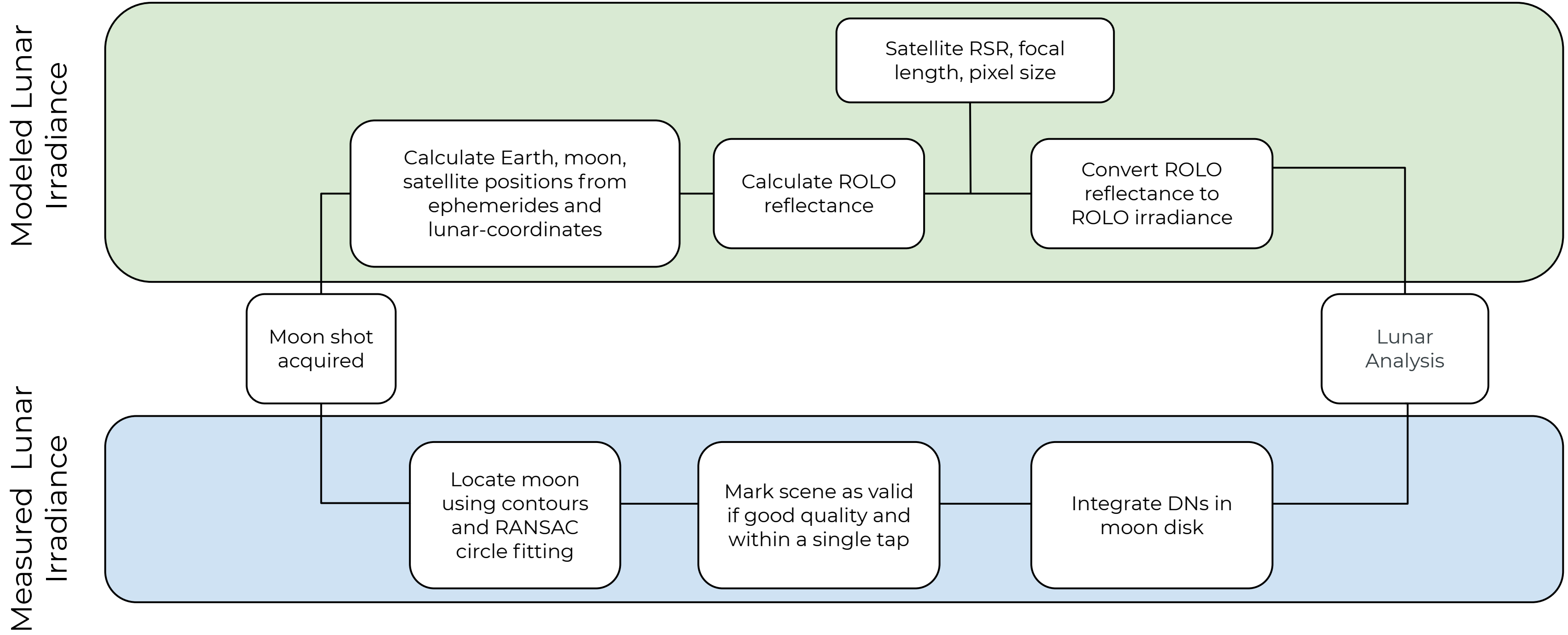
Moon shot maneuver

- Maneuver designed to cover the four taps of Dove Classic

- Computer vision tracks the location of the moon disc to:
    - Mark scenes as within a single tap
    - Provide template for measuring the moon’s irradiance

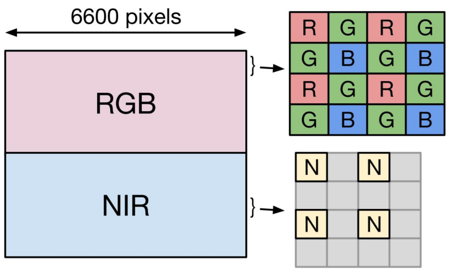
- Takes ~5 minutes when satellites is in eclipse

