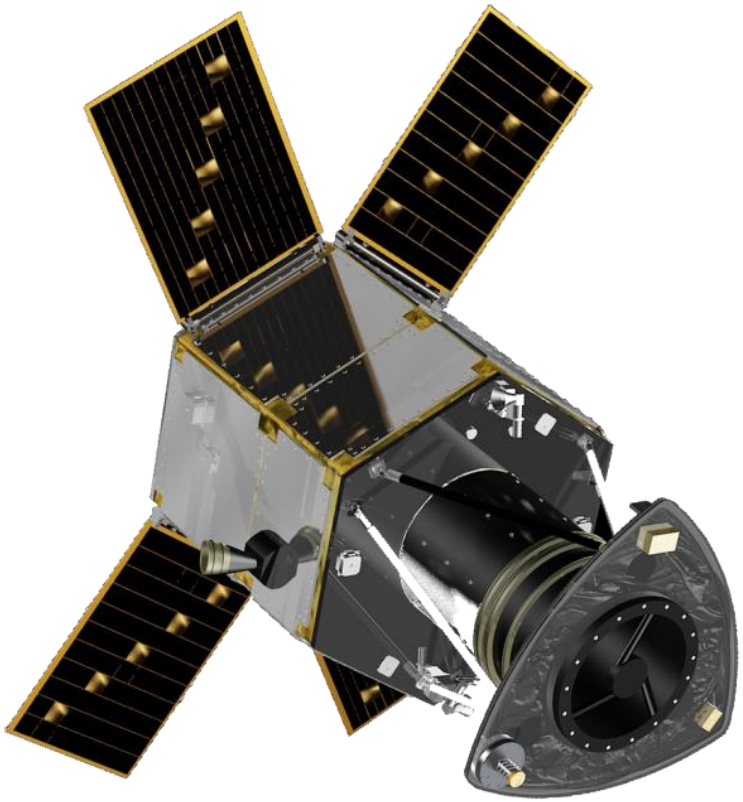

The Deimos-2 Mission: Pre and post-launch calibration and data validation.

Jorge Gil, Alfredo Romo, Cristina Moclan, Fabrizio Pirondini
(Elecnor Deimos Imaging)
Diego Lozano (Elecnor Deimos Space)
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ELECNOR DEIMOS, Spain

JACIE 2013
12th Annual Civil Commercial Imagery Evaluation Workshop
St. Louis, MO - April 16-18, 2013

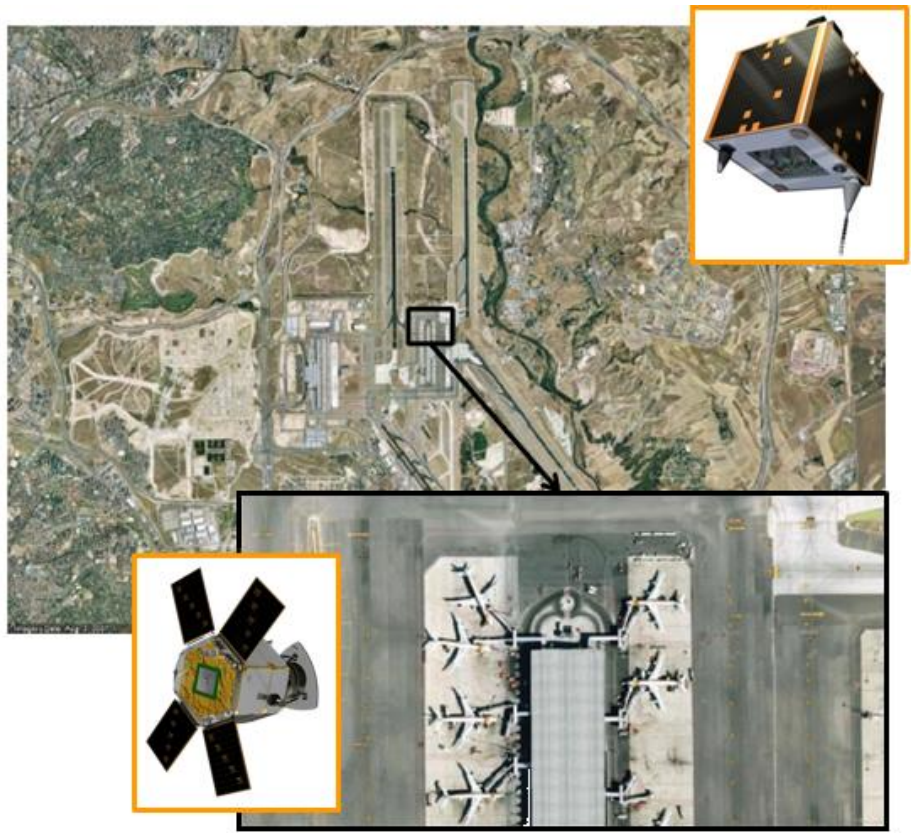
Contents

- **The DEIMOS-2 Earth Observation System**
- **Pre-launch calibration.**
- **Post-launch calibration and data validation.**
- **calval4EO**

1 The DEIMOS-2 Earth Observation System

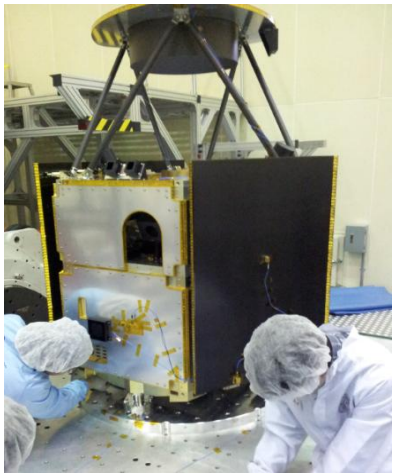
DEIMOS-2 EO System

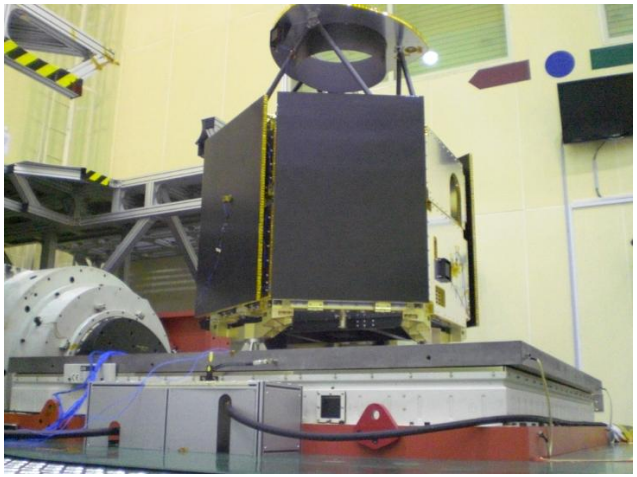
- DEIMOS-1 (22m GSD, 3-band, 650 km swath), owned by ELECNOR DEIMOS, is the first Spanish Earth Observation satellite, launched in 2009
- ELECNOR DEIMOS' EO system will be upgraded in Q4 2013 with the launch a new satellite, the DEIMOS-2
- DEIMOS-2 will be a multispectral optical satellite with very high resolution.
- The DEIMOS-2 end-to-end system has been designed to provide a cost-effective and highly responsive service to cope with the increasing need of fast access to very-high resolution imagery
- Designed and built by SATREC-i (South Korea) in cooperation with ELECNOR DEIMOS. It will be integrated and tested in the new ELECNOR DEIMOS Satellite Systems' premises in Puertollano

