

CEOS WGCV IVOS 31, Perth

Commissioning Phase of the Satellite Mission DESIS

DLR German Aerospace Center

EOC Earth Observation Center & OS Optical Sensor Systems

Martin Bachmann, Kevin Alonso, Emiliano Carmona, Daniele Cerra, Daniele Dietrich, Birgit Gerasch, Uta Heiden, Harald Krawczyk, Rupert Mueller, Raquel de los Reyes, Valentin Ziel, David Krutz, Ilse Sebastian, Burghardt Günther, Ingo Walter, Thomas Säuberlich, Christian Fischer

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Version without 2.2 nm resolution plots



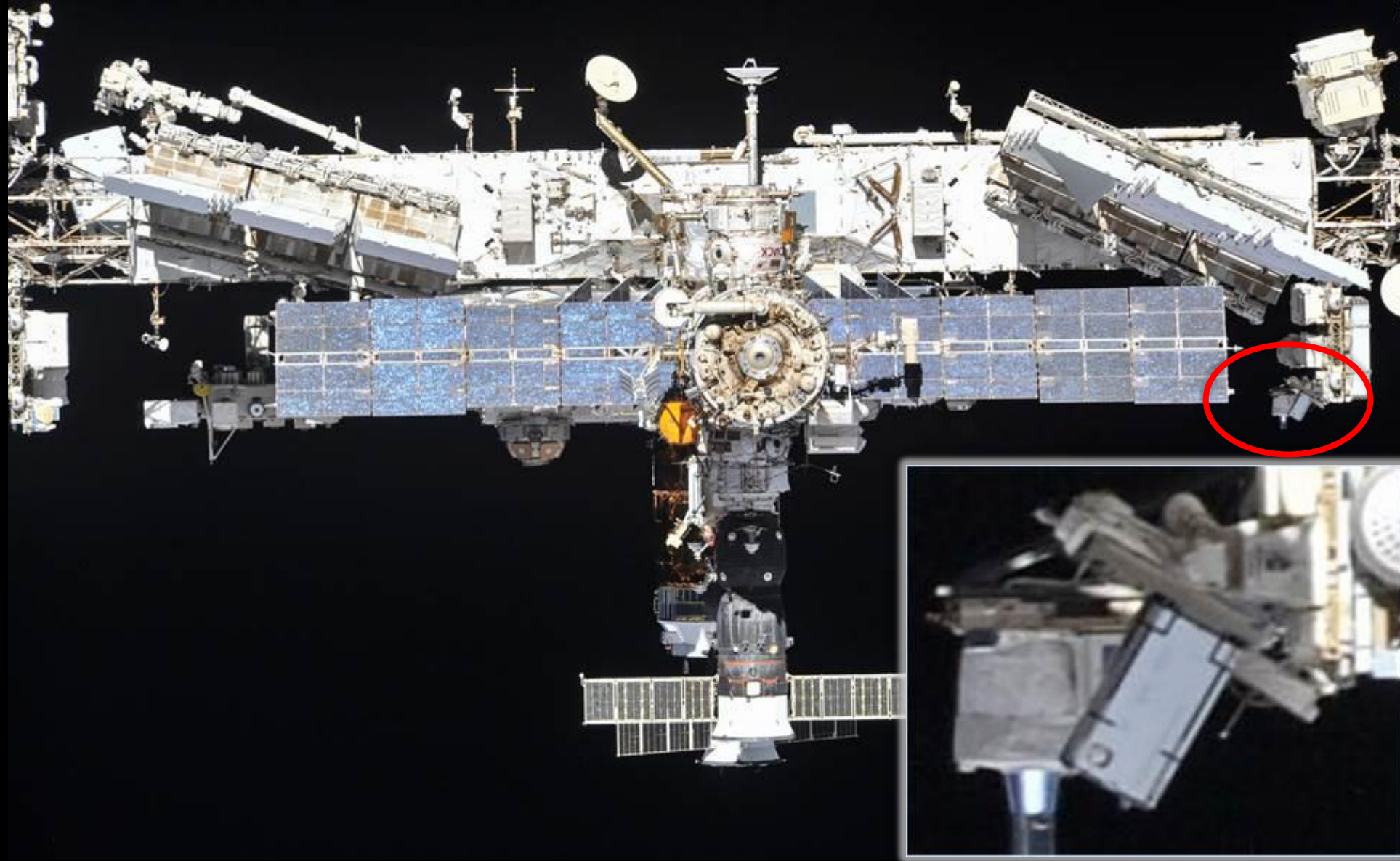
Wissen für Morgen



! PLEASE NOTE !

In agreement with Jack Ickes (Teledyne), please be aware that

- **All data shown is from the commissioning phase,
so all results are not to be considered as official products**
- **Distribution of 2.55 nm spectral sampled data is subject to NOAA approval**







Teledyne Brown Engineering and DLR have partnered to build and operate the DLR Earth Sensing Imaging Spectrometer (DESI) from the Teledyne-owned Multi-User System for Earth Sensing (MUSES) Platform on the ISS

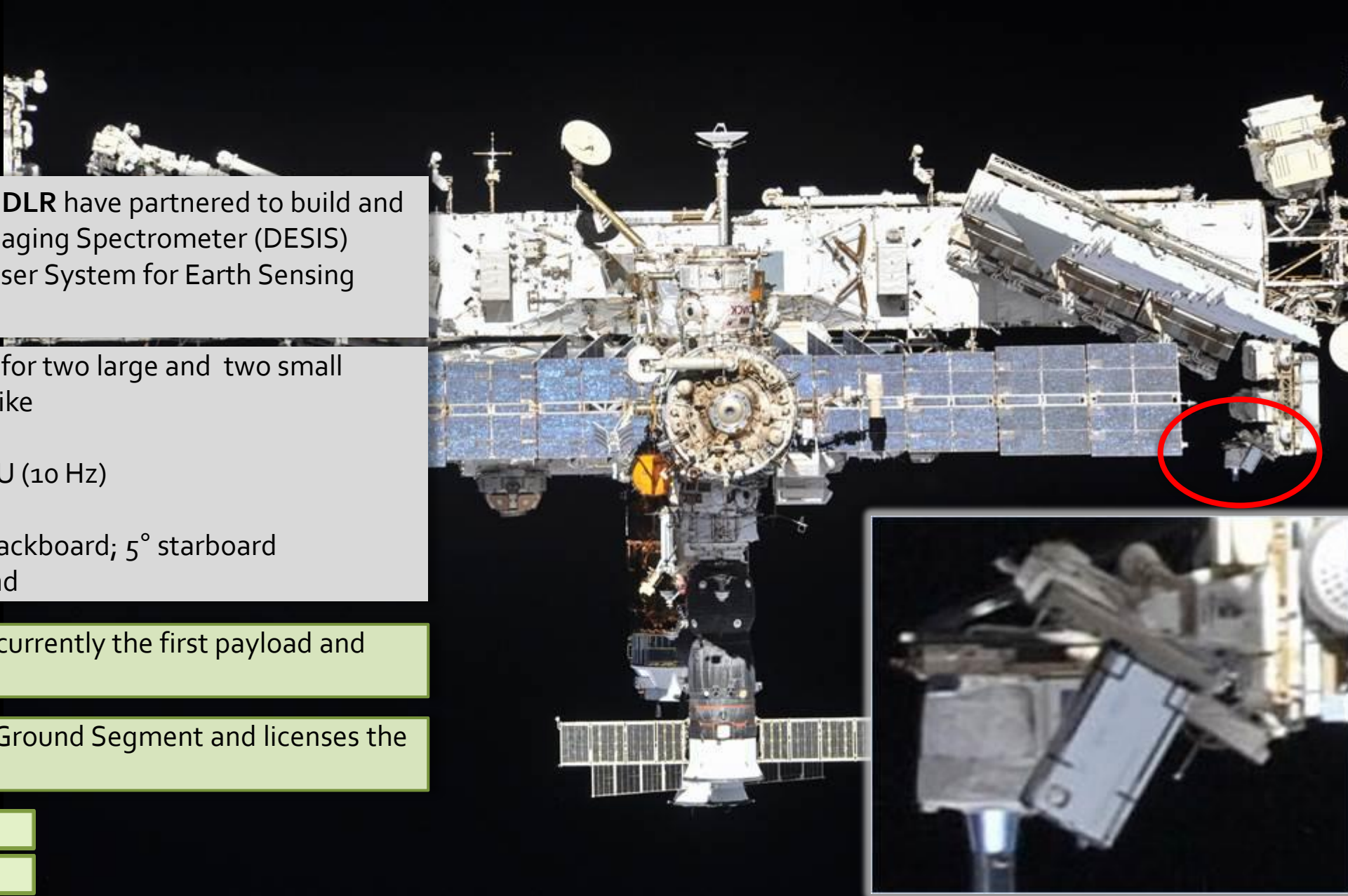
MUSES provides accommodations for two large and two small hosted payloads and core services like

- **Position** via GPS (1 Hz)
- **Attitude** via Startracker + MIMU (10 Hz)
- **Master time** (acc. <150 μ sec)
- **2 Gimbals** $\pm 25^\circ$ for/back; 45° backboard; 5° starboard
- **Downlink** 225 Gbit / day Ku band

The hyperspectral sensor **DESI** is currently the first payload and build by DLR

DLR is responsible to establish the Ground Segment and licenses the SW processors to Teledyne

-  Calibration
-  Processing
-  Archiving
-  Distribution



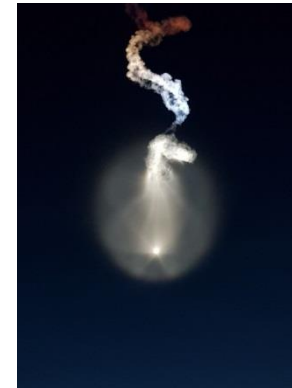
Current Status of the new imaging spectrometer DESIS on the multi-payload platform MUSES installed on the ISS



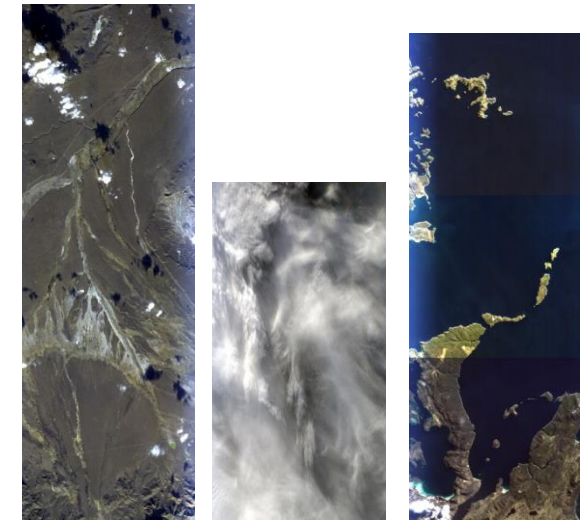
2014 / 2015 Start of MUSES / DESIS mission



