Organisation und Validierung der Requirements im Bodensegment für die hyperspektrale Satellitenmission EnMAP

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EnMAP Ground Segment Team

EOC – Deutsches Fernerkundungsdatenzentrum

Deutsches Zentrum für Luft- und Raumfahrt e.V.
Contents

• Mission Overview
• Development Model
  • Requirements
  • Product Tree
  • Interfaces
• Scenarios
• Verification and Validation
EnMAP – Mission Objectives

**Environmental Mapping and Analysis Program**: German hyperspectral satellite mission

Main objective: investigation of a wide range of ecosystem parameters comprising

- Agriculture
- Forestry
- Land Degradation
- Geology
- Coastal Zones, inland waters
EnMAP – Mission Parameters

Pushbroom-type HSI:
- 228 spectral bands
- Sampling VNIR 6.5 nm, SWIR 10 nm
- Signal-to-Noise-Ratio
  - VNIR > 500 @ 495 nm
  - SWIR > 150 @ 2200 nm
- Radiometric quantification 14 bit

SWIR FOV
900 nm < \( \lambda \) < 2450 nm
(134 spectral bands)

VNIR FOV
420 nm < \( \lambda \) < 1000 nm
(94 spectral bands)

FOV Separation:
600 m

Ground Pixel:
30 m x 30 m

Satellite
Ground Track

Pointing Range:
+/- 30° off-nadir

Swath: 30 km wide
EnMAP Satellite Parameters

- Total Weight: ~ 870 kg
- Total Size: ~ 3.1 m x 1.7 m x 1.3 m
- 512 Gbit mass memory
- 1000 km/Orbit, 5000 km/Day
- 320 Mbit/s X-Band data downlink
- Lifetime in Orbit: > 5 years

EnMAP Team

Mission Management – DLR Space Agency

Principal Investigator – GFZ Potsdam

Space Segment Project –
  • Instrument: Kayser-Threde GmbH
  • Bus: OHB System AG

Ground Segment Project –
  DLR – EOC and GSOC
  Berlin, Neustrelitz und Oberpfaffenhofen
EnMAP Ground Segment - Tasks

Planning and Operation

Communication

Satellite

Processing and Archiving
## Project Phasing and Planning

### Ground Segment

<table>
<thead>
<tr>
<th>Phase</th>
<th>Objective</th>
<th>Activities</th>
<th>Reviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 0/A 2005</td>
<td>Mission Analysis and Feasibility</td>
<td>Identify characteristics, constraints, concepts. Assess feasibility.</td>
<td>GSSRR, GSCKM</td>
</tr>
<tr>
<td>Phase B 11/06-03/08</td>
<td>Preliminary Design</td>
<td>Define requirements on GS and establish GS baseline.</td>
<td>GSPDR</td>
</tr>
<tr>
<td>Phase C 10/08-08/10</td>
<td>Detailed Design</td>
<td>Complete GS Design to configuration item level and start implementation.</td>
<td>GSCKM</td>
</tr>
<tr>
<td>Phase D / Production and Validation 08/2010 – 08/2014</td>
<td>Production Phase D1</td>
<td>Procure GS systems, develop software and/or upgrade and modify existing facilities.</td>
<td>GSTVVRR, GSTVVR</td>
</tr>
<tr>
<td></td>
<td>ITVV Phase D2</td>
<td>Integrate, verify, and validate GS systems. (includes preliminary validation of mission data)</td>
<td>GSCDR</td>
</tr>
<tr>
<td></td>
<td>Operational Validation Phase D3</td>
<td>Train people and validate full Ground Segment (includes people and mission data).</td>
<td>VOVR, ORR, FQR</td>
</tr>
<tr>
<td>Phase E / Operations 08/2014 – 10/2019</td>
<td>LEOP and Commissioning Phase E1</td>
<td>Acquire mission orbit and configuration and qualify space segment.</td>
<td>IOOR, ELR</td>
</tr>
<tr>
<td></td>
<td>Routine Operations Phase E2</td>
<td>Operate and exploit mission in-orbit</td>
<td></td>
</tr>
<tr>
<td>Phase F 2019</td>
<td>Disposal</td>
<td>Space and Ground Segment Disposal</td>
<td></td>
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</tbody>
</table>


- **GS-TVVRR**: 2013-01-25
- **Launch**: 2014-10-06
- **GS-TVVRR**: 2013-11-15
- **FQR**: 2015-01-12
- **OVRR**: 2013-11-15
- **IOOR**: annually Oct starting ’15
- **ORR**: 2014-08-14
- **ELR**: 2019-10-18
- **MCOR**: 2019-11-18

