Sustainable Space Operations – A Case Study by DLR

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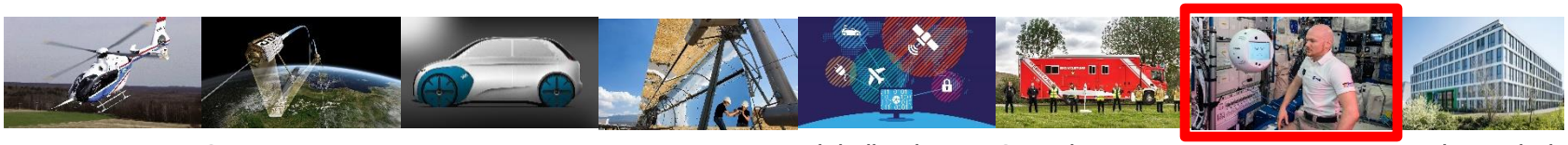
DLR - German Aerospace Center



Aerospace | Space | Transport | Energy | Digitalization | Security | Space Agency | Project Admin.

- Largest German research institution
- ~ 9.000 employees across 55 institutes and facilities at 30 sites
- Offices in Brussels, Paris, Tokyo and Washington
- Head of board:
  Prof. Dr. Anke Kaysser-Pyzalla

From: „Das DLR in Zahlen und Fakten“, 2018

DLR Space Agency

- **National Space Agency Germany,** independent branch within DLR, head: Dr. Walther Pelzer
- **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 Program for Space and Innovation – from advice on funding decisions to technology transfer
- **Supervised** by the Federal Ministry of Commerce and Energy (BMWi)