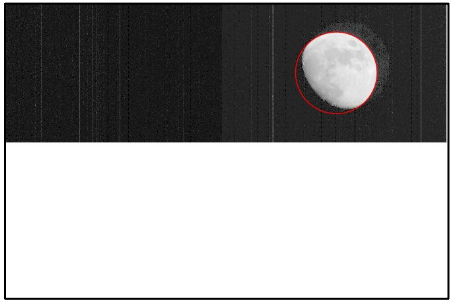
Lunar Pipeline
for Dove Classic



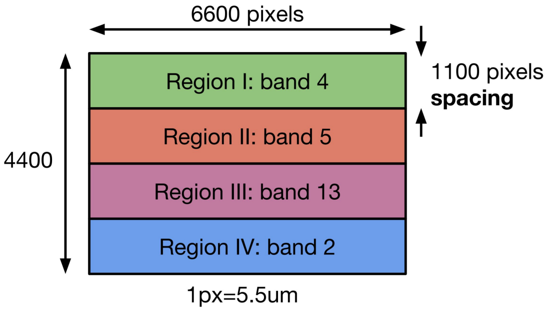
Multi-Stripe Dove

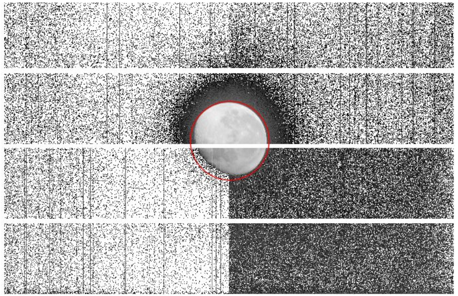
Dove Classic



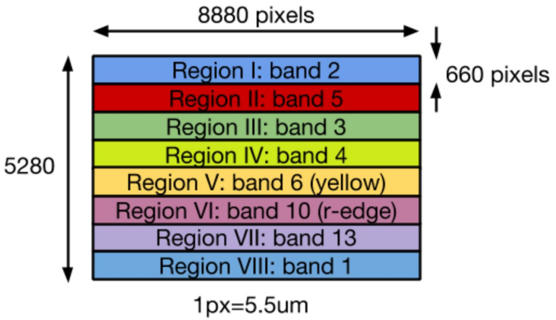


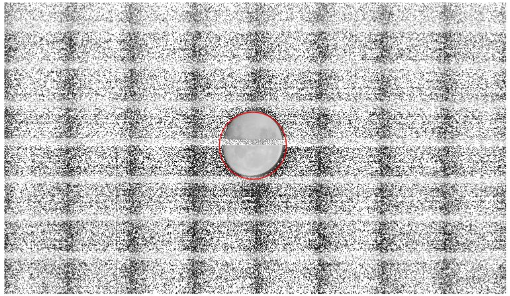
Dove-R





SuperDove





Multi-Stripe Moon Measurements

Requires Registration

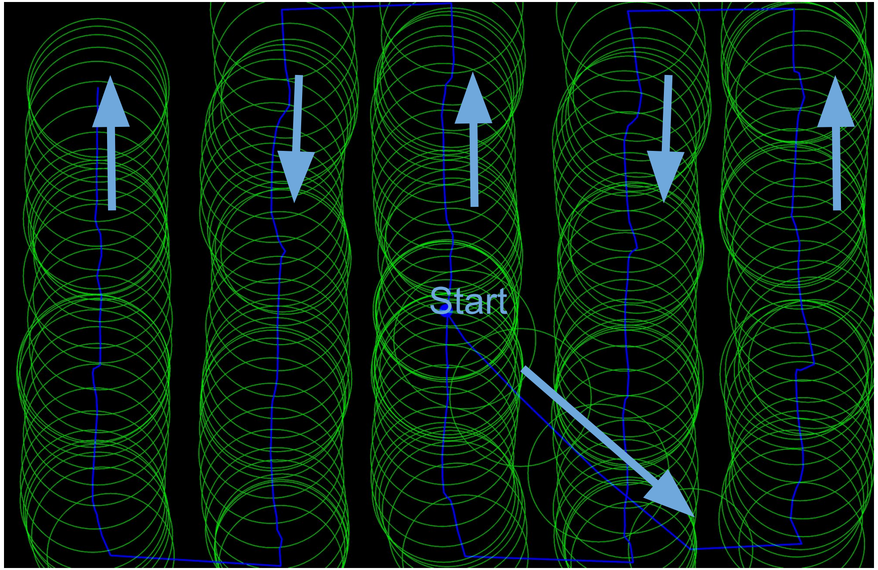
- ROLO model only calculates unresolved irradiance of entire moon disc
- SuperDove filter heights are not large enough to contain the entire moon disc
  - Multiple scenes must be registered together to create a single moon disc

Two main problems to solve to construct Moon discs

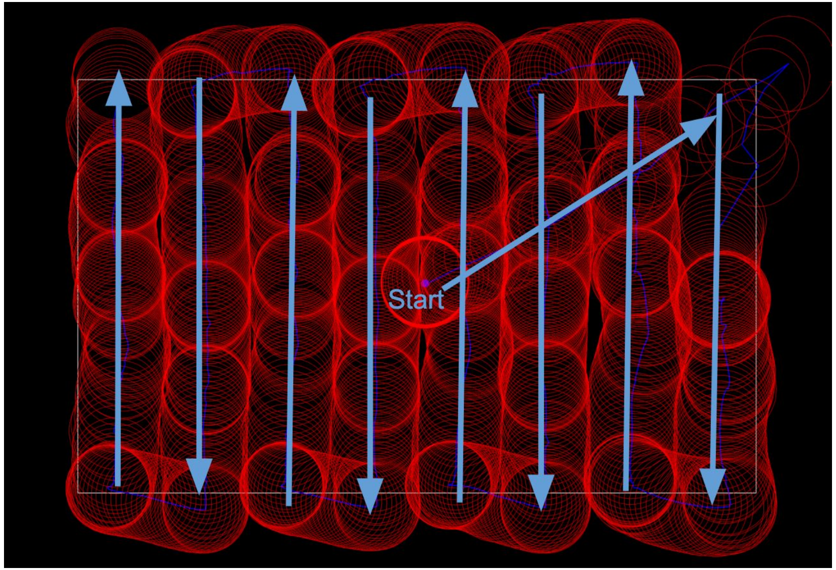
1. Which scenes to include to construct each filtered observation of the moon?	2. How to adapt current registration algorithms to lunar scenes?

