EnMAP Mission Status

Emiliano Carmona for the EnMAP Ground Segment Team
EnMAP launched on 1\textsuperscript{st} April 2022 on a SpaceX Falcon 9 rocket from Cape Canaveral.

- Precise launch and separation. First contact ~30 minutes later.
- Commissioning Phase in progress.
### Instruments Parameters

<table>
<thead>
<tr>
<th>Parameters</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>

### Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit type</td>
<td>Sun-synchronous</td>
</tr>
<tr>
<td>Orbit height</td>
<td>653 km</td>
</tr>
<tr>
<td>Orbit Period</td>
<td>97 minutes</td>
</tr>
<tr>
<td>Repeat Cycle</td>
<td>27 days (398 orbits)</td>
</tr>
</tbody>
</table>

### SWIR
- \(900 \text{ nm} < \lambda < 2450 \text{ nm}\)
- (135 spectral bands, 10 nm)
- SNR > 150 @ 2200 nm

### VNIR
- \(420 \text{ nm} < \lambda < 1000 \text{ nm}\)
- (95 spectral bands, 6.5 nm)
- SNR > 500 @ 495 nm

Source: DLR, OHB
EnMAP – Hyperspectral Instrument

- Three mirror anastigmatic telescope ±1.3° across track
- Independent VNIR and SWIR spectrometers
- Curved prism design
- 2D focal planes acquiring 14 bit resolution data at 230 Hz

EnMAP – Processing Workflow and user products

- In-flight calibration observations are processed to generate updated calibration tables

- Three level of users products can be ordered (L1B / L1C / L2A) from Earth observations

- User products annotated with quality information (metadata) plus periodic quality and validation reports

- Quality Control (GS) and Independent Validation (GFZ) performed on user products

Source: DLR
EnMAP – First Image data

27. April 2022
09:29 (UTC)

Source: DLR

red: 637 nm
green: 547 nm
blue: 461 nm

red: 859 nm
green: 650 nm
blue: 547 nm

red: 2176 nm
green: 1633 nm
blue: 1213 nm
EnMAP – First Image data

Spectral Profiles (Top-Of-Atmosphere Radiance)

red: 637 nm
green: 547 nm
blue: 461 nm

red: 859 nm
green: 650 nm
blue: 547 nm

red: 2176 nm
green: 1633 nm
blue: 1213 nm

Source: DLR
EnMAP – First Image data

- Red: 637 nm
- Green: 547 nm
- Blue: 461 nm

- Red: 859 nm
- Green: 650 nm
- Blue: 547 nm

- Red: 2176 nm
- Green: 1633 nm
- Blue: 1213 nm

Source: DLR
Distribution of chlorophyll-a concentration at water surface. Indicator for algal biomass in the upper water layer

Source: DLR
EnMAP – More Images

Oberpfaffenhofen (Ger)
12. June 2022

Chile
27. July 2022

Baltoro (PAK)
28. June 2022

red: 863 nm
green: 647 nm
blue: 550 nm

8. June 2022
19:05 (UTC)

SWIR principal components (7, 5, 6)
EnMAP – On-Board Calibration

- Closed Shutter [dark]
  - Deep Space [dark] →
- Sun Calibration [absolute radiometric]
  - White Spectralon [relative radiometric] →
- Doped Spectralon [absolute spectral]
  - Focal Plane LED [linearity] →
EnMAP – On-Board Calibration

• Closed Shutter [dark]
  • Deep Space [dark] →

• Sun Calibration [absolute radiometric]
  • White Spectralon [relative radiometric] →

• Doped Spectralon [absolute spectral]
  • Focal Plane LED [linearity] →
EnMAP – On-Board Calibration Equipment

- White Spectralon [relative radiometric]
- Doped Spectralon [absolute spectral]
- Focal Plane LED [linearity]

Source: OHB
EnMAP – On-Board Calibration Equipment

Source: OHB
EnMAP – Lamp and Spectral Calibrations

Lamp calibration: 5 intensity levels

Spectral calibration:

VNIR
req. spectral accuracy:
0.5 nm for VNIR
1.0 nm for SWIR
spectral sampling distance:
4.8-8.2 nm
for VNIR (450-1000 nm)
7.4-12.0 nm
for SWIR (900-2450 nm)

Source: OHB, DLR
EnMAP – Lamp and Spectral Calibration

Constant spectral shift for 1st spectral calibration of -0.47 spectral sampling distance* (expected due to gravity release)

Spectral shift between 1st & 2nd spectral calibration of 0.002 SSD* (expected stability)

Confirmed vicariously:

Source: OHB, DLR
EnMAP – Sun and Linearity Calibrations

Absolute calibration from Sun Measurement (also RNU correction and gain matching)

Requirement radiometric accuracy: 5%

\[
\Delta = \| \text{DN}_{\text{meas}} - \text{DN}_{\text{ref}} \|_{2}^{\text{min-max}}
\]

max. trend line: \( \mathbf{m}_{\text{max}} \)

\[ \text{Comissioning phase} \quad t_{n+1} \quad t < t_{n+1} \quad t = t_{n+1} \]

- Linearity Calibration
  - Monthly
  - Only sensor
  - Only for monitoring

Source: OHB, DLR
EnMAP – Sun and Linearity Calibrations

Absolute calibration from Sun Measurement (also RNU correction and gain matching)

Requirements for radiometric accuracy: 5%

SWIR detector very stable after a few weeks in operation

VNIR detector shows higher variability with time

Preliminary results show no problem to reach radiometric requirement

- Linearity Calibration
  - Monthly
  - Only sensor
  - Only for monitoring

Source: OHB, DLR
EnMAP – Radiometric Calibration (RNU)

Corrected using pre-flight

Corrected using in-flight

PICS Algeria 3
red: 625 nm
green: 508 nm
blue: 456 nm
EnMAP – Geometry Calibration

• Like spectral and radiometric characterization, extensive geometric pre-flight characterization in laboratory
• After launch, vibrations and gravitational release demand monitoring of geometric performance and the possibility of geometric calibration
• Boresight misalignment angles can be computed on Earth observations based on automatically extracted GCPs on EnMAP scenes and reference Sentinel-2 scenes
• Requirements:
  • Geolocation accuracy with GCPs at nadir look <1 pixel (30 m) w.r.t. reference images, <100 m without GCPs
  • VNIR / SWIR co-registration < 0.2 pixel

Source: DLR
EnMAP – Geolocation Accuracy

Palm Islands, UAE

23.2° westwards tilt
11. June 2022 07:23 (UTC)

27.7° eastwards tilt
12. June 2022 07:48 (UTC)
EnMAP – Geolocation Accuracy

• EnMAP (using matching) to Sentinel-2 reference (1 tile)

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>X [pixel]</th>
<th>Y [pixel]</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.06.2022, 07:23</td>
<td>0.10</td>
<td>-0.64</td>
</tr>
<tr>
<td>Mean Deviation</td>
<td>0.24</td>
<td>0.70</td>
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<tr>
<td>12.06.2022, 07:48</td>
<td>0.26</td>
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<tr>
<td>Mean Deviation</td>
<td>0.36</td>
<td>0.53</td>
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</table>

• EnMAP processing (3 tiles)

<table>
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<th>X [pixel]</th>
<th>Y [pixel]</th>
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<tbody>
<tr>
<td>11.06.2022, 07:23</td>
<td>0.1</td>
<td>0.6</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.1</td>
<td>0.6</td>
</tr>
<tr>
<td>12.06.2022, 07:48</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.3</td>
<td>0.5</td>
</tr>
</tbody>
</table>
EnMAP – Product annotation

- EnMAP Products conformant with CEOS-ARD for LAND (CARD4L) at Threshold Specification

- CEOS Analysis Ready Data (CEOS-ARD) are satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with minimum of additional user effort and interoperability both through time and with other datasets.
Thanks!

Funded by

Federal Ministry for Economic Affairs and Climate Action

Source: DLR