CNES Experience in Image Quality and Illustration with Pleiades Very High Resolution Data

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Image Quality and Performance Assessment at CNES (1)

35 Years of Experience in 'Image Quality' of Optical Satellite Imaging Sytems:

Ground Characterization, Calibration, Validation, Performances Assessment, Processing Algorithms… Through:

- **SPOT 1, 2 & 3** (10m Panchro and 20m Multispectral - VNIR)
- **SPOT 4** (10m Panchro and 20m Multispectral – VNIR + SWIR)
- **SPOT 5** (2.5m Panchro and 10m Multispectral – VNIR + SWIR – F/B Stereo)
- **VGT** (1km Daily Global Coverage - VNIR + SWIR)
- **POLDER/PARASOL** (Polarization and Multiangle Viewing – VNIR)
- **Pléiades** (0.7m Panchro and 2.8m Multispectral - VNIR)
- **Sentinel 2** (10m Multispectral – VNIR + SWIR)
- **Venμs** (5m Multispectral – VNIR – 2 days revisit)

Experience extended to other Earth Observation Systems: TIR Sounding (IASI), Thermal IR Imaging (Calipso/IIR), Passive Microvawe (Megha-Tropiques)

Image Quality and Performance Assessment at CNES (2)

CNES concept of ‘Image Quality’:

- Image performance considered at system level (board+ground)
  - Satellite / instrument / ground processing…
  - Image quality budget performed at system level
  - End to end simulations
- Continuity in the responsability of image performance for all the project phases
  - Design / development / commissionning / exploitation
  - Image quality manager member of the project team
- Operational image quality monitoring during exploitation phase
  - Dedicated team, dedicated tools, dedicated environment
  - Strong link between expertise/monitoring

In CNES we prefer ‘Image Quality Commissionning’ than ‘Calibration/Validation’.
The same but even more…

Image Quality and Performance Assessment at CNES (3)

Development of generic tools, data bases, sites catalogs

Both for radiometry and geometry

- **SADE: measurements data base over calibration sites (desert, snow, ocean …)**
- **MUSCLE: calibration tools environment**
- **ROSAS: calibration over instrumented site (La Crau, Gobabed…)**
- **High accuracy GCPs data base**
- **AGILE: Geometrical performances assessment workshop**
- **SIGMA/Euclidium: viewing modelization and geometrical corrections**
- **Images correlation**
- **Optimized resampling**
- **MTF assessment**
- **Denoising…**

Image Quality and Performance Assessment at CNES (4)

But also…

Dedicated tools and methods developed to deal with satellite/instrument/mission specificities

- **Very high resolution image location assessment (Pléiades)**
- **Microvibrations assessment (SPOT5, Pléiades)**
- **Stereo performances assessment (SPOT5/HRS, Pléiades, Venμs)**
- **Polarization parameters determination (POLDER/PARASOL)**
- **Stray light correction assessment (POLDER,Venμs)**
- **Moon calibration thanks to satellite agility (Pléiades, Venμs)**
- **Radiometric calibration over clouds (VGT, POLDER, MERIS)**
- **…**

Illustration with Pléiades

How to use satellite agility to assess Image Quality?

PLEIADES Mission Overview

Spatial resolution:

- Panchromatic: 0.70 m (product resampled @ 0.5m)
- XS (B, G, R, NIR): 2.80 m

Swath: 20 km

- Revisit Capability: 1 day with 2 satellites

Mode	Band	Spectral characteristics
Multi spectral	1	430 – 550 nm
	2	490 – 610 nm
	3	600 – 720 nm
	4	750 – 950 nm
Panchromatic	P	480 – 830 nm

- PHR1A launch: December 17, 2011
- PHR1B launch: December 2, 2012

PLEIADES Satellite

New Concept

A small ((<1000 kg) and very agile satellite to improve operational capability and minimize the conflicts between users

Designed for high agility

Compact and rigid satellite with low inertia and fixed solar array

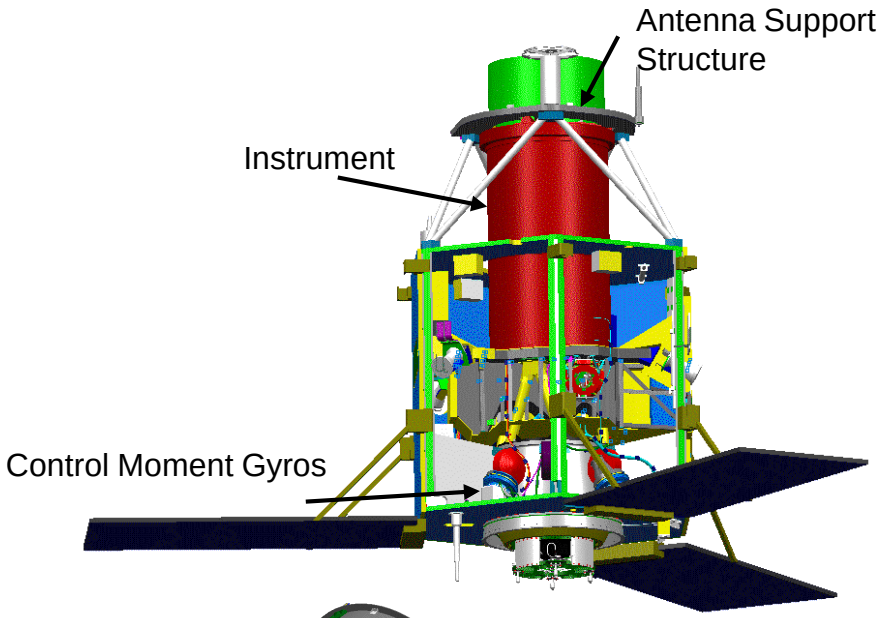
Attitude control system with 4 powerful CMG (Control Moment Gyros) actuators

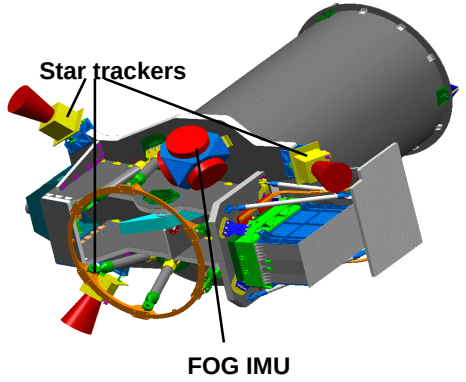
- ☞ **agility (roll and pitch):**
  - **5° in 8 seconds**
  - **10° in 10 seconds**
  - **60° in 25 seconds**