Multi-Stripe Moon Maneuver

Dove-R (~500 scenes)



SuperDove (~1400 scenes)

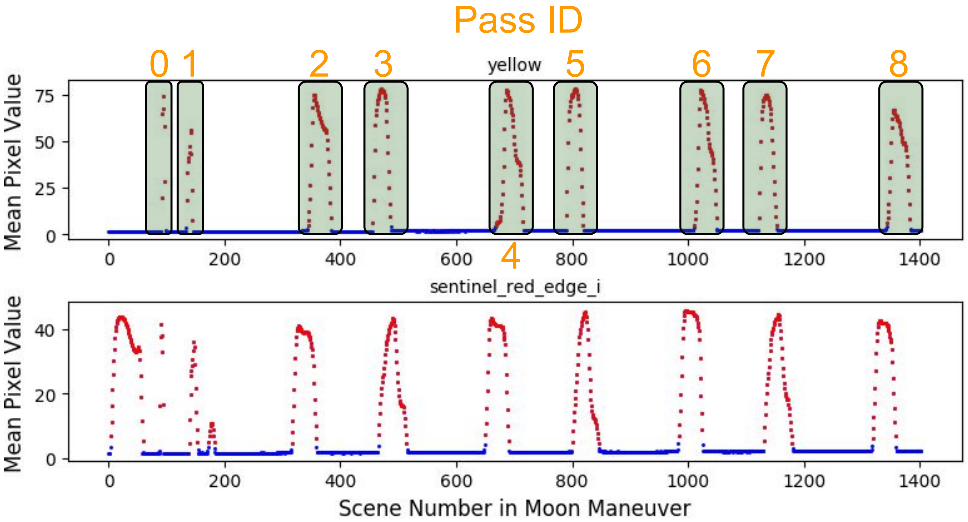


Scene selection requires knowing which scenes have the moon on which filters, ideally without loading every scene

Multi-Stripe Moon Registration

Scene Selection

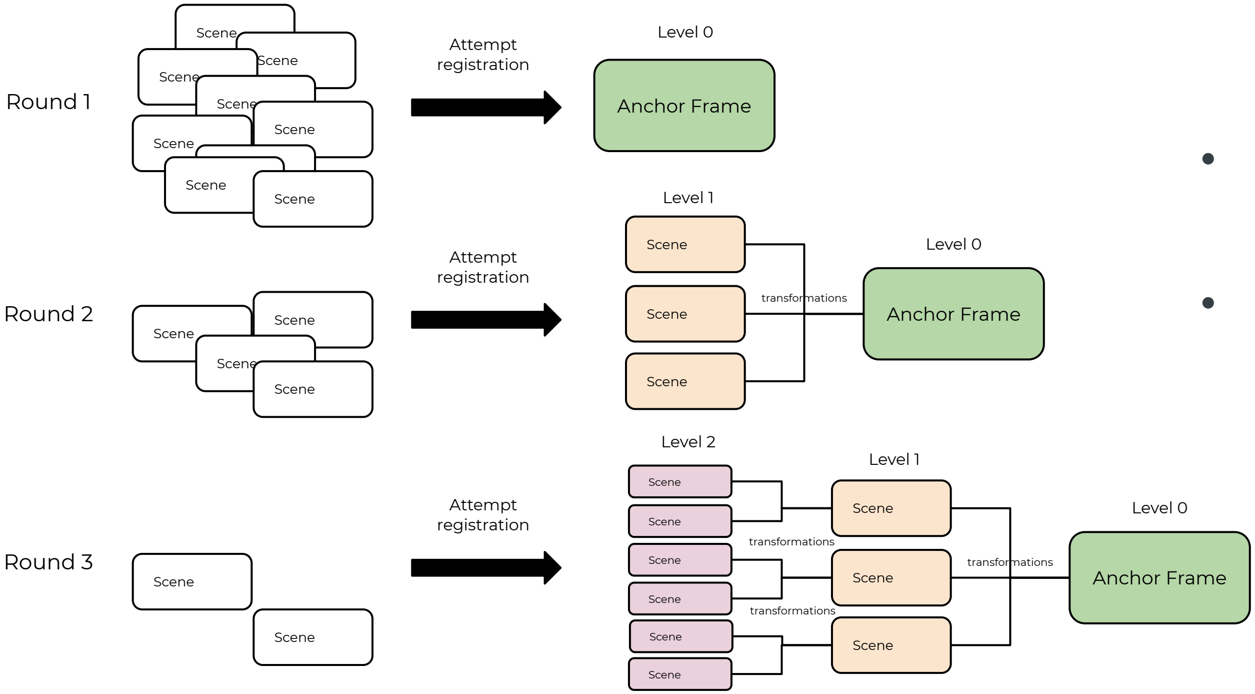
- Metadata *stats_by_filters* contains statistics for each scene broken out by filter
- Iterative asymmetric sigma clipping for each scene mean pixel value (on each filter) can separate out scenes which contain the moon
- Separates moon maneuver into 'passes' for scene registration and combination
- All *space facing* scenes now have *stats_by_filters* regardless of image quality



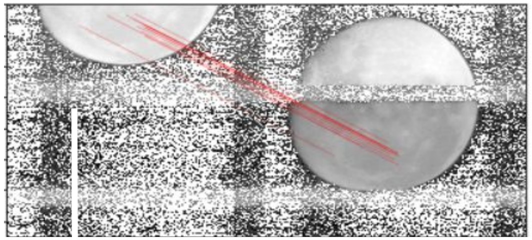
Scene selection using metadata is more computationally and memory efficient, naturally defines "passes" for scene registration.