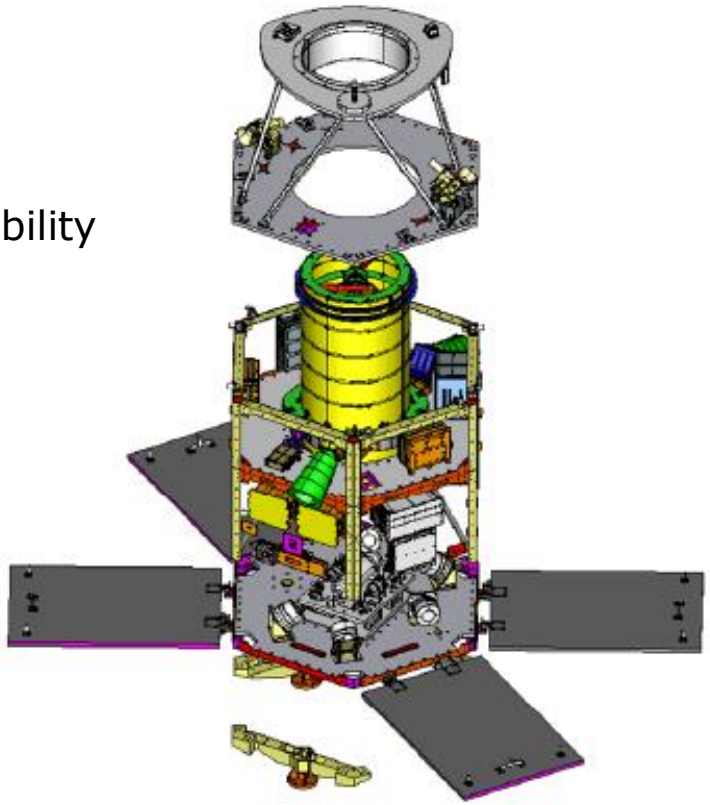


DEIMOS-2 EO System

- Built by SATREC-i (South Korea) in collaboration with ELECNOR DEIMOS.
- Proven design with significant heritage (Dubaisat-1, -2)
- Nominal lifetime >7 years
- Mass: 310 Kg
- Agile platform (±45º across-track)
- High-performance AOCS for pointing accuracy & stability
- Xenon gas engines for orbit maintenance







DEIMOS-2 EO System

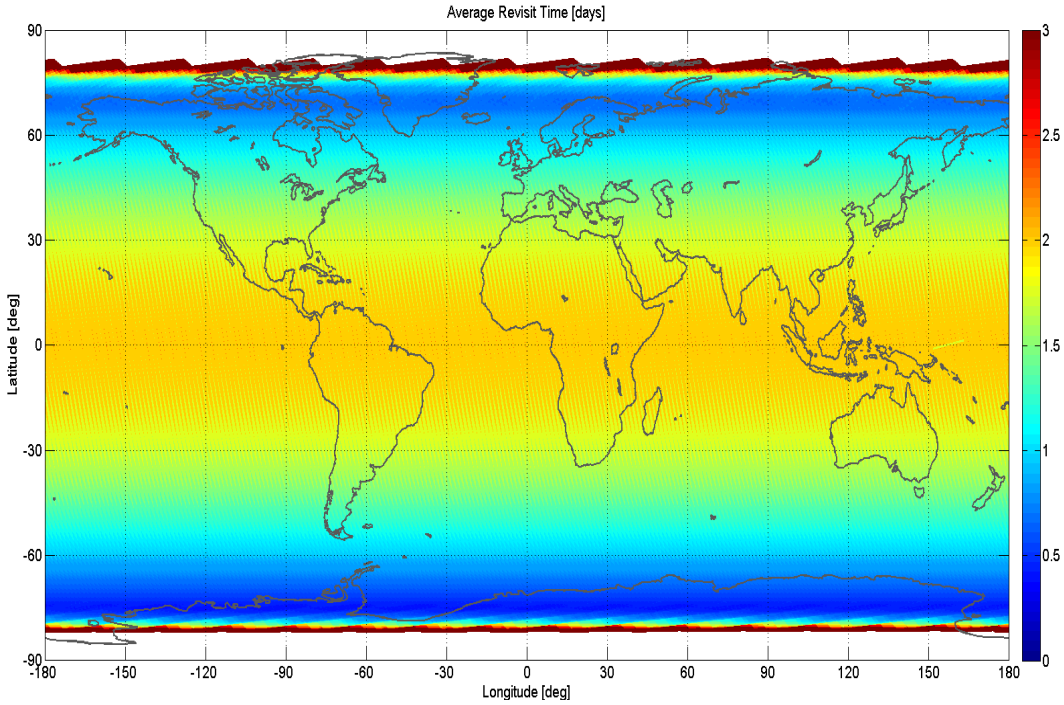
- Orbit type: Sun-synchronous, LTAN 10:30, 620 km nominal altitude
- Orbit determination: via GPS, with metric accuracy
- Orbit information availability to users: with telemetry and on-ground POD

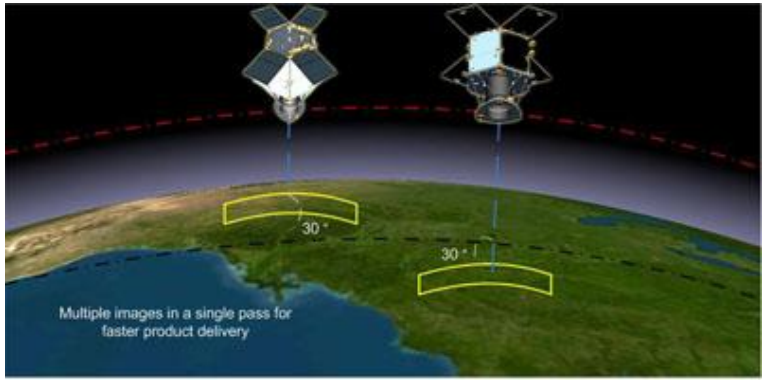
- Viewing angle: nominal ±30º, emergency ±45º
- Geolocation accuracy: ~100 m without GCPs