Designed for high geometric image quality

Very stable instrument with very accurate sensor heads mounted on the optical bench (3 star trackers and 4 fiber optical gyrometers

Autonomous navigation with DORIS/DIODE system





PLEIADES Instrument

Korsch camera:

- **focal length = 13 m**
- **input diameter = 0.65 m**

PA retina : 5 TDI detectors

XS retina : 5 four-color CCD

Radiometric resolution: 12 bits

On-board detectors normalization

Wavelet compression: from 1.4 to 3.33 bits/pixel

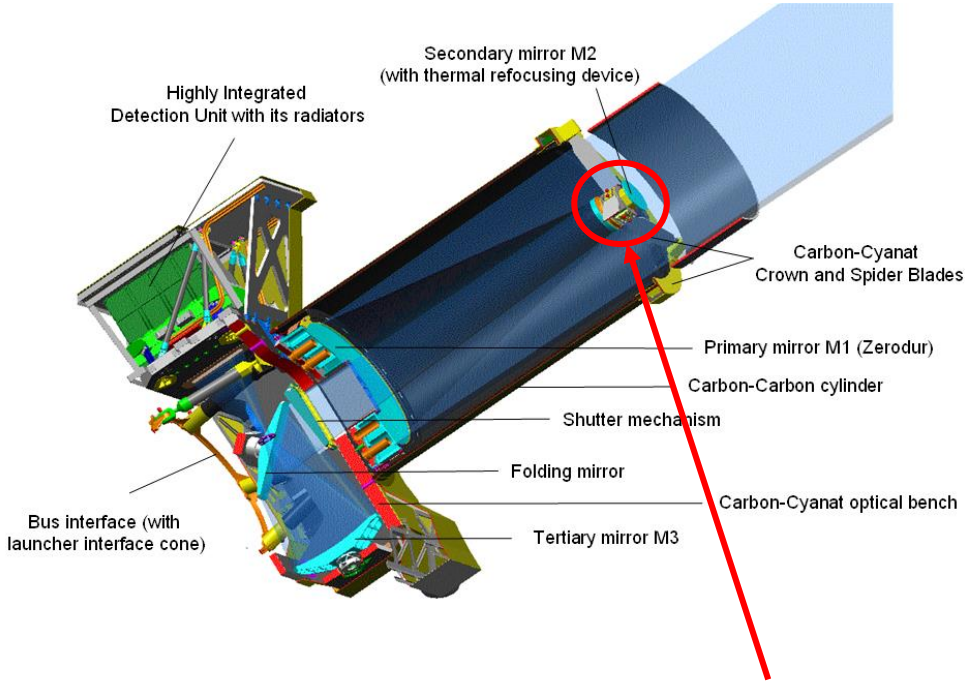
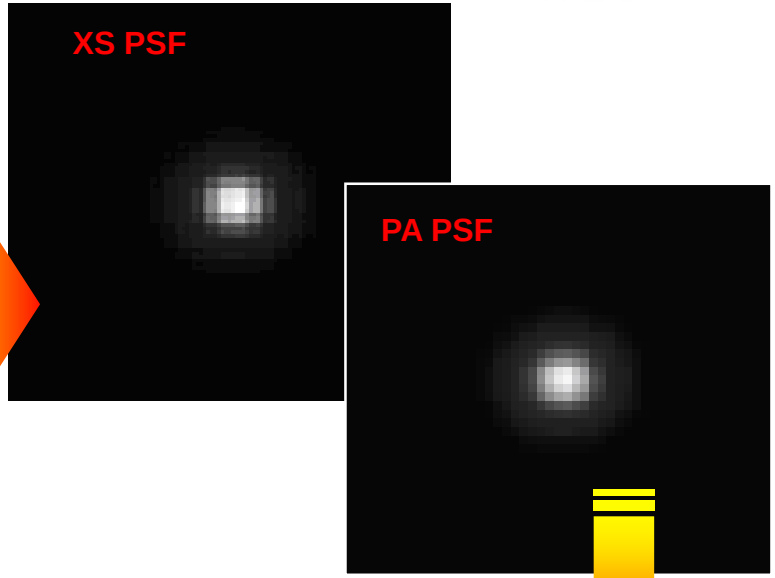


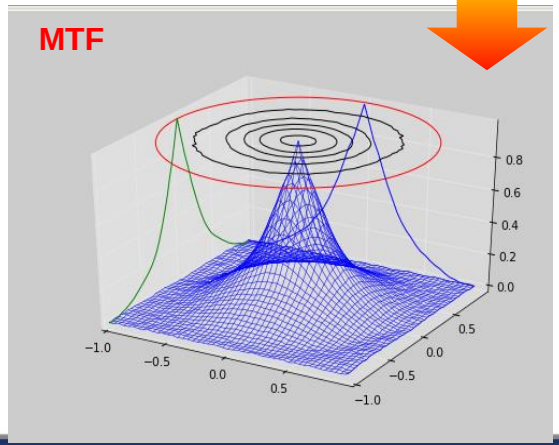
Illustration of PLEIADES Agility

Mecca ”tower clock” viewed by PLEIADES 1B every 90 sec. in a single pass to see 3 faces of the building…

…and the minutes needle moving!

Viewing the Stars for MTF Assessment and Refocusing (1)

