Post-Launch Calibration of a Line-Of-Sight Model for PlanetScope

Graham Mills

Lake Okeechobee, Florida, USA • July 1, 2016

Overview

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Introduction to the Planet satellites

02
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03
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Conclusions

LONDON ARRAY WIND FARM · United Kingdom · April 17, 2016

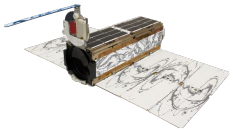
Introduction to Planet's satellites

Singapore Strait · Singapore · July 29, 2016

Agile Aerospace

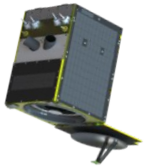
Through our agile aerospace approach, we've created a unique data set

CURRENT CONSTELLATIONS



SuperDove

- ~180 satellites
- Up to 300 million km^2 / day
- 8-band
- Unique scanning

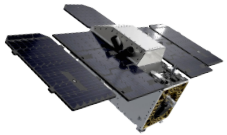


SkySat

- ~20 satellites
- 50cm resolution
- RGB, NIR, and Pan bands
- Sub-daily tasking

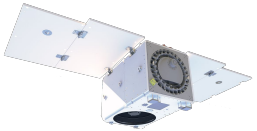
PLANNED HIGH RESOLUTION UPGRADE

PLANNED FUTURE CONSTELLATIONS



Tanager

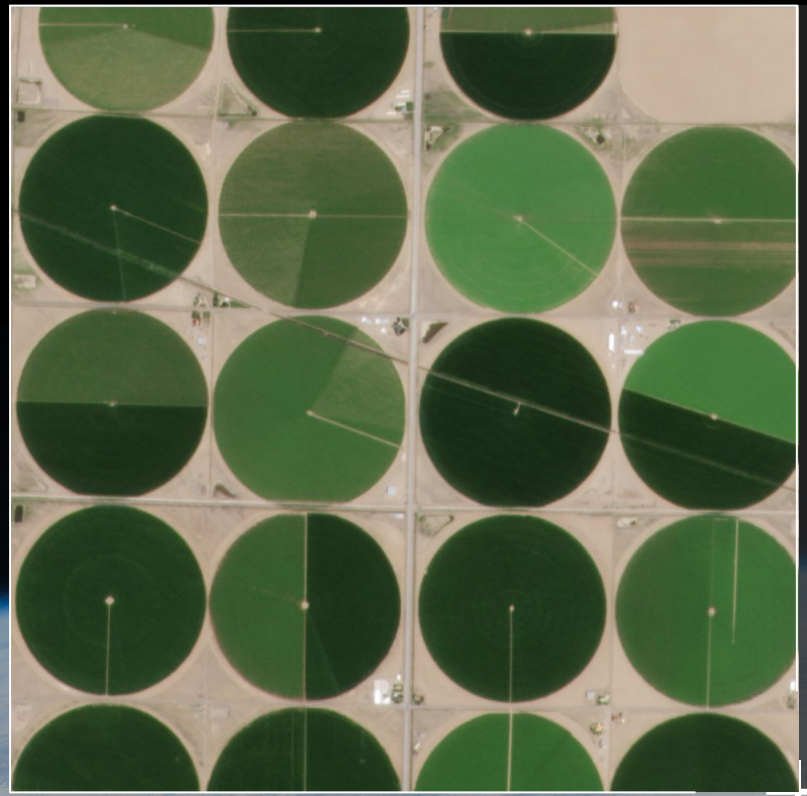
- 400 - 2500 nm
- ~400 5nm bands
- Technical demo planned to launch in 2024



Pelican

- Initial constellation of up to 30 satellites[1]
- Up to 30cm resolution
- Pan + 6 RGB+NIR bands
- Up to 30 revisits/day

[1] *Does not include initial 2 demonstration satellites planned.*

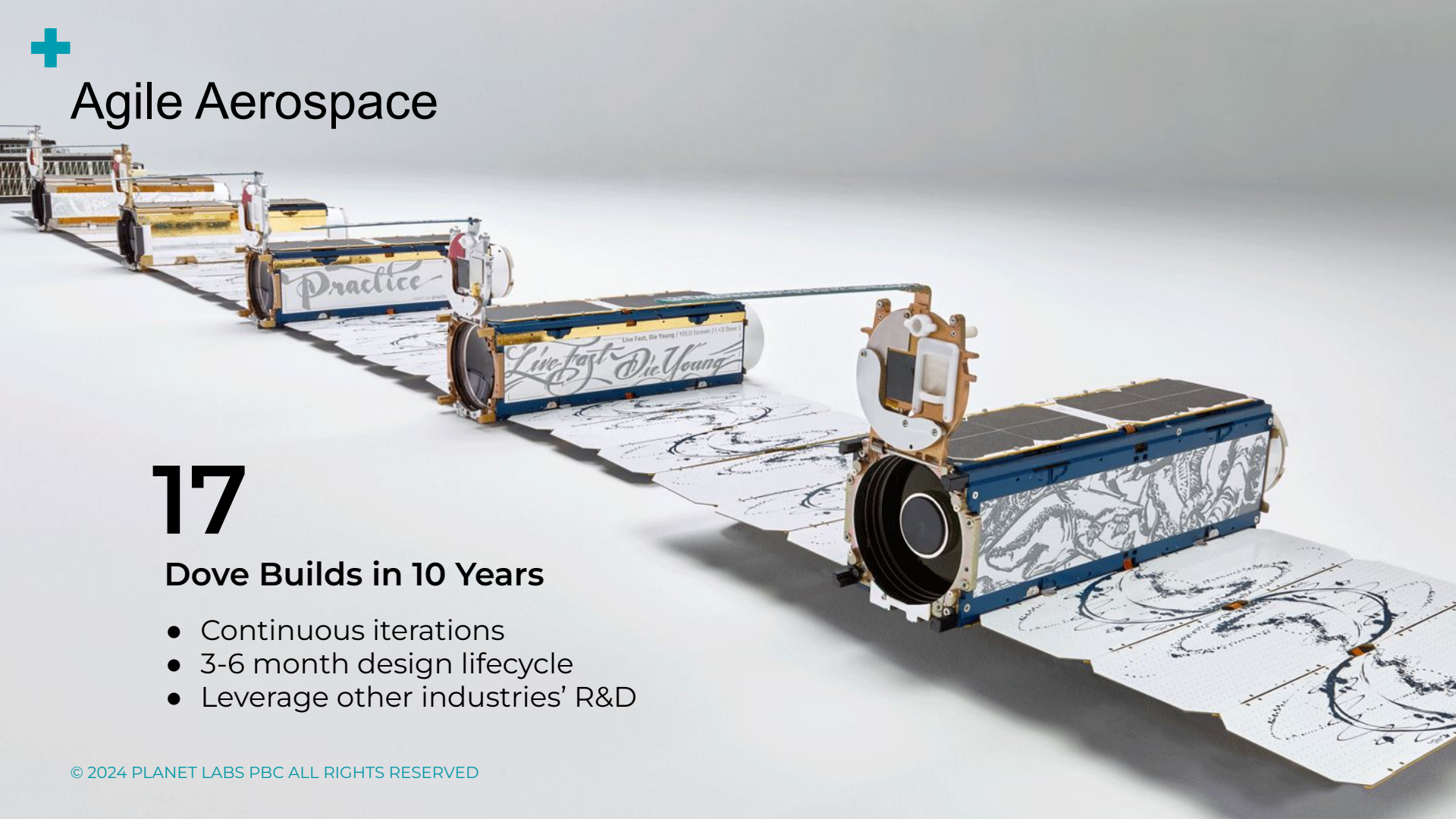


SuperDove

SATELLITES	RESOLUTION	CAPACITY
~180	**3.7 m**	**350 million km²**/day

ORBIT ALTITUDE	SPECTRAL BANDS
475 km	**RGB + Coastal Blue, Green II, Yellow, Red Edge,** and **NIR**

Agile Aerospace



17

Dove Builds in 10 Years

- Continuous iterations
- 3-6 month design lifecycle
- Leverage other industries' R&D

Line Of Sight Model Development

LAKE TUBORG · Canada · May 30, 2015

Motivation

- PlanetScope's rectification pipeline is being modified to use a physical model of the imaging system.
  - RPCs (rational polynomial coefficients) directly fit new image captures to reference imagery.
  - Line-of-sight approach will project image captures through pinhole camera model.
- Collected imagery is matched with reference imagery via ground control points (**GCPs**) to provide residuals for rectification.
  - Same GCPs can be used for calibration