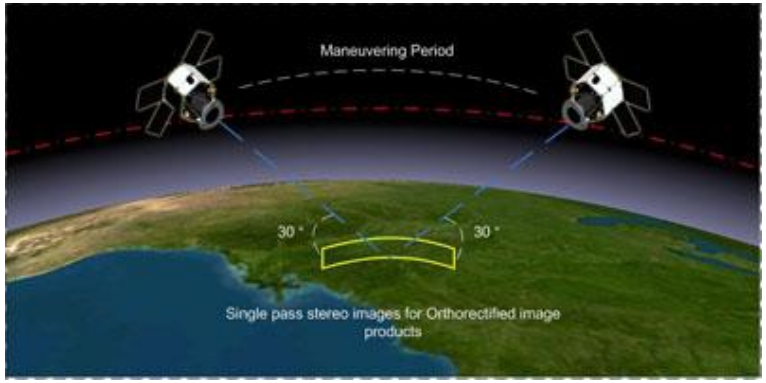
- OBDH:
- On-board recording (256 Gb, equivalent to 1,400km-long strip)
- Image data lossless compression, encryption, CCSDS encoding during transmission
- Solid state X band transmitter, with 160 Mbps download rate

DEIMOS-2 EO System

- Up to 150,000 Km2/day
- Global average revisit time: 2 days (±45º ACT)
- Average revisit time at 45º Lat: 1 day (±45º ACT)

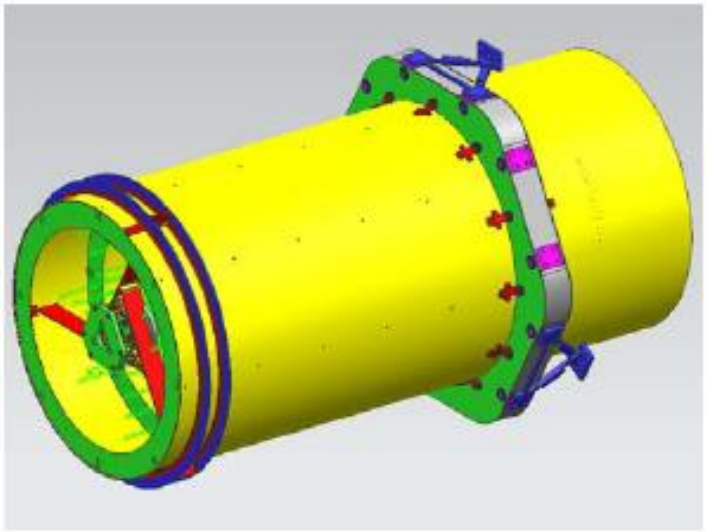


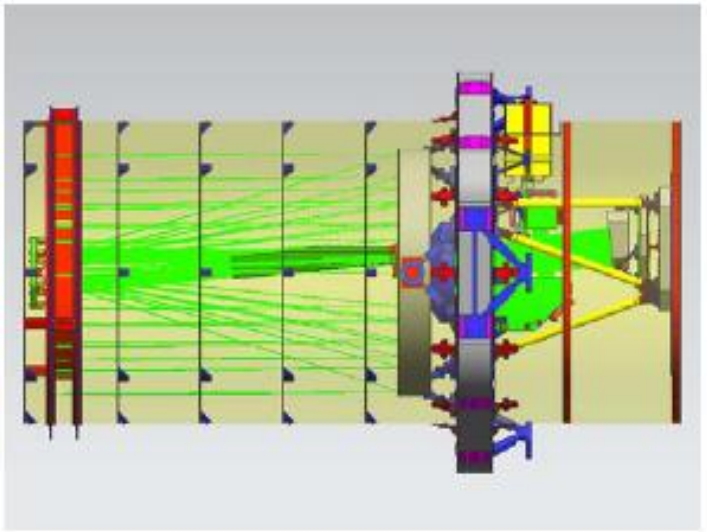




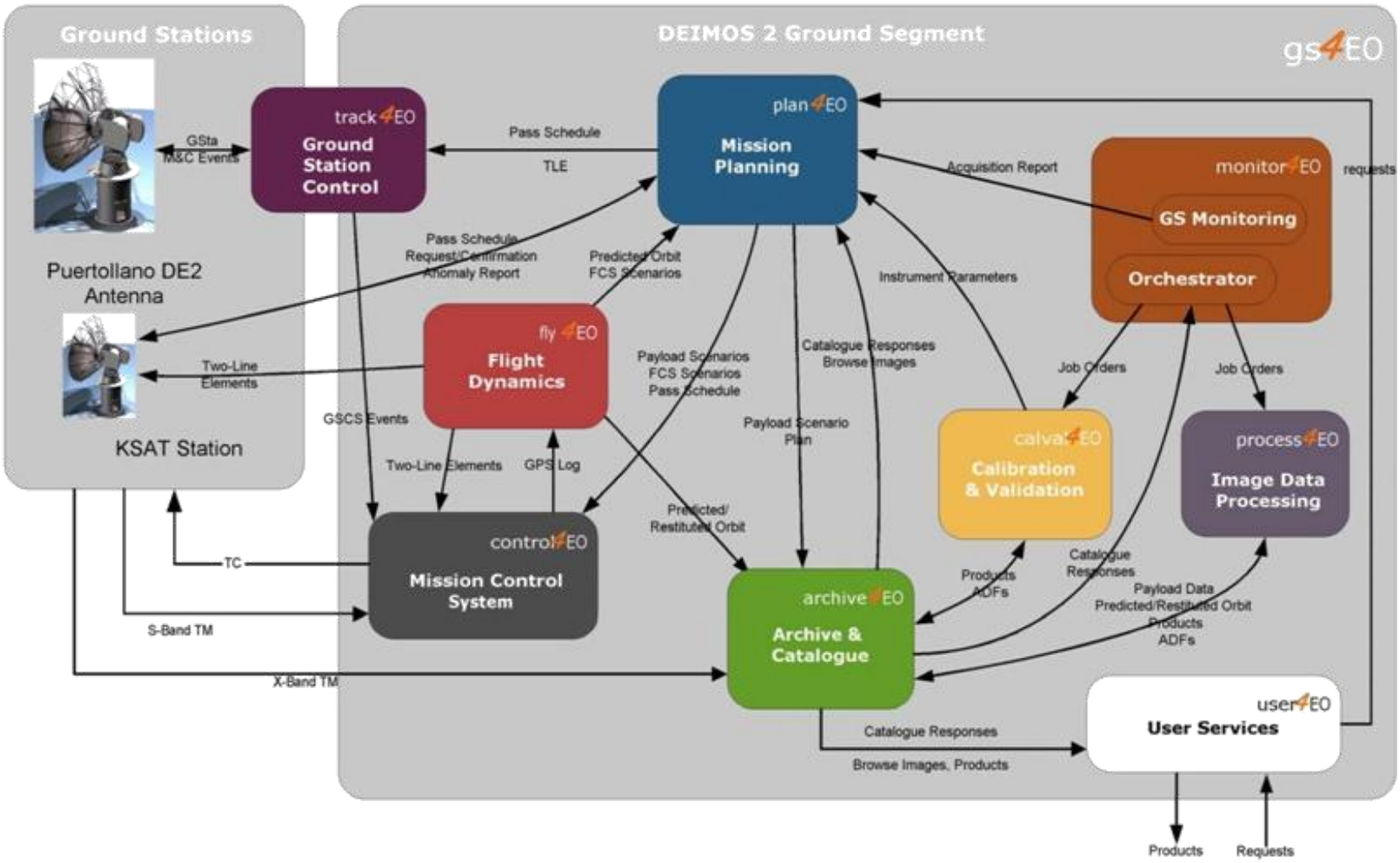
DEIMOS-2 EO System

- Pan/Multispectral high-res camera (1m GSD Pan, 4m GSD MS)
- 40-cm Korsch 4-mirror telescope (5.75 m focal length, 1.2º FoV)
- Pan (450-900 nm) + 4 bands (R,G,B, NIR)
- 12 km swath (24 km in wide area mode)
- Capacity for stereo-pair acquisitions
- Radiometric resolution 10 bits
- TDI sensor
  - PAN : 6, 12, 24, 48
  - Blue, Green : 4, 8, 16
  - Red, NIR : 2, 4, 8