7. June 2017 MUSES installed on ISS



29. June 2018 DESIS launched from Cape Canaveral to ISS via SpaceX Dragon

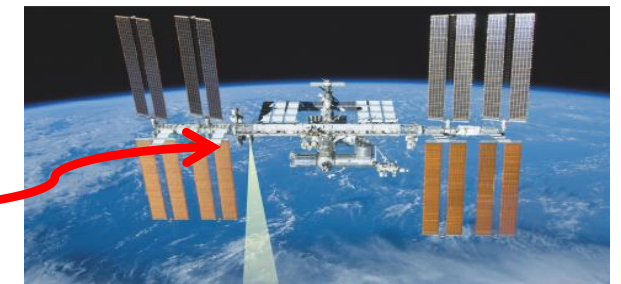
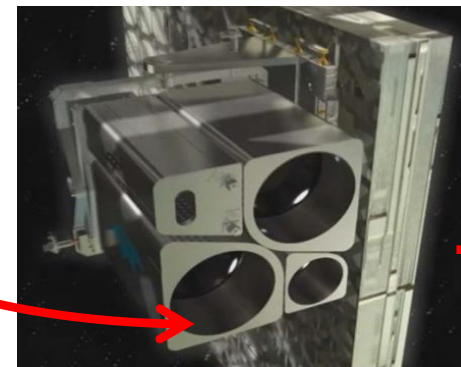
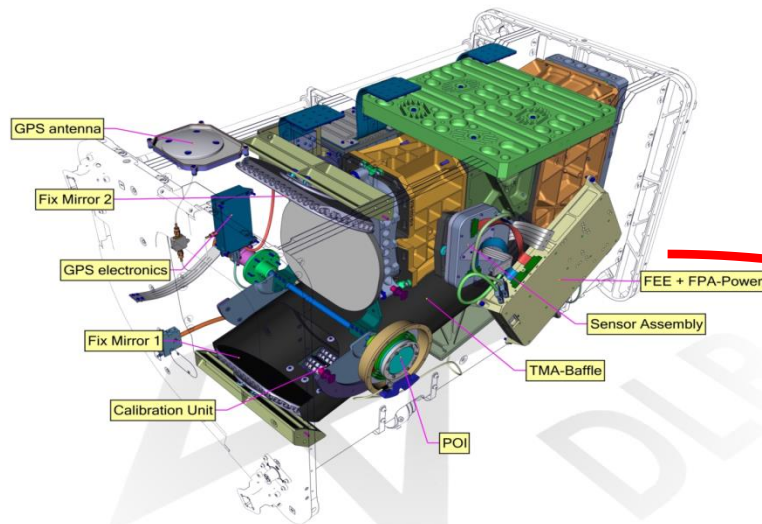


29. August 2018 first images

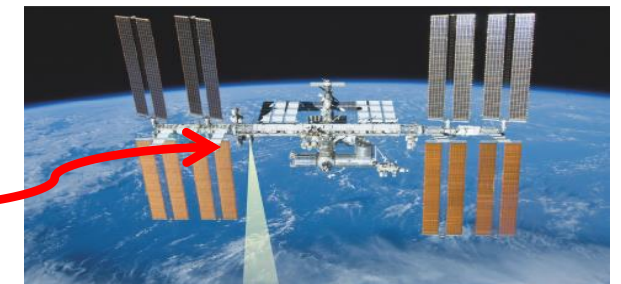
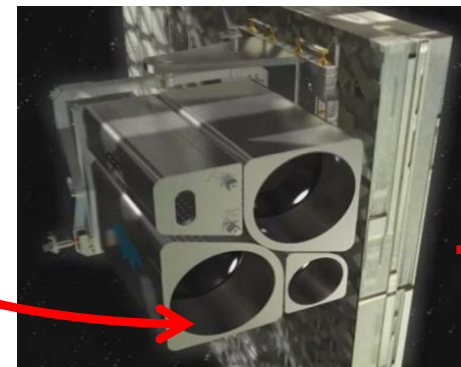
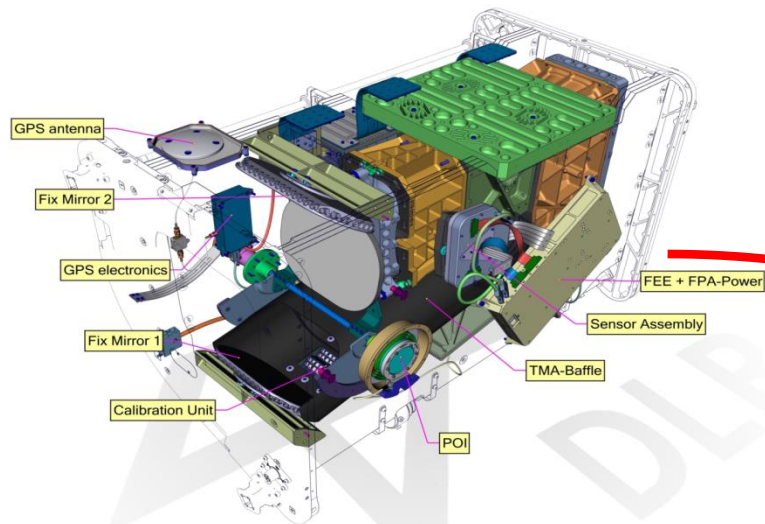
Development of the Instrument and the Ground Segment

Commissioning Phase

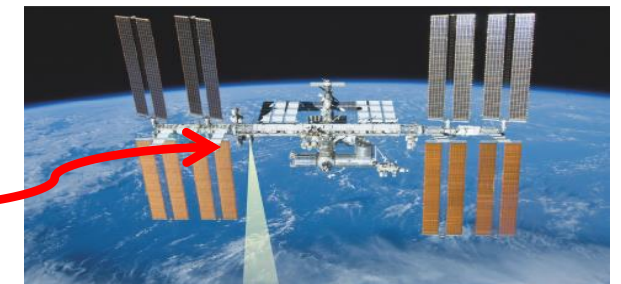
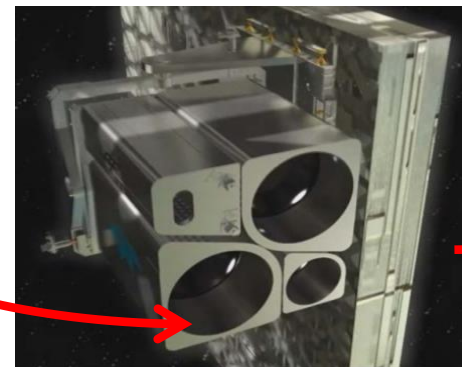
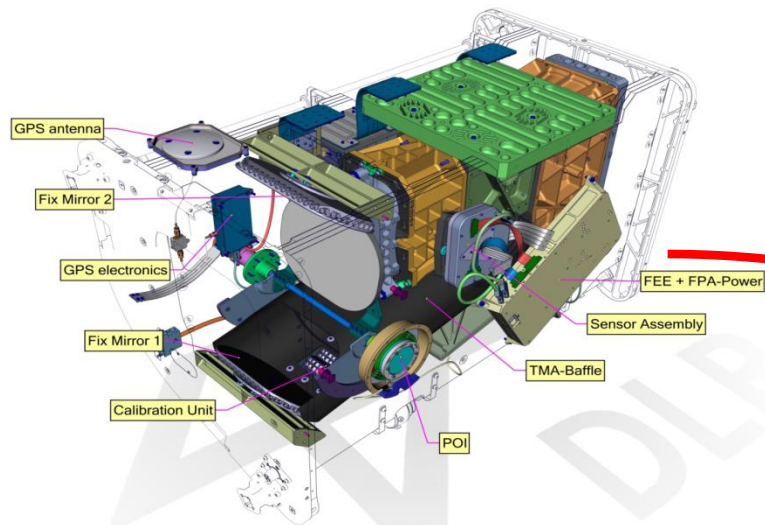
Mission Instrument	ISS/MUSES DESIS	EnMAP HSI (2 instruments)
Off-nadir tilting (across-track, along-track)	-45° (backboard) to +5° (starboard), -40° to +40° (by MUSES and DESIS)	-30° to +30°, 0° (by EnMAP)
Spectral range	400 nm to 1000 nm	420 nm to 2450 nm
Spectral (res., acc.)	2.55 nm, (*)	6.5 nm, 0.5 nm (VNIR), 10.0 nm, 1.0 nm (SWIR)
Radiometry (res., acc.)	13 bits, (*)	14 bits, 5%
Spatial (res., swath)	30 m, 30 km (@ 400 km)	30 m, 30 km
SNR (signal-to-noise)	205 (no bin.)/406 (4 bin.) @ 550 nm	500 @ 495 nm, 150 @ 2200 nm
Instrument (mass)	88 kg	350 kg
Capacity (km, storage)	2360 km per day, 225 GBit	5000 km per day, 512 GBit



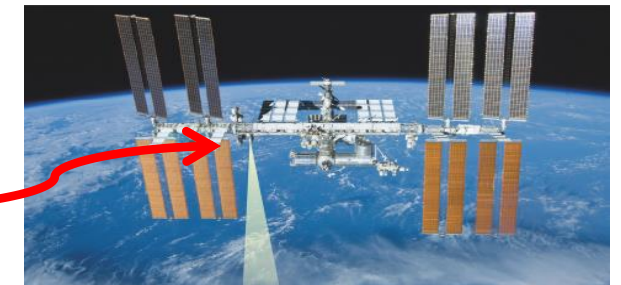
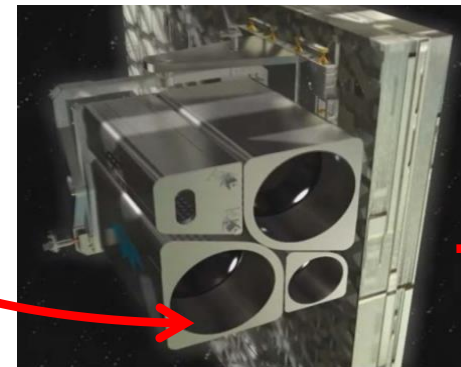
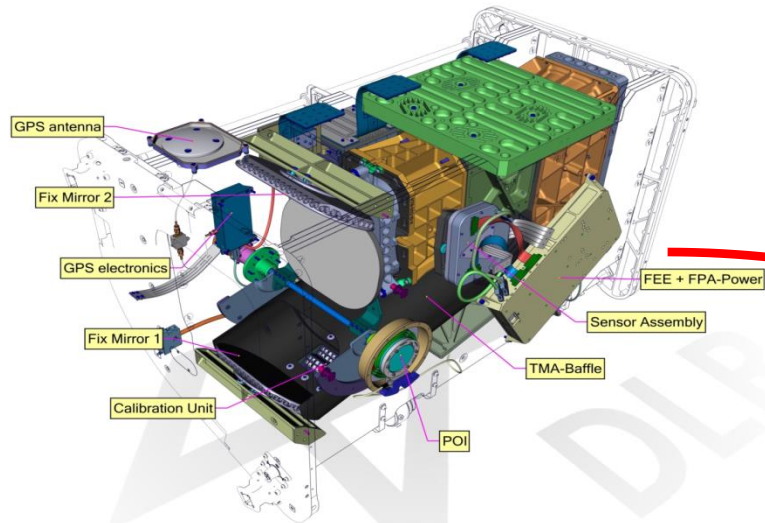
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Target lifetime	2018-2023	2020-2025
Satellite (mass, dimension, usage)	455 t, 109.0×97.9×27.5 m ³ (multi-purpose)	1 t, 3.1×2.0×1.7 m ³ (single-purpose)
Orbit (type, local time at equator, inclination, height, repeat cycle)	not Sun-synchronous, various, 51.6°, 320 km to 430 km, no repeat cycle	Sun-synchronous, 11:00, 98.0°, 653 km, 398 revolutions in 27 days
Coverage	55° N to 52° S	74° N to 74° S
Revisit frequency	3 to 5 days (average)	≤ 4 days, ≤ 27 days (±5° tilting)

