THE ENMAP MISSION: STATUS OF ACQUISITIONS AND DATA ACCESS

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ABSTRACT

The hyperspectral mission EnMAP has been launched in April 2022 delivering data products with a quality exceeding the expectations. There were challenges in the context of planning and processing the data, especially serving the demand over regions with many acquisition requests. The EnMAP Ground Segment provides the infrastructure responsible for the operation of the mission and it acts as the interface between the users and the satellite. In this contribution we present the status of the EnMAP mission and show how the adoptions accomplished improved the mission's performance over the years. Among others this includes the tasking of the instrument such as the background and the foreground missions accompanied by the enabling of back-to-back imaging, and the incorporation of the additional ground station of Inuvik. It further is shown how the availability of data for the User Community has improved over the years and shows the current possibilities to get access to EnMAP data.

Index Terms— Earth Observation, Hyperspectral, Spaceborne Mission, Ground Segment, Operations

1. INTRODUCTION

EnMAP (Environmental Mapping and Analysis Program, enmap.org) [1] is a scientific mission for measuring, deriving, and analyzing diagnostic parameters, which describe vital processes on the Earth's surface encompassing agriculture, forestry, soil and geological environments, as well as coastal zones and inland waters. It was designed with the aim of providing the scientific community with high-quality hyperspectral data from space.

EnMAP was successfully launched on April 1st, 2022, from Cape Canaveral aboard a Falcon 9 rocket. The two spectrometers (VNIR and SWIR) aboard can image the Earth with 224 bands in the wavelength range 420 − 2450 nm using a push-broom configuration with a dual-spectrometer. The satellite follows a Sun-synchronous orbit with a 27-day repetition cycle. It has a revisit capability of less than 4 days for any point on the Earth's surface due to a possible tilting angle of ±30 deg in the across-track direction. The spatial resolution of the instrument is 30m×30m, covering a swath width of 30 km and a swath length varying between 30 and 990 km. Each 30kmx30km portion is called tile in the following.

EnMAP is a mission allowing user-driven tasking for targeted site acquisitions. This is complemented by the foreground mission and campaign support implementing highest-priority acquisitions based on user feedback to address the strong demand in Germany and Europe with long datatakes of ~1000km. The background mission implements lower-priority acquisitions based on relevant target sites to fill the mission's capacity and enhance global coverage.

In this work the improvements of the Ground Segment (jointly decided with the Space Agency at DLR) regarding availability of acquisitions and mission exploitation are shown. This includes the successful incorporation of an additional ground station, the introduction of the foreground mission, the background mission and back-to-back-imaging. Their implication on key parameters of the mission is shown (Section 2). Then the access to EnMAP data over the different User Portals is discussed showing the differences of the available data products (Section 3).

2. DATA ACQUISITIONS

The goal of providing high quality hyperspectral data (see e.g. [9] [10]) has been reached. This partly is due to regular processor and calibration updates by the Ground Segment.