**European Cooperation**

**ECSS**

**FOR SPACE STANDARDIZATION**

**DLR**
Development Model

Ground Segment Requirement

Subsystem Requirement

Subsystem

Component

Item

Requirements

Product Tree

Interfaces

Assemblies and Test Plans

Assemblies and Test Reports
Product Tree

EnMAP Ground Segment

1= MOS
   1:4
   4:32
   32:79
   I-1XX-YY-ZZ

2= PGS
   1:7
   7:49
   49:86
   I-2XX-YY-ZZ

3= PCV
   1:4
   4:19
   19:37
   I-3XX-YY-ZZ

1 Grd. Segment
3 Systems
15 Subsystems
100 Components
202 Items
(Type: Facility)
Schematic Interaction of Subsystems

Communication Subnet (CAF part) and Infrastructure (GSOC part)
### Internal and External Interfaces

- Number within circle stating number of interface items between subsystems.
- 32 interfaces broken down into 229 interface items
- The ground segment has 8 interfaces with 54 interface items (+ S- and X-Band) to ESE

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#### EnMAP Ground Segment Subsystems

<table>
<thead>
<tr>
<th>MOS</th>
<th>PGS</th>
<th>PCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>EnMAP Ground Segment Interface Matrix</td>
<td>MOS</td>
<td>PGS</td>
</tr>
<tr>
<td>Interfaces between Subsystems with Interface Identifiers</td>
<td>MOS</td>
<td>PGS</td>
</tr>
<tr>
<td>MOS</td>
<td>PGS</td>
<td>PCV</td>
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<tr>
<td>S-110 Flight Operation System</td>
<td></td>
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<tr>
<td>S-120 Mission Planning System</td>
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<td>S-130 Flight Dynamics System</td>
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<tr>
<td>S-140 Infrastr. &amp; Ground Data Sys</td>
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<td></td>
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<tr>
<td>S-210 Neustrelitz Ground Station</td>
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<td></td>
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<tr>
<td>S-220 Data &amp; Information Mgmt. System</td>
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<td></td>
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<tr>
<td>S-235 Processing System HSI</td>
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<tr>
<td>S-240 Instrument Planning</td>
<td></td>
<td></td>
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<tr>
<td>S-250 Production Management</td>
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<tr>
<td>S-310 HSI Development Processor</td>
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<td></td>
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<tr>
<td>S-320 Onboard Spectr./Rad Calibration</td>
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<tr>
<td>S-330 Quality Control / Grd. Calibration</td>
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<td>S-340 Instrument Monitoring</td>
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### EnMAP Ground Segment Subsystems External Interfaces with Interface Identifiers

- MOS
- PGS
- PCV

- Established Interfaces

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- Established Interfaces

- MOS
- PGS
- PCV

- Subsystem Internal Interfaces
EnMAP Project Management Support Tool (PMS)

Perl based web-interface for the
- generation,
- manipulation, and
- visualization
of the content of a mysql-database.
Scenarios – Basis for Requirements Verification and Validation
Scenario – Summary

- Scenarios illustrate the dynamic behaviour of the ground segment; they are complementary to the static architecture of the ground segment with its product tree and interfaces.
- Ground segment scenarios
  - connect the ground segment’s elements according to their usage,
  - are described on subsystem level.
- The activities taking place within the scenarios are described in the corresponding subsystem design documents.
- The scenarios provide the basis for ITVV planning on ground segment level, i.e. the verification if requirements are met.
Origin and Distribution of Requirements

**User Requirements**

**Mission Requirements**

**Customer Requirements**

**Ground Segment Requirements**

- **Requirements**
  - Ground Segment (GS)
  - Mission Operations (MO)
  - Mission Planning and Scheduling Archiving (MP)
  - Command & Control (CC)
  - Health Monitoring (HM)
  - Performance Monitoring and Evaluation (PM)
  - Flight Dynamics (FD)
  - Onboard Software Maintenance (SM)
  - Payload Data Recording & Replay (Rec)
  - Payload Data Handling (DH)
  - Data Reception and Archiving (RA)
  - Data Processing, Calibration and Validation (PCV)
  - Product Dissemination and User Services (US)
  - EnMAP Data Policy (DP)

- **Assumptions**
  - Orbit and General Operations (M)
  - S/C Platform (SC)
  - S/C Instrument (HSI)
  - S/C Orbit and Attitude (AOC)
  - S/C TM/TC (TMC)
  - X-Band-Downlink (X)
  - S/C Simulators (SS)
  - S/C Onboard Software Maintenance (SM)
  - S/C Launcher (Lau)
  - Development Schedule (Ph)
  - Documentation to be delivered (Doc)
Ground Segment Requirements

- Text
- Compliance
- Remark
- Constituent Subsystem Requirements

Subsystem Requirements

- Text
- Compliance
- Remark
- Origin Ground Segment Requirements
- Obligation
- Verification Method

Changes only with Configuration Control!
Requirements – Compliance Documentation

• Traceability Matrices for:
  • Ground Segment Requirements to Subsystem Requirements
  • Subsystem Requirements to Ground Segment Requirements

• Compliance to Requirements is documented in Compliance Matrix
• Compliance is specified the following way:
  • FC: Full Compliance
  • PC: Partial Compliance
  • NC: Non-Compliance
  • TBD: To-Be-Determined
• Status-Quo: FC: 160, PC: 6, TBD: 27, NC: 0
• The ground segment is FC, if for all systems (MOS, PGS, PCV) FC is stated, this results in a full compliance of the Ground Segment:
• Otherwise the ground segment is PC, NC, or TBD as stated in the GS column
Requirements – Verification Strategy

• Test: Verification is achieved by measuring product performance and function under various simulated environments.