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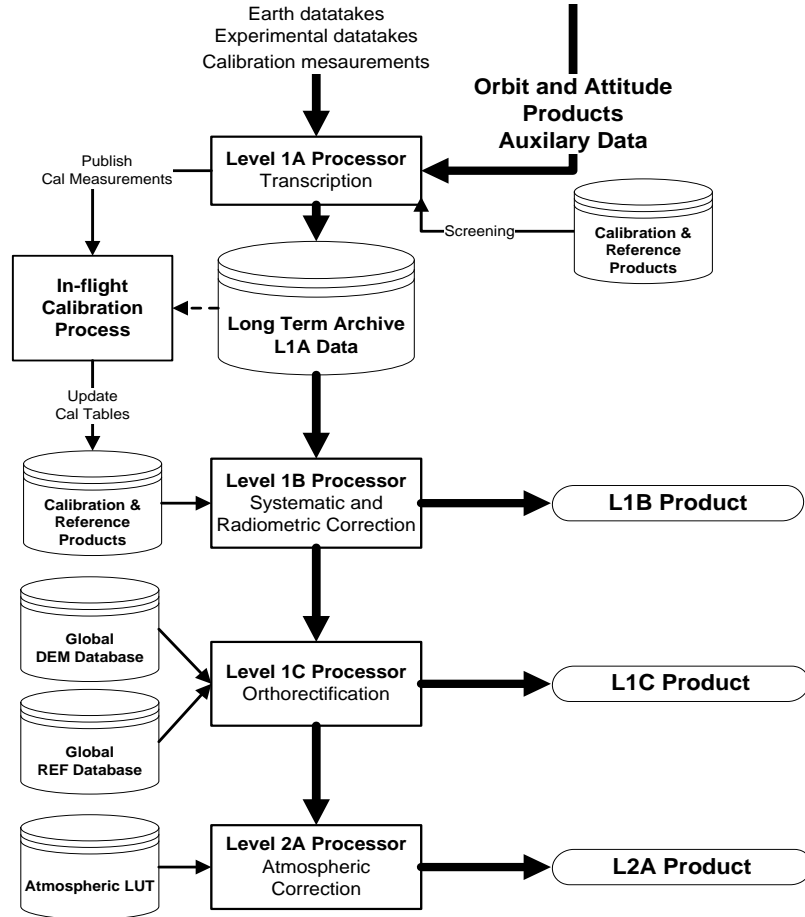
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- Acquisition Modes**
- Earth
 - BRDF
 - Forward Motion Compensation
 - Var. binning modes
 - Var. gain modes
 - Calibration
 - Dark Current



Ground Segment Processors



Processors at the Ground Segments

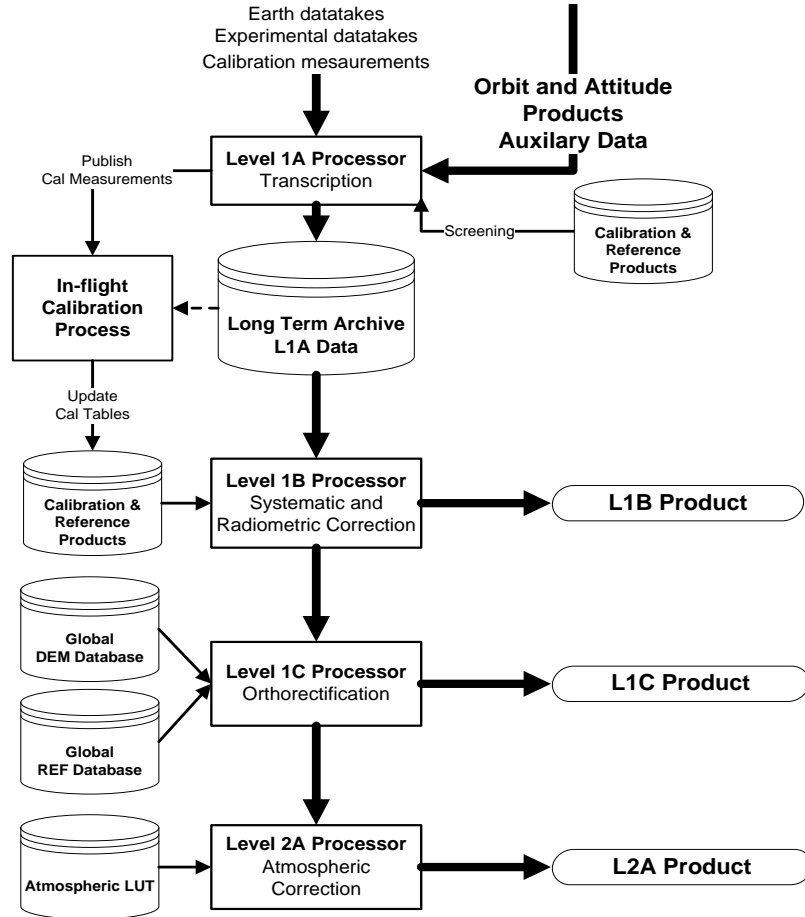
- Fully automated
- Run 'on-request' over archived data
- Two instances: one at Teledyne (Amazon Cloud), one at DLR

Products:

- **Level 0 (L0)**
 - Raw data
- **Level 1A (L1A)**
 - L0 data with correction and calibration computed and appended.
- **Level 1B (L1B)***
 - Top of Atmosphere (TOA) radiance ($\text{W}\cdot\text{m}^{-2}\cdot\text{sr}^{-1}\cdot\mu\text{m}^{-1}$)
 - Systematic and radiometric correction (rolling shutter, keystone, smile)
- **Level 1C (L1C)***
 - Level 1B data ortho-rectified, re-sampled to a specified grid
 - Global DEM, sensor model refinement using global reference image (Landsat-8 PAN with 12m CE90)
- **Level 2A (L2A)***
 - Ground surface reflectance (i.e. after atmospheric corrections)
 - Smile taken into account

* Delivery product

Ground Segment Processors



Processors at the Ground Segments

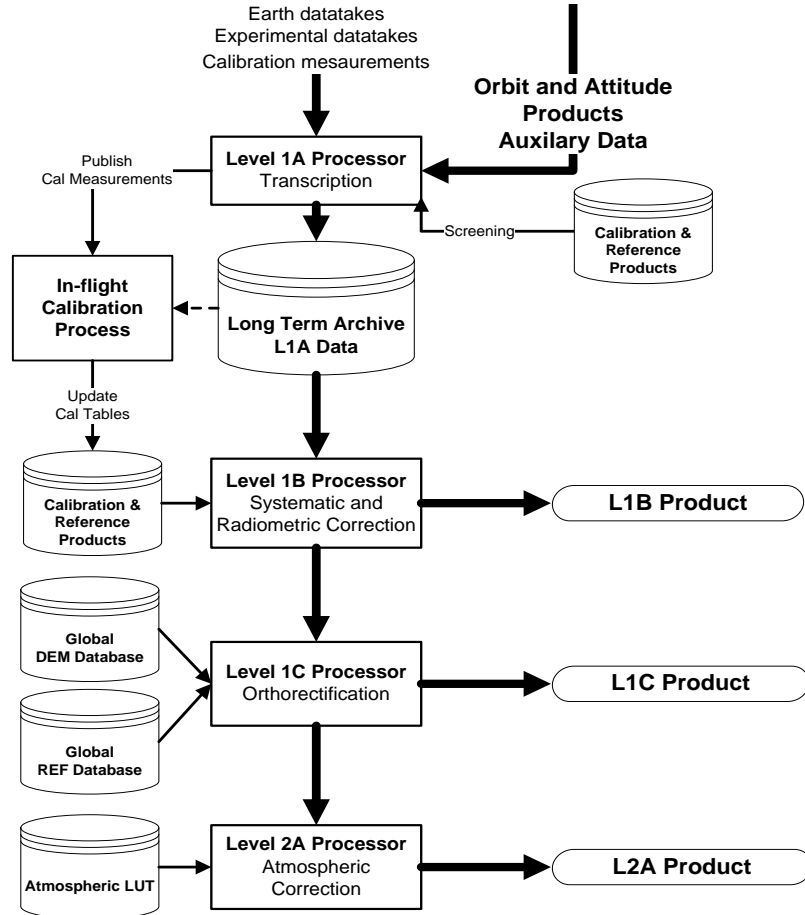
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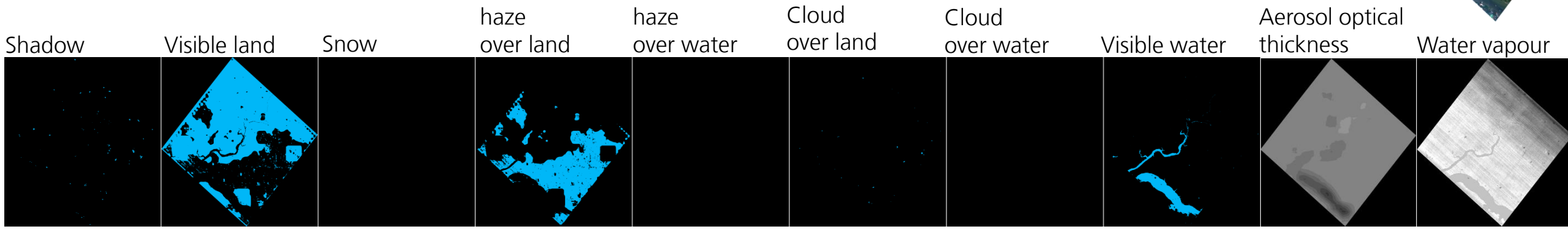
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Quality Layers and Metadata

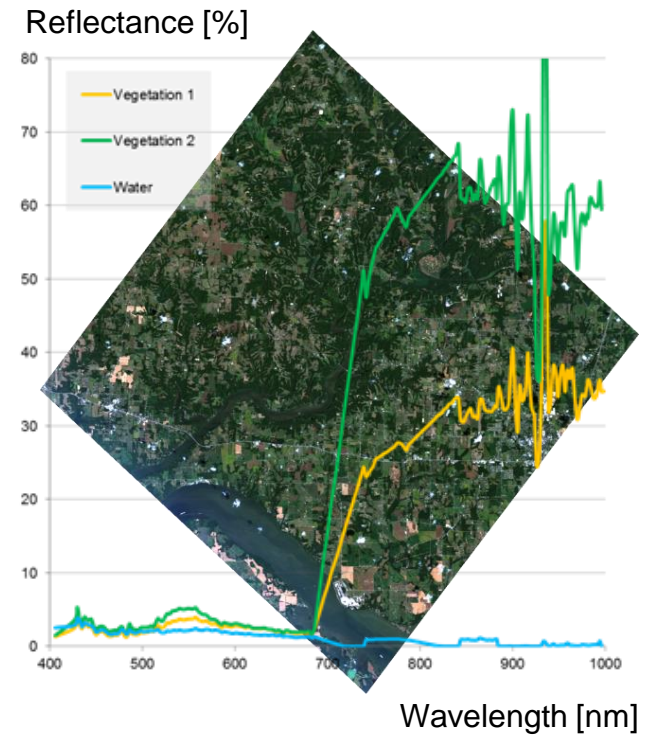
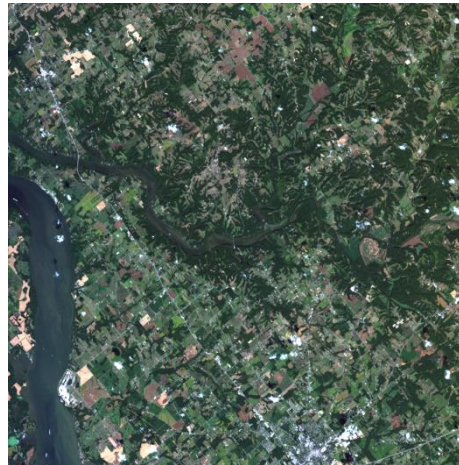
Quality Layer (Geotiff)	L1A	L1B	L1C	L2A
Dead pixels		X	X	X
Suspicious pixels		X	X	X
Too high radiance level		X	X	X
Too low radiance level		X	X	X
Shadow				X
Land				X
Water				X
Haze over land				X
Haze over water				X
Cloud over land				X
Cloud over water				X
Aerosol optical thickness				X
Perceptible water vapour				X
Detector Map (Digital Number)	X			
Detector Map (Radiance Level)	X			

- Dead Pixels
 - generated through calibration
- Suspicious pixels
 - Generated by comparison between measured radiances and calibration
- Data Screening
 - Temperatures, Voltages, Currents, CRC
- Geometric accuracy
 - Subset of matching points with reference
- Bad columns/lines (based on detector maps)
 - Generated by statistical tests
- Smile Indication
 - Based on Absorption Bands (like O₂ at 760 nm)