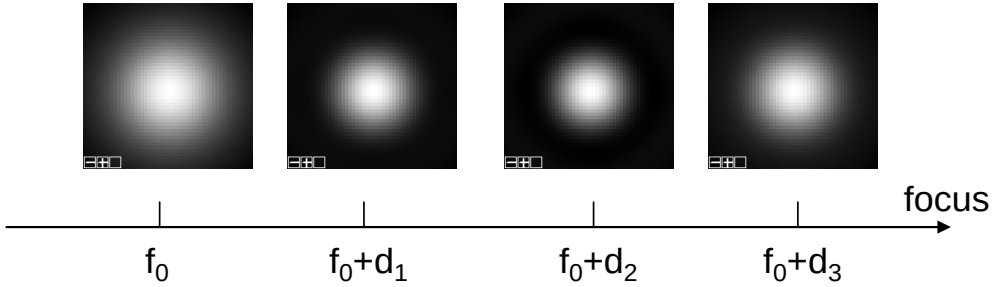


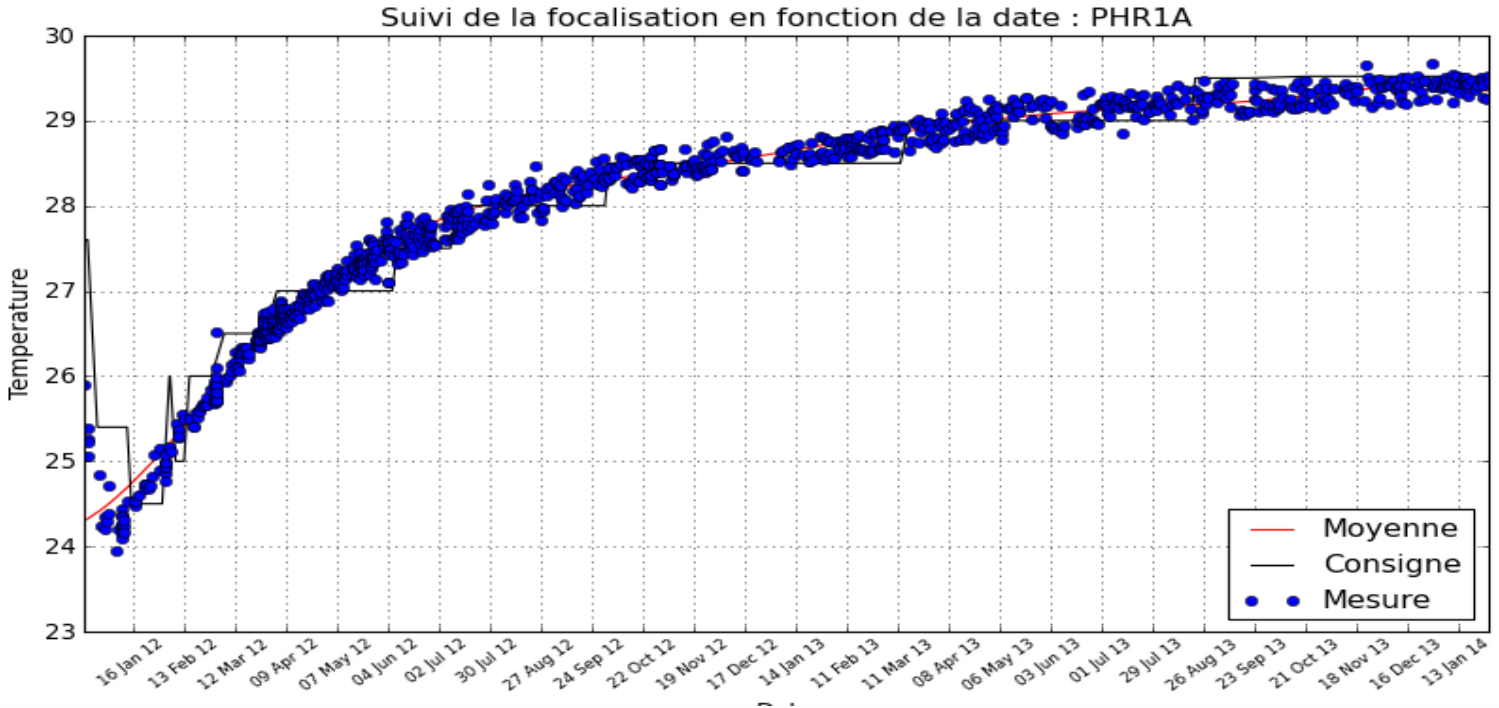


- Few images are needed
- No atmosphere
- Good accuracy
- 2D MTF assesment

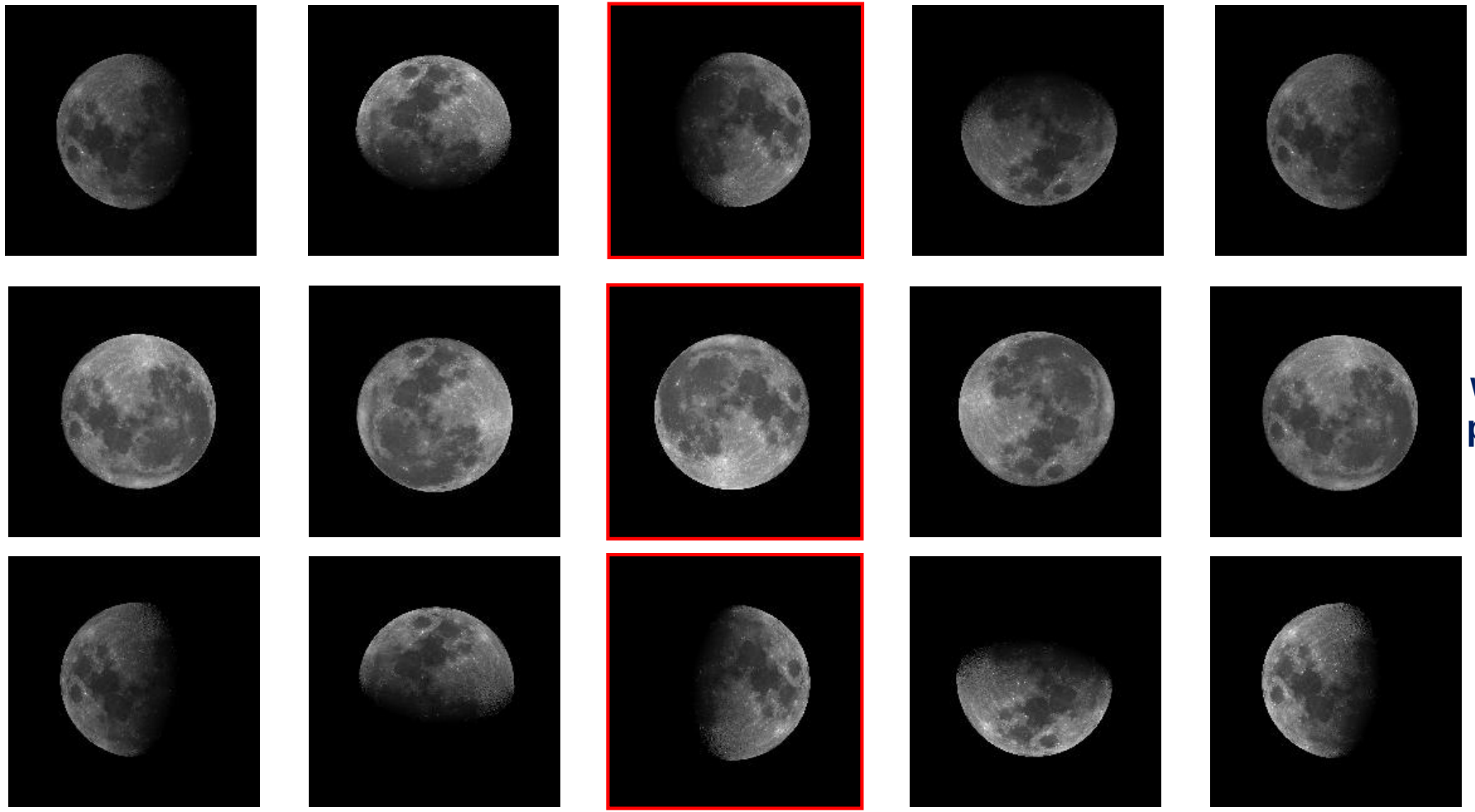
Viewing the Stars for MTF Assessment and Refocusing (2)

