Space Debris Mitigation Compliance at ESA

ESA-ECSL Space Debris Workshop 20 March 2019

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Space Debris Mitigation at ESA

2002 : IADC Space Debris Mitigation Guidelines (it was updated in 2007)

2007 : UNCOPOUS " Space Debris Mitigation Guidelines " approved by 63 Member Nations

Space Debris Mitigation at ESA

2004: European Code of Conduct

- Identifies Practises for SDM. “ Help to manage space debris hazard “
- “ Should “ , no design/operations mandatory requirements

2008: ESA/ADMIN/IPOL(2008) 2 SDM Policy

- ESA endorsement of the European Code of Conduct
- ESA Design/Operations Requirements for ESA projects
- Projects to report compliance to the Director General
- Prime contractor responsible for the implementation
- Space Debris Mitigation Document to be reviewed in the project reviews

Space Debris Mitigation at ESA

2014 : ESA/ADMIN/IPOL(2014)2 Space Debris Mitigation Policy for Agency Projects

- ESA adoption of design/operations requirements in ECSS-U-AS-10C (ISO 24113)
- Use an International Standard for Design/Operations Requirements for ESA projects
- Identification of an ESA Technical Authority(TA)responsible for the supervision of the verification of compliance
- Policy shall be complied by ESA staff with responsibilities for implementation/review/approval
- Space Debris Mitigation Document to be reviewed in the project frame of project reviews and assessed for approval by ESA TA

Re-entry casualty risk

ISO 24113 Space Debris Mitigation Requirements doc does not contain a requirement for the acceptable re-entry casualty risk.

Requirement is found in the ESA policy (ESA/ADMIN/IPOL(2014) 2)
“ ...the maximum acceptable casualty risk shall not exceed 1 in 10000”

Re-entry casualty risk requirement now captured in the ESSB-ST-U-004 ESA Re-entry safety requirements 4/12/2017

ESA SDM Policy and Requirements

ESA
Director General's Office

ESA/ADMIN/IPOL(2014)2
Att.: Annexes 2
Paris, 28 March 2014
(Original: English)

Distribution: all staff
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Space Debris Mitigation Policy for Agency Projects

1. INTRODUCTION

As a consequence of spaceflight activities, the number of functional and non-functional (i.e.: space debris) human-made objects in Earth orbit continues to grow. To minimise the impact of space operations on the orbital environment, to reduce the risk of collision on orbit and to ensure the safety of the public on ground during re-entry, mitigation and safety measures must be anticipated as from the conception of a space system.

In May 2011, the 2nd edition of ISO 24113 "Space Systems – Space Debris Mitigation Requirements" was issued as the international standard which establishes the design and operations requirements to minimise the impact of space operations on the orbital environment. On 10th February, 2012, this standard was adopted by the European Coordination on Space Standardization (ECSS) as the ECSS-U-AS-10C standard (Adoption Notice of ISO 24113: Space Systems – Space debris mitigation requirements).

The present Instruction establishes the ESA standard for the technical requirements on space debris mitigation for Agency projects, it sets out the principles governing its implementation and the definition of responsibilities.

2. POLICY

In order to ensure a corporate approach on space debris mitigation, it is the Agency's policy that the ECSS-U-AS-10C is established as the ESA standard ("the standard") for the

ESA/ADMIN/IPOL(2014)2
Space Debris Mitigation Policy for Agency Projects (28/03/2014)