Line of Sight Model parameters

Intrinsic parameters: Describe sensor hardware

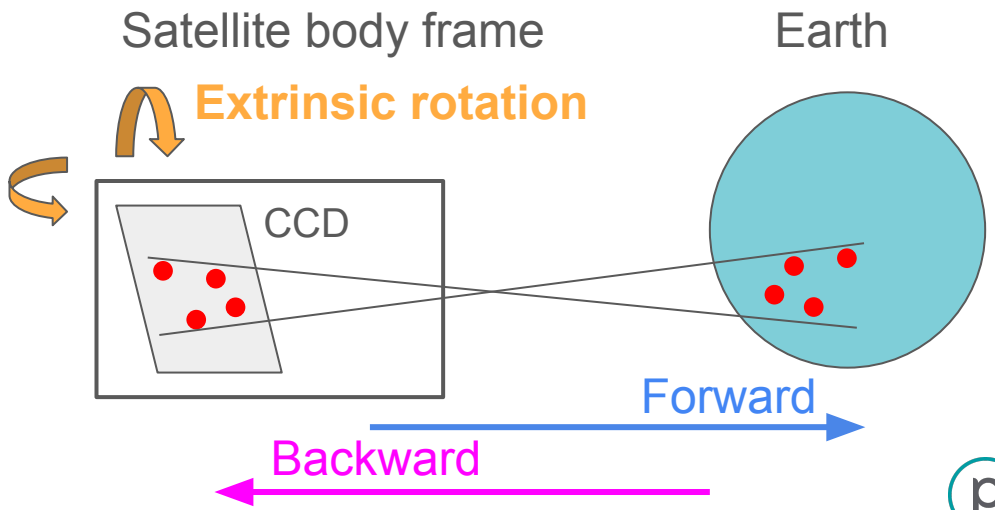
r1, ***r2*** : Radial distortion, **forward** direction (satellite -> Earth)

r1i, ***r2i*** : Radial distortion, **backward** direction (Earth -> satellite)

of_x, ***of_y*** : Principal point offset

f : Focal length

Unique for a given satellite



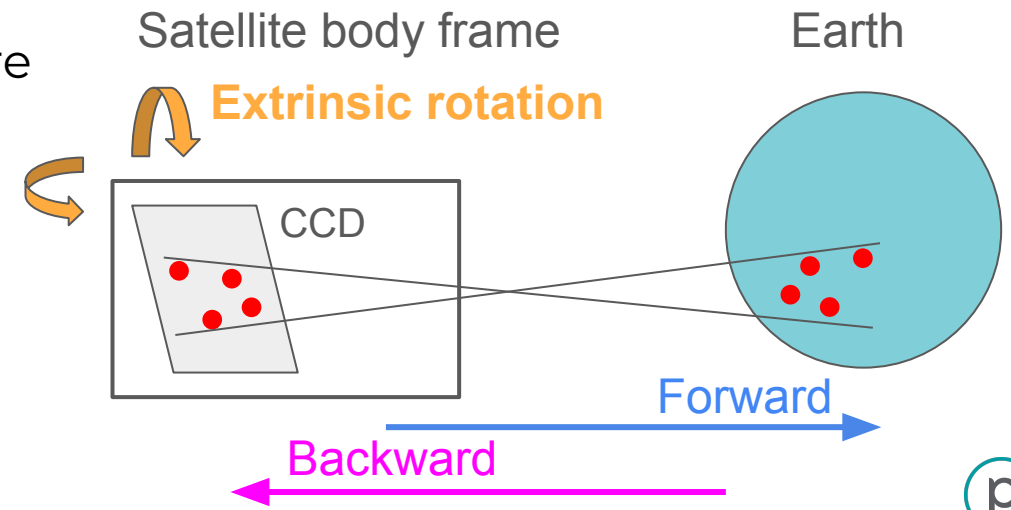
Line of Sight Model parameters

Extrinsics: Locate Satellite in space

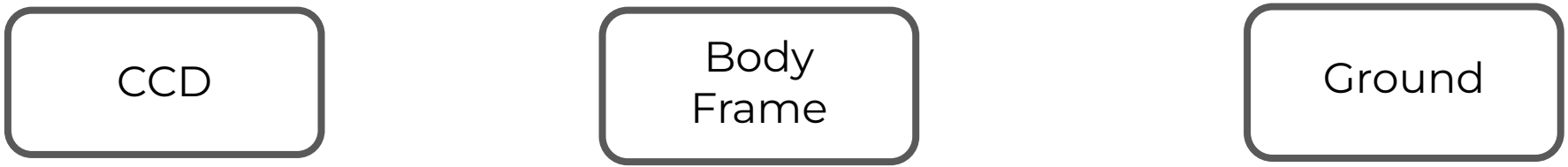
3D translation (unoptimized)

Quaternion (optimized)

Unique for a given image capture



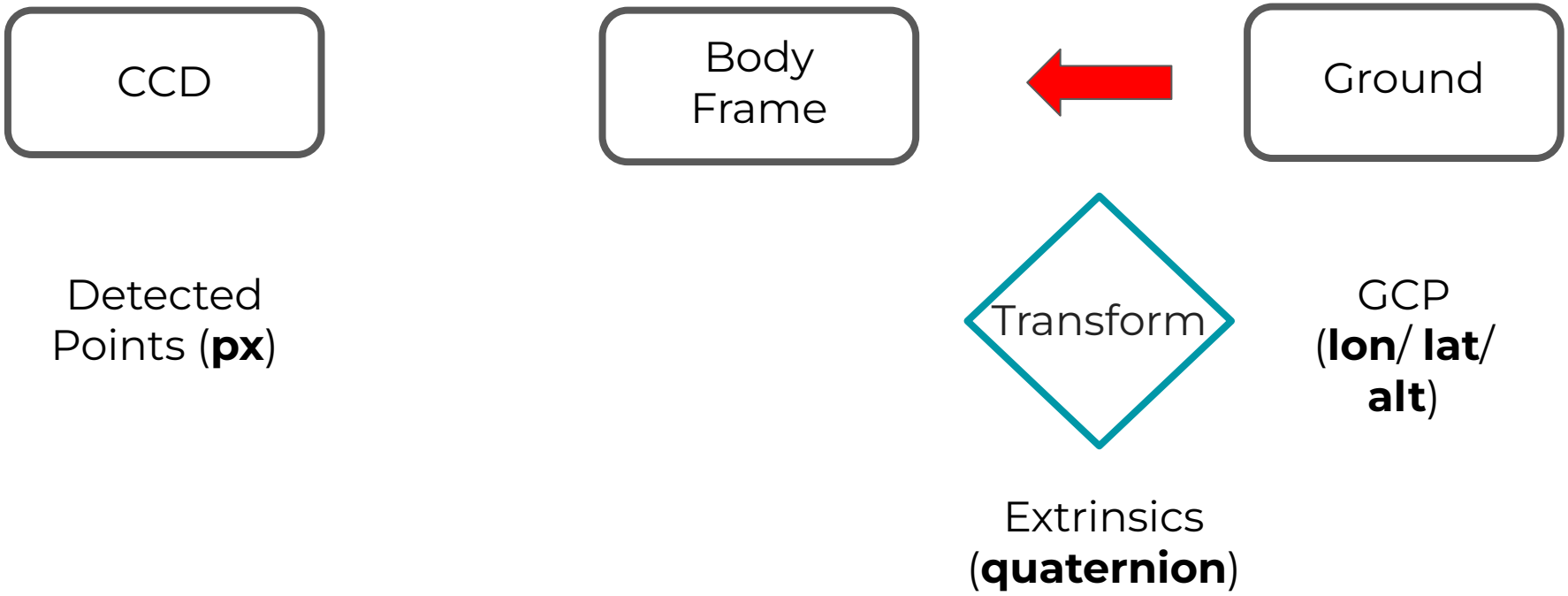
Backward Direction (Earth to Satellite)



Detected Points (**px**)

GCP (**lon**/ **lat**/ **alt**)

Backward Direction (Earth to Satellite)



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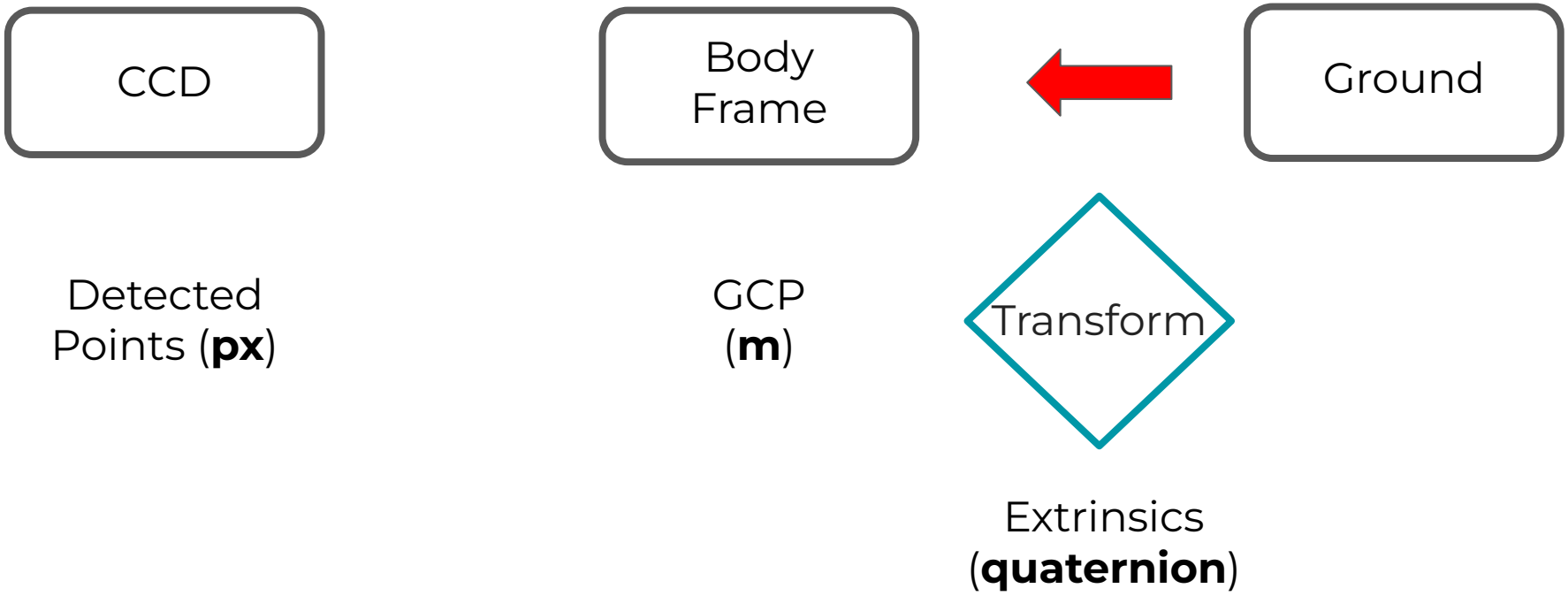