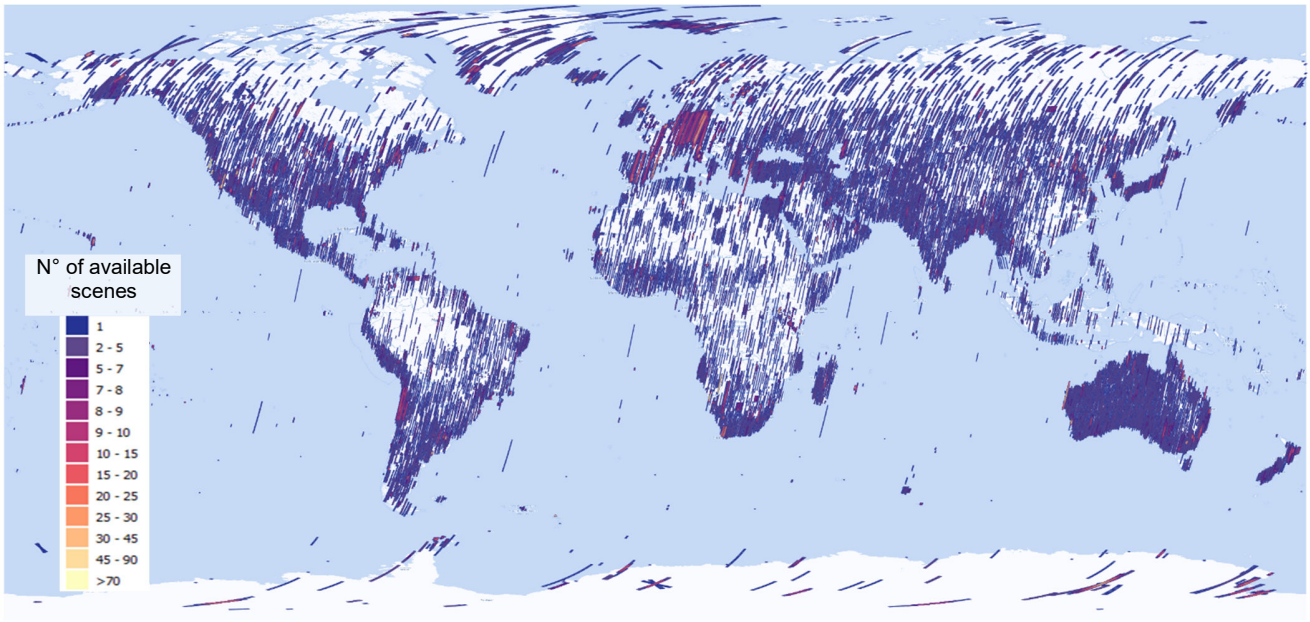


Fig. 1: Datatakes since launch until 30th of June 2026.

Furthermore, actions were taken to identify problems and minimize their impact on the mission. These are discussed in this section.

When discussing the impact of the adaptions of the mission since launch, the spatial (Fig. 1) as well as the temporal (Fig. 2) distribution of datatakes has to be considered.
The absolute and relative numbers of data collected over the past four years is shown in Table I.

TABLE I: NUMBER OF DAYS, ACQUISITIONS, TILES, TILES/ACQUISITION AND TILES/DAY.

Year	#days	#acq.	#tiles	Øtiles/ acq.	Øtiles/day
2022	181	2841	16926	5.95	93.54
2023	296	4622	30249	6.54	102.22
2024	347	6607	70016	10.60	201.78
2025	341	7452	76400	10.25	224.05
2026	176	2648	29901	11.29	169.89
Total	1341	24170	223505	9.25	166.67

Until June 30th 2026 the EnMAP Mission collected over 223505 30km x 30km tiles of the Earth's surface, distributed over 24170 datatakes, covering all parts of the world as shown in Fig. 1, some of them visited over 25 times. If we look at the availability, it is worth to consider Table 1, where the number of acquisition days, number of acquisitions, tiles per year, the average per day, and the number of datatakes are displayed.

The introduction of all the below measures allowed the increase of the number of acquisitions significantly after 2023 from an average of around 100 products per day in 2023 to over 200 in 2024, which even exceeds the mission's requirements of ~167 products per day.

One cause for the significant increase of the acquisitions can also be seen in the table: the extension of the length of the datatakes from ~6 in 2023 to over 11 in 2025.

This is due to different measures in the Ground Segment discussed in the following: at the beginning of the mission it turned out that the average user requested observations only covering 2.4 tiles (~72km), so that other user requests could not be considered in the same orbit, leading to a mutual blocking situation over areas with high demand (especially over Europe).

As a consequence, the foreground mission was introduced in Q1/2024. It consists of high priority observations, originally over Germany, later extended to Southern Europe, resulting in long stripes of acquired data. An online map with the status of (planned and new) acquisitions is available at [8].

Besides the Foreground Mission, the minimum swath length was changed from 30 km (1 tile) to 90 km (3 tiles) for new observation requests. This change increased the total data volume.

In order to discuss another improvement, the acquisition strategy has to be understood: the acquisition requests posted timeline by the Mission Planning System, which arranges