ESA Policy,
applicable to all ESA Projects

ECSS-U-AS-10C
10 February 2012

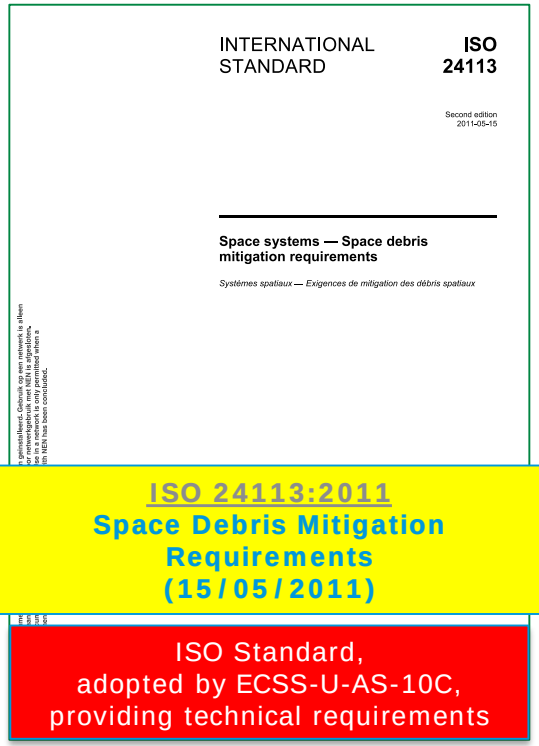
EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

Space sustainability

Adoption Notice of ISO 24113: Space systems - Space debris mitigation requirements

ECSS-U-AS-10C
Space sustainability - Adoption Notice of ISO 24113 (10/02/2012)

ECSS Standard,
adopting ISO 24113:2011,
applicable to Prime Contractors



INTERNATIONAL STANDARD

ISO 24113

Second edition
2011-05-15

Space systems — Space debris mitigation requirements

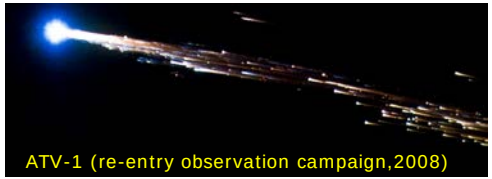
Systèmes spatiaux — Exigences de mitigation des débris spatiaux

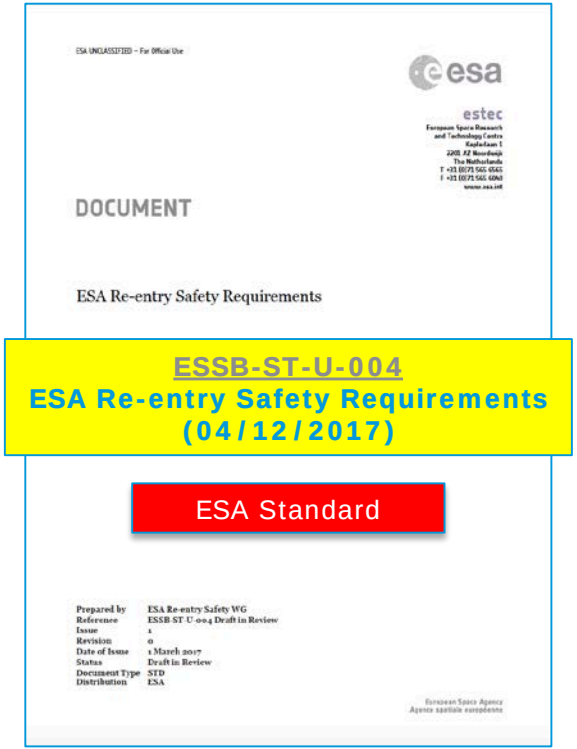
ISO 24113:2011
Space Debris Mitigation Requirements (15/05/2011)

ISO Standard,
adopted by ECSS-U-AS-10C,
providing technical requirements

ESA Re-entry Safety Requirements

- ESSB-ST-U-004 is the ESA Re-entry Safety Requirements document for ESA space systems, which has the objectives of:
  - ✓ Enforce the applicability and verification of the re-entry casualty risk requirement established by the ESA Space Debris Mitigation Policy;
  - ✓ Introduce requirements from SDM guidelines (ESSB-HB-U-002) and lessons learnt from the 5 ESA Automated Transfer Vehicles (ATVs) controlled re-entries);
  - ✓ Define specific safety requirements to cover the hazards for human life and environment, including:
    - ❑ Impacting fragments,
    - ❑ Floating fragments,
    - ❑ Pressurized or explosive fragments,
    - ❑ Hazardous chemical substances,
    - ❑ Radioactive substances;
  - ✓ Provide additional requirements and perform:
    - ❑ Safe re-entry operations,
    - ❑ Re-entry notifications,
    - ❑ Retrieval operations.