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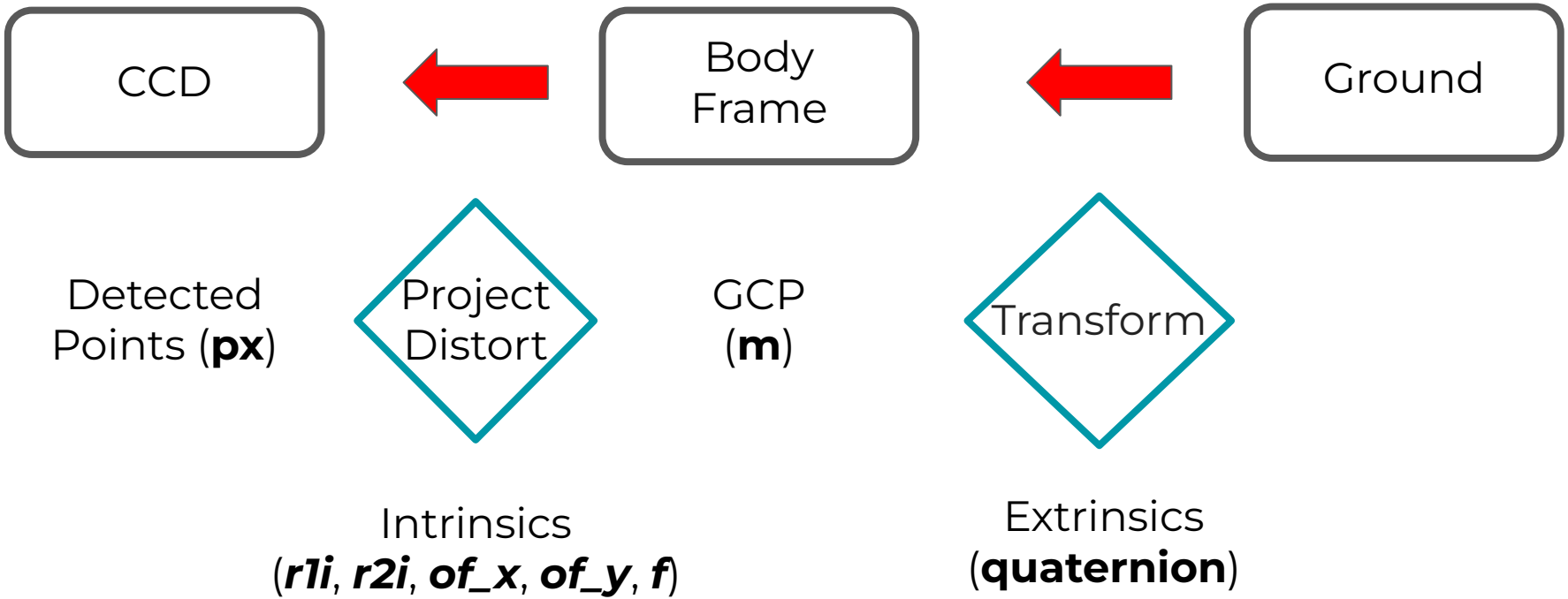

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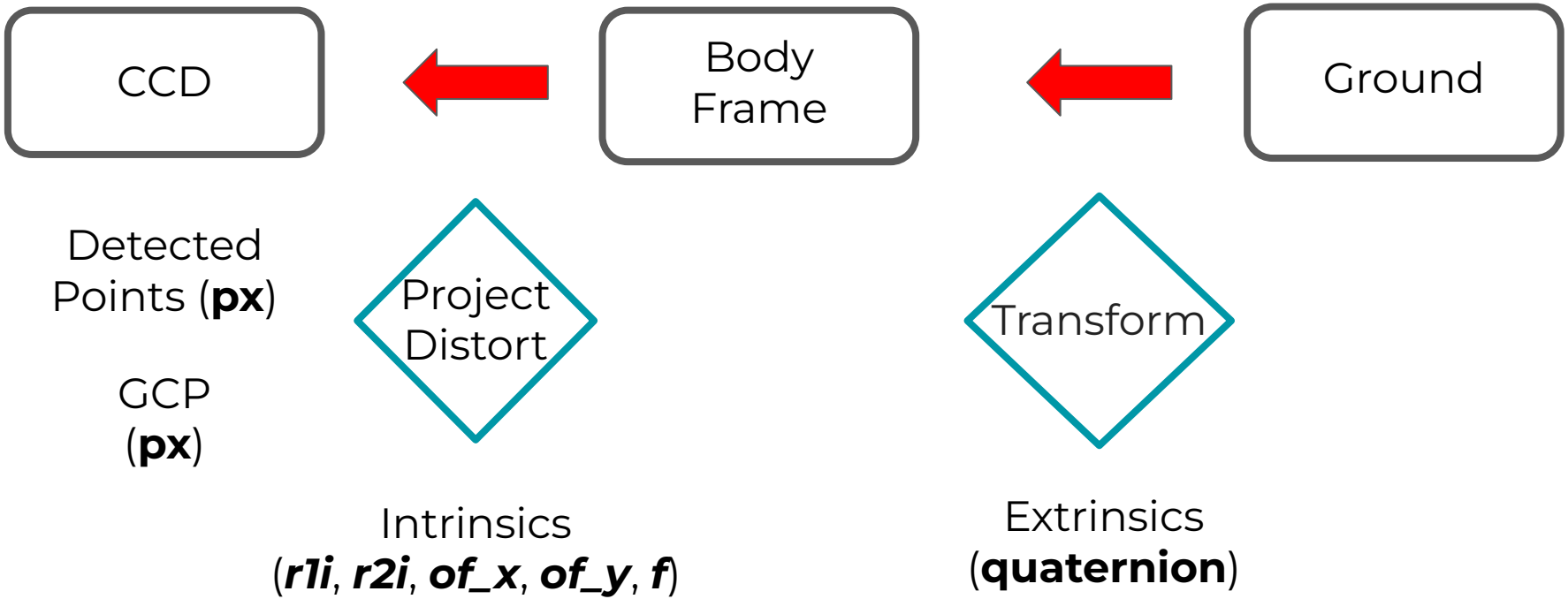
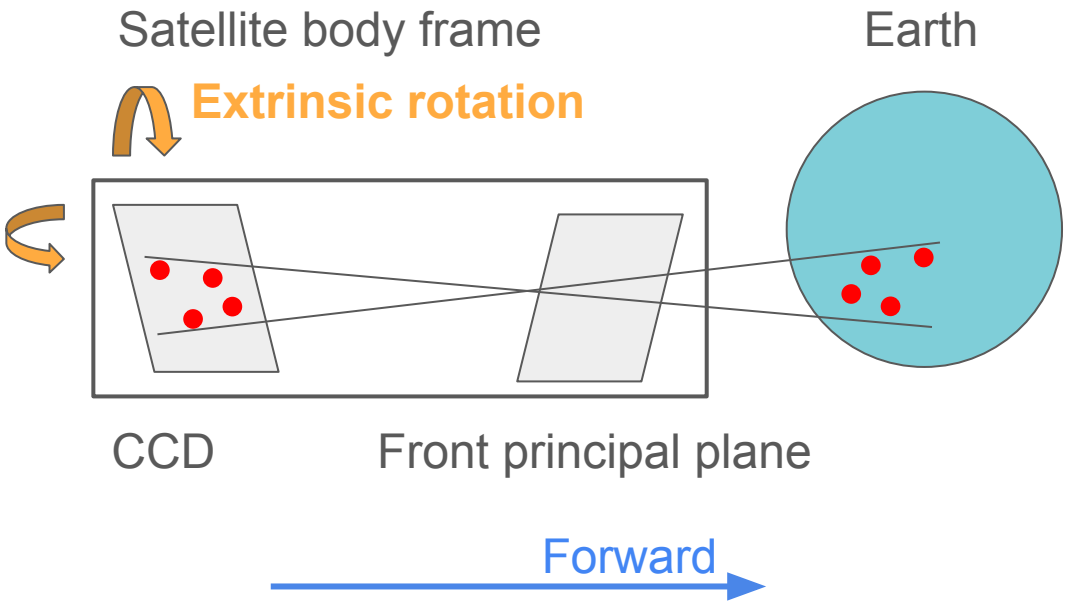
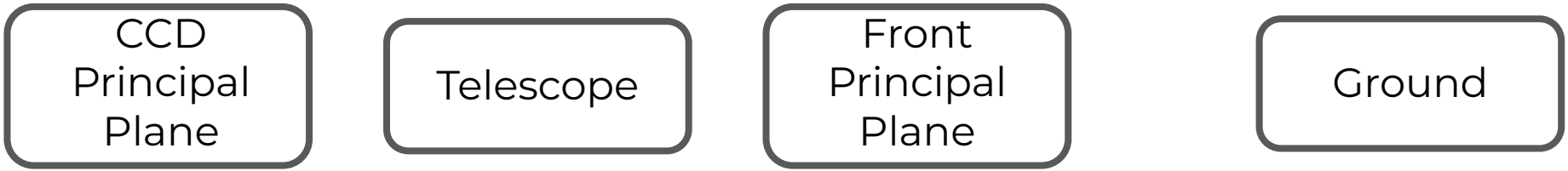