A

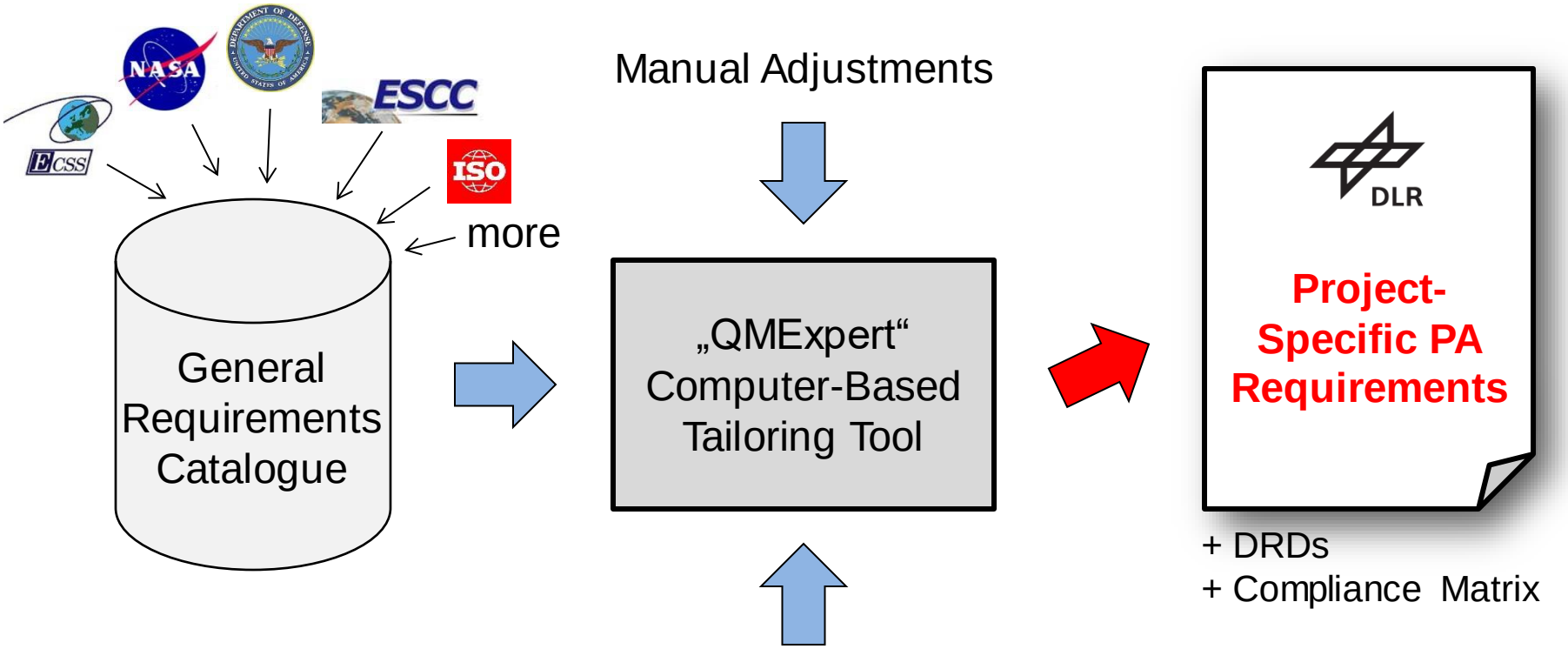
German Space Strategy

- Released by the **Federal Government** in 2010
- **Foundation** for governmental space activities in Germany
- Principles:
  - Research and development
  - Solutions to challenges of modern society: climate change, mobility, communication and security
  - Important for Germany's high tech economy
  - **Sustainable space activities**
  - International, especially European corporation

Link

A.3

PA/Safety Requirements Tailoring Overview



Project-SpecificTailoring Parameter

Budget	Type	Complexity	Lifetime	Tech. Risk	Risk Policy	…

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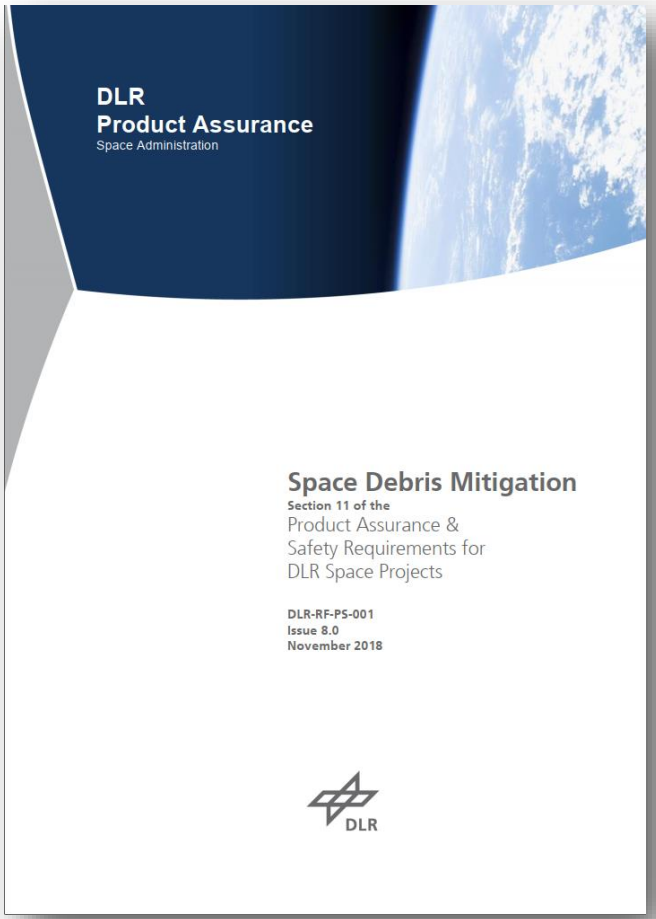
A.3

DLR Space Debris Mitigation Requirements

- Established in 2009, last updated in 2018
- **Applicable for all space mission projects** within DLR National Program
- Requirements derived from/refer to:
  - **UN** Space Debris Mitigation Guidelines
  - **IADC** Space Debris Mitigation Guidelines
  - ISO Standards, mainly ISO 24113
- Requirements **tailored to the specific needs** of projects of the DLR national program
- **DLR monitors the implementation/ verification** of the requirements and decides on possible waivers



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Major Mitigation Measures Requested by DLR