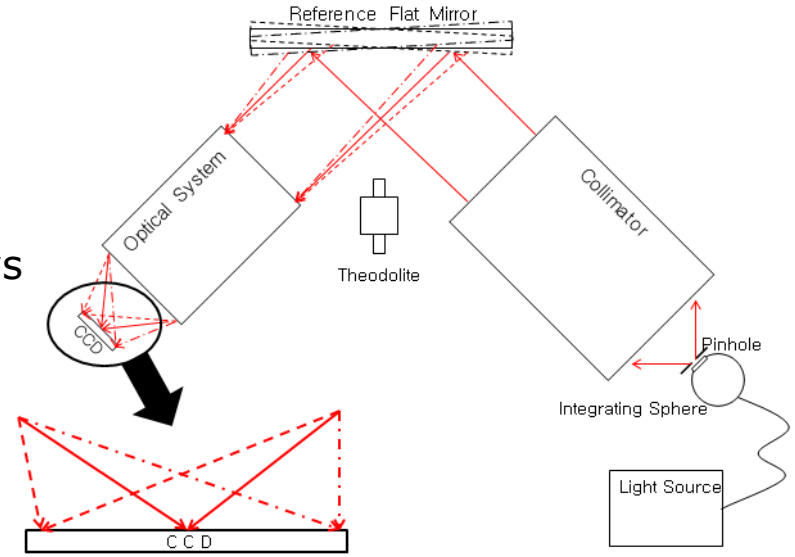
DEIMOS-2 EO System



2 Pre-launch calibration

Geometric calibration

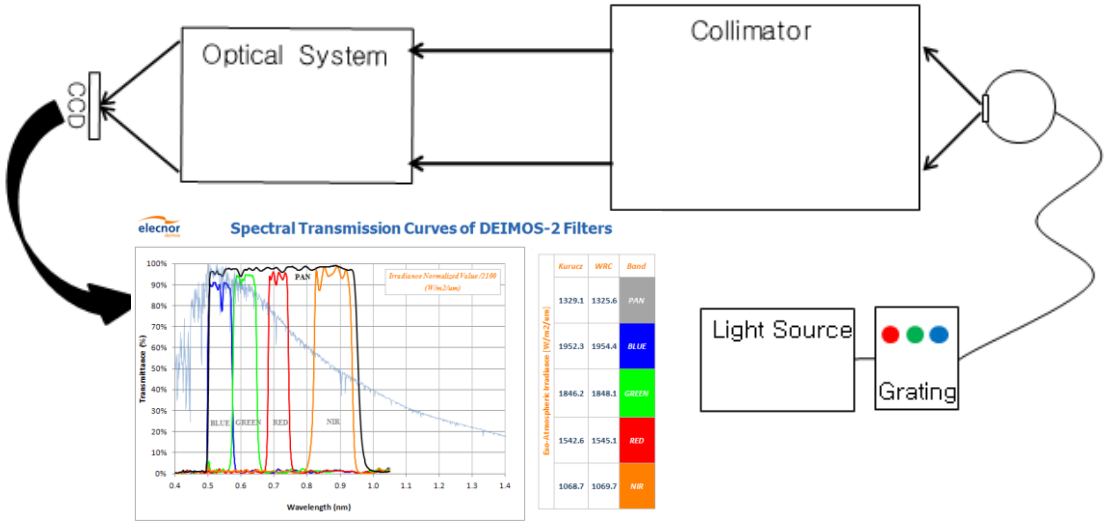
- The geometric calibration of D-2 is intended to qualify and to obtain the parameters of the **rigurous sensor model**. These includes:
  - Effective Focal Length (EFL)
  - FOV and IFOV
  - Pixel Line of Sight (LOS)
    - Band-to-band registration of CCD arrays
    - Distortion map of CCD arrays
  - Knowledge of the camera optical axis.



- Measurement Setup
  - Pinhole at collimator focus
  - The pinhole image is relayed by flat mirror and projected into D-2 Camera System
  - The image is captured by CCD arrays
  - The measurement is controlled by the motion of the flat mirror
  - The measurement covers whole arrays of FPA1 and FPA2

Spectral calibration

- The purpose of this measurement is to characterize the spectral transmisivity profile of each band and the response of the CCD arrays
- Measurement Setup
- Integrating sphere is positioned at collimator focus
  - The output of monochromator is relayed to the integrating sphere
  - The output is at specific spectral wavelength
  - The dispersion is controlled with the slits at the entrance and exit



- The image of the aperture of the integrating sphere is projected directly into D-2 Camera System
- The measurement is repeated through each spectral band of FPA1 and FPA2

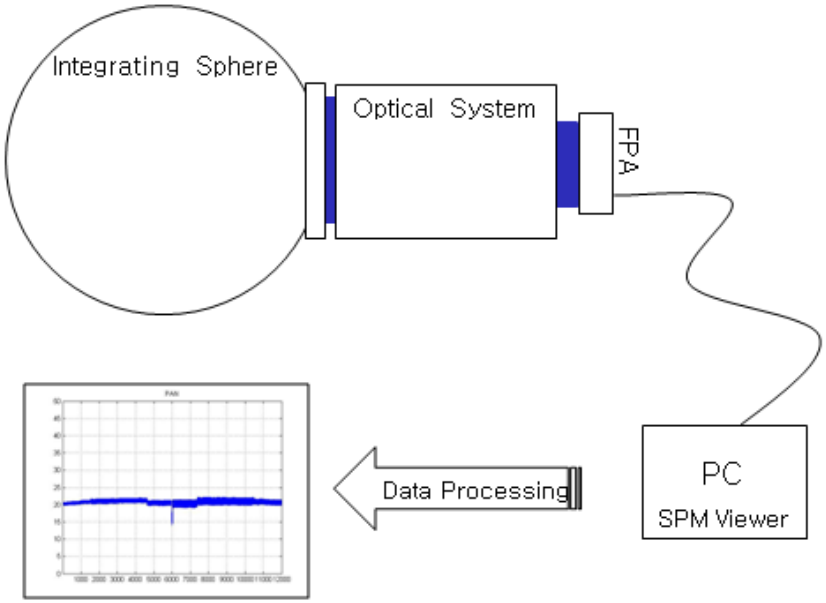
Radiometric calibration

- The aim this calibration is to characterize the optical sensor in order to obtain absolute physical measurements.