Monitoring of the best focus



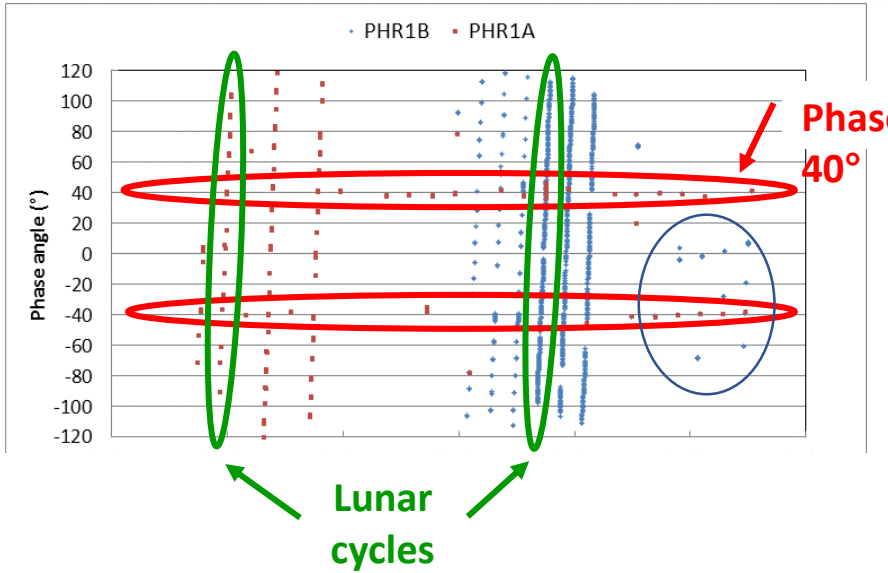


Viewing the Moon for Radiometric Calibration (1)

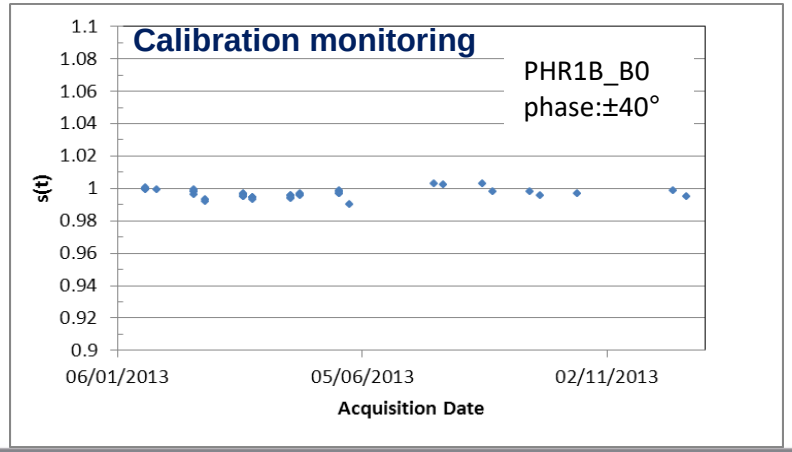


PLEIADES dataset : more than 1200 images of the Moon with multiple phase angles and orientations

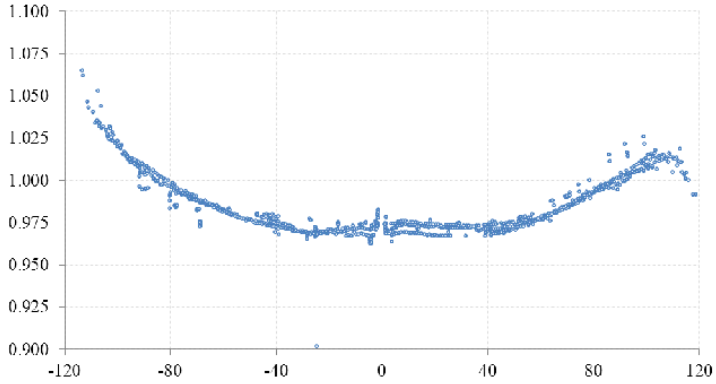
Viewing the Moon for Radiometric Calibration (2)



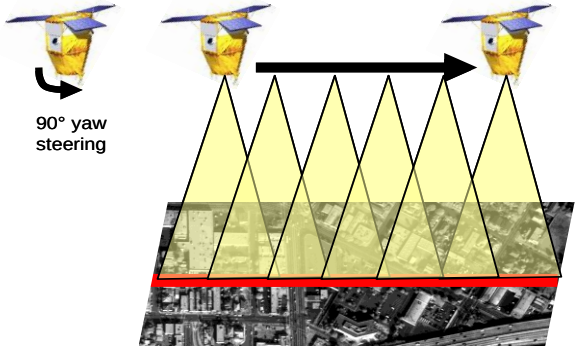
PLEIADES Moon dataset used to enhance the Lunar radiometric calibration model (ROLO)