Line of Sight Model parameters



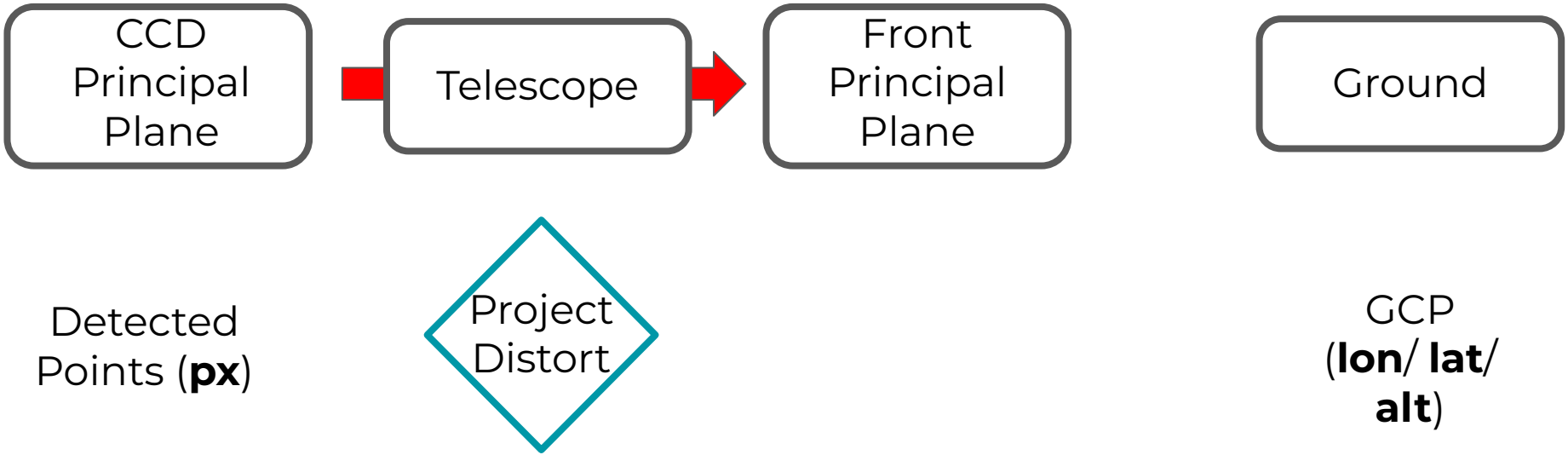
Forward Direction (Satellite to Earth)



Detected Points (**px**)

GCP (**lon**/ **lat**/ **alt**)

Forward Direction (Satellite to Earth)



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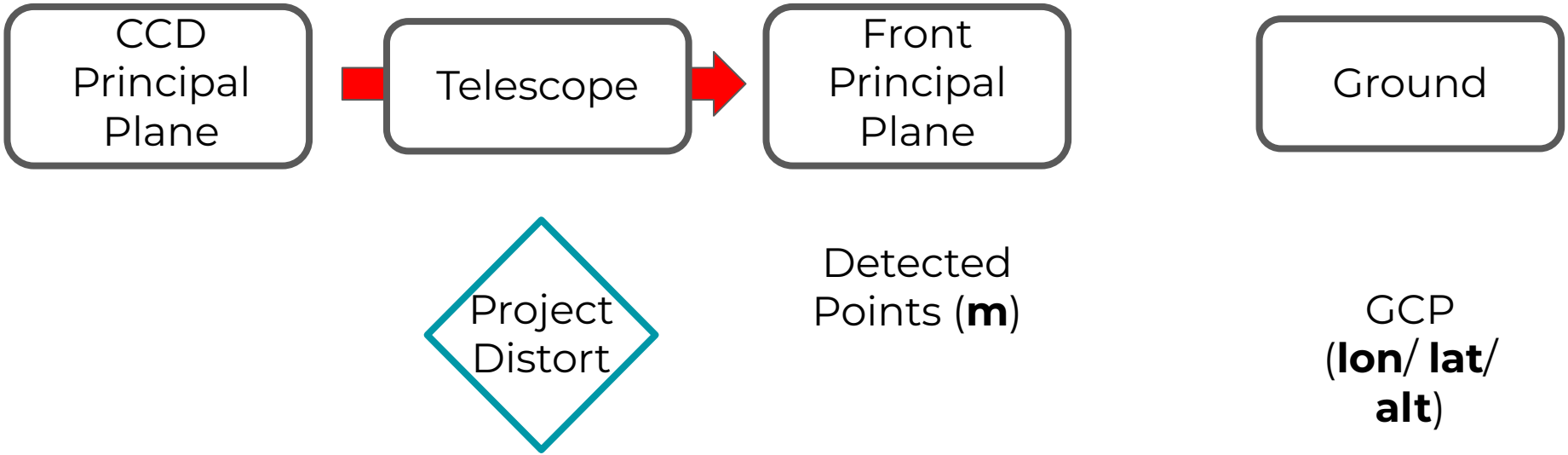

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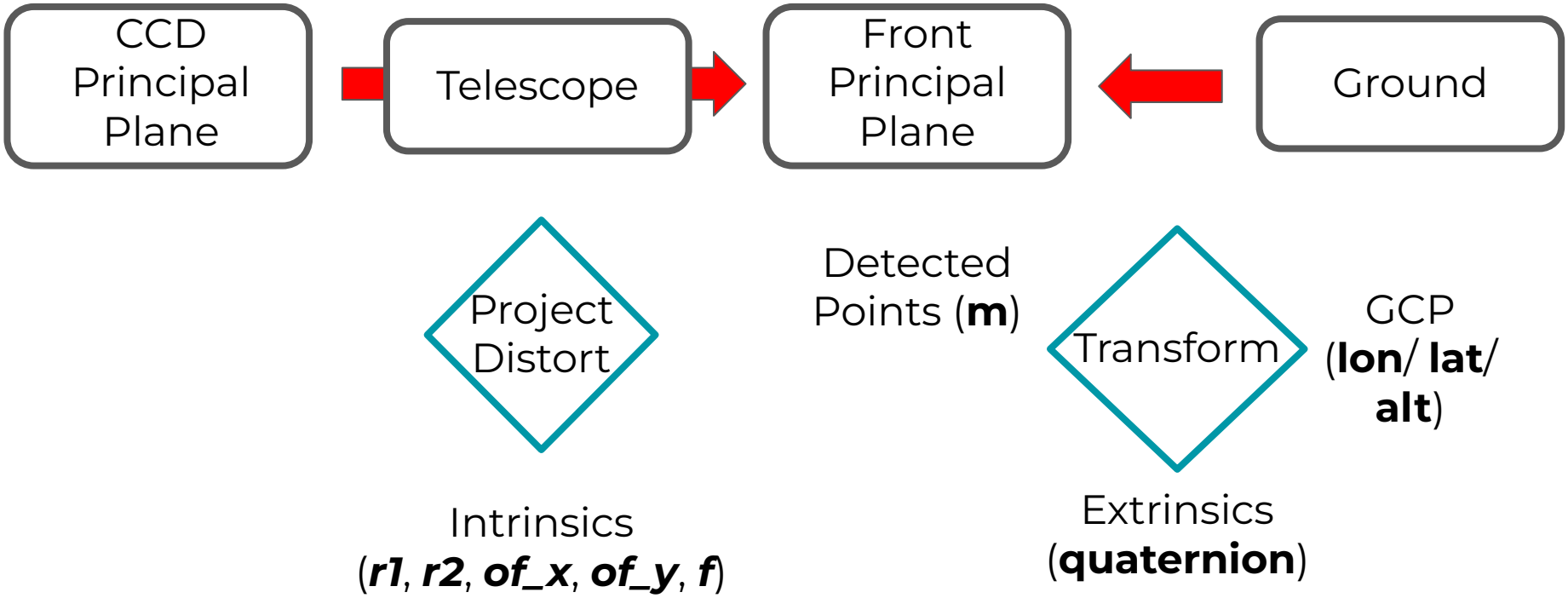