ATV-1 (re-entry observation campaign,2008)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DOCUMENT

ESA Re-entry Safety Requirements

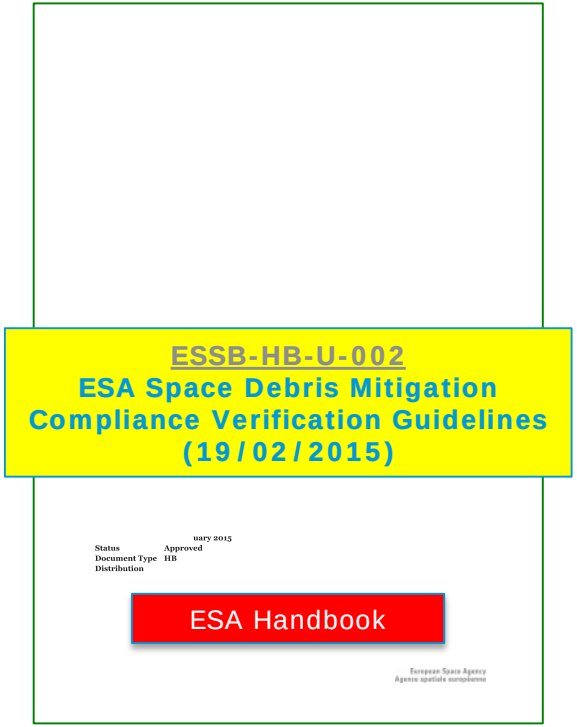
ESSB-ST-U-004
ESA Re-entry Safety Requirements
(04/12/2017)

ESA Standard

Prepared by	ESA Re-entry Safety WG
Reference	ESSB-ST-U-004 Draft in Review
Issue	1
Revision	0
Date of Issue	1 March 2017
Status	Draft in Review
Document Type	STD
Distribution	ESA

ESA SDM Compliance Verification Guidelines

- ESSB-HB-U-002 is the ESA reference handbook providing guidelines for the verification of the ESA Space Debris Mitigation requirements.
- The handbook covers several disciplines, i.e. space environment and modeling, system engineering, astrodynamics, aerothermodynamics, power systems, propulsion systems, structural engineering, thermal engineering, materials science, Reliability, Availability and Maintainability (RAM), Safety, etc.
- Since Space Debris Mitigation is a continuous evolving subject, the guidelines are regularly updated to reflect the:
  - o feedback from the ESA Industrial partners;
  - o outcome of research and technological development activities;
  - o international agreements/standards to cope with space sustainability.



ESA Responsibilities for SDM in the ESA Policy

Role in ESA	Responsibility
Directors (D/All)	Implementation of the policy within their respective areas
Study / Project / Mission Managers	Preparation and maintenance of the Space Debris Mitigation Plan (SDMP) and Space Debris Mitigation Report (SDMR) in accordance with the Implementation Requirements
Director of Technology, Engineering and Quality (D/TEC)	Approval of waivers to the Space Debris Mitigation requirements, delegated by the Director General
Programme Director (D/Programme)	Approval of waivers to the Space Debris Mitigation requirements, delegated by the Director General
Head of the Department of Product Assurance and Safety (TEC-Q)	Management of the implementation of the policy, and the approval of the SDMP at the time of the System Requirements Review (SRR) and the SDMR at the time of the Acceptance Review (AR)
Inspector General (DG-I)	Coordination of Technical Project Reviews, including assurance of SDMP and SDMR being reviewed
Head of the Independent Safety Office (TEC-QI)	Technical Authority for the: • Custodianship/maintenance of the Space Debris Mitigation Policy with the related requirement; • Independent supervision of SDM requirements verification of compliance; • Processing of waivers with the technical support from the Directorate of Technology, Engineering and Quality Directorate (TEC) and the Space Debris Office (OPS-GR); • Reporting on the status of implementation of the ESA Space Debris Mitigation Policy.