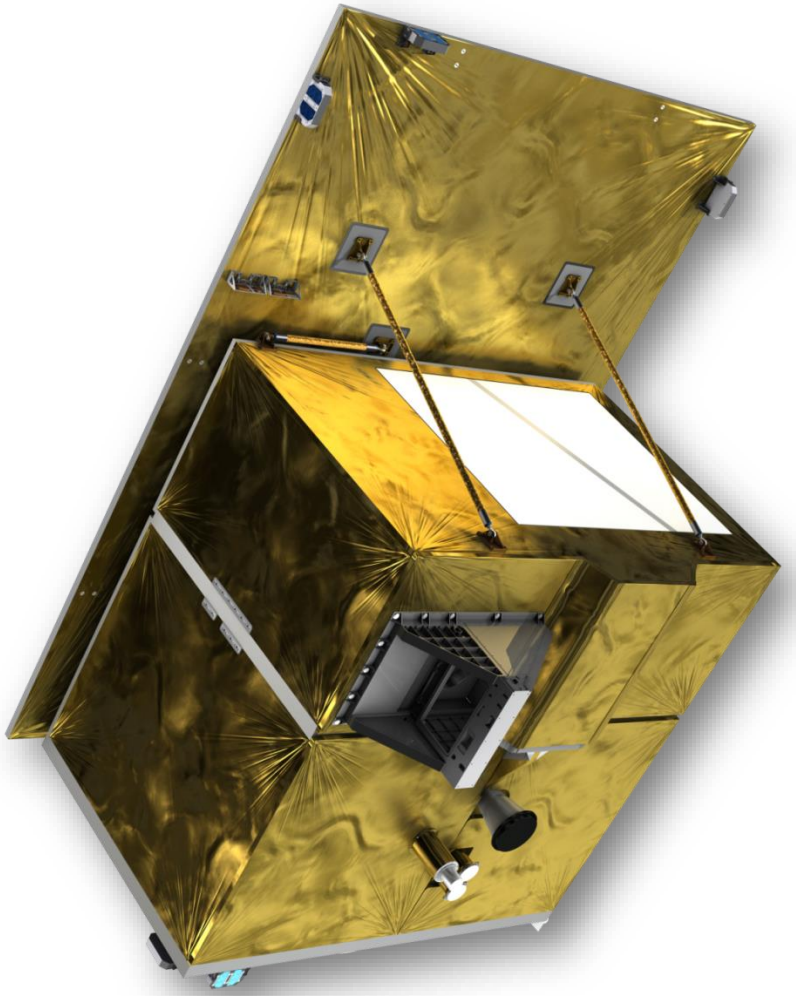
- Limiting the **generation of debris** associated with space operations
- Limiting the **probability of impact** with other objects in orbit
- Limiting the **consequences of impact** by existing orbital debris or meteoroids
- **Depleting onboard energy** sources after completion of mission
- Limiting **orbital lifetime** in LEO and transferring GEO spacecrafts into **graveyard orbit** after mission completion
- Limiting the **human casualty risk** from space system components surviving reentry
- Protection the **Earth's environment, airspace, seafaring and property** from reentering space objects

Requested Project Documentation

Document	Scope	To be delivered
SDM Declaration	Brief summary of all design measures and ops procedures relevant for limiting space debris generation	PRR … FRR
SDMAR-1	Debris released during normal operations	PRR … FRR
SDMAR-2	Spacecraft accidential breakups and potential for explosions	PRR … FRR
SDMAR-3	Spacecraft potential for on-orbit collisions	PRR … FRR
SDMAR-4	Spacecraft postmission disposal plans and procedures	PRR … FRR
SDMAR-5	Spacecraft re-entry hazards	PRR … FRR
End of Mission Plan (EOMP)	Decommisioning and disposal of spacecraft including passivation, identification of milestones/events affecting the EOM, EOMP shall be evaluated/updated through whole mission lifetime	PRR … **EOM**

Example: EnMAP Earth Observation Satellite

Prime Contractor	OHB System AG
Mass	~ 1000 kg
Operational time	2022 – 2027
Orbit	Sun-synchronous, perigee altitude 634 km
Thruster for orbit maintenance	2 x 1 N, hydrazin
Spectral range	420 – 2450 nm
Spectral sampling	6.5 – 10 nm
Ground sampling	30 m
Swath width	30 km
Objective	Accurate, quantitative measurements of the state and evolution of ecosystems



www.enmap.org

The project is funded under the DLR Space Agency 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.

