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

martin.bachmann@dlr.de

Version without 2.2 nm resolution plots
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 (DESIS) 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 µsec)
- **2 Gimbals** ±25° for/back; 45° backboard; 5° starboard
- **Downlink** 225 Gbit / day Ku band

The hyperspectral sensor **DESIS** 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

Do we really need DESIS? For sure certainly

Development of the Instrument and the Ground Segment

Commissioning Phase
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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 (W.m-2.sr-1.μm-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
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<th>L1B</th>
<th>L1C</th>
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<td>Suspicious pixels</td>
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<td>Perceptible water vapour</td>
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- **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)
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
Commissioning Phase Activities – In-Orbit Spectral Characterization

- Using on-board calibration sources (LEDs)

✓ Pre- and post-launch characteristics
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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

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

![Graph of spectral barycenter change over time]

Peak-to-peak (without white and 945nm and 1020nm): <0.3px
Std.-dev.: ~0.1px = 0.2nm

Figure 11: Real DESIS temperatures from the sensors on the SA and the CAL
Commissioning Phase Activities – In-Orbit Spectral Characterization

- Using on-board calibration sources (LEDs)
  - Pre- and post-launch characteristics
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- Using atmospheric absorption features
  - SMILE pre- and post-launch

![Diagram of spectral characteristics](image)
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- Using on-board calibration sources (LEDs)
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  - Incl. temperature stability & other HK / telemetry data

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

No official product! Work in progress!

Database used:
- EC EOSG Earth databases (clear outliers discarded)
- L1B processing of 05.10.2018
- Intermediate product (no smile & rolling shutter correction applied)
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
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[Diagram showing spectral reflectance data with labels: "No official product! Work in progress!"]

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

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

Preliminary
Commissioning Phase Activities – In-Orbit Radiometric Characterization

![Graph showing BOA Reflectance "Pinnacles" and Best Fitting Location]

TC-0001: DESIS-G2019010601

(SW-Binning)

TC-0002: DESIS-G2019010901

M1-2019-01-09-03-54-19-01-01.des
(HW-Binning)

Preliminary
Commissioning Phase Activities – Processing Chain Validation

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

Example: Fiji

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

Fig. excluded

No official product! Work in progress!
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