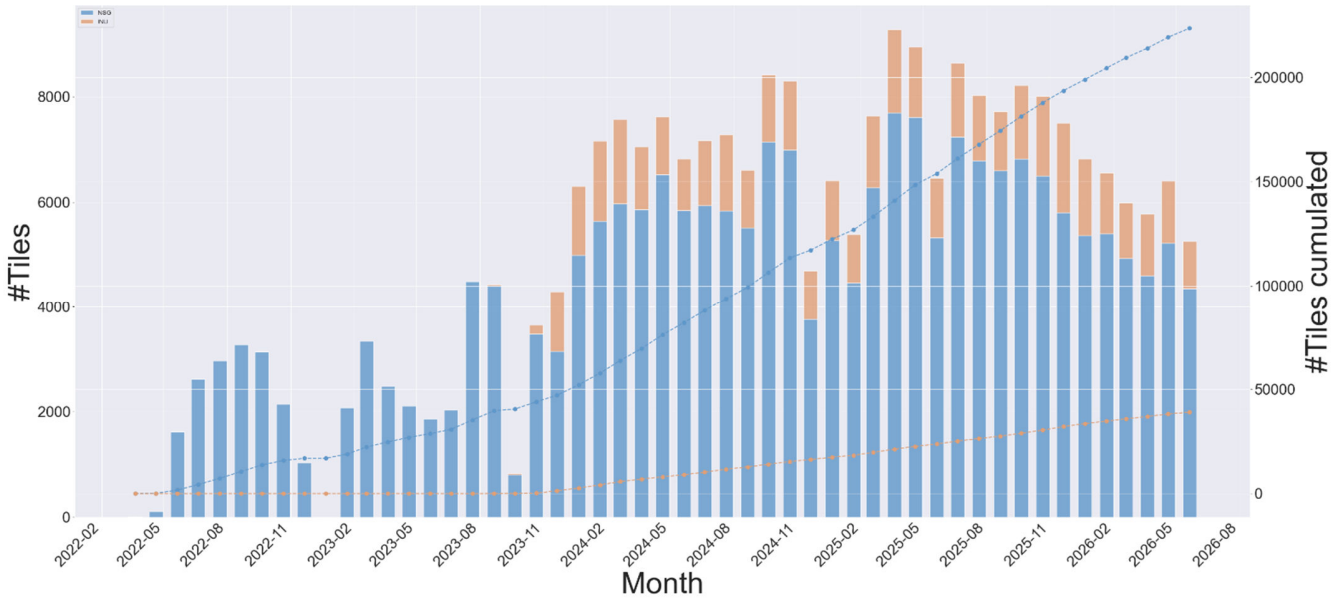


Fig. 2: Tiles received by Ground Stations Inuvik (orange) and Neustrelitz (blue) from Launch on 2022-04-01 until 2026-06-30.

observation requests, data downlinks, and in the Instrument Planning Portal are prioritized and there is no guarantee for an execution. The orders are integrated in a other planned activities in a conflict-free timeline that does not violate any resource constraints. The time elapsing between two observations used to be ~400s, which resulted in a distance of two subsequent targets of ~2750 km on ground. This restriction was overcome by the introduction of back-to-back imaging. This mode allows up to three image acquisitions within one attitude maneuver allowing the distance between consecutive acquisitions to be reduced to 105 seconds (~790 km on ground).

Another strategy exploiting full acquisition capacity of the satellite is the background mission which acquires data of over 600 sites selected by the science team.

The decline of the average number of tiles acquired per day in 2026 is due to the implementation of an enhanced cloud prediction algorithm. This resulted in the acquisition of less scenes containing clouds.

Figure 2 shows the temporal distribution of acquisitions from launch until June 30th, 2026. The mission has experienced a few outages caused by technical difficulties, where no observations could be performed. All outages have been solved with no impact on mission requirements, lifetime or redundancies.

Inuvik was incorporated (orange bars as opposed to the blue bars for Neustrelitz) as second operational ground station for downlinking of data succeeded in Q4/2023. Now Inuvik is accounting for ~22 percent of the ~183000 tiles operationally received in this period since its incorporation. This results in a reduction of the signal response time, an increase of acquisition possibilities, higher-frequent health-monitoring of the satellite and more flexible up- and downlink.

Even though none of the above measurements can't be identified as the single improvement of the EnMAP mission, their interaction shows a significant improvement in production of scenes, as it can also be depicted from Fig. 2.

Besides the measurements taken to improve the availability of acquisitions to scientists, the Ground Segment has also invested considerable effort in improving its processing software and calibration procedures. Accounting for these changes, the Ground Segment has already reprocessed all datasets twice.

3. DATA ACCESS

By June 30th 2026 a total of more than 5700 active users from 134 countries worldwide have registered to work with EnMAP data. A total of over 600 reviewed and released proposals show the interest to get EnMAP data.
The proposals indicate that the main areas of interest are vegetation, geology/soil and water applications.

EnMAP data is publicly available for research institutions and companies and can be ordered after three different levels

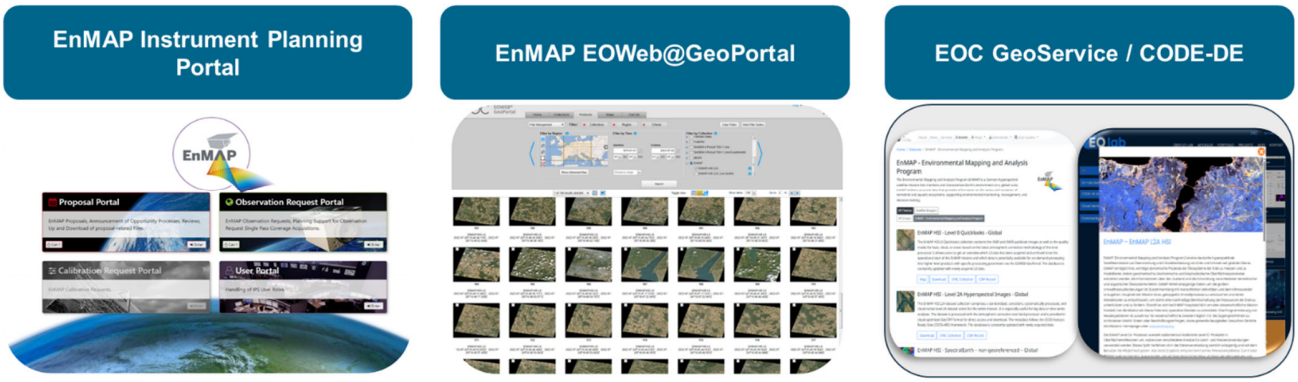


Fig. 3: Data Access Portals of the EnMAP Mission

of processing and with different processing parameters selectable by the users when ordering a product. There are three processing levels following the ESA specification available:

- Level 1B (L1B): radiometrically corrected Top-Of-Atmosphere (TOA) radiance in sensor geometry,
- Level 1C (L1C): L1B products orthorectified to a user selected map projection and resampling model,
- Level 2A (L2A): atmospherically corrected Bottom-Of-Atmosphere (BOA) reflectance. The users can select algorithms for processing land and water and two different water output products: water leaving reflectance and underwater irradiance reflectance. L2A land products processed with the default parameters are compliant with CEOS ARD [2].

There are different ways important to access EnMAP data: (in the above listed different product levels):

- The EnMAP Instrument Planning Portal [4]
- The EnMAP EOWeb GeoPortal [5]
- The EOC GeoService [6]
- The CODE-DE-Lab [7]

In the Instrument Planning Portal [4] users can register and use the following services:

- Proposal handling: users can submit the observation request proposals using this tool (a necessary condition to submit tasking orders to EnMAP).
- Instrument Planning: users with approved proposals can task EnMAP and provide a temporal observation window and select the geographical area of interest.

The EnMAP EOWEB-Portal (EOWEB) provides access to the the German Satellite Data Archive where EnMAP L0 are long-term archived.

EnMAP products can be searched and selected in this service using the user interface with different selection filters. The L1B/L1C/L2A products that can be downloaded from EOWEB do not exist prior to being ordered.

These data are generated on demand based on the user's request and the processing parameters that the user can specify. This allows to offer products tailored to the specific needs of the different applications. The file format can be selected for all products while other options like resampling method and geographic projection are only available on L1C and L2A products. The L2A product contains further specific options for the atmospheric correction that include correction over land or over water (with two different options for the type of output water products) and the possibility to adjust other parameters of the atmospheric correction like the season, ozone column value or the possibility to apply specific correction for cirrus and haze in the image.

There is also the possibility to download L2A data which is CEOS-ARD-compliant (at threshold specification) at

- The EOC GeoService [6], or
- CODE-DE-Lab [7]

The differences between EOWeb and GeoService / CODE-DE-Lab listed in Table II.

This is flanked by the EnMAP web portal [8] on which information updates about the status of the mission are announced and the mission quarterly reports are published. These reports offer many details on different aspects of the mission, calibration and quality of the data products. At the EnMAP web portal users can also find all the information about the Ground Segment services, data product formats and algorithms used during data processing.

TABLE II: DIFFERENCES EOWEB / GEOSERVICE / CODE-DE

EOWeb	Category	GeoService / CODE-DE-Lab
Obtained after registration on EnMAP IPS portal	**Access**	With IPS credentials or new registration
EnMAP GS	**Product Provider**	EnMAP GS
All archived data	**Availability**	All archived data
ftp after on-demand-processing (hours later)	**Data Download**	Direct download
20 products per order, up to 5000	**Download Volume**	Up to 5000
Latest version always	**Processor Version**	Different versions (depending on product generation date)
User selectable	**Processing Options**	Fixed, L2A-land products are CEOS verified ARD
L1B, L1C, L2A	**Product Levels**	Only L2A
Yes	**Water Processing**	No
Geotiff, BIL, BIP, BSQ, JPEG2000	**Product Format**	Cloud optimized geotiff (cog)
No	**API**	Yes, STAC support

4. SUMMARY AND OUTLOOK

In this contribution the up-to-date status in terms of data acquisitions and data access of the EnMAP mission has been shown. The status of the acquisitions has been displayed with their spatial and temporal aspects considering the improvements in the Ground Segment. The problems caused by a mutual blocking of acquisitions over certain areas could be relaxed by introduction of the foreground mission accompanied by back-to-back-imaging. The background mission enables to exploit the mission's full capacity. Furthermore, the successful integration of the additional ground station Inuvik has been demonstrated. A further analysis of the acquisitions' metadata will improve the knowledge of the data acquired and is in preparation.

An extension of the EnMAP mission from 2027 until 2032 is currently under consideration. This would include several potential upgrades (among others) to the systems mentioned above: the complete archive could be reprocessed allowing a direct download of L1B, L1C, L2 ARD products and the tasking and on-demand processing user portals could be updated.

5. ACKNOWLEDGEMENTS

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