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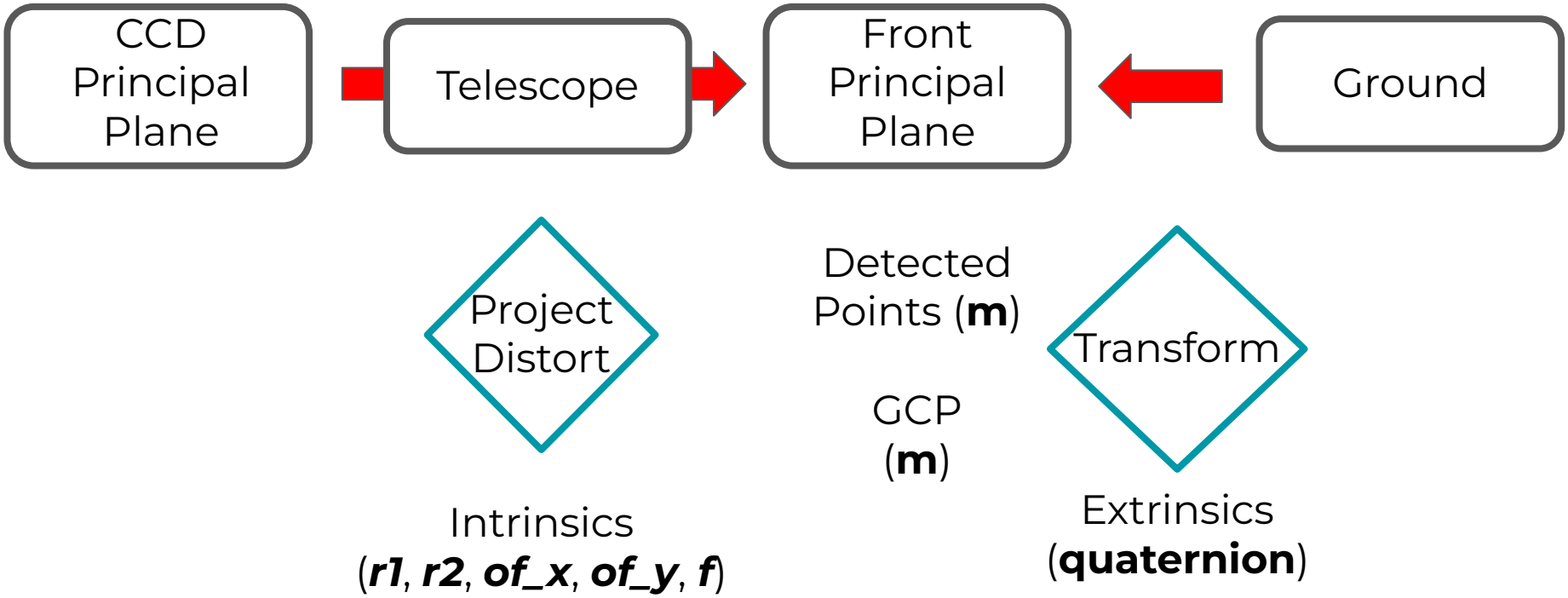

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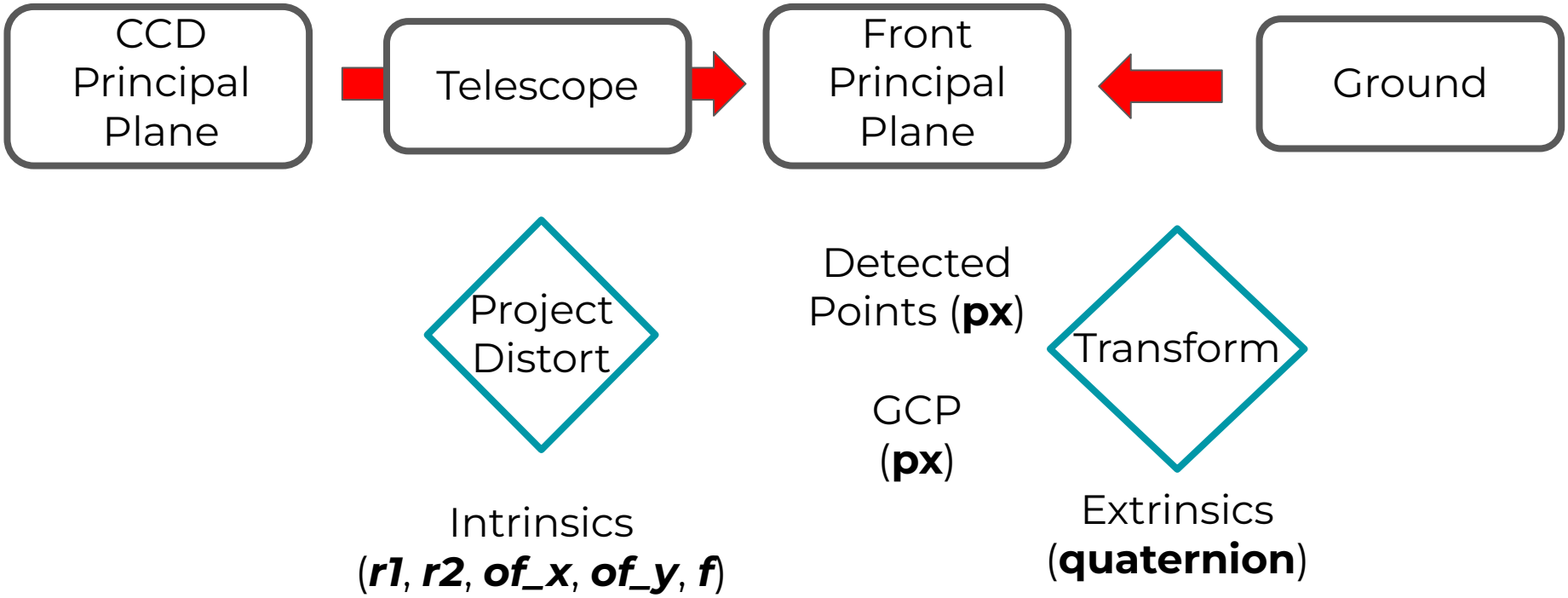
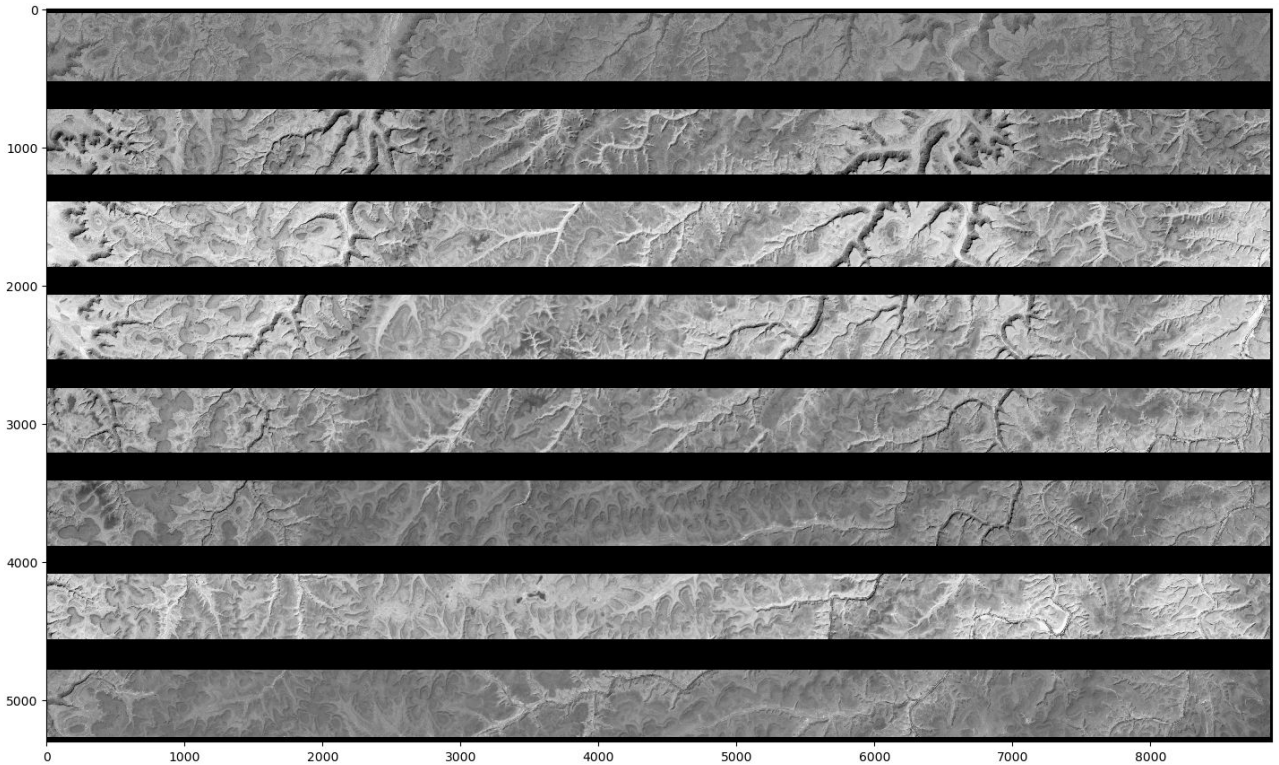