Huntsville, Alabama
04.09.2018

Processing Chain for Standard Products



Raw Data Stream
L0 / L1A

ToA Radiance
L1B

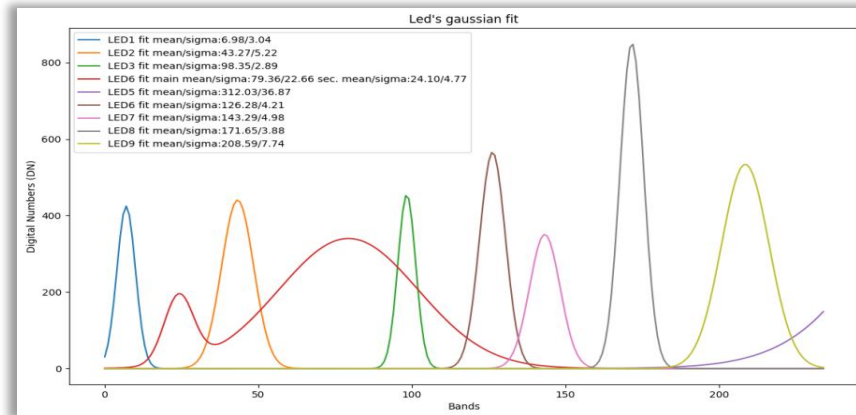
Georeferenced Image
L1C

Atmospheric Compensated
L2A

Commissioning Phase Activities

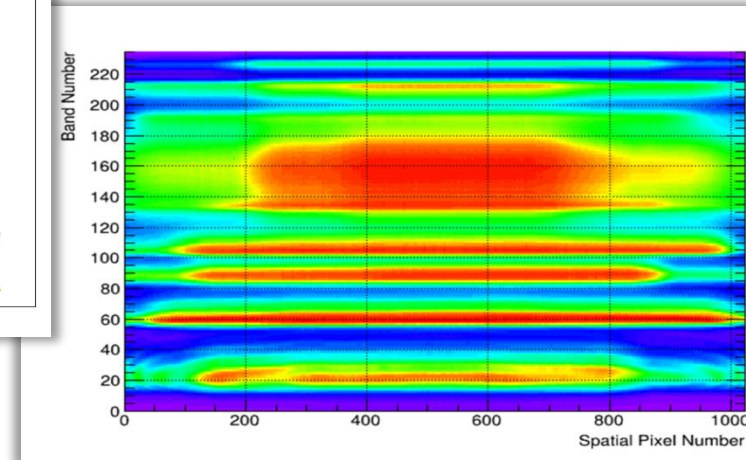
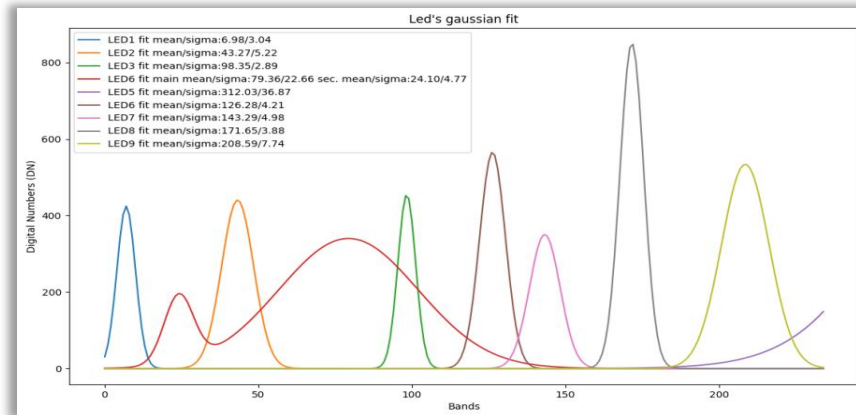
Commissioning Phase Activities – In-Orbit Spectral Characterization

- Using on-board calibration sources (LEDs)
 - ✓ – Pre- and post-launch characteristics
 - Incl. temperature stability & other HK / telemetry data



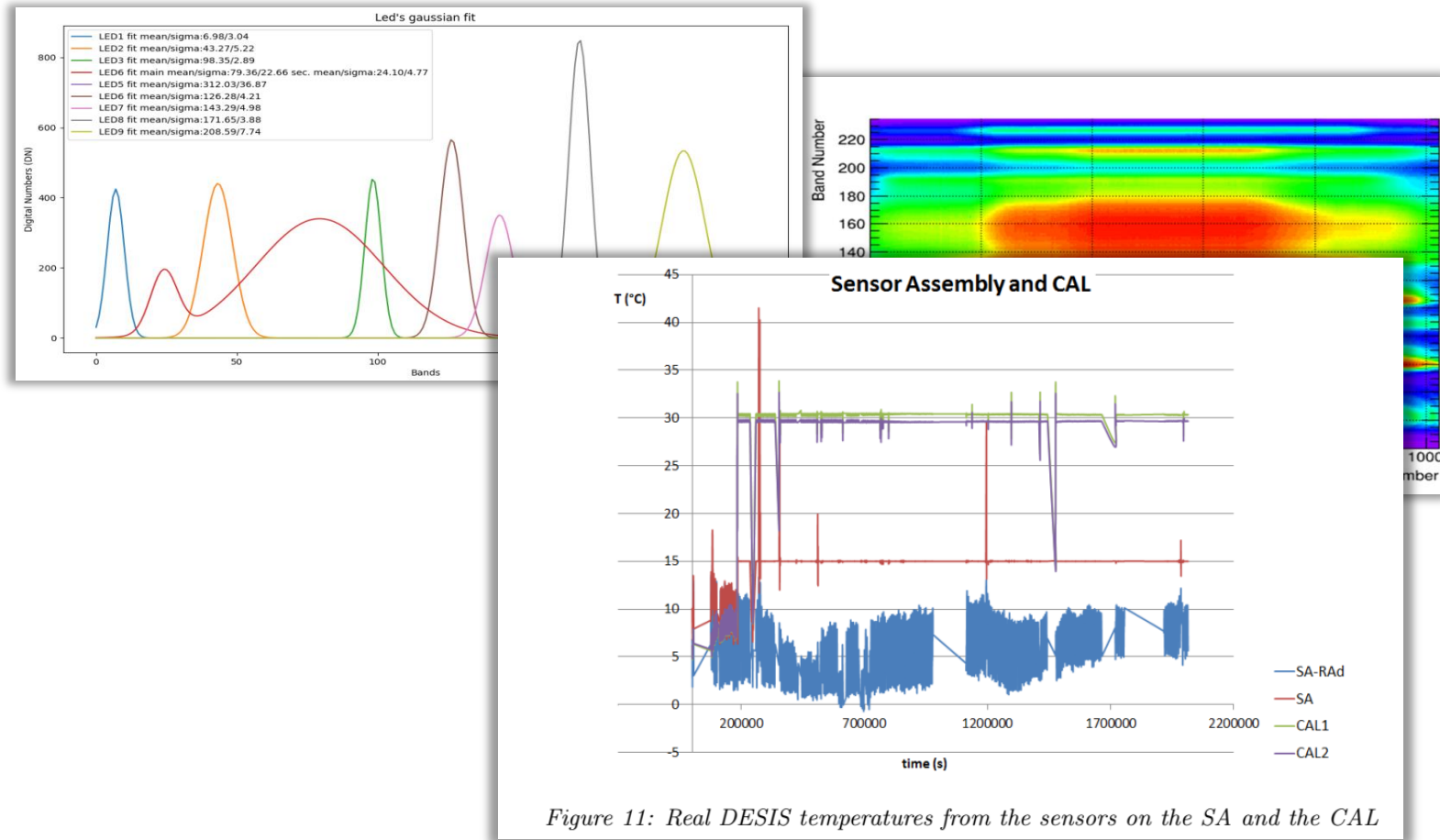
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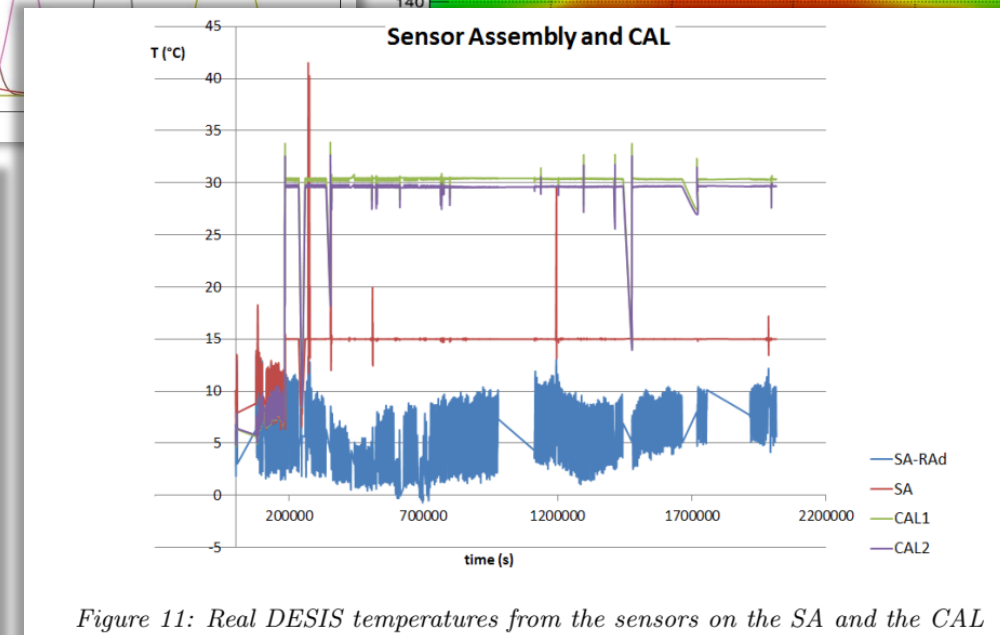
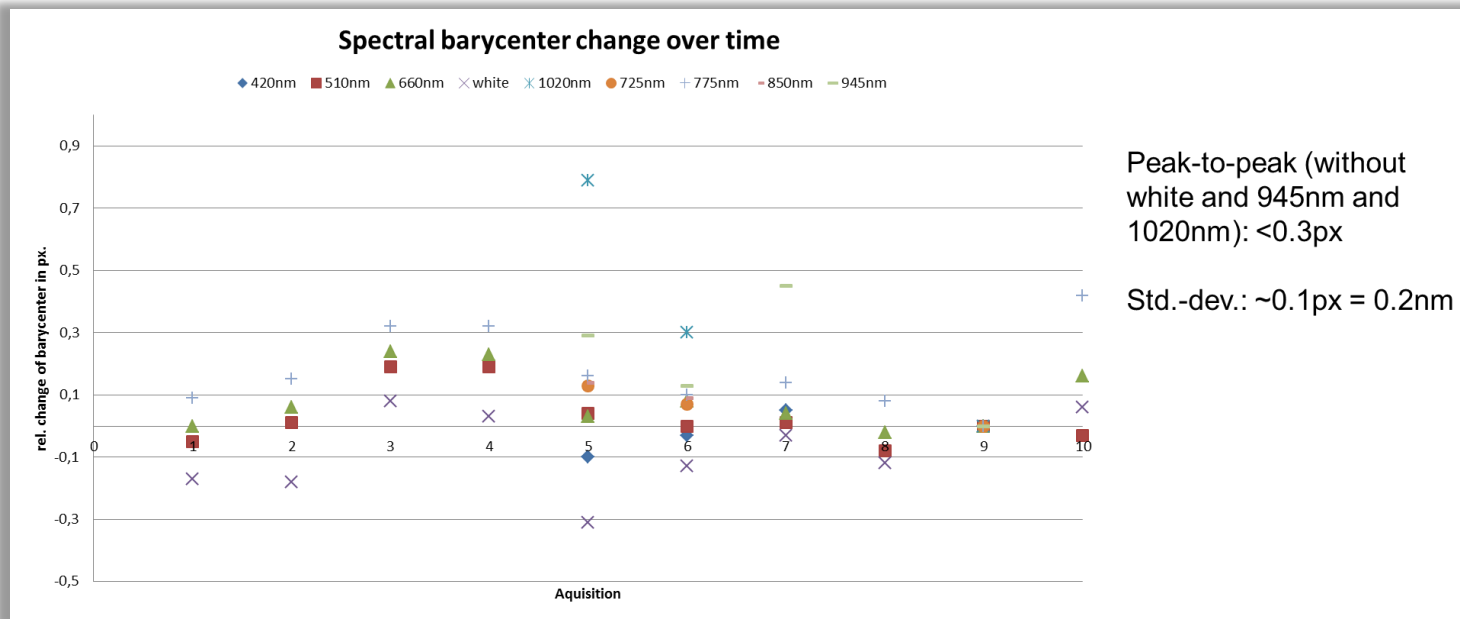
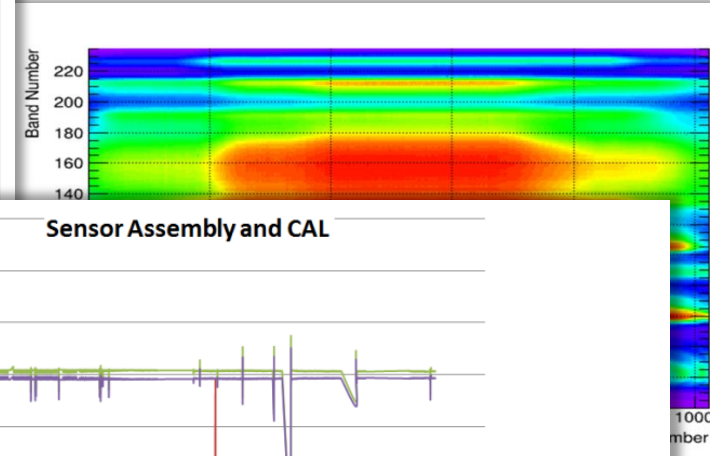
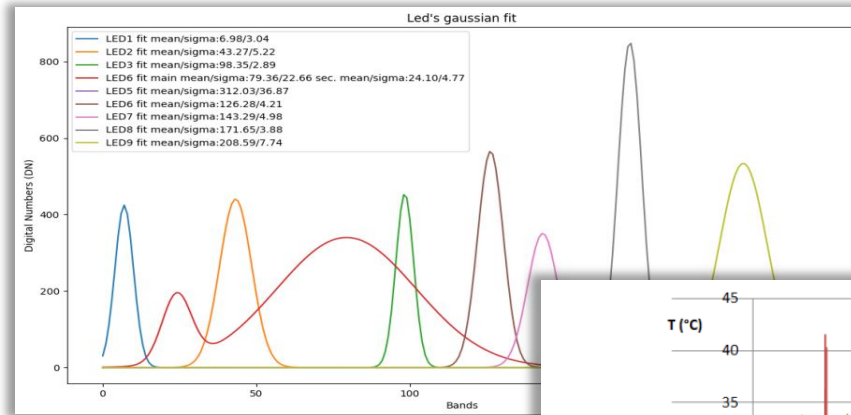
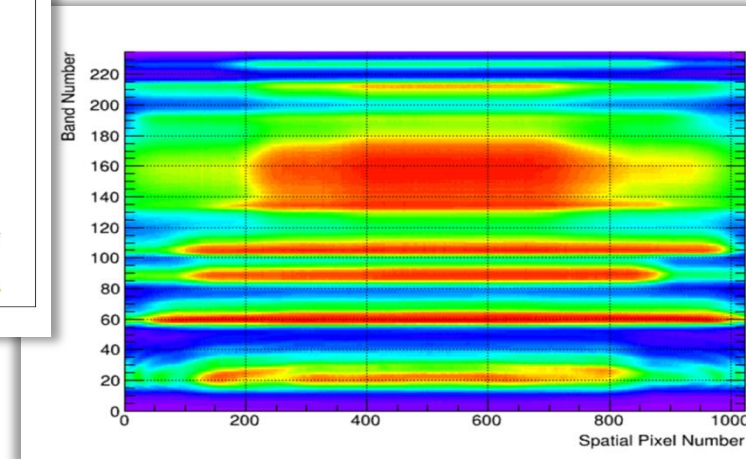
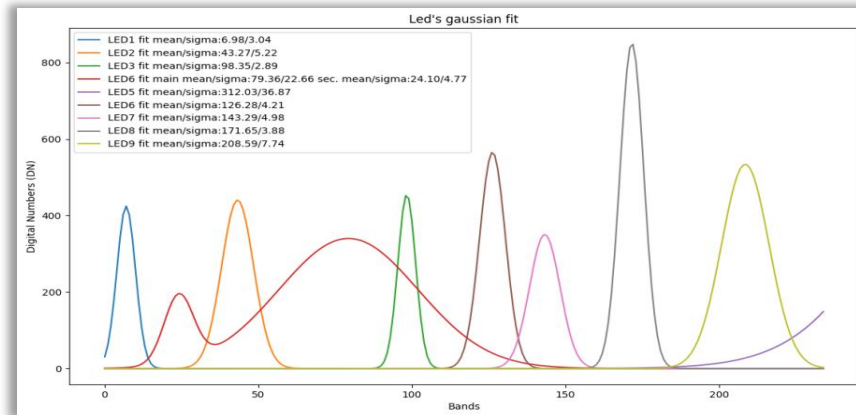