- Including:
  - Response Linearity
  - Dark Signal and Non-uniformity
  - Pixel Response and Non-uniformity
  - Signal-to-Noise Ratio (SNR)
  - Pixel Saturation
  - Absolute calibration

Radiometric calibration

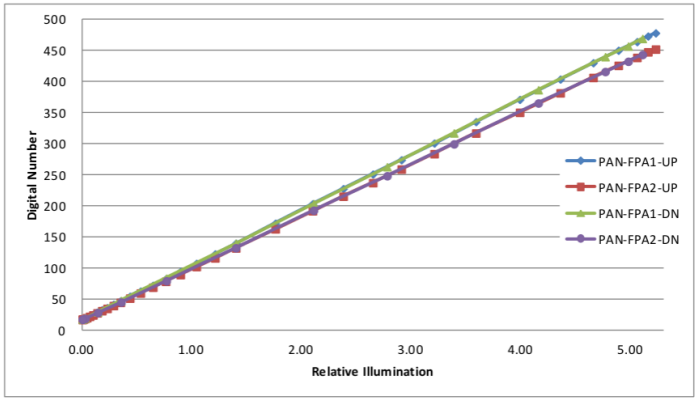
- Measurement Setup
  - Uniform Light Source (ULS) is positioned right in front of DM-2 Camera System
  - The output of ULS is sampled and monitored by spectro-radiometer
  - Output level is controlled with respect to the saturation level
  - The image of ULS aperture is projected on both FPA1 and FPA2, which produce pixel response in digital number



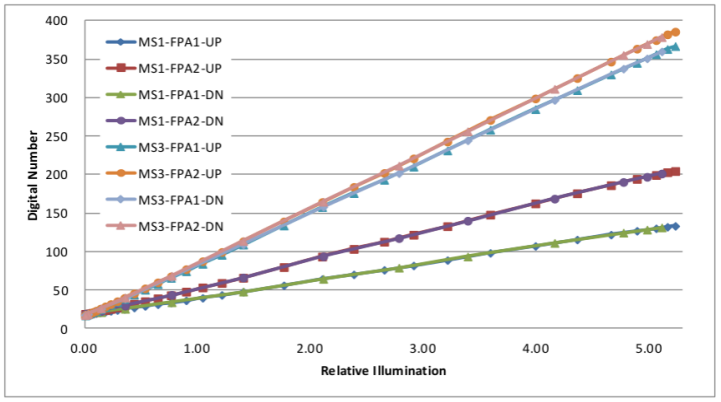
elecnor deimos

Illumination Linearity

- Response linearity to Illumination – PAN

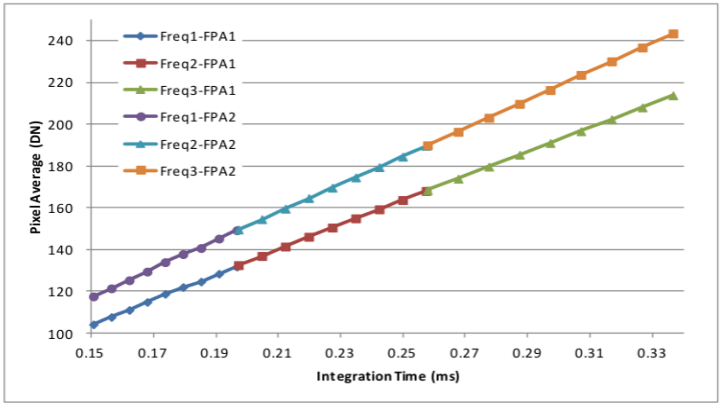


- Response linearity to Illumination – MS1/3

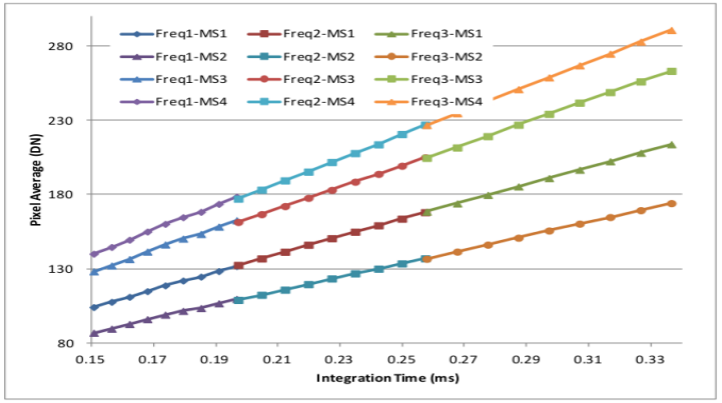


Line Rate Linearity

- Response linearity to Line rates – PAN

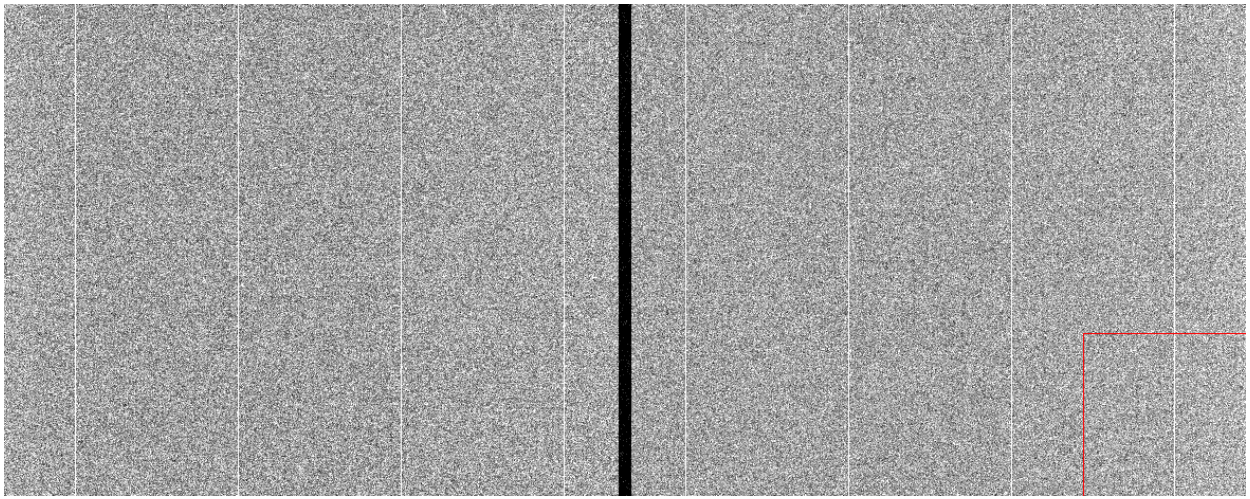


- Response linearity to Line rates – MS FPA1



Radiometric calibration – Dark signal

- Dark signal is measured onboard by blind pixels.
- The original DNs can be retrieved in ground if necessary (calibration).
- The dark signal behaviour is characterized during the pre-launch calibration.