ESA Projects - SDM Policy compliance process

- The ESA Space Debris Mitigation (SDM) Policy requires that the compliance with the Space Debris Mitigation requirements is to be documented at different phases of all ESA Projects.

- The ESA Projects shall provide:

    1. **Space Debris Mitigation Plan (SDMP)**

    2. **Space Debris Mitigation Report (SDMR)**

ESA assessment of the compliance with the SDM requirements

1. **Development phase:**

   The Space System compliance with the Space Debris Mitigation requirements shall be assessed in the frame of the **Technical Project Reviews**.

2. **In case of major deviations during the orbital lifetime:**

   The Space System compliance with the Space Debris Mitigation requirements shall be assessed, prior of the disposal phase, by the **Space Debris Mitigation Review Panel**, chaired by the Head of the Independent Safety Office (TEC-QI) and composed of experts in the relevant technical disciplines.

3. **In case of non-compliance (development or operation phase):**

   The Projects shall apply for a **Request for Waiver**.

   The Space Debris Mitigation Technical Authority shall make recommendations for the approval of the associated Request for Waiver.

SDM Plan and SDM Report approval

The Space Debris Mitigation Plan (SDMP) is approved at the time of System Requirement Review (SRR) .

The purpose of this approval is to prevent proceeding with the development of a spacecraft that does not have adequate plans to comply with SDM requirements.

The Space Debris Mitigation Report (SDMR) is approved at Qualification or Final Acceptance Review.

The SDMR approval confirms that the spacecraft complies with the SDM requirements.

The SDMR will have to be updated and reviewed in case of requests for mission extensions such that compliance to SDM requirement is ensured until the spacecraft is removed from protected regions.

Request for Deviations / Waivers (RFDs / RFWs)

- In case of a non compliance with a SDM requirement, a rationale should be provided with technical explanation on why the requirement can not be met and why additional risk should be taken by ESA.
- The responsibility for approval is shared between two ESA Directors:
  - Director of the Programme,
    and
    Director of ESA Technology, Engineering and Quality (D/TEC)
- The use of RFW is strongly discouraged.

Template in ESSB-HB-U-002

ure:

Guidelines vs Requirements

The Inter Agency Debris Coordination committee issued **guidelines** on how to limit the effects of debris in 2002 with an update in 2007

The United Nations Committee on the Peaceful Use of Space issued **guidelines** with the approval of 67 members state

Guidelines vs Requirements

Guideline indicate the way the space debris problem could be put under control if **all** space exploitation actors were to adopt them.

Guidelines are not binding, they are not requirements nor regulations and therefore are applied on a voluntary base in different way.

Guidelines vs Requirements

In order to bring under control the problem of space debris a regulatory framework shall be applied to all space exploitation actors.

The UN treaty on the Principles Governing Activities of States in Exploration and Use of Outer Space identifies States as the responsible for all their national space activities.

Therefore States can ensure that all their space actors comply with their regulatory framework.

Example : **Guideline** on post mission passivation

Space Debris Mitigation **Guidelines** of the Committee on the Peaceful Use of Outer Space:
Guideline 5 - Minimize potential for post-mission break-ups resulting from stored energy

"…….all on board sources of stored energy **should** be depleted or made safe when they are no longer required …."