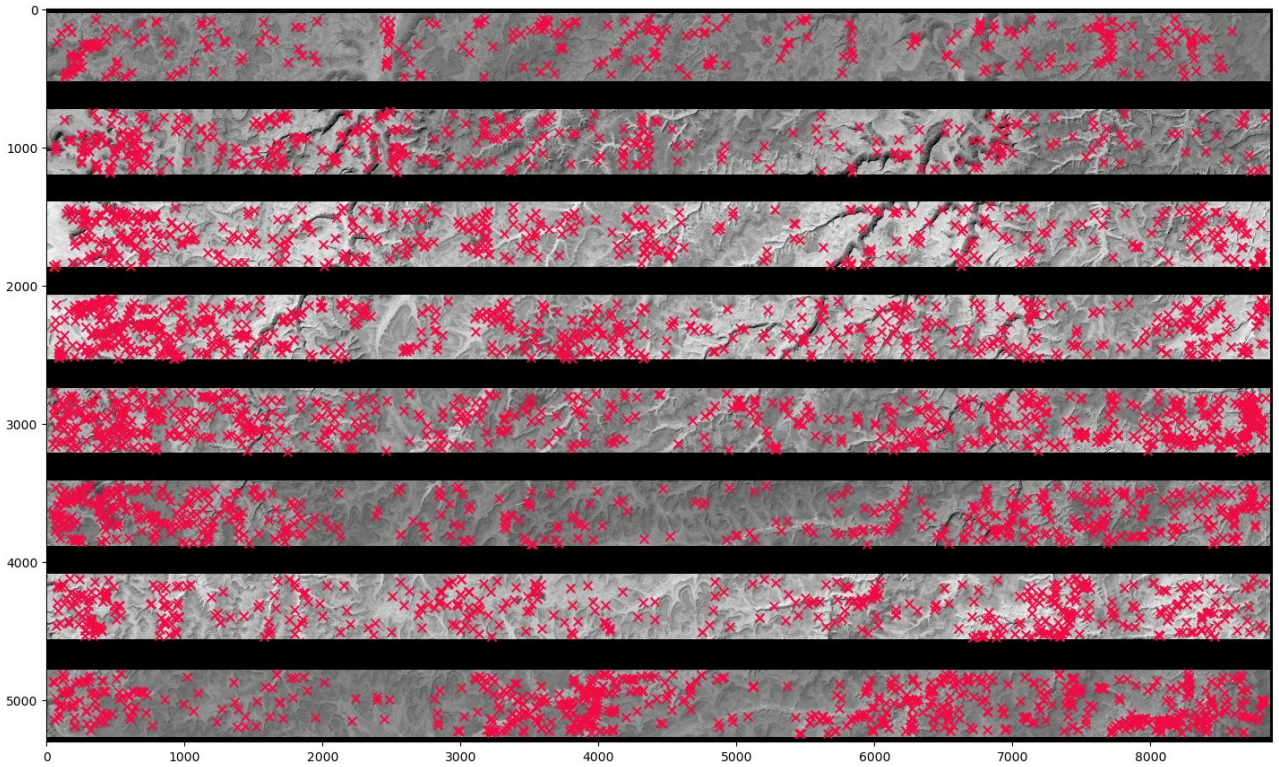
Calibrating the model

CORAL REEF · Belize · April 14, 2019

Calibrating the model



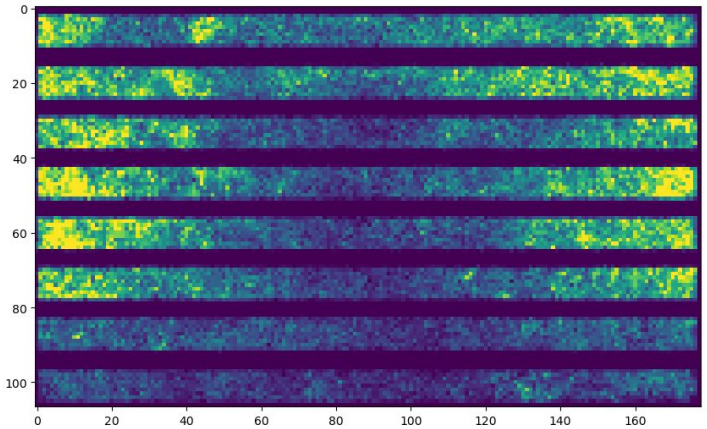
Calibrating the model

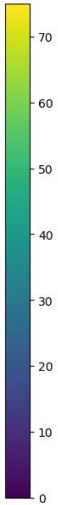


Spatial filter

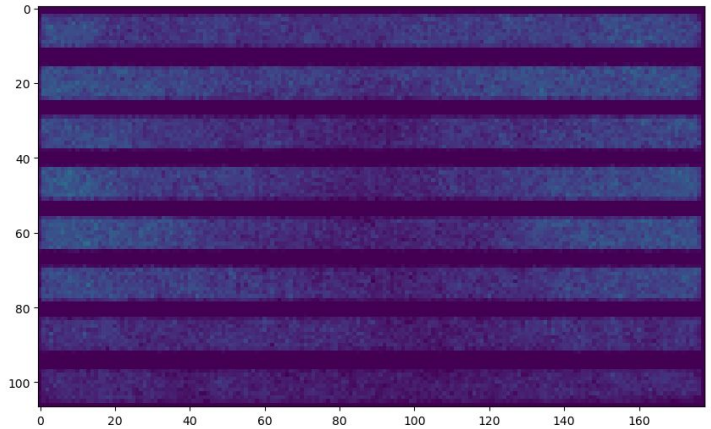
- GCPs are distributed over the sensor FOV irregularly.
  - Spatial filter limits local density of GCPs
  - Regularization– distributes error more evenly across the sensor