Figure 11: Real DESIS temperatures from the sensors on the SA and the CAL

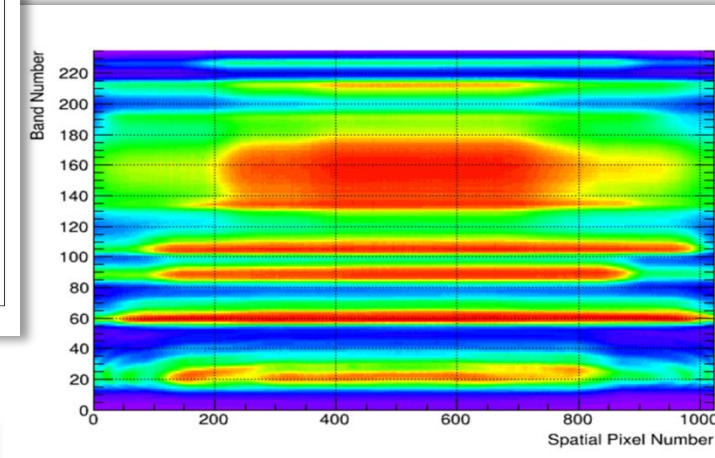
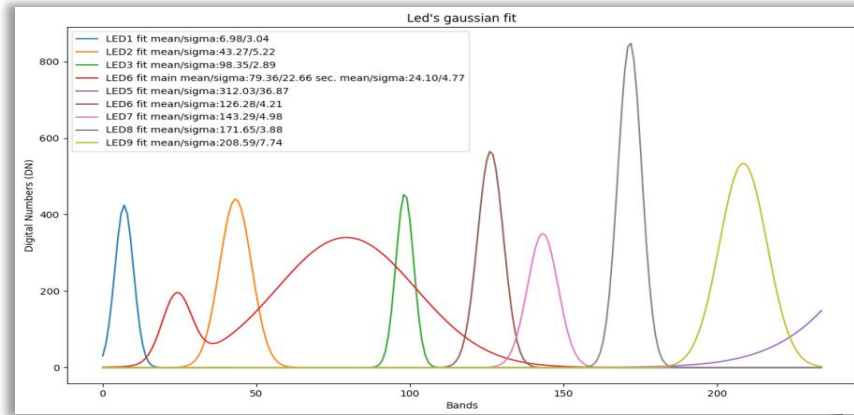
Commissioning Phase Activities – In-Orbit Spectral Characterization

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- Using atmospheric absorption features
 - Smile pre- and post-launch

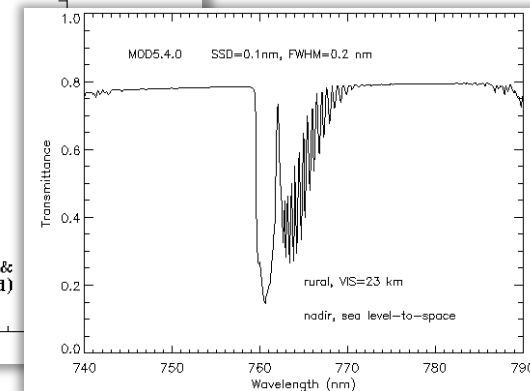
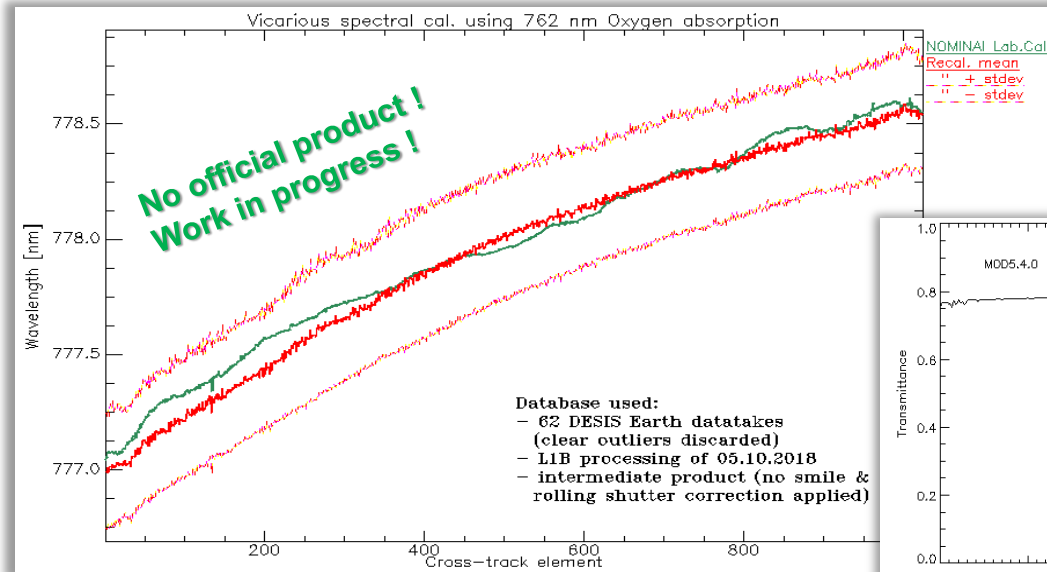


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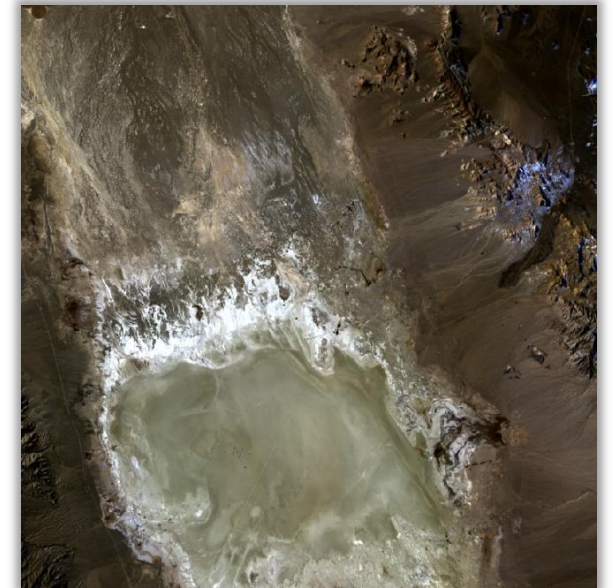


Commissioning Phase Activities – In-Orbit Radiometric Characterization

- Using CEOS RadCalNet sites, e.g. Railroad Valley
 - So far only **BOA** reflectance validation, **TOA** ongoing