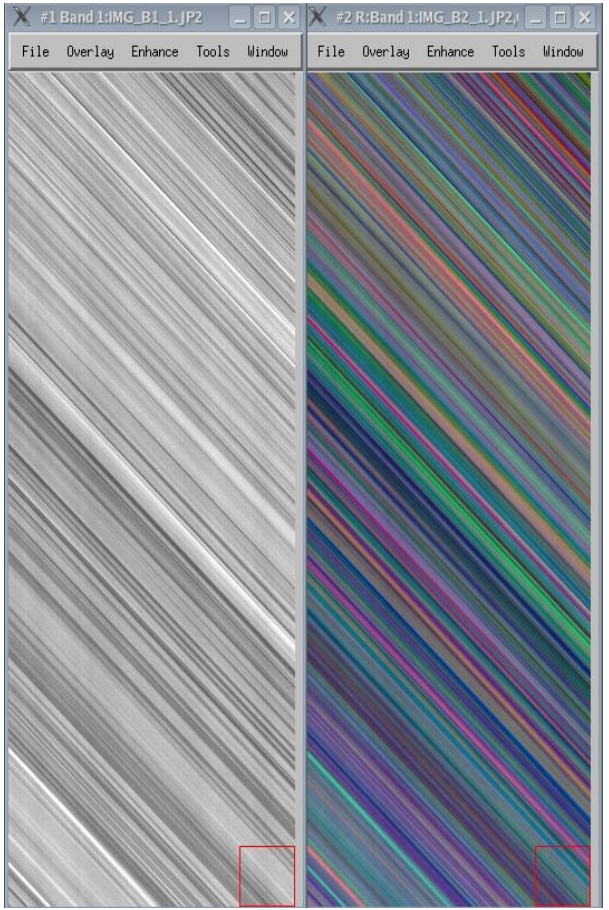
Phase angle dependence



90° Rotation of the Satellite for Uniformity Calibration

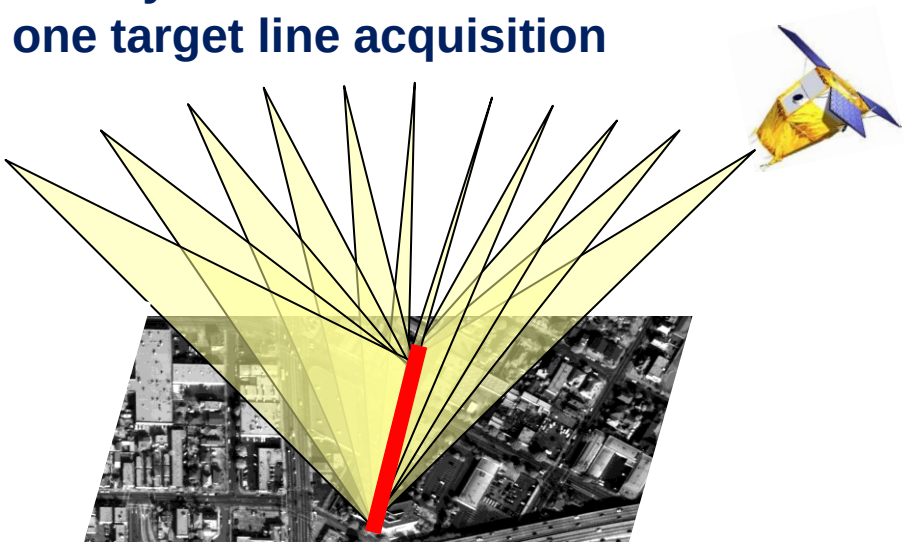


AMETHIST Mode:
each pixel successively views the same landscape



Repetitive Acquistion for Signal to noise Assessment

Steady Mode:
one target line acquisition

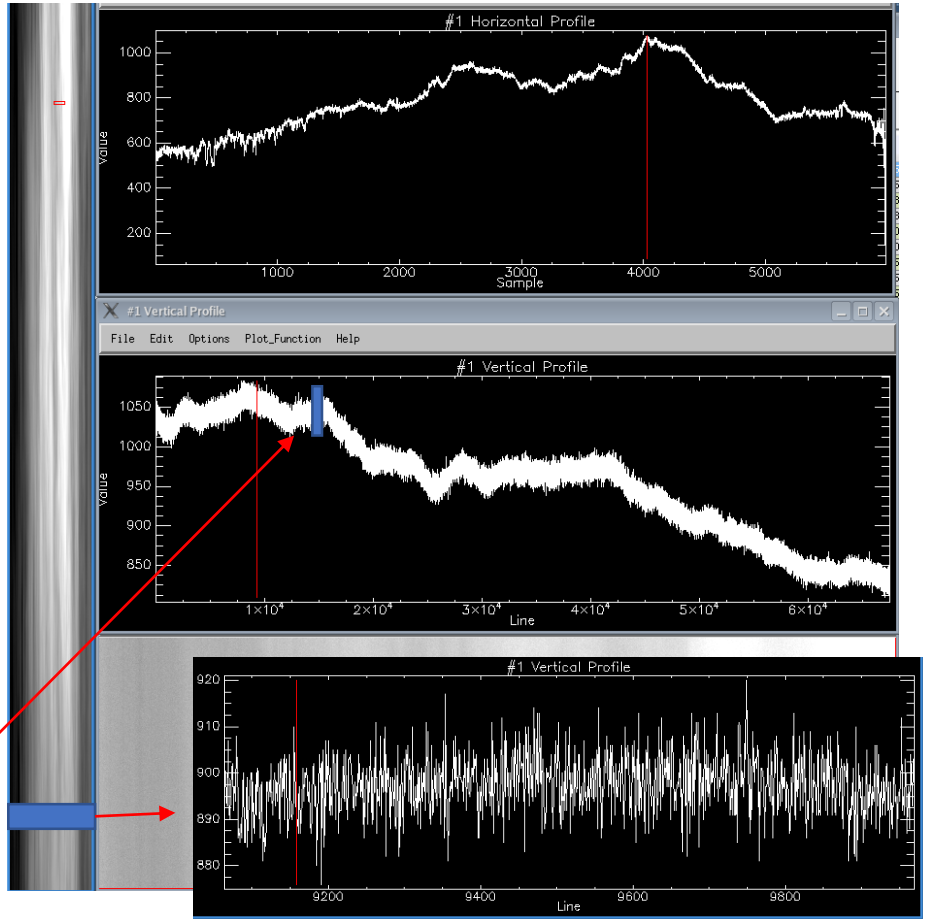


Acquisition duration

- ***a few seconds***
- ***about 60000 rows***

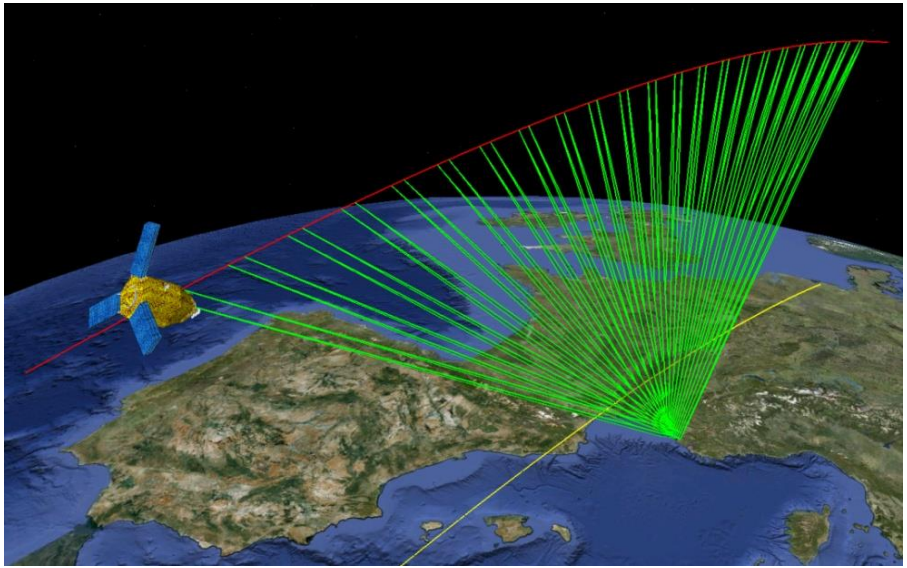