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History of SDM Measures for the EnMAP Mission

Phase B:

- Introduction of SDM requirements based on European Code of Conduct, Issue 1 (2004)

Beginning of Phase C

- Request for Waiver. The following was accepted:
  - Exceedance of penetration probability by MMOD
  - No formal verification of compliance with accidental destruction req.
  - No passivation of battery, wheels. Remaining hydrazine in tank.

Beginning of Phase D, after CDR

- New DLR Space Debris Mitigation Requirements were made applicable
- Major consequences:
  - Re-run of collision risk analysis
  - Implementation of active collision avoidance (ops capabilities + dedicated fuel)
  - Re-run of reentry analysis to demonstrate compliance with limiting on-ground casuality risk
  - Major updates of existing project documentation to meet requirements

B.4

EnMAP Disposal and Collision Avoidance

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

- Collision risk analyzed 2014 by the **ESA Space Debris Office**
  - 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

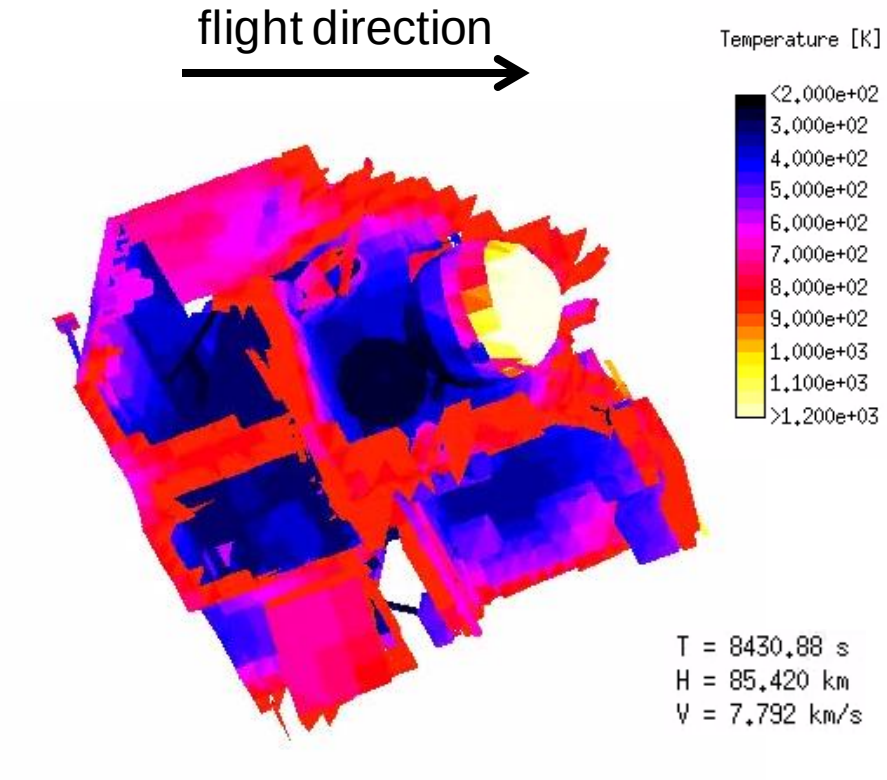
- **Active collision avoidance** was implemented in mission operations
  - Δv = 4 m/s or 2 kg hydrazine foreseen in propellant budget
  - Currently, budget includes an additional margin of Δv = 6 m/s

- No controlled re-entry feasible

B.9

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

- Space activities by DLR Space Agency are consistently aligned with the **idea of sustainability**
- A process to verify and improve implementation of the **UN COPUOS LTS Guidelines** is established
- DLR Space Agency established and continuously maintains **Space Debris Mitigation requirements** based on recognized international standards and guidelines

- Example: EnMAP Earth observation mission
  - During the typical time span of a space project the **SDM situation may change drastically**
  - **SDM measures might need to be adapted** to ensure compliance in a changing environment
  - Further more: regulators may decide to **update the SDM requirements** for a running project
  - EnMAP is good example for **balancing mission objectives and changing space sustainability needs**