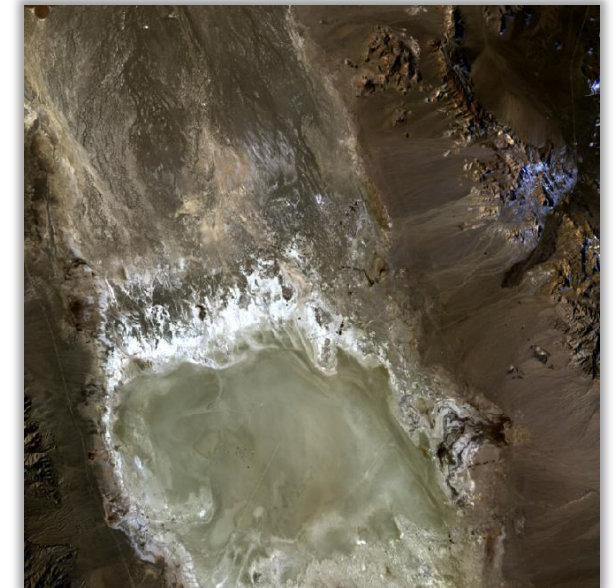
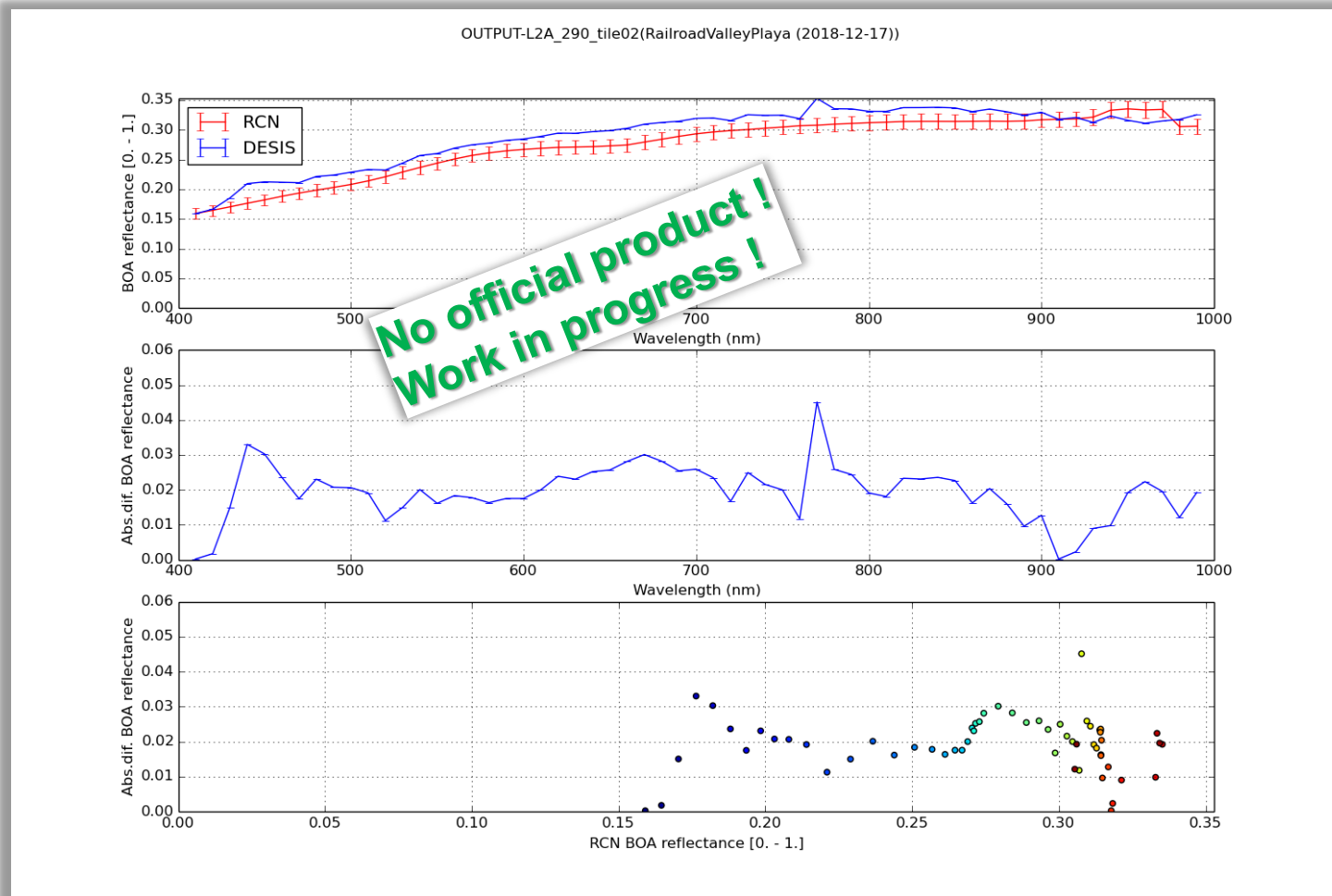
Lybia4
SZA = 49.76



Railroad Valley

Commissioning Phase Activities – In-Orbit Radiometric Characterization

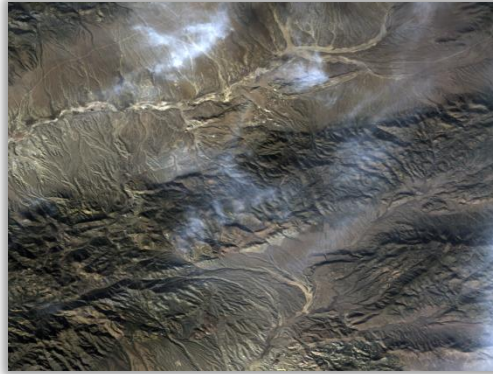
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- So far only **BOA** reflectance validation, TOA ongoing



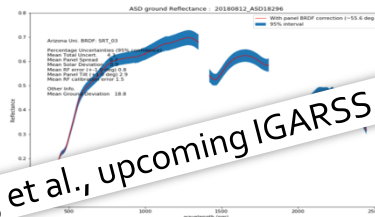
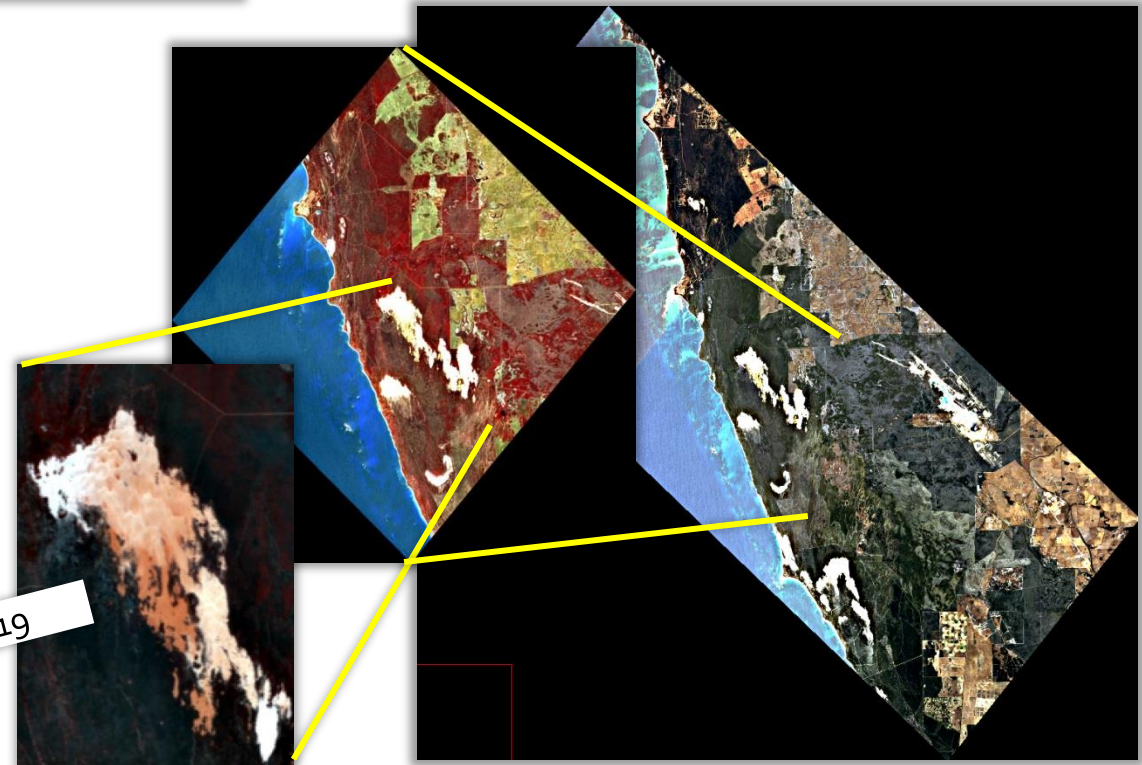
Railroad Valley

Commissioning Phase Activities – In-Orbit Radiometric Characterization

– Using CEOS RadCalNet sites, e.g. Railroad Valley



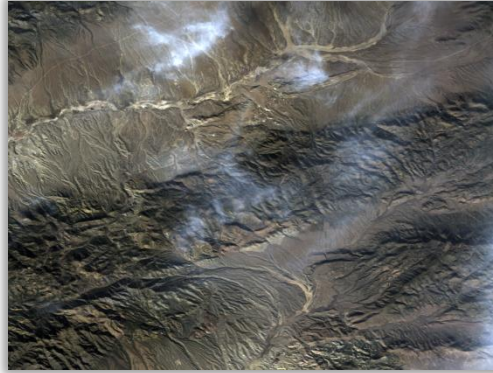
– Using CEOS PICs sites & Pinnacles site (CSIRO)



See Ong et al., upcoming IGARSS 2019

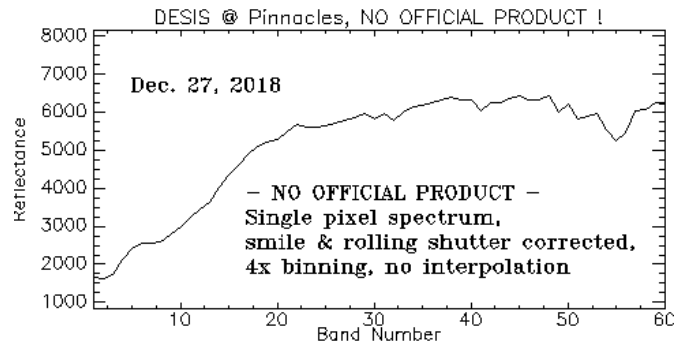
Commissioning Phase Activities – In-Orbit Radiometric Characterization

