Space Debris Mitigation – Implementation by DLR

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DLR - German Aerospace Center

- Largest German research institution
- ~ 8,200 employees across 40 institutes and facilities at 20 sites
- Offices in Brussels, Paris, Tokyo and Washington
- Head of board: Dr. Pascale Ehrenfreund
DLR Space Administration

- National Space Agency Germany

- Preparation of German space planning on behalf of the Federal Government

- Representation of German space interests in the international environment, especially with respect to ESA

- Contracts and grants for research and development tasks in the National Programme for Space and Innovation – from advice on funding decisions to technology transfer
German Space Strategy – Sustainable Use of Space

- Released by the **Federal Government** in 2010
- **Foundation** for governmental space activities in Germany
- Space activities shall be consistently aligned with the **idea of sustainability**:  
  - Space debris mitigation  
  - Protection of space systems  
  - Establishment/Evolution of national and international regulatory frameworks
### Structure of the German Space Programme

<table>
<thead>
<tr>
<th>ESA</th>
<th>NP</th>
<th>DLR</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESA programmes, EUMETSAT</td>
<td>National programme</td>
<td>DLR / Helmholtz Association (HGF) R&amp;D programmes</td>
<td>EU, BMBF programmes, German Research Foundation (DFG), universities, Fraunhofer Society (FhG), HGF, Max Planck Society (MPG), public bodies, industry</td>
</tr>
</tbody>
</table>

#### Application
- Communications
- Navigation
- Earth observation

#### Technology
- Space transport
- Space station
- Technology of space systems

#### Research
- Research under space conditions
- Space exploration
Requirements Tailoring for Projects within National Space Programme

General Requirements Catalogue

Manual Adjustments

„QMExpert“ Computer-Based Tailoring Tool

Project-Specific PA Requirements

Project-Specific Tailoring Parameter

<table>
<thead>
<tr>
<th>Budget</th>
<th>Type</th>
<th>Complexity</th>
<th>Lifetime</th>
<th>Tech. Risk</th>
<th>Risk Policy</th>
<th>…</th>
</tr>
</thead>
</table>

more
Space Debris Mitigation Standards for DLR Space Projects

• Established in 2009, last updated in 2018

• Requirements are consistent with CoC as well as with IADC and UN guidelines

• Applicable for all space projects within DLR National Programme

• DLR monitors the implementation/verification of the requirements and decides on possible waivers
Major Mitigation Measures Requested by DLR (1/2)

- Limiting the *generation of debris* associated with space operations
- Limiting the *probability of impact* with other objects in orbit
- Limiting the *consequences of impact* by existing orbital debris or meteoroids
- Limiting the *debris hazard posed by tether systems*
- **Depleting onboard energy** sources after completion of mission
- Limiting *orbital lifetime* of space systems after mission completion in or passing through LEO protected region
Major Mitigation Measures Requested by DLR (2/2)

- Limiting the **human casualty** risk from space system components surviving reentry

- **Protection of human health** and life due to generated space debris

- **Transferring** a GEO space system that has completed its mission into higher orbit

- **Reducing the time** during which the orbital stage left in GTO can interfere with GEO
Space Debris Mitigation Assessment

- Each programme/project shall conduct a **formal assessment** for the potential to generate orbital debris.

- The assessments shall be documented in form of **Space Debris Mitigation Assessment Reports** (SDMARs).

- Each SDMAR shall follow a defined format and include the content indicated at requirements.