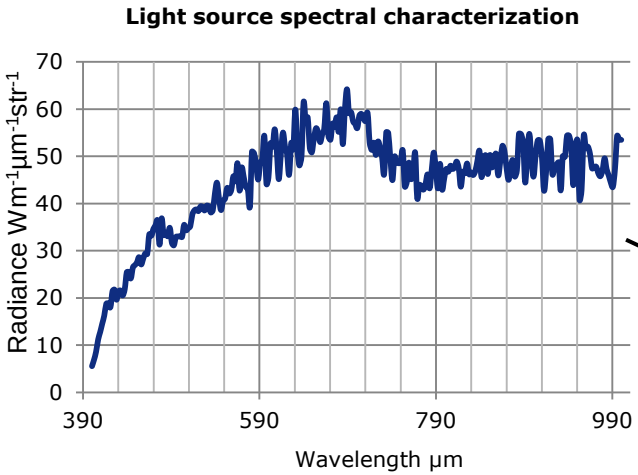
NIR band.
Pixels: 1574316 Min: 17 Max: 23 Mean: 20.146395 Stddev: 0.880218

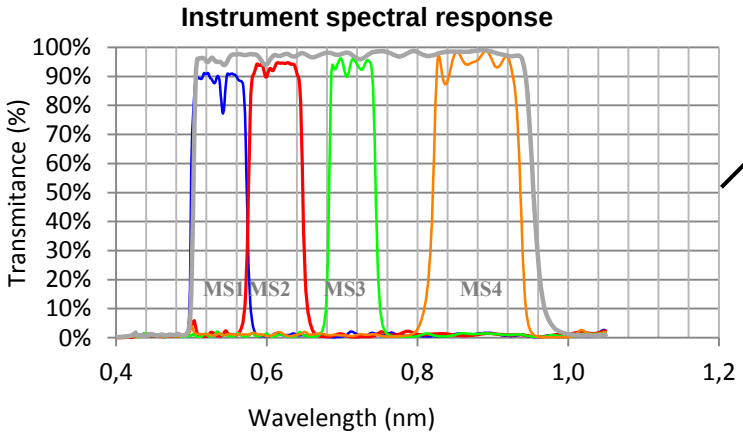
Radiometric calibration – Pixel Response Non Uniformity.

PRNU characterization.

- By manufacturing, each detector has different response to equal illumination conditions.
- To equalize the detectors, their response to an uniform light source shall be characterized.
- The response is linear to the radiance. So a LUT with gain/bias values for each detector string can be calculated.
- The response of each detector string is not expected to be linear with TDI modes so:
  - A LUT shall be defined for each TDI mode.
  - Or, perhaps, a parametric model could be used, maybe polynomial.

Radiometric - Absolute Calibration





- PRNU characterization
- DS characterization

Absolute Calibration

Camera parametrization:

- TDI mode
- Gain
- Line rate

Radiometric calibration - SNR

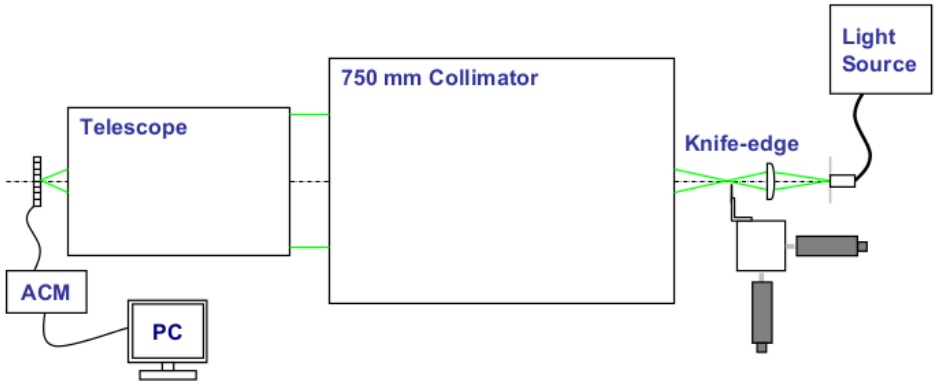
- Uniform illumination source (UIS) + Telescope + FPA + ACM (Aux. Camera Electronics)
- UIS output levels are adjusted to simulate the spectral radiance for the SNR requirement for each spectral band.

BAND	PAN	MS1	MS2	MS3	MS4
TDI Steps	12	4	4	2	2

- Simulated conditions:
  - MODTRAN 1976 US Standard Atmosphere model
  - No multiple scattering
  - Rural extinction, visibility = 23 km
  - Target reflectance = 0.3 (diffuse)
  - Solar zenith / observer zenith = 0 deg
- Requirement is **SNR >= 90** for all spectral bands.

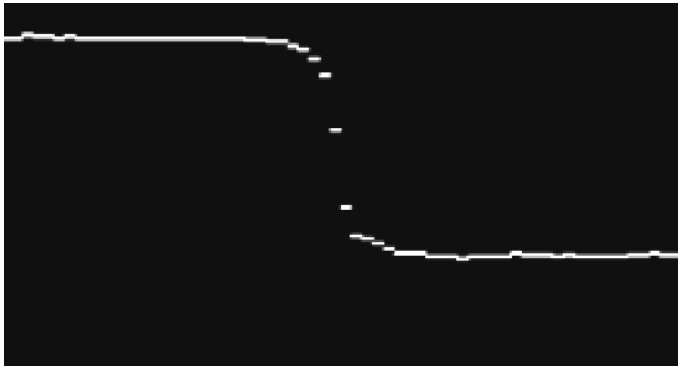
MTF measurement.

Knife-edge scan method.