– Using CEOS RadCalNet sites, e.g. Railroad Valley

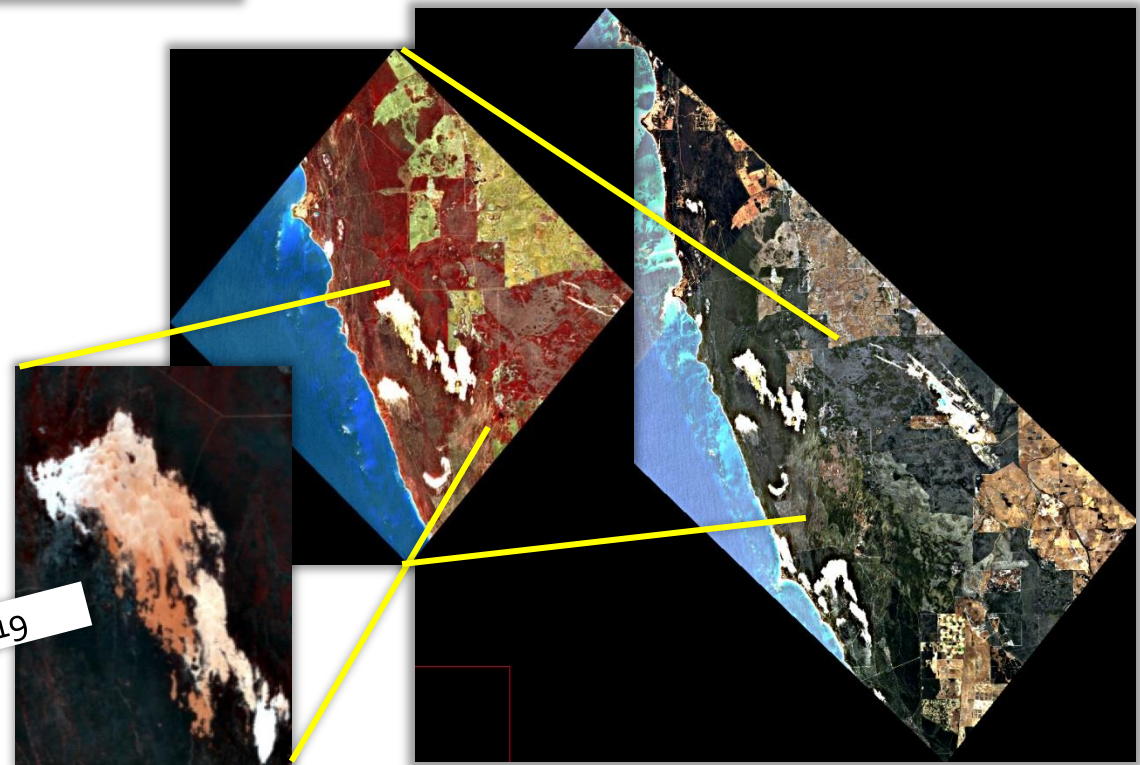


– Using CEOS PICs sites & Pinnacles site (CSIRO)
– Checking the binning modes

Fig. excluded



See Ong et al., upcoming IGARSS 2019



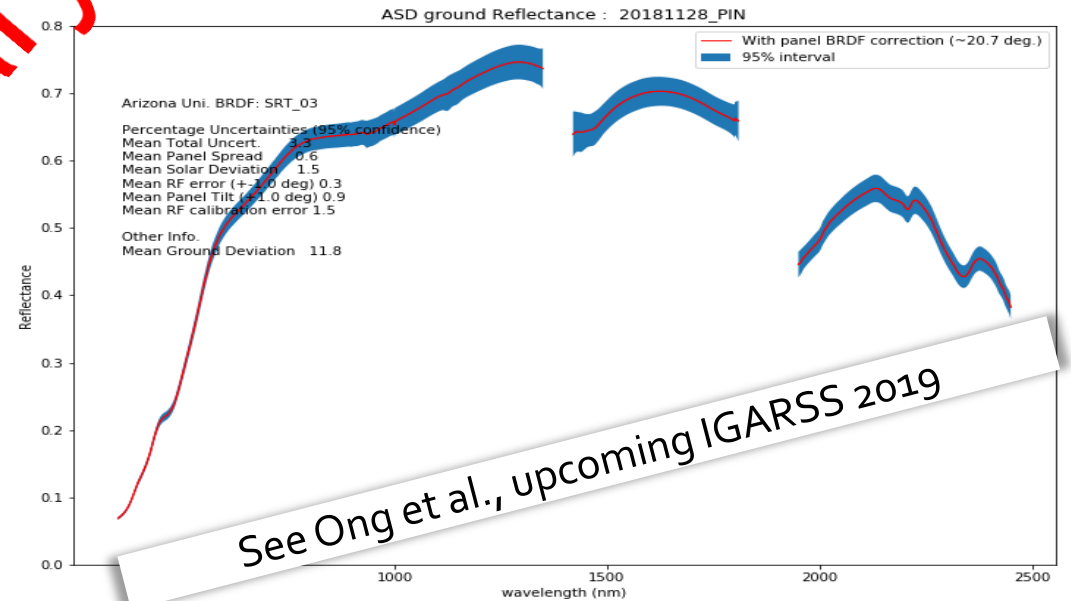
Commissioning Phase Activities – In-Orbit Radiometric Characterization

- No binning: acquired Nov. 3, 2018
- 4x binning: acquired Dec. 27, 2018

Fig. excluded

Fig. excluded

Preliminary



Commissioning Phase Activities – In-Orbit Radiometric Characterization

- No binning: acquired Nov. 3, 2018
- 4x binning: acquired Dec. 27, 2018

Fig. excluded

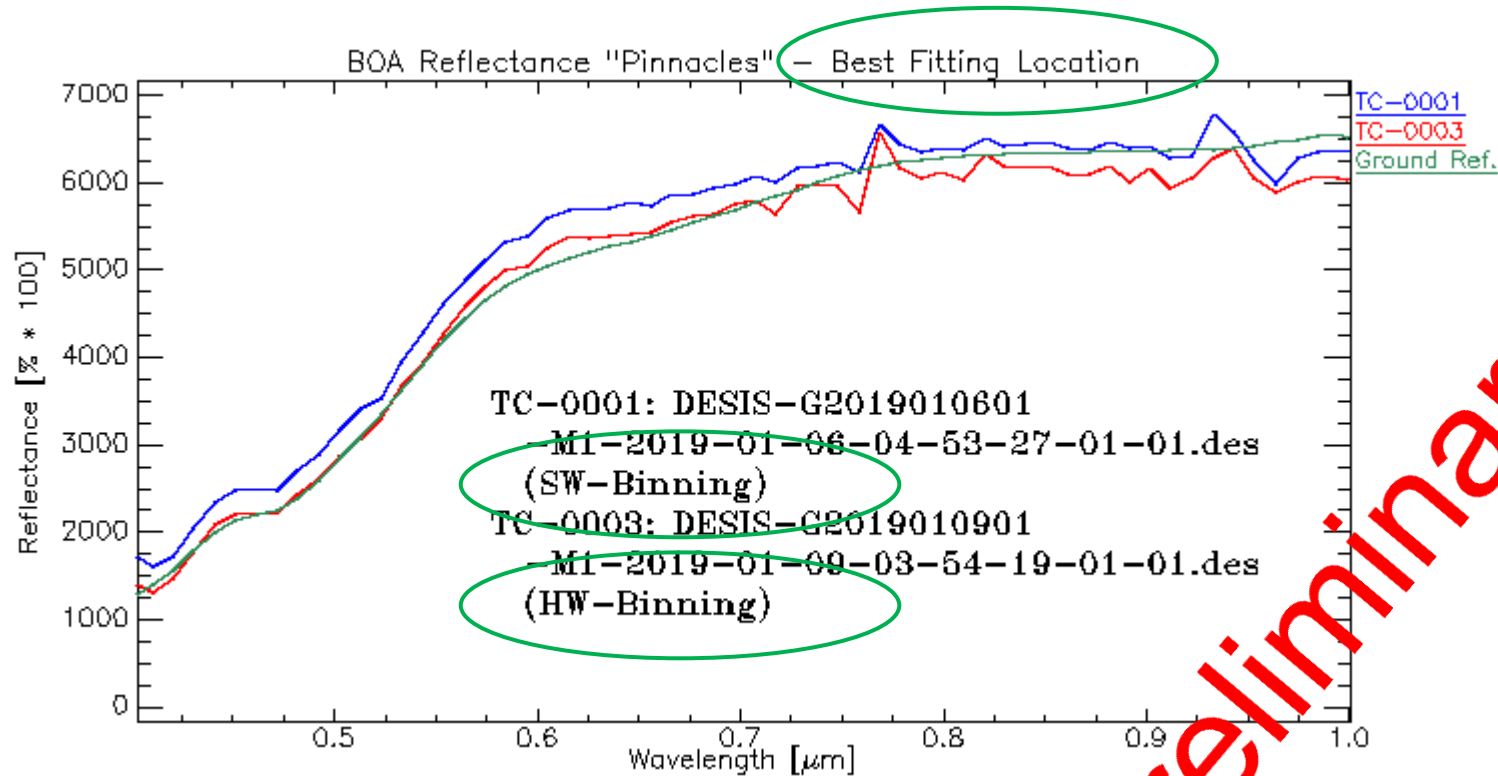
Fig. excluded

Preliminary



Fig. excluded

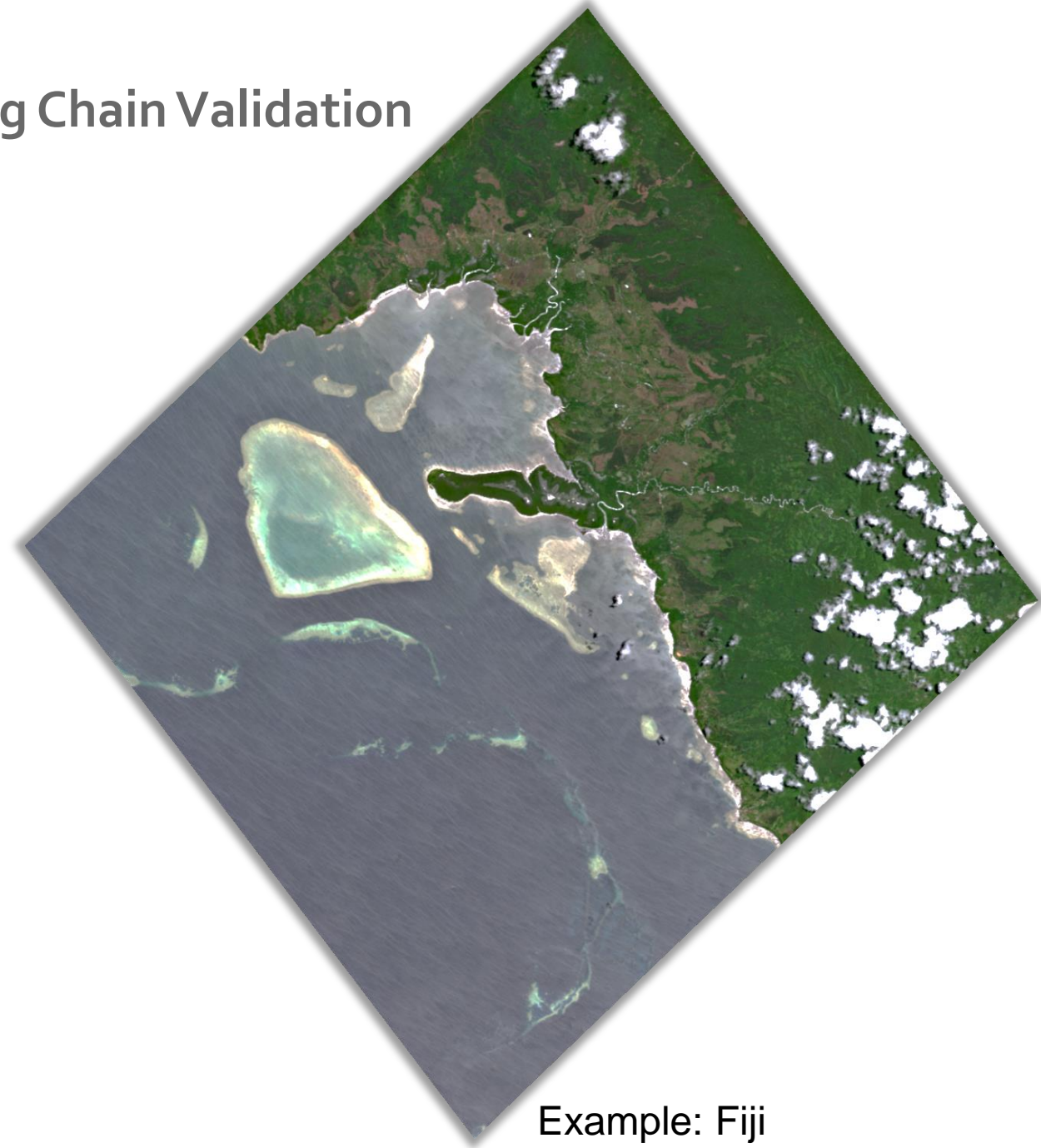
Commissioning Phase Activities – In-Orbit Radiometric Characterization



Preliminary

Commissioning Phase Activities – Processing Chain Validation

- Consistency in atmospheric correction
 - Cross-check using
 - PACO (DESIIS operational processor)
 - ATCOR (interactive, DLR-ReSe development)
 - FLAASH (interactive, 3rd party SW)



