CEOS WGCdV IVOS 31, Perth

EnMAP Status Update

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EnMAP – mission status overview

**Space Segment / Instruments**
- VNIR FM: camera integrated, fine aligned and characterized
- SWIR FM:
  - 1st: environmental tested, integration started
  - 2nd: environmental testing started
- OBCA FM - 2 integrating spheres: integrated & characterized @ PTB
  - full aperture solar diffuser: BRDF to be characterized

**Ground Segment**
- Phase D1 (TVVRR) successfully completed in Dec. 2018, re-tests to be completed by this week
- D2 (ITVV) interface tests & system-wide tests done by July / Dec. 2019

**Overall**
- Launch foreseen Dec. 2020
EnMAP – linkage to ARD / CARD4L

CARD4L for EnMAP L2A products
- Self assessment: „Threshold“ will be achieved with foreseen metadata update
- Review for compliance ?

### GENERAL METADATA

<table>
<thead>
<tr>
<th>#</th>
<th>Item</th>
<th>Threshold (minimum requirements)</th>
<th>COMMENTS BY PCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Traceability</td>
<td>Not required</td>
<td></td>
</tr>
</tbody>
</table>

### RADIOMETRIC AND ATMOSPHERIC CORRECTIONS

<table>
<thead>
<tr>
<th>Item</th>
<th>Threshold (minimum requirements)</th>
<th>COMMENTS BY PCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Measurement</td>
<td>Pixel values that are expressed as a measurement of</td>
</tr>
</tbody>
</table>

### PER-PIXEL METADATA

<table>
<thead>
<tr>
<th>Item</th>
<th>Threshold (minimum requirements)</th>
<th>COMMENTS BY PCV</th>
<th>Target (desired) requirements</th>
<th>COMMENTS BY PCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Metadata machine readability</td>
<td>ok</td>
<td>As threshold, but metadata is formatted in accordance with ISO 19115-2.</td>
<td>ok, as ISO 19115 (plus ISO 19119) are INSPIRE, so conformity is given</td>
</tr>
<tr>
<td>2.2</td>
<td>No data</td>
<td>ok</td>
<td>As threshold.</td>
<td>ok</td>
</tr>
<tr>
<td>2.3</td>
<td>Incomplete testing</td>
<td>ok</td>
<td>The metadata identifies which tests have, and have not, been successfully completed.</td>
<td>ok (could be added by extending the quality flags)</td>
</tr>
<tr>
<td>2.4</td>
<td>Saturation</td>
<td>ok</td>
<td>Metadata indicates which pixels are saturated for each spectral band.</td>
<td>can be easily done. But this would imply that the quality quicklook will largely increase in size.</td>
</tr>
<tr>
<td>2.5</td>
<td>Cloud</td>
<td>ok</td>
<td>As threshold, with referencing (DOI) to a peer-reviewed algorithm for cloud detection.</td>
<td>can be done - currently no publication available for &quot;land&quot;</td>
</tr>
<tr>
<td>2.6</td>
<td>Cloud shadow</td>
<td>ok</td>
<td>As threshold, with referencing (DOI) to a peer-reviewed algorithm for cloud shadow detection.</td>
<td>can be done - currently no publication available for &quot;land&quot;</td>
</tr>
<tr>
<td>2.7</td>
<td>Land/water mask</td>
<td>ok</td>
<td>The metadata indicates whether a pixel is assessed as being land or water.</td>
<td>can be done - currently no publication available for &quot;land&quot;</td>
</tr>
<tr>
<td>2.8</td>
<td>Snow/ice mask</td>
<td>ok</td>
<td>The metadata indicates whether a pixel is assessed as being snow/ice or not.</td>
<td>can be done - but only possible when DEM is provided and the accuracy will depend on the DEM itself.</td>
</tr>
<tr>
<td>2.9</td>
<td>Terrain shadow mask</td>
<td>ok</td>
<td>The metadata indicates pixels that are not directly illuminated due to terrain shadowing</td>
<td>can be done - but only possible when DEM is provided and the accuracy will depend on the DEM itself.</td>
</tr>
<tr>
<td>2.10</td>
<td>Terrain occlusion</td>
<td>ok</td>
<td>The metadata indicates pixels that are not visible to the sensor due to terrain occlusion during off-nadir viewing.</td>
<td>currently not possible.</td>
</tr>
<tr>
<td>2.11</td>
<td>Illumination and viewing geometry</td>
<td>ok</td>
<td>The solar incidence and sensor viewing angles are identified for each pixel, including coefficients used for terrain illumination correction.</td>
<td>currently, we are providing these values for the corners and the center of the scene. Could be extended.</td>
</tr>
</tbody>
</table>
## EnMAP Mission