Multi-Stripe Moon Registration

Via Recursive Tree

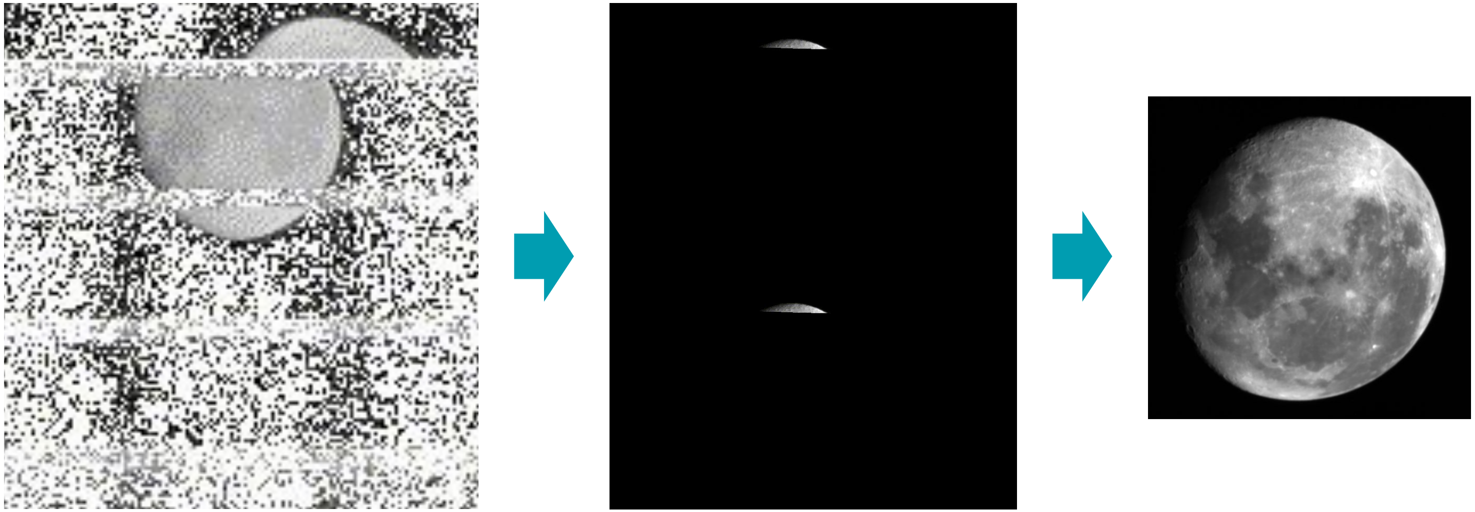


- Registration features identified on all images within moon ellipse mask
  - Each filter separately contour stretched
- An image with the most number of feature is named the Anchor Frame
- Recursive algorithm run to attempt to transform each image to the anchor



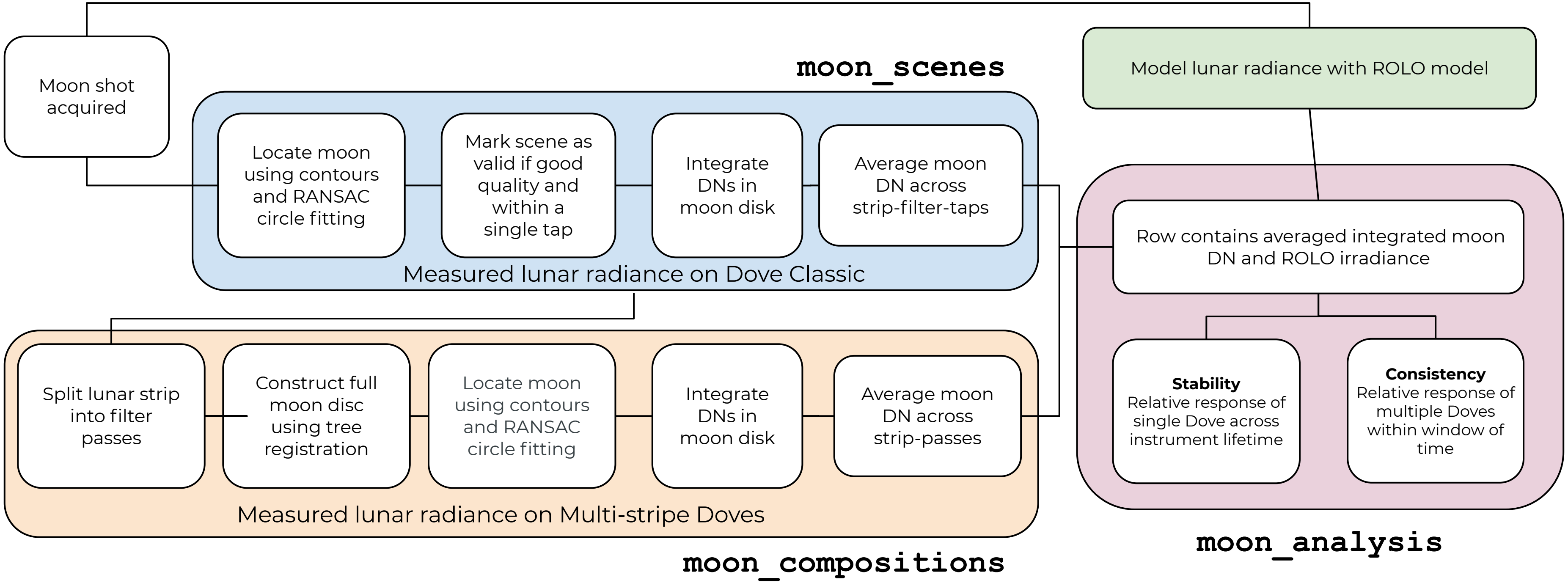
Multi-Stripe Moon Registration

Lunar images in single filter-pass
registered and combined to produce moon disc for comparison with ROLO model