Example: Fiji

Commissioning Phase Activities – Processing Chain Validation

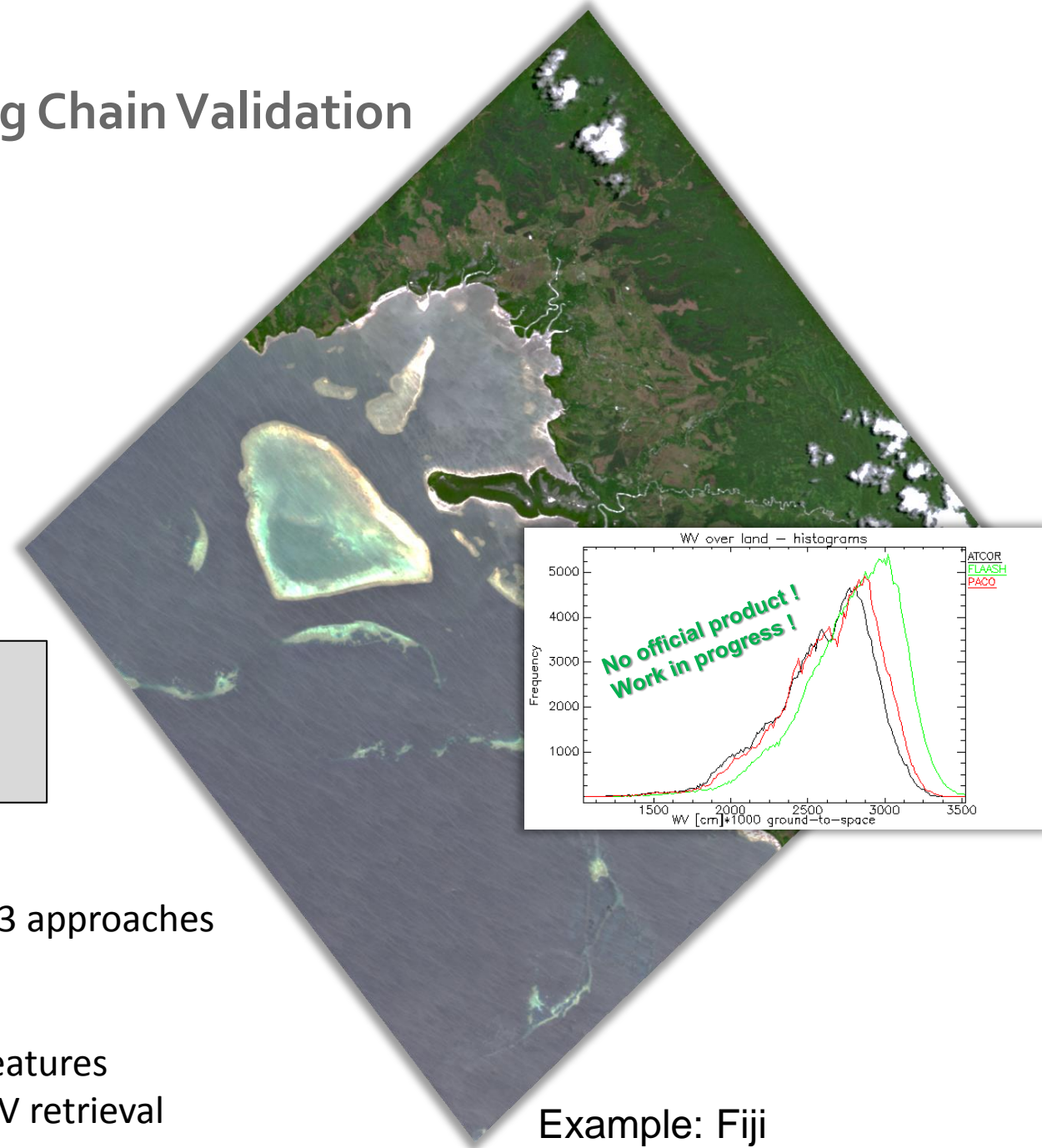
- Consistency in atmospheric correction
 - Cross-check using
 - PACO (DESI operational processor)
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 - FLAASH (interactive, 3rd party SW)

Fig. excluded

Fig. excluded

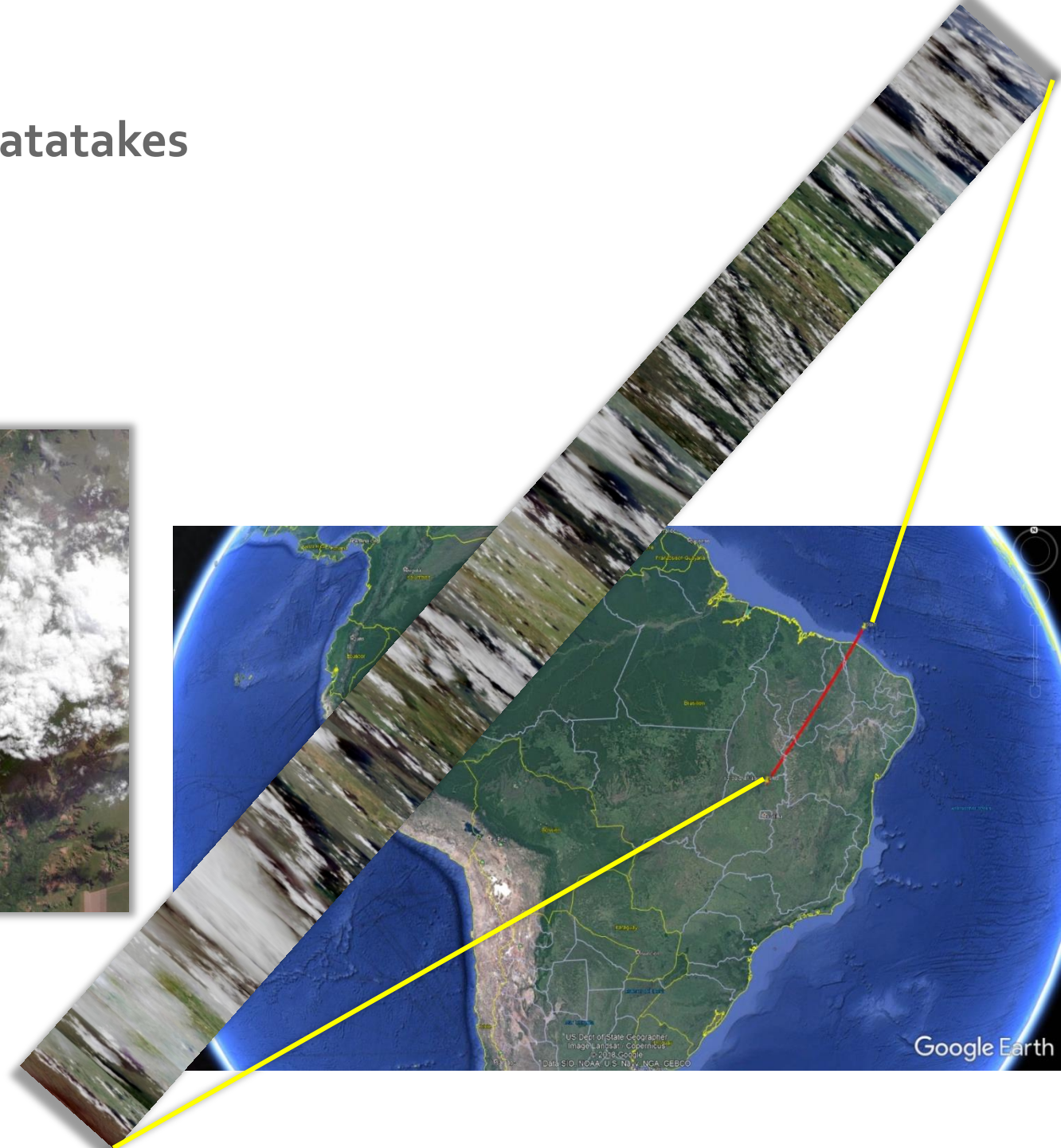
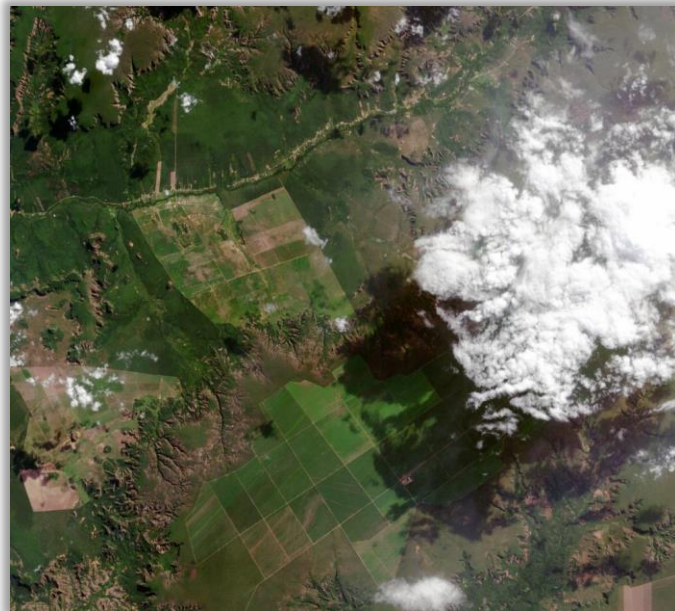
Overall good agreement between all 3 approaches

- ✓ well within 2% up to 700 nm
- ✓ within 4% above 700 nm
- ✓ “spikes” in atm. absorption features
- ✓ overall good agreement in WV retrieval

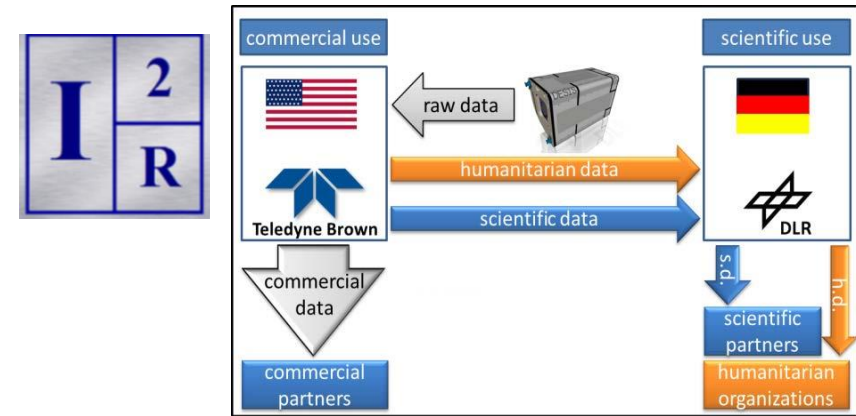


Also including first applications – Brazil datatakes (context: Brumadinho mining accident)

Datatake of 55 tiles, ~ 1600 km lengths,
Image cube: 56.320 pix * 1024 pix * 235 bands



Data Policy



- DESIS is to be operated by Teledyne (TBE):
 - TBE will receive the raw data
 - TBE has the exclusive right to license or transfer image data for commercial use.
- For scientific and humanitarian purposes, DLR has the right to:
 - Task DESIS, 2000 minutes/year
 - Request archived data
- Distribution of 2.55 nm spectral sampled data is subject to NOAA approval
- For scientific purposes only:
 - DLR can share DESIS scientific data with other scientific organizations within projects; Data are free in this case
 - Scientific use includes:
 - basic and application oriented research,
 - projects by national and international educational or research institutions or by governmental institutions,
 - development and demonstration of future applications for scientific and/or operational use and
 - preparation and execution of government-funded education, research and development programs.

Summary and conclusions



- DESIS launch & in-orbit functional tests successful
- Key commissioning phase findings
 - Very few defective / unstable pixels (0.3%)
 - Temperature stability well within specification
 - Very high DC stability
 - Processing chain up and running to L2A
 - Incl. smile & rolling shutter correction
 - Geometric accuracy within 1 pixel (image-to-image matching)
 - Spectral characteristics consistent pre-/post- launch
 - Radiometric characterization ongoing
- Cross-calibration with HISUI foreseen