Measurement setup

LSF

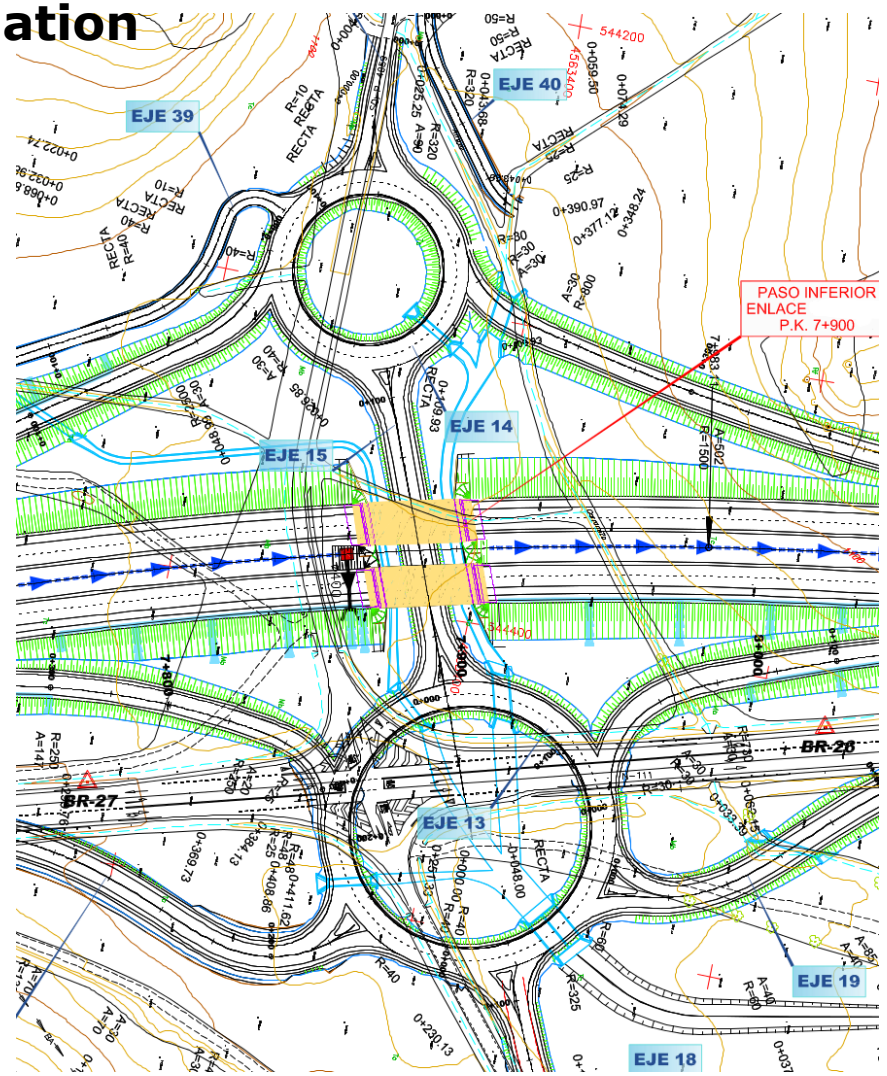


- Requirements:
  - PAN MTF @ Nyqyist >= 9% full FOV
  - MS MTF @ Nyqyist >= 18% full FOV

2 Post-launch calibration

Geometric calibration and validation

- Launch vibrations and other effects can affect the the payload
- Centimeter location accuracy targets must be used
- Modern highways and railways in Spain are will be used
  - National network of geodetic vertices.
  - National network of high precission leveling (REDNAP).
  - Differential GPS infrastructure.
- Pixel LOS, IFOV, EFL and other parameters will be estimated.



Radiometric calibration.

- Closely follow CEOS CAL/VAL recommendations and sites

- PRNU measurements using uniform and high reflectivity Land Non Equipped Sites (LNES)

  - Dome-C around winter solstice

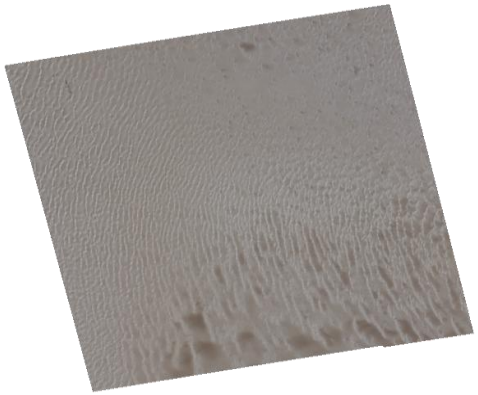
  - Greenland around summer solstice

- Dark signal measurements using night images over the north pacific, where light sources (natural or anthropogenic) are unlikely.

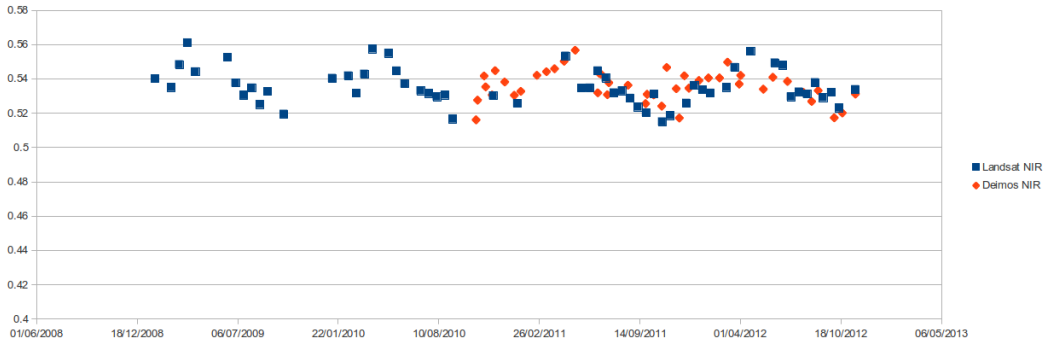
Deimos-1 image from Dome-C

Radiometric calibration.

Libya-4 LNES (pseudo-invariant) for **sensor trending**



Deimos-1 image of Libya-4



Landsat-7 vs Deimos-1 TOA reflectance. Libya-4.

- A sinusoidal with yearly period effect is expected (BRDF)

- For Deimos-1, Landsat-7 is the "gold standard". Their spatial resolutions are similar and their spectral responses match closely

- For Deimos-2 there is no "gold standard", so we will rely on **vicarious calibration** for absolute calibration

Radiometric calibration.

- Vicarious calibration and validation:

- Rely on CEOS land equipped sites (LES)

- Candidate CEOS LES sites
  - La Crau, CNES (France).
  - Tuz Gölü salt lake, TÜBİTAK Uzay (Turkey).
  - Railroad valley playa, The University of Arizona (USA).

- And to set up a new vicarious calibration site: **CIBA**, in Spain.

- It is planned to perform systematic **absolute calibration** measurements in CIBA and **validate** using one or several of the aforementioned CEOS LES sites.

Radiometric calibration

- CIBA (Centro de Investigación de la Baja Atmósfera. Low atmosphere research center)
- Managed by the University of Valladolid (Spain)
- Permanent personnel
- Run by more than 30 years
- Located over a flat area (grass and scrubland).
- Surface: 10acre expandable up to 500acre
- Instrumented to measure low atmosphere parameters

- Planned to enhance the instrumentation to comply with CEOS LES sites
- Planned to deploy large high reflectance artificial targets to perform radiometric measurements suitable for a 1m/4m GSD satellite images

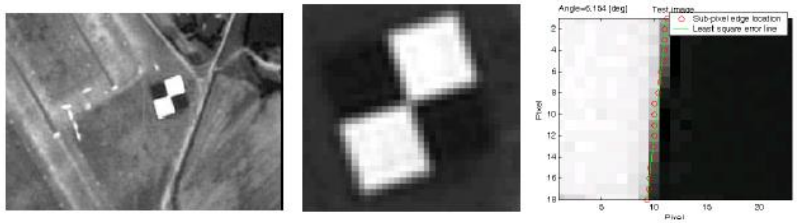
MTF measurement

- The MTF estimation will be performed using the **slanted edge methodology**. Same as Deimos-1 but using artificial targets instead of field transitions