Up to the spacecraft developer/operator to decide whether and to what extent to deplete/make safe sources of stored energy

Implemenation of depletion/make safe depends on the developer/operator interpretation

This will not ensure that all space missions adopt adequate energy depletion/ make safe strategies

Example : **Requirement** on post mission passivation

ISO 24113 Space Debris Mitigation Requirements
“ ..... A spacecraft or launch vehicle orbital stage **shall** permanently deplete or make safe all remaining on-board sources of stored energy “

The spacecraft developer/operator is **obliged** to implement stored energy depletion measures

In the case of a regulating entity imposing the requirement, the spacecraft developer/operator is expected to provide evidence of the implementation to the satisfaction of the regulating entity (verification process)

Examples of Space Debris Mitigation Policy Implementation

METOP-SG

MetOp-SG before SRR (2013)

Before System Requirements Review (SRR) - 2013

Spacecraft Wet Mass: 3754 kg
Total Propellant Mass: 254 kg
Thrust: 16 x 5 N

→ Disposal by de-orbit and uncontrolled re-entry:
Delta-v: 88 m/s
Propellant Mass: 145 kg

→ Re-entry casualty risk
> 10^{-4}
($7x10^{-4}$)

→ Not Compliant with ESA Policy for re-entry

See next chart

Orbit: 817 km x 817 km, inc. 98.7°

MetOp-SG changed to comply to SDM Requirements (SRR 2014)

Design trade-off for system re-design required

Main impacts at system design and operation level:
- Higher thrust engine
- Bigger propulsion tank (mono-propellant with re-pressurization tanks)
- Propellant mass increase (by 3)
- Higher system reliability
- Increase features for disposal manouvers
- Ground operation control required until re-entry

After System Requirements Review (SRR) - 2014

Spacecraft Wet Mass: 4400 kg
Total Propellant Mass: 760 kg
Thrust: 1 x 400 N (backup 8 x 20 N)

Disposal by controlled re-entry:
Delta-v: 237 m/s
Propellant Mass: 438.5 kg

Re-entry casualty risk
$<< 10^{-4}$
(controlled re-entry targeting SPOUA)

SDMP Approved


esa

MEMO

Date 20/10/2014 Ref TEC-QI/14-183

From W. Veith (TEC-QI) Visa

To G. [illegible] (EOP-PK) Copy R. Nasca (TEC-QI)

Subject: Approval of the MetOp-SG Space Debris Mitigation Plan

Dear Colleague,

We would like to inform you that, in compliance with the ESA policy on Space Debris Mitigation, ESA/ADMIN/IPOL(2014)2, the MetOp-SG Space Debris Mitigation Plan (MOS-PLAD5F-SYS-1000000600, Issue 1, Airbus Space and Defence, 01/08/2014), has been reviewed and it is approved on the basis that the MetOp-SG Satellites A and B are planned to be compliant with the Space Debris Mitigation requirements and no major issues have been identified.

The following recommendations are provided for the next phase of the project and their implementation shall be documented in the MetOp-SG Space Debris Mitigation Report:

1) The status of the compliance of the SCA (scatterometer) with the requirement ECSS-U-AS-10C / ISO 24113 6.1.2.1 should be confirmed (release of small particles).

2) The probability of accidental break-up should be verified to be less than 10^{-3} both for MetOp-SG A and MetOp-SG B spacecraft.

3) A more detailed re-entry analysis should be performed such to identify with good accuracy the location and extension of the debris footprint within the South Pacific Uninhabited Area.

We would like to thank the project for the effort gone into complying with the recent release of the Space Debris Mitigation requirements.

W. Veith

Head of the Product Assurance and Safety Department

Attachment:

MOS-PLAD5F-SYS-1000000600, Issue 1, Airbus Space and Defence.