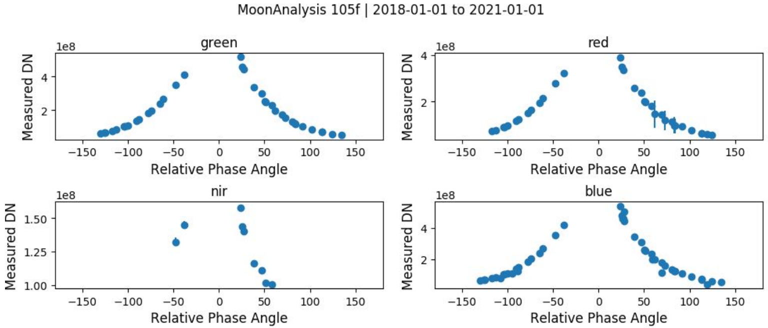
Lunar Pipeline

for Dove Classic and Multi-Stripe Doves

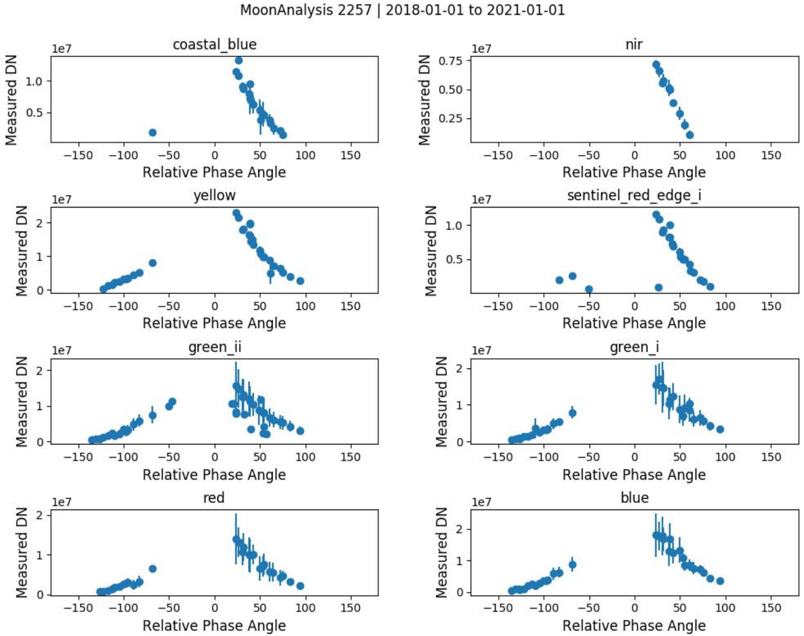


Measured Lunar DN
Correlates with Phase Angle

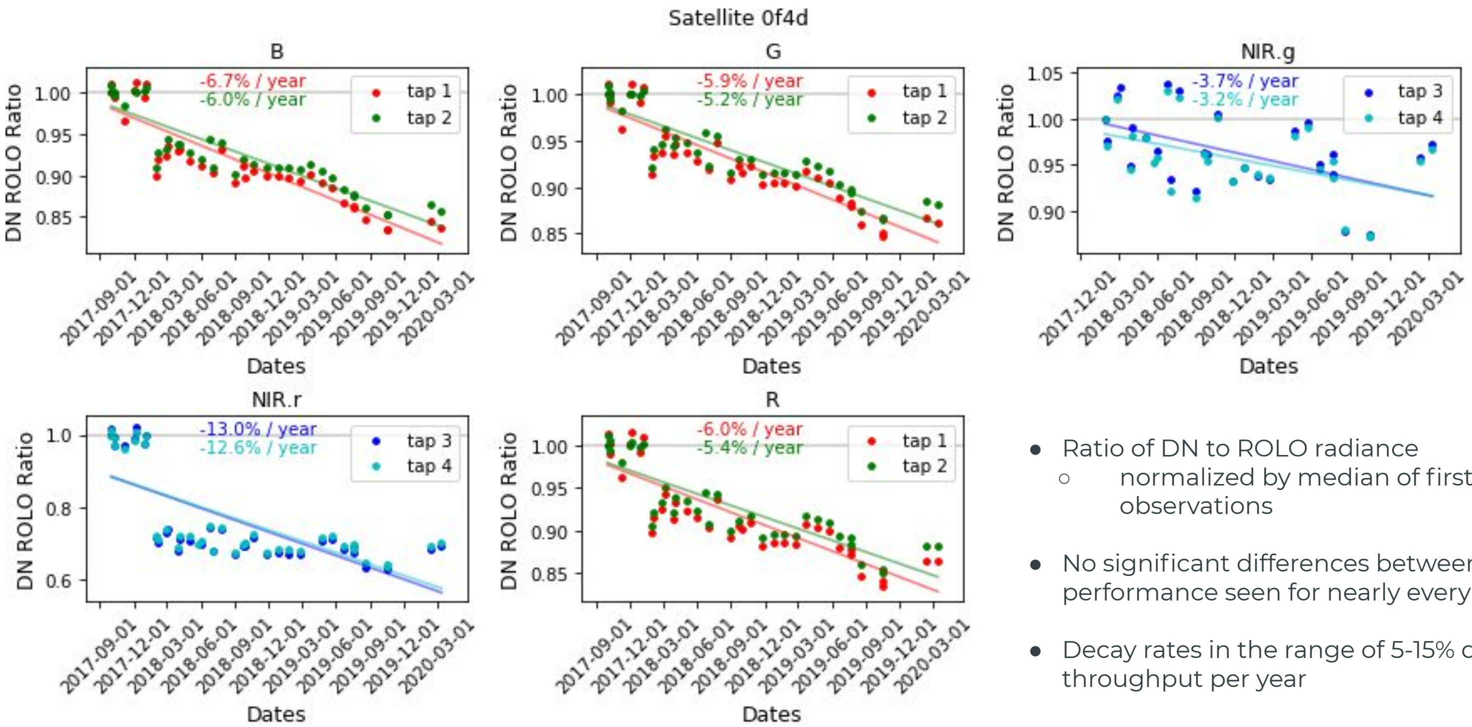
Dove-R



SuperDove

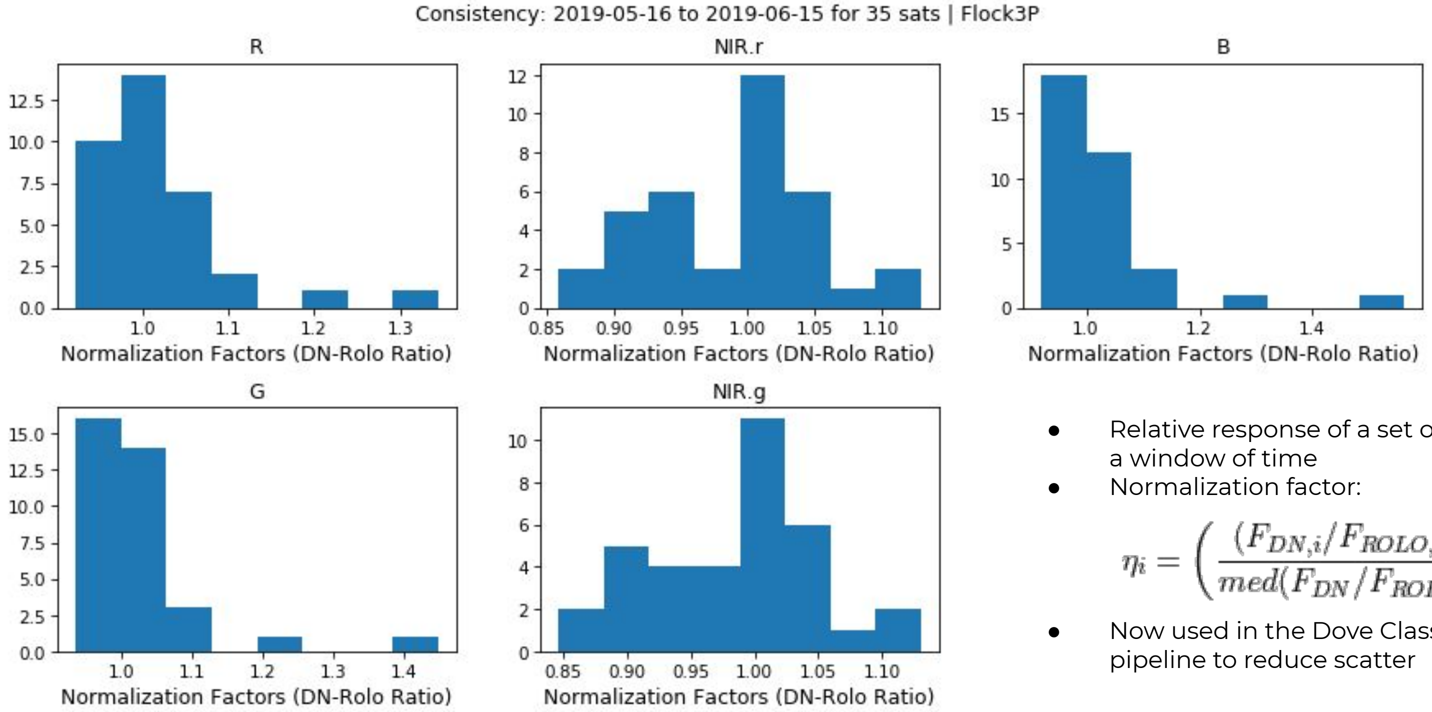


Instrument Stability



- Ratio of DN to ROLO radiance
  - normalized by median of first three observations
- No significant differences between tap performance seen for nearly every Dove Classic
- Decay rates in the range of 5-15% decline in throughput per year

Flock Consistency



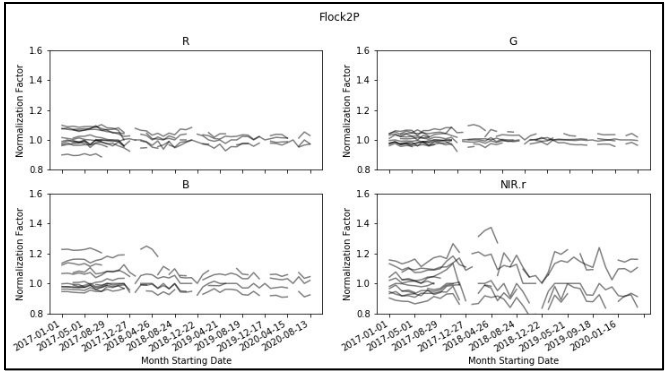
- Relative response of a set of satellites within a window of time
- Normalization factor:

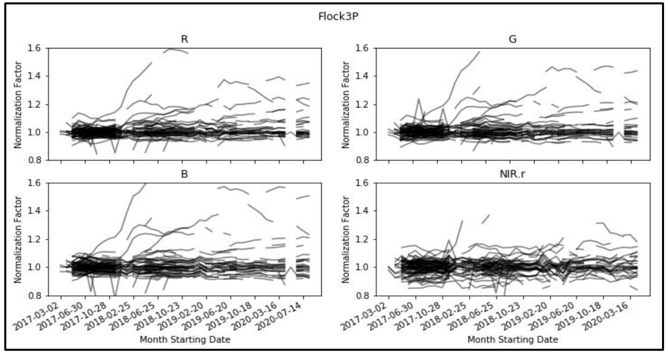
$$\eta_i = \left(\frac{(F_{DN,i}/F_{ROLO,i})}{med(F_{DN}/F_{ROLO})} \right)^{-1}$$

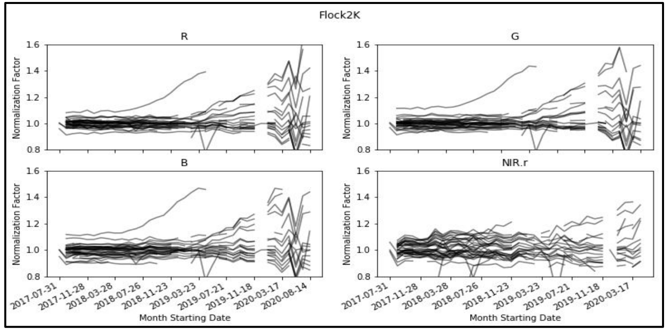
- Now used in the Dove Classic calibration pipeline to reduce scatter

Flock Consistency
Over Time

- Normalization factor is the relative response of a set of satellites within a window of time
- Consistency for each satellite remains fairly stable across time, as seen by the “smooth flow” of lines
- Flock 2P: Variance in consistency remains fairly stable
- Flock 3P: Variance in consistency remains fairly stable
- Flock 2K: Variance in consistency remains fairly stable for the first ~2 years, then rapidly spreads out

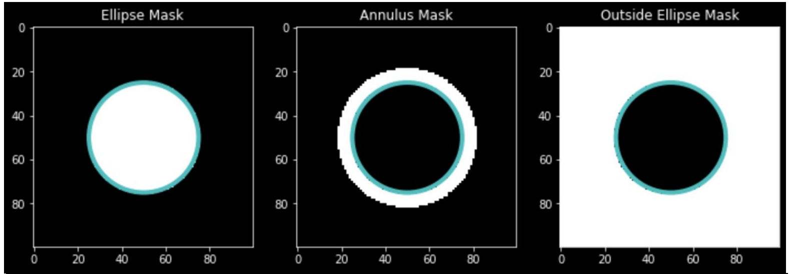


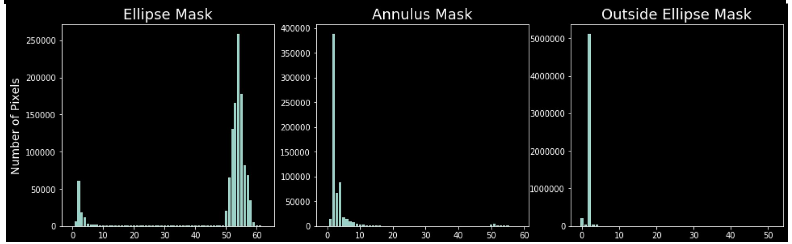


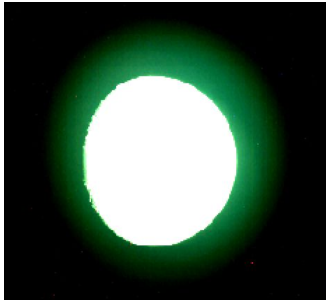


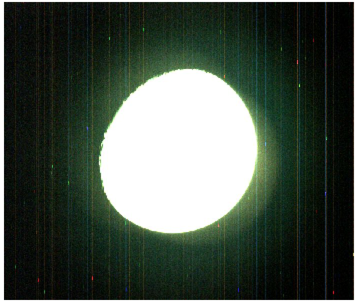
Identifying Image Haze

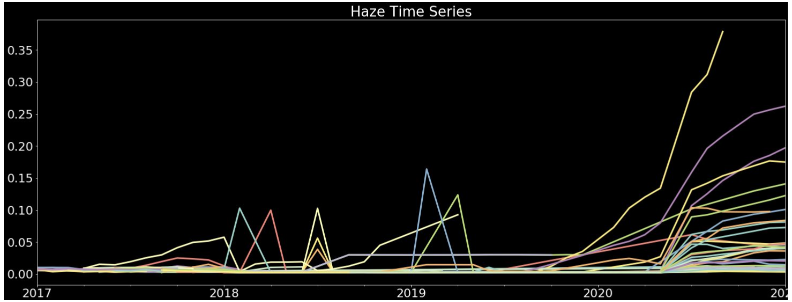
- Aging satellites can begin to suffer from haze due to deteriorating electronics
- Calculating the average brightness in the annulus surrounding the moon can alert operators to satellites that need to be inspected and/or decommissioned