- The SDMARs are considered as **design documents** and are basically final when Flight Readiness Review (FRR) was carried out.
Requested Project Documentation

<table>
<thead>
<tr>
<th>Document</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDM Declaration</td>
<td>Brief summary of all design measures and ops procedures relevant for limiting space debris generation</td>
</tr>
<tr>
<td>End of Mission Plan (EOMP)</td>
<td>Decommissioning and disposal of spacecraft including passivation, identification of milestones affecting the EOM, EOMP shall be evaluated/updated through whole mission lifetime</td>
</tr>
<tr>
<td>SDMAR-1</td>
<td>Debris released during normal operations</td>
</tr>
<tr>
<td>SDMAR-2</td>
<td>Spacecraft accidental breakups and potential for explosions</td>
</tr>
<tr>
<td>SDMAR-3</td>
<td>Spacecraft potential for on-orbit collisions</td>
</tr>
<tr>
<td>SDMAR-4</td>
<td>Spacecraft postmission disposal plans and procedures</td>
</tr>
<tr>
<td>SDMAR-5</td>
<td>Spacecraft re-entry hazards</td>
</tr>
</tbody>
</table>
Methodology and Tools

• In principle, use of state-of-the-art methods and tools is required in our space projects

• However, no specific tools are provided by DLR or required to perform e.g. residual orbital lifetime estimations after EOL or re-entry risk analyses

• The SDM documentation is reviewed at least during all major project reviews (PRR, PDR, CDR, FRR)
### Example: EnMAP Earth Observation Satellite

<table>
<thead>
<tr>
<th>Prime Contractor</th>
<th>OHB System AG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>~ 1000 kg</td>
</tr>
<tr>
<td>Operational time</td>
<td>2020 – 2025</td>
</tr>
<tr>
<td>Orbit</td>
<td>Sun-synchronous, perigee altitude 634 km</td>
</tr>
<tr>
<td>Thruster for orbit maintenance</td>
<td>2 x 1 N, hydrazin</td>
</tr>
<tr>
<td>Spectral range</td>
<td>420 – 2450 nm</td>
</tr>
<tr>
<td>Spectral sampling</td>
<td>6.5 – 10 nm</td>
</tr>
<tr>
<td>Ground sampling</td>
<td>30 m</td>
</tr>
<tr>
<td>Swath width</td>
<td>30 km</td>
</tr>
<tr>
<td>Objective</td>
<td>Accurate, quantitative measurements of the state and evolution of ecosystems</td>
</tr>
</tbody>
</table>

The project is funded under the DLR Space Administration with resources from the German Federal Ministry for Economic Affairs and Energy (support code 50 EP 0801) and contributions from DLR, OHB System AG, and GFZ.

www.enmap.org
EnMAP Mission Characteristics and Disposal Concept

• Launch planned in 2020

• Operational phase of 5 years

• Disposal manoeuvre planned to lower perigee altitude to ≤ 500 km
  • ~ 1/3 of the total propellant mass will be used in this manoeuvre

• Active collision avoidance implemented in mission operations
  • $\Delta v = 4 \text{ m/s of 2 kg hydrazine foreseen in propellant budget}$
  • Currently, budget includes an additional margin of $\Delta v = 6 \text{ m/s}$

• No controlled re-entry feasible
EnMAP Collision Avoidance Analysis

• Performed 2014 by the ESA Space Debris Office HSO-GR

• Results:
  
  • The baseline for the EnMAP disposal orbit (perigee = 500km) has **enough margin for a decay within 25 years**
  
  • Even under conservative assumptions **EnMAP complies with collision risk probability requirements** (object > 10 cm) of < 0.001
  
  • **Active Collision Avoidance is necessary** with reasonable ACPL of 0.0001
EnMAP Re-Entry and Casualty Risk Analysis

- Performed 2014 by HTG Hyperschall Technologie Göttingen GmbH, Germany using the tool SCARAB

- 3 cases with different initial orientations analysed

- < 20 surviving fragments

- Weighted casualty area ~ 5.6 m²

- Weighted casualty risk < 1:13.400
Summary

• DLR Space Administration is principal and funding agency for the German space programme

• German space activities shall be consistently aligned with the idea of sustainability

• DLR established Space Debris Mitigation Standards for space projects in 2009

• Each project shall create Space Debris Mitigation Assessment Reports (SDMARs)

• SDMARs are reviewed by DLR during major project reviews and are considered final after Flight Acceptance Review (FRR)
Thank you for your attention!