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral Accuracy</td>
<td>0.5 nm (VNIR); 1.0 nm (SWIR)</td>
</tr>
<tr>
<td>Radiometric Accuracy</td>
<td>5.0% (absolute); 2.5% (relative)</td>
</tr>
<tr>
<td>Geometric Accuracy</td>
<td>100 m (30 m with control points)</td>
</tr>
</tbody>
</table>

### Satellite

- **Ground Track**: 900 nm < $\lambda$ < 2450 nm
  - (135 spectral bands, 10 nm)
  - SNR > 150 @ 2200 nm

- **Pointing Range**: $\pm$ 30° off-nadir

- **Swath**: 30 km wide

### VNIR

- **420 nm < $\lambda$ < 1000 nm**
  - (95 spectral bands, 6.5 nm)
  - SNR > 500 @ 495 nm

### SWIR

- **900 nm < $\lambda$ < 2450 nm**
  - (135 spectral bands, 10 nm)
  - SNR > 150 @ 2200 nm

### Ground Pixel Size

- **30 m x 30 m**

### Covered Area/Day

- **5000 km x 30 km**

### On-Board Calibration Equipment

- **Orbit**: Sun-synchronous, 11:00, 398/27
- **Launch**: 12/2020

Source: DLR, OHB
EnMAP On-Board Calibration Equipment

- **Main Sphere (White Spectralon)**
  - Halogen Lamps (Redundant IPU)
  - Redundant LED
  - Nominal Photodiode
  - Halogen Lamps (Nominal IPU)
  - Nominal LED
  - CAL. OPTICS

- **Doped Spectralon**
  - Halogen Lamps (Redundant IPU)
  - Nominal Photodiode
  - Halogen Lamps (Nominal IPU)
  - NOMINAL LED

- **Slit Assembly**
  - SHUTTER/CALIBRATION MECHANISM

- **Other components**
  - Sun
  - Earth
  - Diffuser Protection
  - Telescope Baffle

- **EnMAP Cover Structure**
  - EnMAP Imager
  - Diffuser Assembly
EnMAP On-Board Calibration Equipment

- Closed Shutter [dark]
- Deep Space [dark]
- Sun Calibration [absolute radiometric]
- **White Spectralon** [relative radiometric]
- Doped Spectralon [absolute spectral]
- Focal Plane LED [linearity]

Source: OHB
EnMAP White Spectralon [Pre-Flight]

- 5 (+1) Illumination levels
- 5 Field positions (homog.)
  - 0 mm, ±6 mm, ±11.5 mm
- 4 Light sources
  - Nom. (work & spare) / Red.
- 3 Temperatures (stabil.)
  - 20° C, 21° C, 22° C (&air/vac.)
- Characterized using
  - Vac. Fourier-transf. spectrom.
  - 3 beam-splitter detectors
  - 2 radiative transfer standards

Source: PTB, OHB
EnMAP White Spectralon [In-Flight] [Measurement]

- **White Spectralon** [relative radiometric]
  - Weekly
  - Full optical system: Not telesc.
  - Aging known: Medium
  - For Calibration Coefficients: No

- **Sun Calibration** [absolute radiometric]
  - Monthly (or less)
  - Full optical system: Yes
  - Aging known: High
  - For Calibration Coefficients: Yes

Source: OHB
dark between levels not considered
## EnMAP In-Flight Calibration Frequencies