• Analysis: Verification is achieved by performing theoretical or empirical evaluation by accepted techniques.

• Review-of-design: Verification is achieved by evidence of validated design documents or, when approved, design reports, technical descriptions, engineering drawings, show the requirement is met.

• Inspection: Verification is achieved by visual determination of physical characteristics.
Assumptions and Requirements - Synopsis

GS Assumptions

Subsys. Requirements

GS Requirements

provided by Agency

provided by Ground Segment

<table>
<thead>
<tr>
<th>GS Assumption</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSR Identifier</td>
<td>ASP.Lau.0050</td>
</tr>
<tr>
<td>GSR Test</td>
<td>The S/C from launcher separation will be such that the maximum angular velocities of the EnMAP satellite after release from the launcher will not be more than ±3.0° sec in roll, pitch and yaw.</td>
</tr>
<tr>
<td>GSR Origin</td>
<td>Lau.0050</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GSR Attribute</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsys Identifier</td>
<td>GRD.CC-0000</td>
</tr>
<tr>
<td>GS Test</td>
<td>The EnMAP Ground Facilities shall monitor the link quality for each ground station pass and log transmission errors (missing frames, corrupted frames, bit errors)</td>
</tr>
<tr>
<td>GSR Compliance</td>
<td>GRS, MOS, PCV, PGS</td>
</tr>
<tr>
<td>GSR Remark</td>
<td>MOS: monitoring of S-band downlink, MOS: monitoring of X-band downlink</td>
</tr>
<tr>
<td>GSR Constituents</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SR Attribute</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR Identifier</td>
<td>MOS-SR-1040.FOS-FUN</td>
</tr>
<tr>
<td>SR Test</td>
<td>The MOS shall be able to check the quality of the S-Band telemetry downlink and log transmission errors (missing frames, corrupted frames, bit errors)</td>
</tr>
<tr>
<td>SR Subsystem</td>
<td>S-110 MOS Flight Operation System</td>
</tr>
<tr>
<td>SR Verification</td>
<td>T</td>
</tr>
<tr>
<td>SR Origin</td>
<td>GRD.CC-0040, GRD.CC-0090, GRD.RA-0110</td>
</tr>
<tr>
<td>SR Remark</td>
<td></td>
</tr>
</tbody>
</table>
Requirements - Configuration Control

NCR: Non-Conformance-Report
SCR: System-Change-Request
ECR: Engineering Change Request
ICR: Implementation Change Request
CCN: Contract Change Notice
RfD: Request for Deviation
RfW: Request for Waiver
Technical Verification of Requirements

EnMAP Ground Segment

- Element 1
  - Sub-element 2.1
    - Sub-element 2.1.1
    - Sub-element 2.1.2
    - ... Sub-element 2.1.K
- Element 2
  - Sub-element 2.2
  - ... Sub-element 2.2.M
- ... Element N

Integration Planning
Integration Execution
Integration Strategy

Subsystem Assembly

Subsystem Assembly

Subsystem Assembly

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GS Assembly

Integration Strategy (EN-GS-PLN-2007, p. 30)

Subsystem Requirements fulfilled => Subsystems ready for integration

Interface Tests

Covering of Scenarios => Ground Segment Requirements are fulfilled
Phases for Requirements Verification

• Assemblies on subsystem-level
  • show that the subsystem requirements are fulfilled,
  • subsystem internal data-flow is implemented correctly,
  • show that subsystem is ready for integration into the ground segment.

• Assemblies of subsystem pairs
  • enable fast verification runs along the operational chain of scenarios,
  • allow the complete test of the multitude of parameter combinations on interface level.

• Assemblies based on scenarios
  • comprise the activities of the ground segment to be performed for successful operation,
  • guarantee that preconditions for the final end-to-end test are met.
  • Prove the fulfillment of the ground segment requirements
Interaction of Phases during System Verification - Schedule

- Subsystem Verification Development Environment
- Subsystem Verification Operational Environment
- Ground Segment Integration and Verification Pairs of Subsystems
- Ground Segment Integration and Verification Scenarios
- End-to-End-Tests
- Operational Validation

GS-CDR

Production Phase (D1)

ITVV Phase Operational Validation Phase (D3)

GS-TVVRR GS-TVVR ORR
Development Model for the meeting of requirements
Conclusions

- Mission Overview
- Development Model
  - Product Tree
  - Requirements
  - Interfaces
- Scenarios
- System Verification and Validation regarding the Requirements

Questions:
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