50 frames: No filter- 7500 GCP/ frame

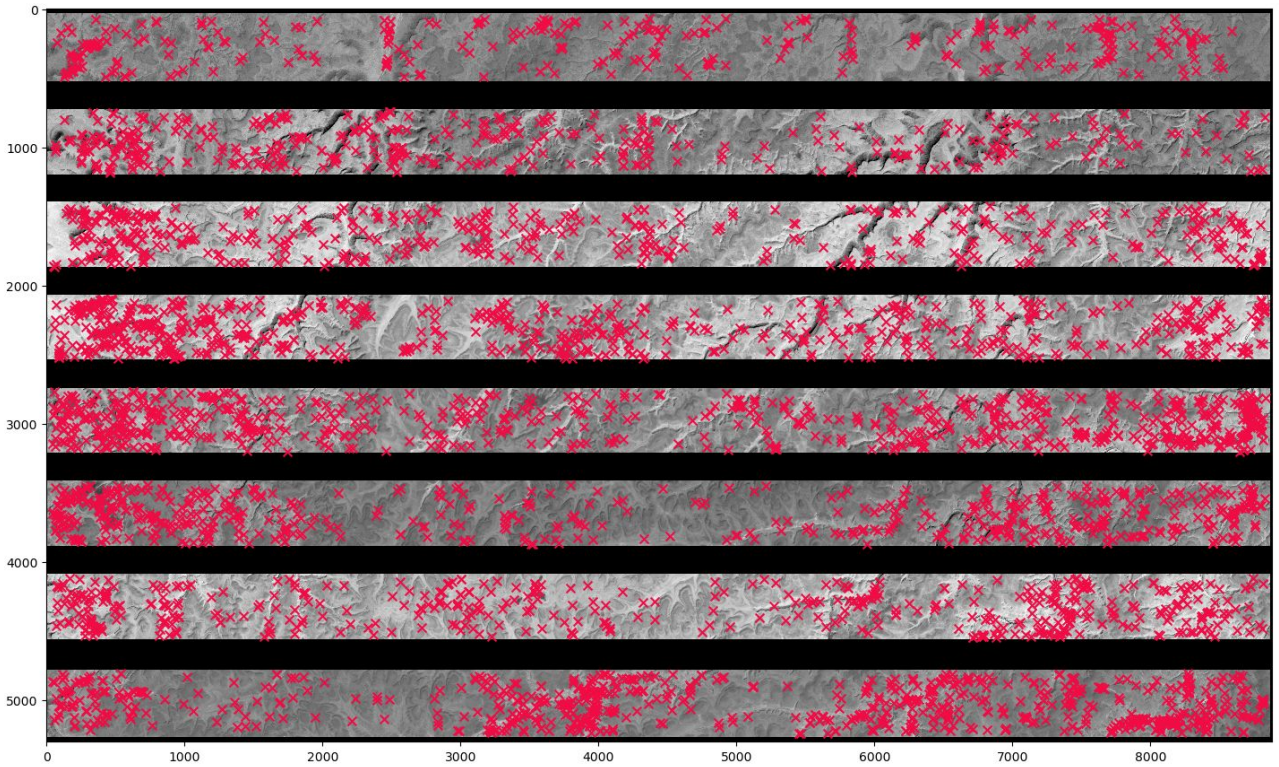




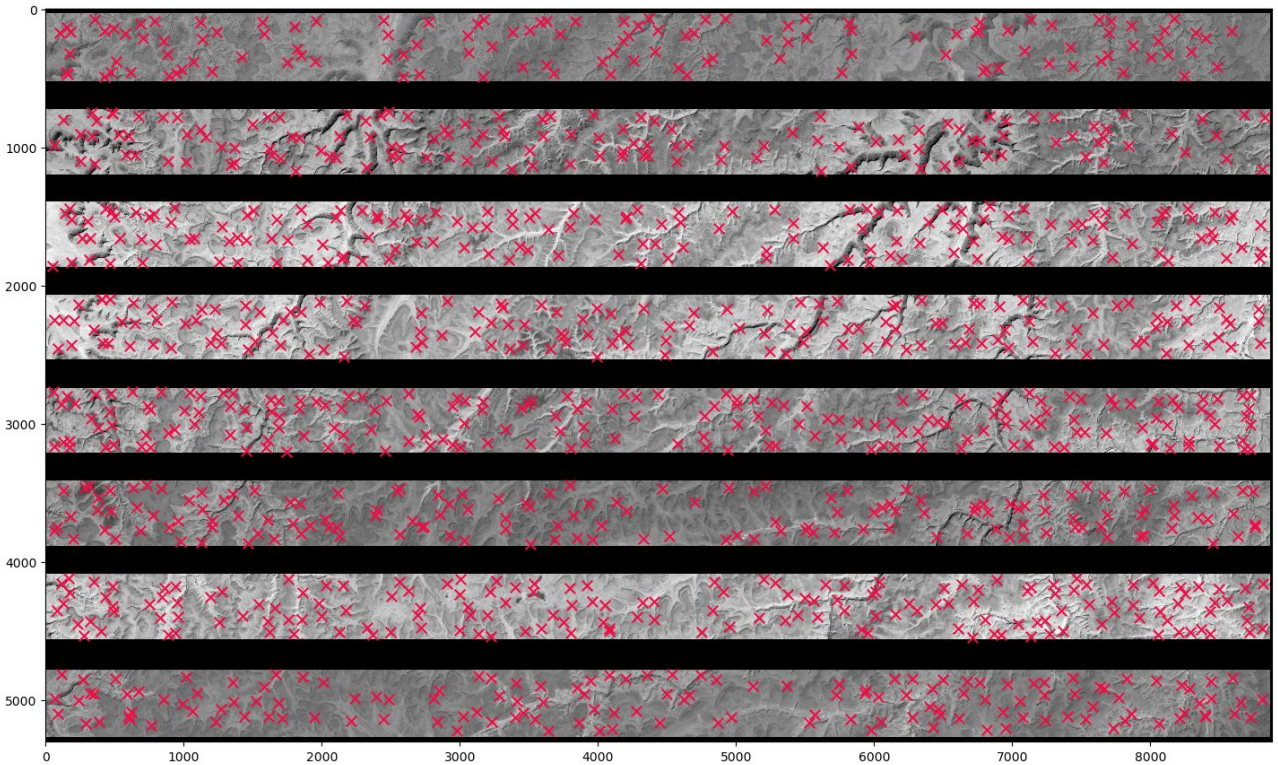
Filtered- 2800 GCP/ frame



Spatial filter



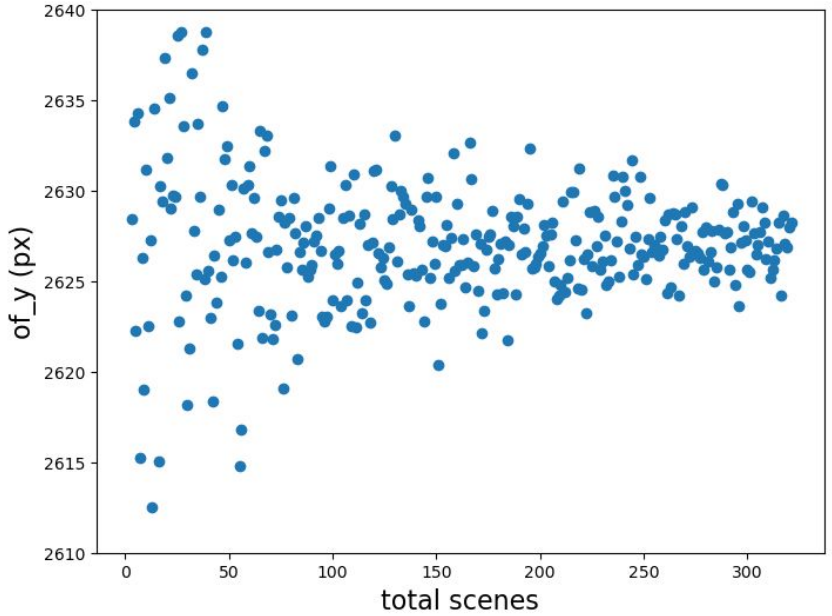
Spatial filter



Combining estimates

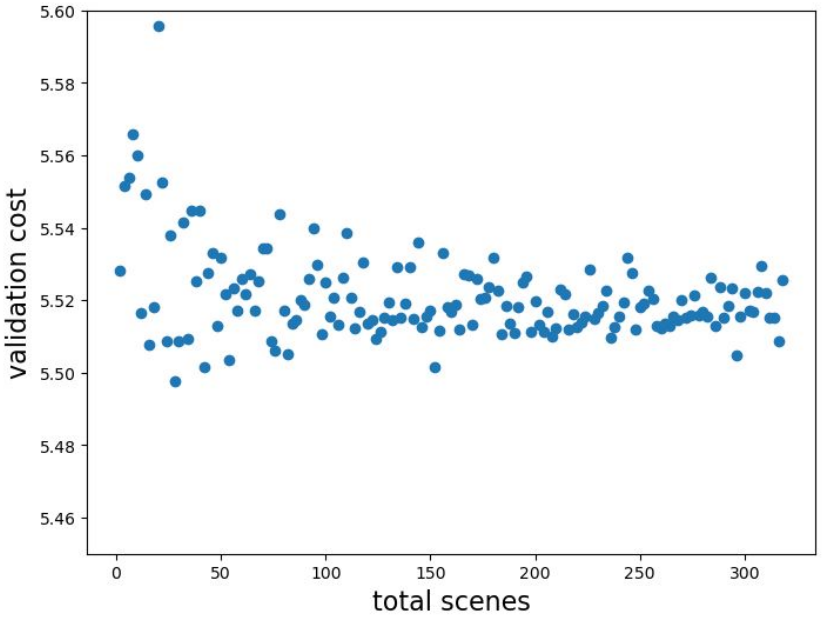
- Center pixel Y coordinate (***of_y***)-correlated with pointing direction
- Average many trials into one estimate

Intrinsics
(***r1***, ***r2***, ***of_x***, ***of_y***, ***f***)



Combining estimates

- Average many trials into one estimate
- Calibration results are validated against held out datasets
- Cost decreases and then converges with small scene count