<table>
<thead>
<tr>
<th>Calibration type</th>
<th>Time</th>
<th>Frames</th>
<th>Data Volume</th>
<th>Expected Amount of Measurements</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>Dark (shutter)</td>
<td>23 sec</td>
<td>$2 \times 128$ (2 gains)</td>
<td>0.27 GB</td>
<td>~ 36500</td>
<td>each datatake</td>
</tr>
<tr>
<td>Dark (deep space)</td>
<td>30 sec</td>
<td>$1 \times 1024$ (2 gains)</td>
<td>1.38 GB</td>
<td>~ 20</td>
<td>every 4 months</td>
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<tr>
<td>Relative radiance calibration</td>
<td>17 min 13 sec</td>
<td>$1 \times 512$ (5 steps)</td>
<td>1.66 GB</td>
<td>~ 260</td>
<td>weekly</td>
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<tr>
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<td>$2 \times 1024$</td>
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<td>~ 60</td>
<td>monthly</td>
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<tr>
<td>Spectral calibration</td>
<td>5 min 13 sec</td>
<td>$1 \times 1024$</td>
<td>0.83 GB</td>
<td>~ 120</td>
<td>every 2 weeks</td>
</tr>
<tr>
<td>Linearity measurement</td>
<td>&lt; 5 min</td>
<td>$2 \times 128 \times 40$ (2 gains)</td>
<td>5.8 GB</td>
<td>~ 60</td>
<td>monthly</td>
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in total: ~ 11 TB
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EnMAP In-Flight Calibration – Life-Limited Item

\[ \Delta = \| \text{DN}_{\text{meas}} - \text{DN}_{\text{ref}} \|_2^{\text{min-max}} \]

- **max. trend line:** \( m_{\text{max}} \)
- **average trend line:** \( m_{\text{av}} \)

new average trend line after calibration measurement at time \( t_n \) to determine current calibration table generation time in order to decide stop of data delivery or not

\[ \Delta t: \text{estimated time to generate calibration table (5-7 days incl. downlink)} \]

- **Commisioning phase**
  - \( t < t_{n+1} \)
  - \( t = t_{n+1} \)
Dead Pixels Map \rightarrow Saturated and Dead Pixels Flagging

Non-Linearity LUT \rightarrow Non-Linearity Correction

Closed Shutter Measurements

Stray-Light Matrix \rightarrow Stray-Light Correction

used for: Dead Pixels Map, Signal-to-Noise Information

Relative Radiometric Reference

(1st: based on (radiometric) pre-flight calibration campaign)

Averaging for each Illumination Level

Dark Signal Correction

Gain Matching

Saturated and Dead Pixels Flagging

[In-Flight] [Calibration]

[White Spectralon] [Calibration]

Calibration Coefficients

based on Sun Calibration

Relative Radiometric Reference

Update Relative Radiometric Reference

OK

not OK

Repeatable: Yes

Repeatable: No

Request for (repeated) White Spectralon or Sun Calibration

Source: DLR, OHB
Dead Pixels Map \(\rightarrow\) Saturated and Dead Pixels Flagging

Non-Linearity LUT \(\rightarrow\) Non-Linearity Correction

Offset Value \(\rightarrow\) Shutter Thermal Emission Correction for SWIR

Closed Shutter Measurements \(\rightarrow\) Dark Signal Correction

Gain Matching \(\rightarrow\) Stray-Light Correction

Stray-Light Matrix \(\rightarrow\) Spectral Referencing

Spectral Calibration File \(\rightarrow\) Conversion to At-Sensor Radiances

Calibration Coefficients

Data Quality

Digital Number [instrument]

mW·cm\(^{-2}\)·sr\(^{-1}\)·µm\(^{-1}\) [at-sensor radiances]

e.g., spaceborne ALOS/AVNIR-2

Source: DLR, ESA, JAXA, OHB
**Ground Segment**

**EnMAP**

- **White Spectralon**
- **[In-Flight]**
- **Data Quality**

**Suspicious pixel at band 31**

Difference of approx. 30% (in radiance) to spatially and spectrally neighboring detector elements

Normalized detector map of one scene, mean DN for every band and every across-track detector element

- **Automated processes for each product**
  - e.g. striping artefacts
  - meta and image data
- **Interactive procedures for selected products**
  - e.g. cloud classification
  - reports
- **Independent vicarious validation**

Source: DLR

**Earth Observation**

**Hyperspectral imager**

• Automated processes for each product
  - e.g. striping artefacts
  - meta and image data
• Interactive procedures for selected products
  - e.g. cloud classification
  - reports
• Independent vicarious validation

Source: DLR

e.g., airborne HySpex
EnMAP Summary on Radiometric...