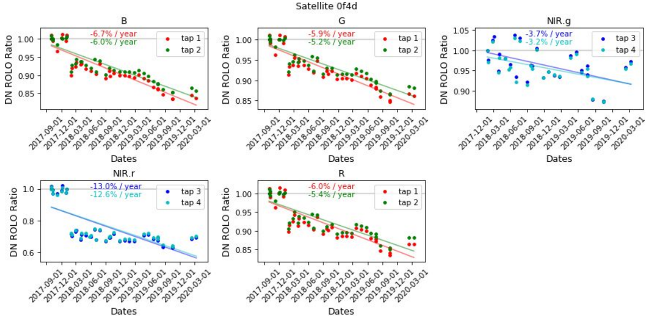


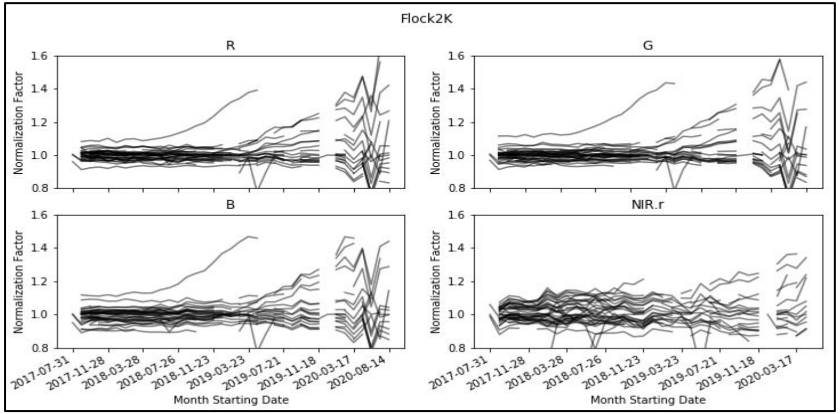


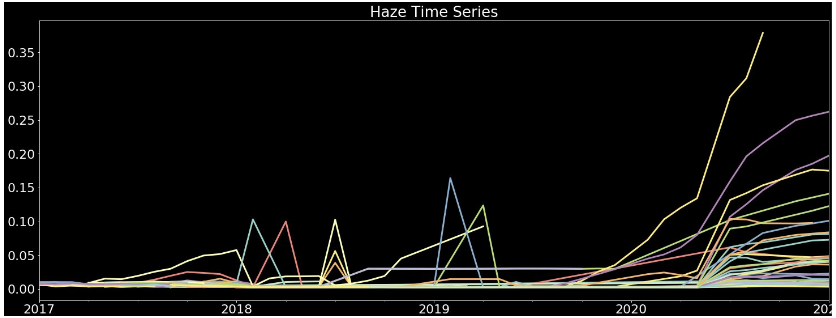
In Summary

- Lunar database provides valuable insight into the health of our growing heterogeneous fleet

- More insights to come!



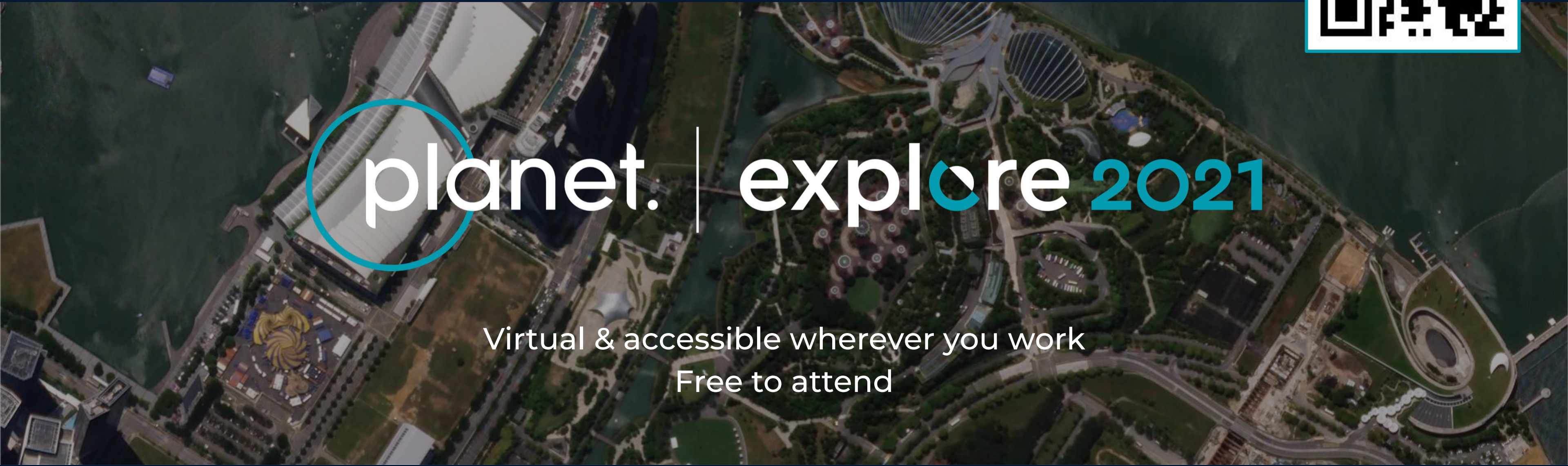




Save the date: October 12-13

Planet Explore 2021 Global Connection

Scan to Register



For more information, you may find us here:

Official Website

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Great Barrier Reef, Australia – July 8, 2016