Spacecraft Wet Mass increase: 600Kg
Total Propellant Mass increase: 506 kg
New Propulsion 1X400 N

Controlled re-entry
Delta-v increase: 149 m/s
Propellant Mass Increase: 293 kg

Re-entry casualty risk
$< 10^{-4}$

SENTINEL 2 A/B

Sentinel-2 A/B – Design Phase

Wet mass: 1225 kg
Dry mass: 1002 kg
Orbit: 786 km x 786 km, inc. 98.5°

Re-entry casualty risk analysis with DRAMA:

- Low fidelity modeling
- Re-entry casualty risk = $1.6\text{-}3.3 \times 10^{-4}$

→ Not compliant

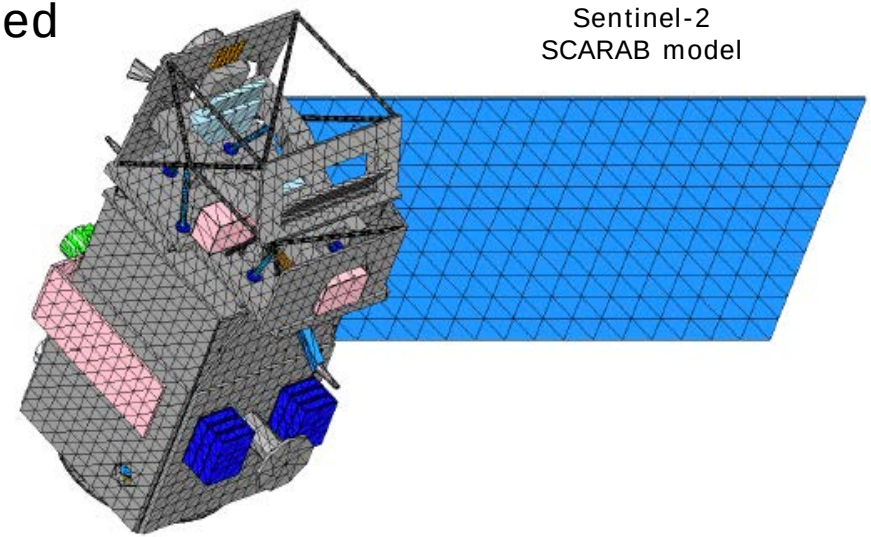
Detailed re-entry casualty risk analysis with SCARAB:

- High fidelity and more detailed modeling
- Re-entry casualty risk = 9.998×10^{-4}

  → Compliant

No design changes were required

S-1A launch: 11 June 2015
S-1B launch: 7 March 2017



Sentinel-2
SCARAB model

BIOMASS

Biomass – Design Phase

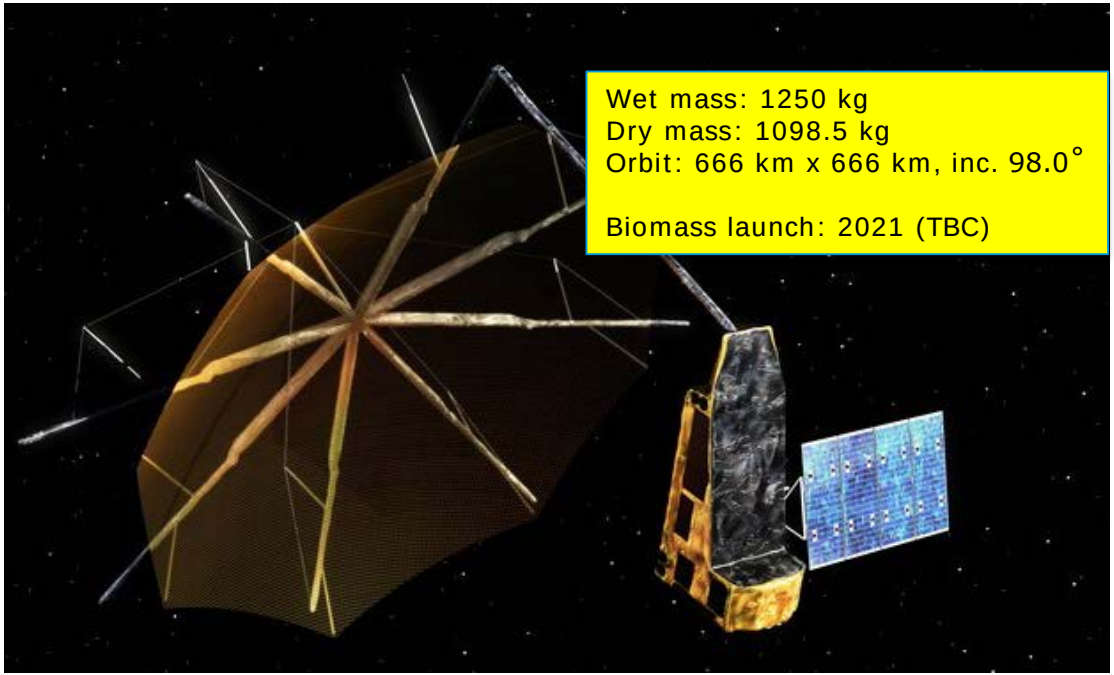
Analysis with DRAMA:

- Low fidelity modeling
- Re-entry casualty risk = 8.9×10^{-5}
- Compliance is marginal results and spacecraft design and re-entry model is to be consolidated

Next step:

Detailed analysis with SCARAB:

- High fidelity and more detailed modeling
- Analysis most likely will demonstrate compliance with 10^{-4} re-entry casualty risk

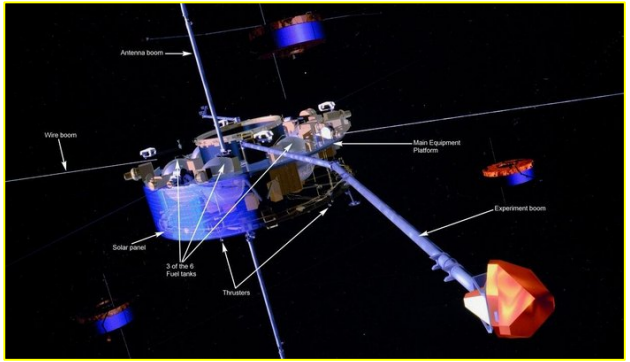


In the past

CLUSTER II

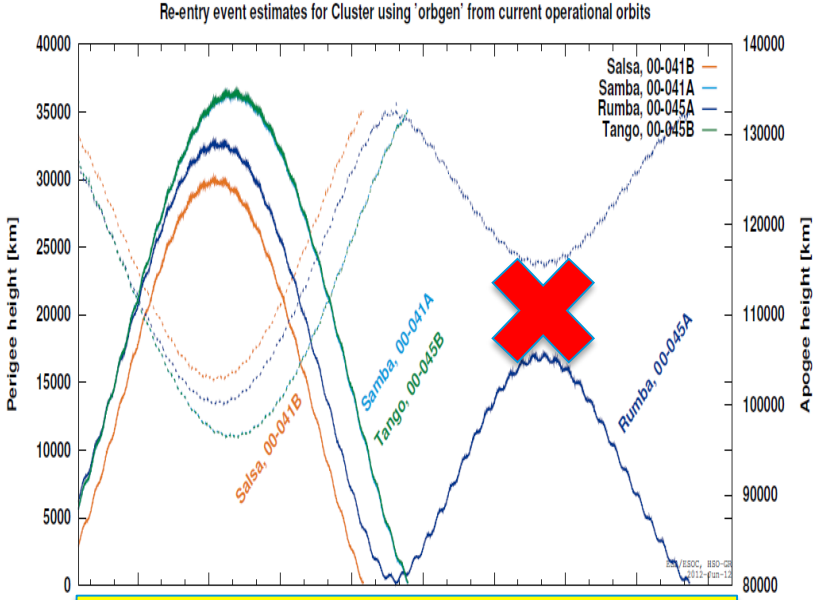
Cluster-II – Operation Phase

- ESA/ADMIN/IPOL(2014)2 was not applicable at time of launch (2000)



- Outcome of assessment in 2014 to comply with ESA/ADMIN/IPOL(2014)2:
  - Perform Manoeuvre to change the inclination for the Cluster-II Rumba spacecraft (March 2015)

    → re-entry in 2025/2026 at high southern latitudes with lower population density.
  - Perform further analysis (close to the end of mission) to tune perigee altitude for all Custer-II spacecraft
    → prevent the risk of circularization and ensure adequate perigee decrease pattern to fulfil the compliance with 10^{-4} casualty risk requirement (re-entry foreseen in 2024/2026).