Relative good line-of-sight stability

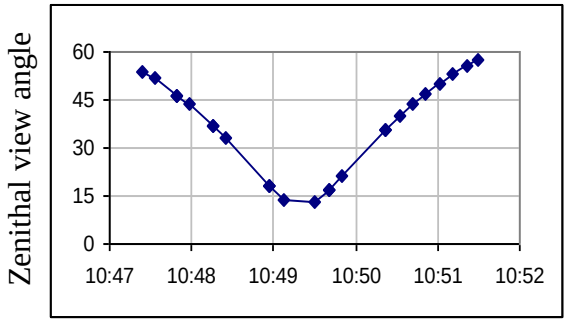
- ***use of 1000 rows***

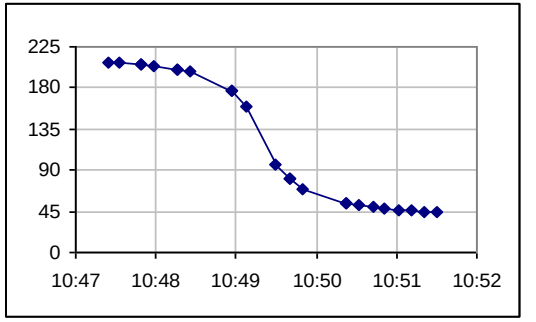


Vertical profile of 1 column and for 1000 rows

Multiangle Viewing for Radiometric Calibration over La Crau (1)

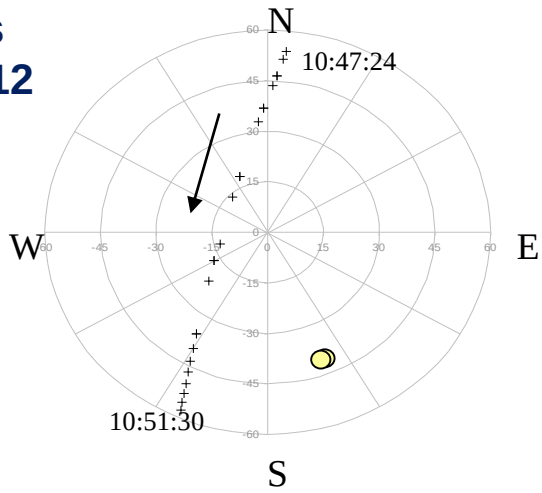




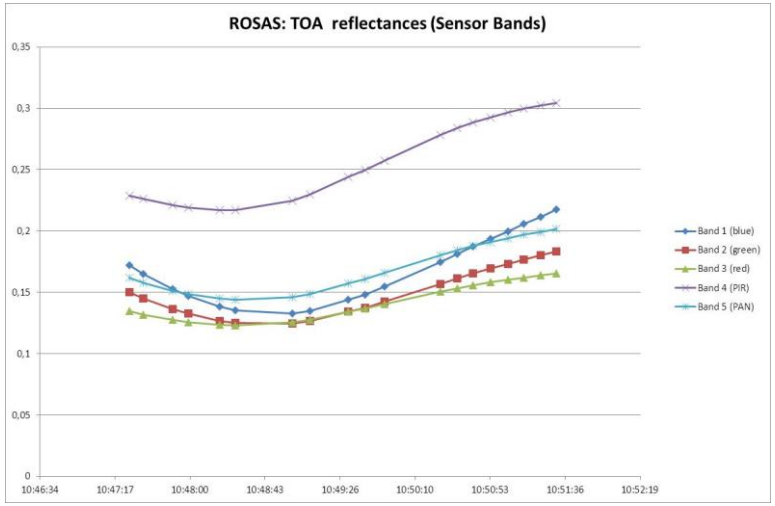


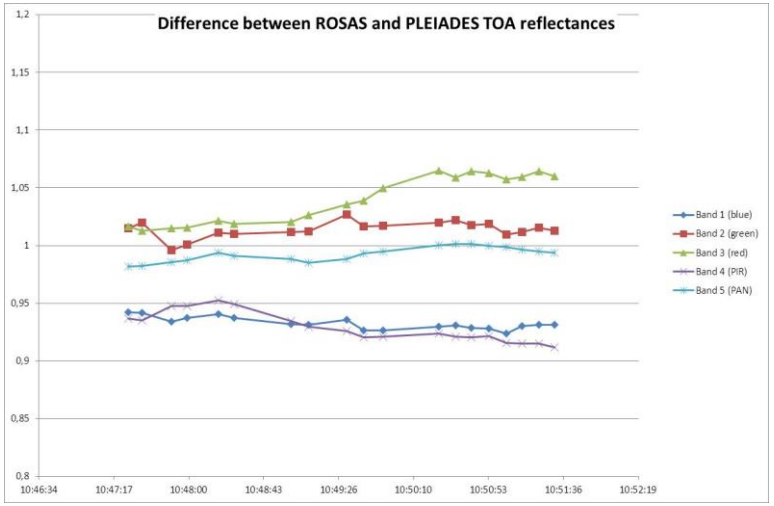
PHR1-A Video acquisitions over La Crau - March 28, 2012