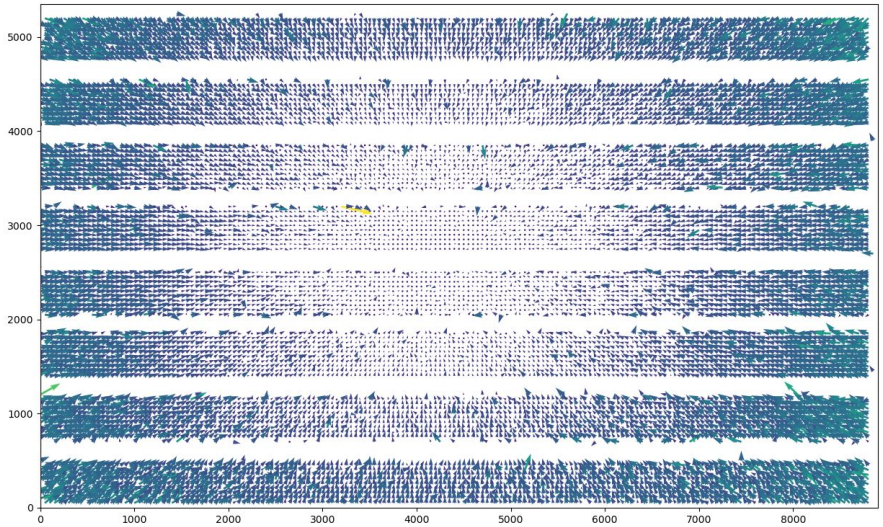
Conclusions

AGRICULTURE · North Caucasus, Russia · June 27, 2016

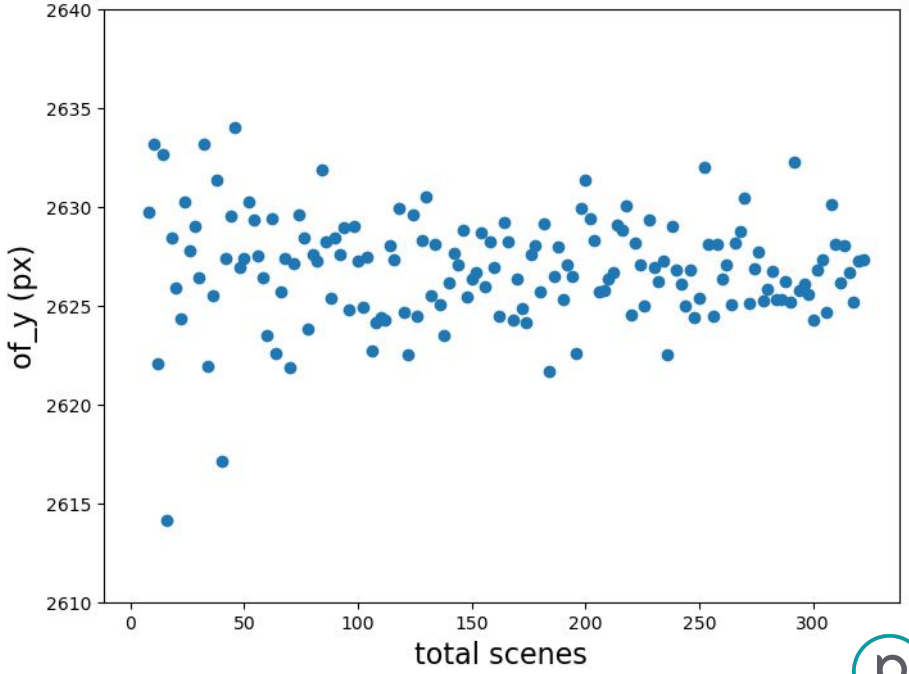
Low data volume

Pre-calibration

320 scenes, 153k points, cost/ point: **13.22**



Parameter convergence



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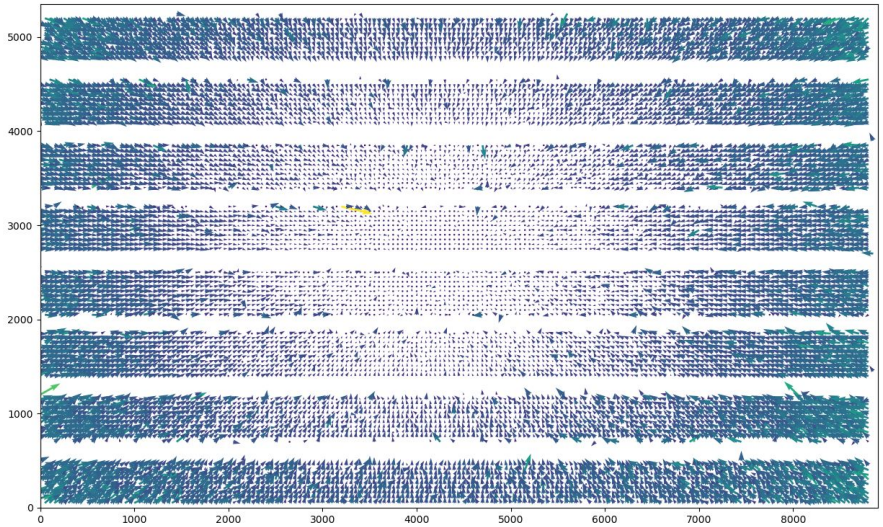
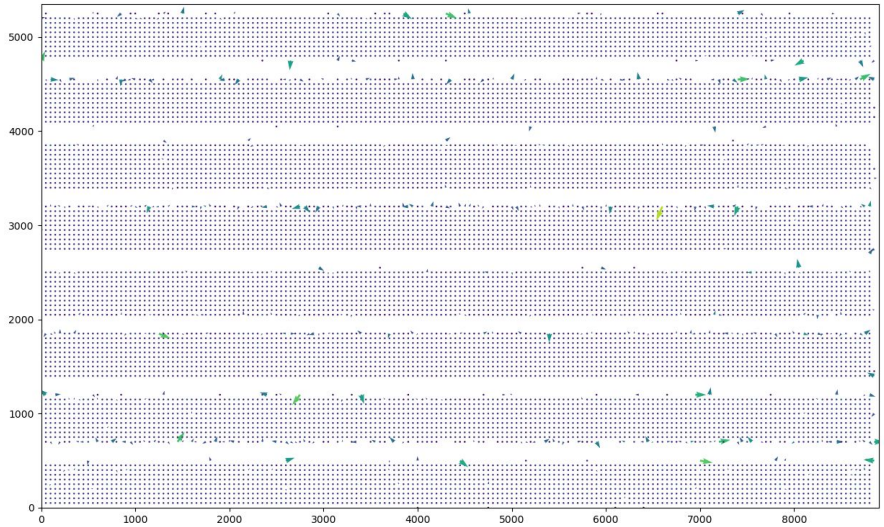


Validation

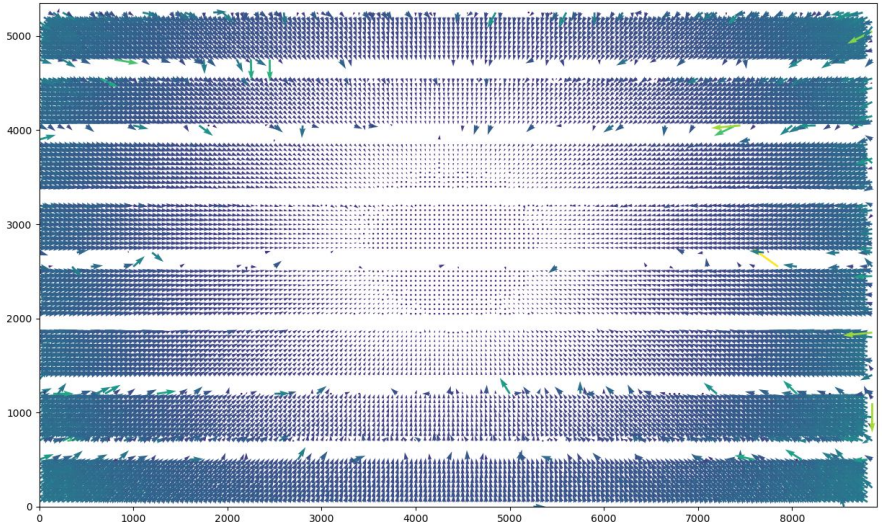
1160 scenes, 517k points, cost/ point: **4.75**

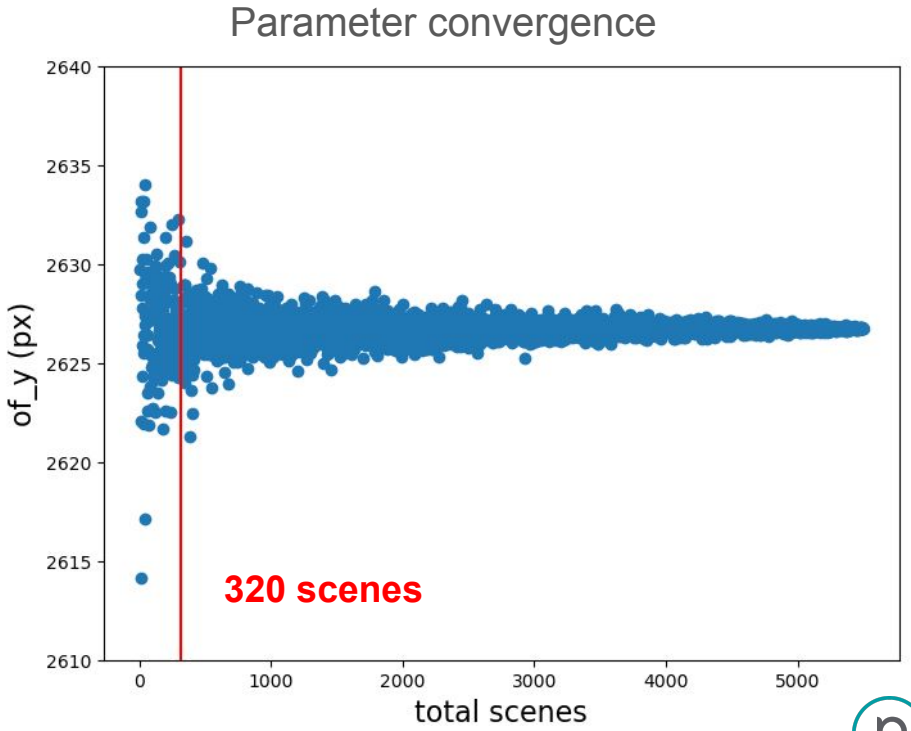


High data volume

Pre-calibration

5507 scenes, 2.7M points, cost/ point: **13.79**

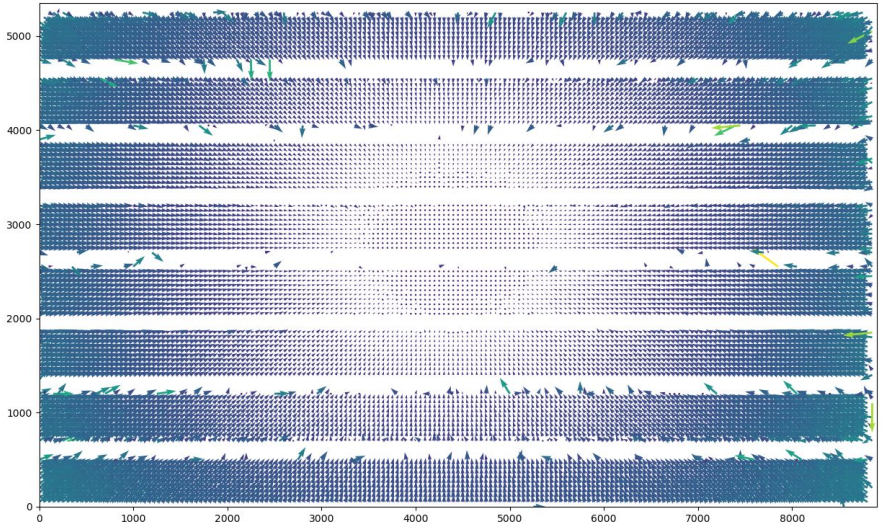




High data volume

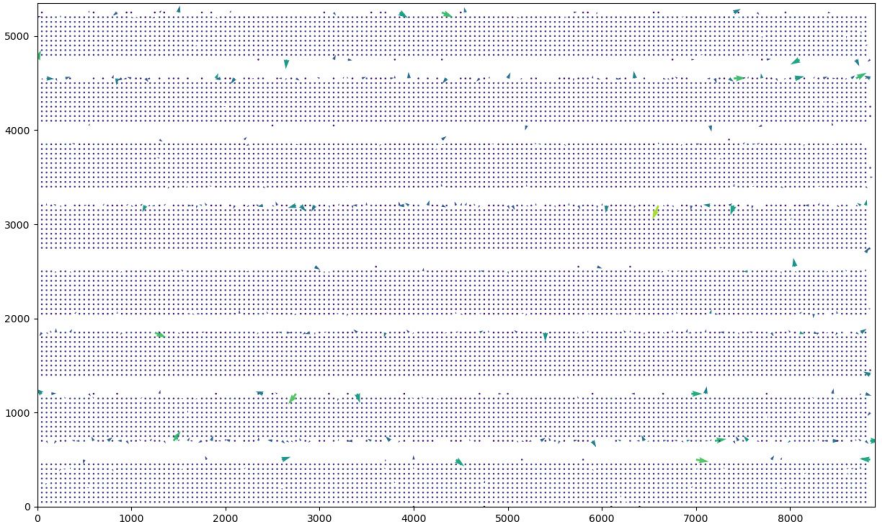
Pre-calibration

5507 scenes, 2.7M points, cost/ point: **13.79**



Validation

1160 scenes, 517k points, cost/ point: **4.76**



Conclusions

- Findings:
  - Physical camera model meets performance expectations
  - Data volume needed for calibration is small compared to available data
- Goals:
  - Study temporal evolution of optimal parameters
  - Validate with lunar imagery
- Outlook: On-orbit geometric calibration
  - **Monitors** satellite health over lifespan
  - Provides diagnostics **on demand**
  - Offers feedback to iterative design process