- The basis of this methodology is to oversample the edge taking advantage of its tilt along the track, assuming that it is straight

- Source data will be raw data after DS and PRNU correction, which is simply aplying a linear function to each column to remove stripping. No convolution or resampling will be applied

- Viewing geometry and line rate will be taken into account



3 calval4EO

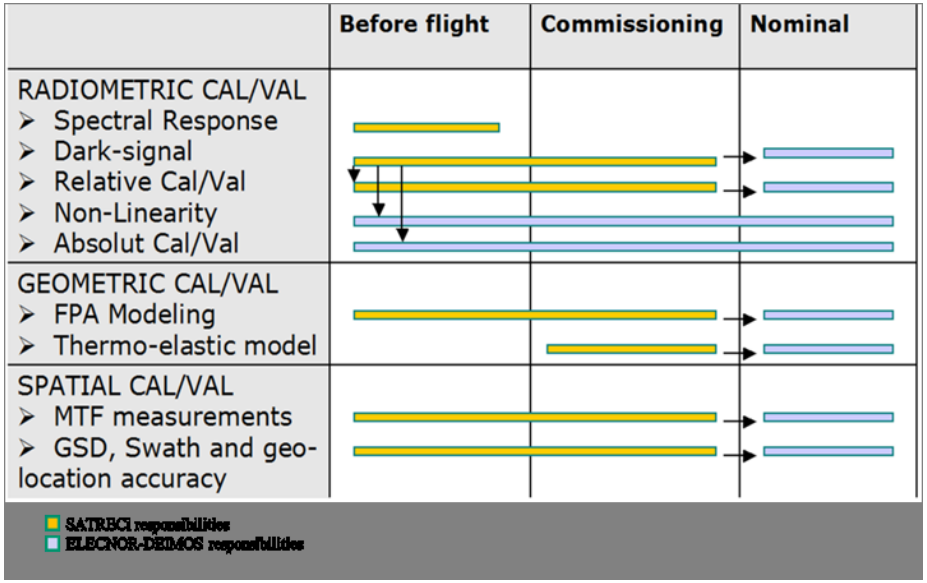
calval4EO
calibration & validation

- Cal/Val operations are the process of updating and validating on-ground configuration parameters to ensure the image data quality requirements

- Calibration Expert Team, which is responsible for the calibration and validation of the instrument products

- Calibration is based on characterization measurements performed on-ground before launch and in-flight

- **calval4EO** will be used during the commissioning and nominal operations



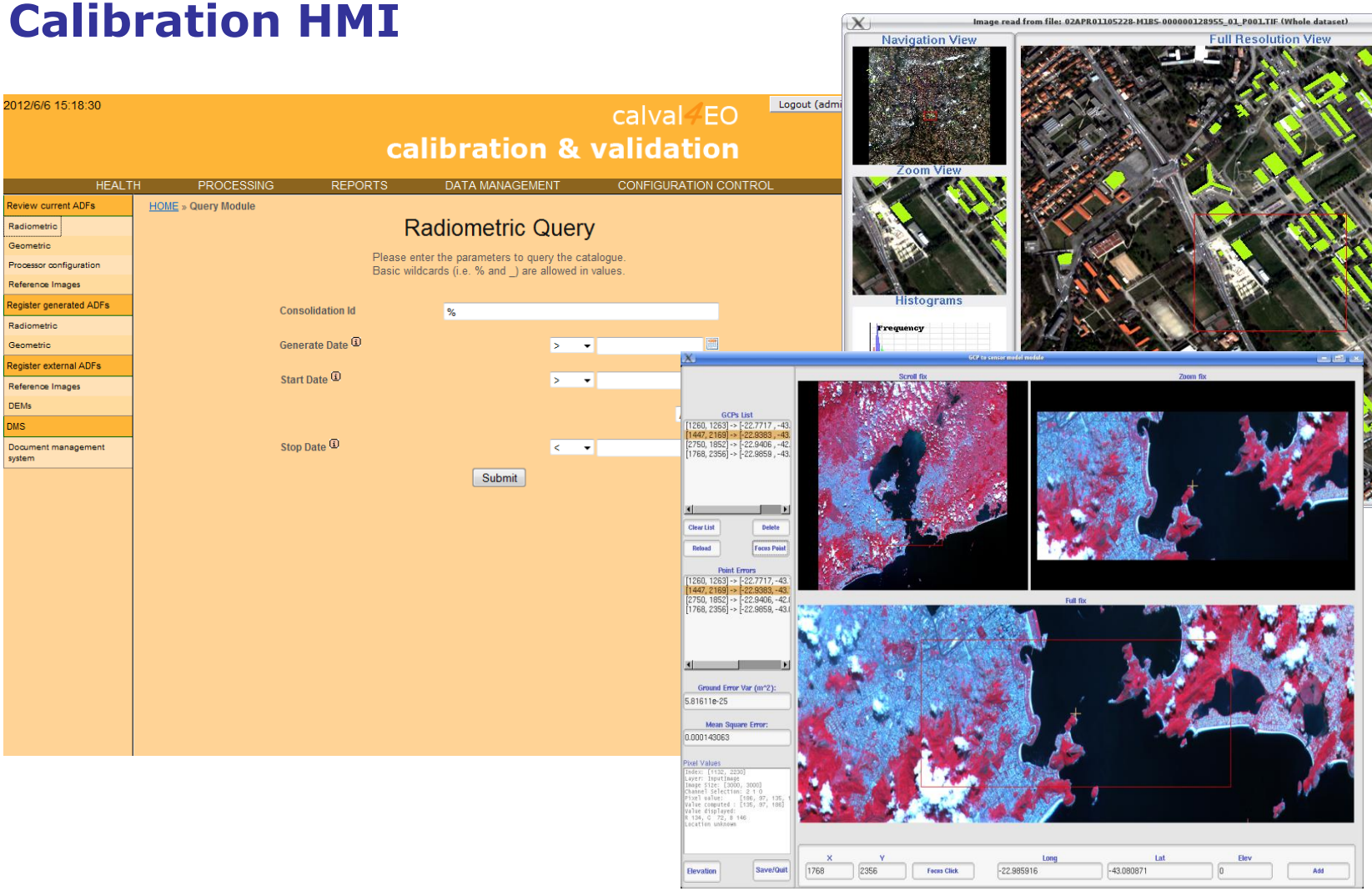
CVT provides the following services:

calval4EO
calibration & validation

- Systematic extraction of calibration data
- Production of calibration reports, with basic statistical figures and trends
- User interface to allow the operation to view, analyze and export the calibration reports (text and graphics)
- User interface to view and edit the calibration database, in a standard format (XML, NetCDF or similar) with a defined schema
- Toolboxes for updating of the calibration database from images in calibration sites
- Storage, under configuration control, of the calibration database and the calibration reports
- Dissemination of the calibration database and reports, via de Mission Archive and Catalogue.

elecnor deimos

Calibration HMI



Thank you!

Questions?

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