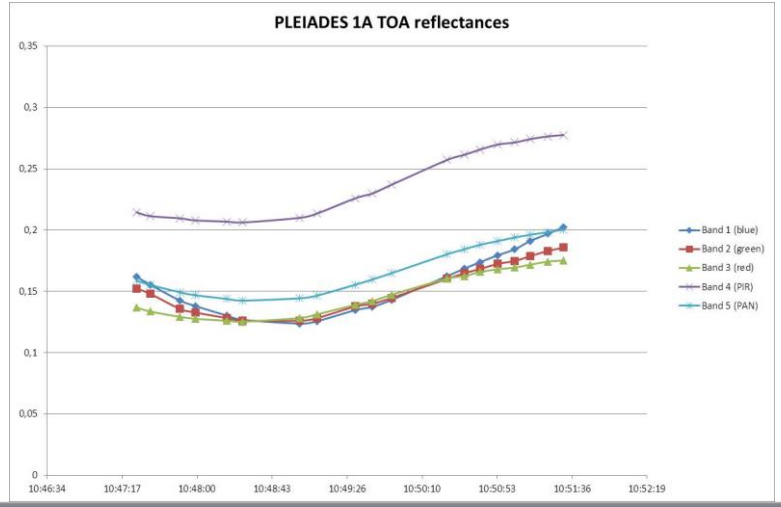
19 measurements
4 min. total duration
θs ≈ 42 deg
θv min = 13.2 deg
θv max = 57.7 deg



Multiangle Viewing for Radiometric Calibration over La Crau (2)



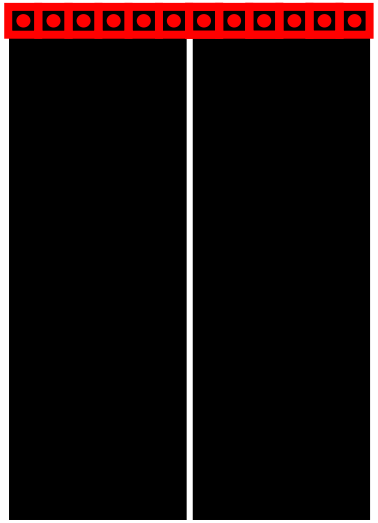




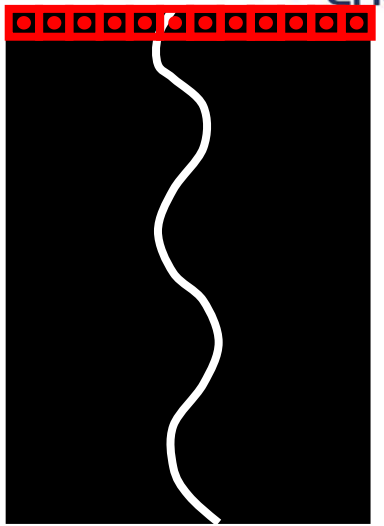
BRDF modelling and correction

Bands	Ak ROSAS / Ak Ground (mean)	Standard deviation	Max-Min	Ak Official / Ak Ground	Ak ROSAS / Ak Official
B1 (blue)	**0.92**	0.0053	0.0183	**1.05**	**12.5%**
B2 (green)	**1**	0.0060	0.0308	**0.95**	**5%**
B3 (red)	**1.025**	0.0031	0.0522	**0.96**	**6.5%**
B4 (PIR)	**0.915**	0.0029	0.0406	**0.94**	**2,5%**
B5 (PAN)	**0.975**	0.0045	0.0198	**0.95**	**2,5%**

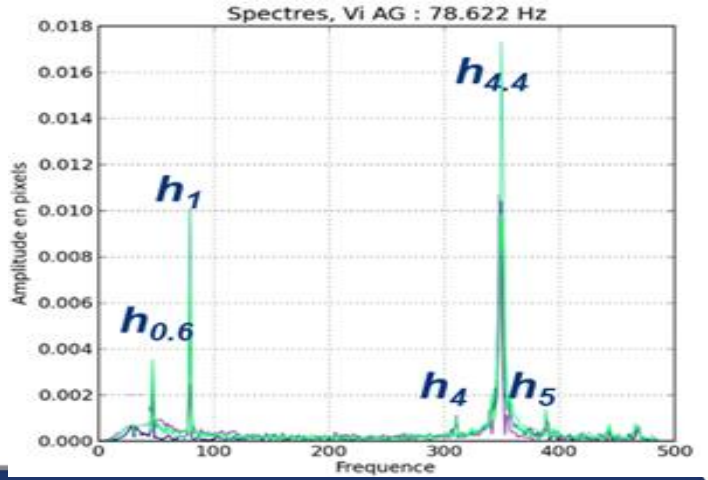
Viewing the Stars for Microvibration Assessment



without µvib



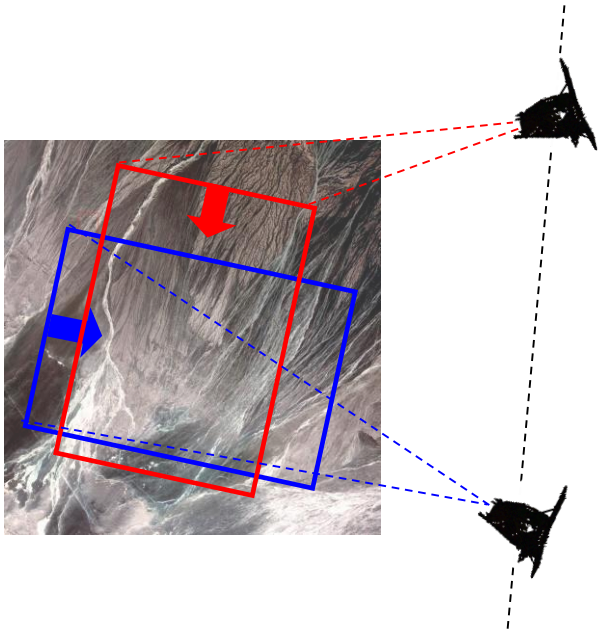
with µvib

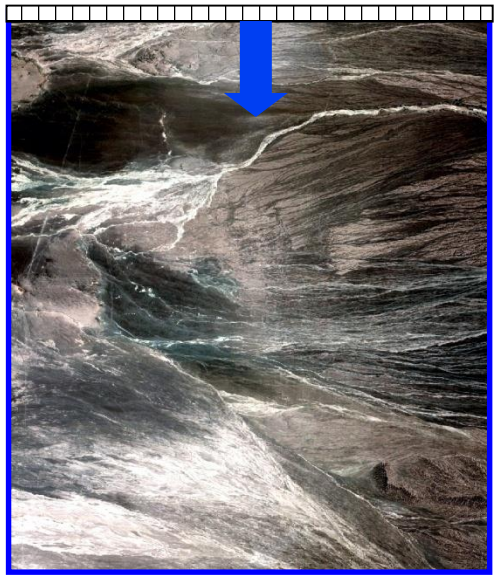


- Microvibration amplitude <0.02 pixels
- Accuracy: few nrad

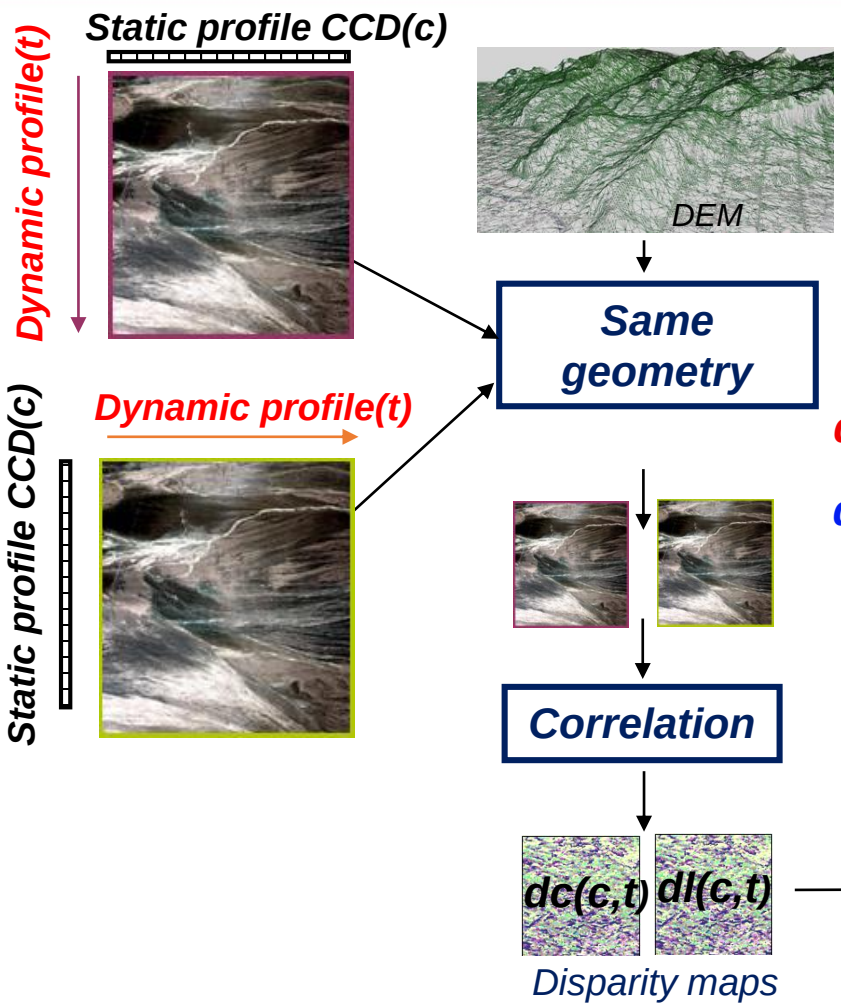
Crosswise Viewing for Focal Plane Cartography (1)

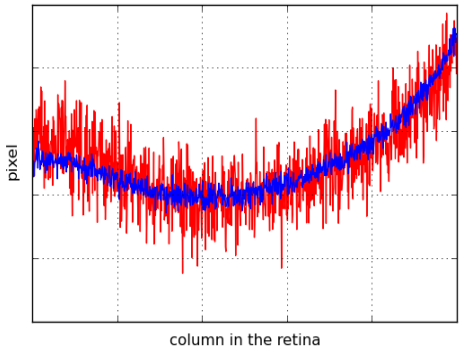
Use of images taken in a crosswise mode (LOS orientation variation = 90°) to separate dynamic and static phenomenon which are specific to the push-broom acquisition principle





Crosswise Viewing for Focal Plane Cartography (2)





In red : classical method
In blue : crosswise mode
σ : 0.03 pixel

To conclude…

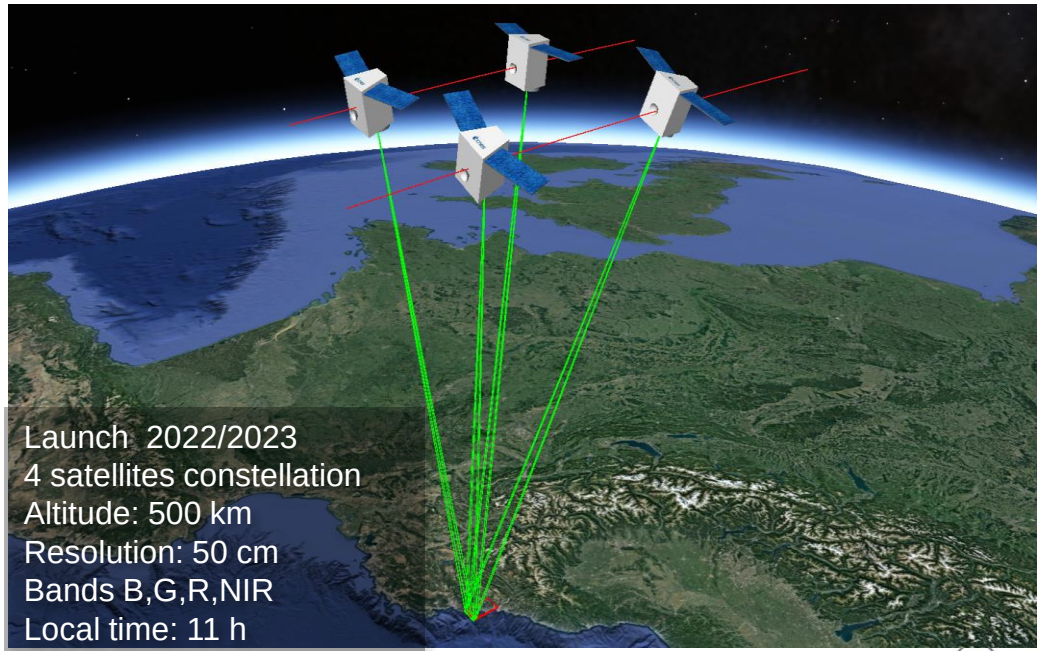
Image Quality is considered at CNES as a specific skill

- **Sharing experience from one mission to other ones**
- **Knowledge transmission ensured thanks to a dedicated organization**
- **3 generations of ‘Image Quality’ experts since the 80’s (SPOT1) !!!**

Ensuring high Image Performances and Efficiency

Next one is : CO3D !!!

- 3D global coverage in 5 years
- Relative altimetric accuracy: 1 m (B/H~0,3)
- Synchronous acquisition per satellites pair
- Capacity for urban quadri-stereo every 2 days
- Massive 3D production based on cloud facilities




Thank you
for your attention