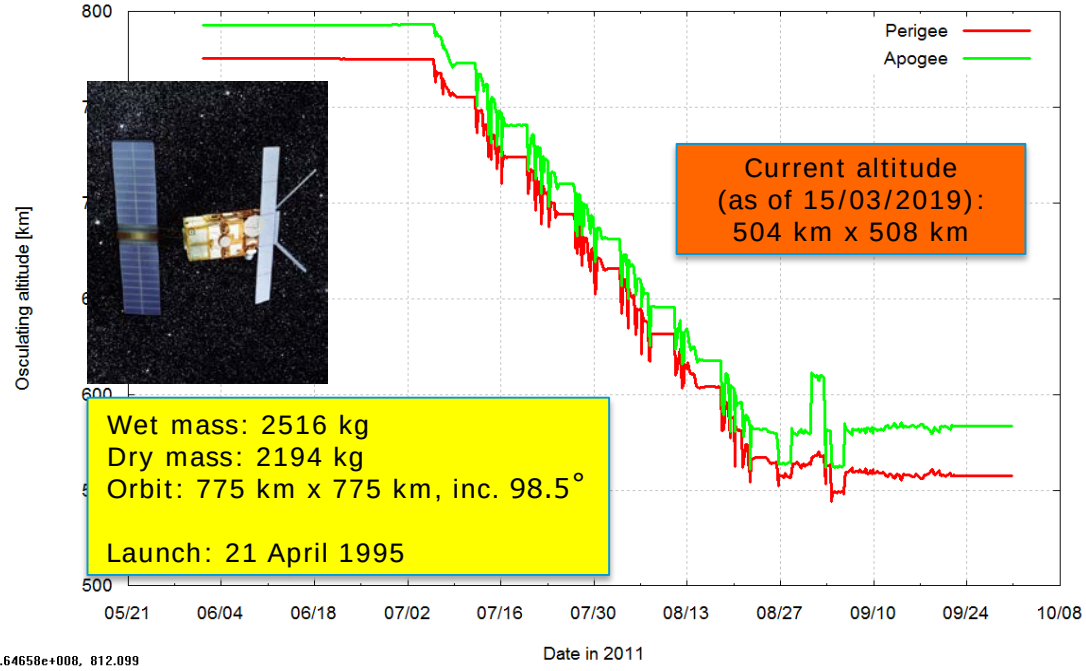
- 4 spacecraft: Salsa, Samba, Rumba, Tango
- Wet mass: 1200 kg
- Dry mass: 550 kg
- Variable inter-distance (4-100000 km)

In the past

ERS-2

ERS-2 – end of mission

- Launched in 1995 (before IADC guidelines)
- Life was extended up to 2011. Several gyroscopes non operational since 2001. Deorbited to comply with ESA SDM Policy IPOL(2008)2.
- Series of de-orbit maneuvers, performed in 6-8 weeks, to decrease altitude to about 560 km (from 775 km) in order to minimize presence in orbit (<25 years).
- Two additional 40 min burns were required to empty tanks (underestimated residual propellant)
- Expected re-entry in 2025
- $5.64X10^{-4}$ re-entry casualty risk cannot be further mitigated,



In the past

ENVISAT

ENVISAT– end of mission

Wet mass: 8000 kg
Dry mass : 7680 kg
Orbit:sun-synchronous 790 km

Launch: 1 March 2002

Mission Duration 5 years

Mission was extended in 2007

In April 2012 lost contact

Casualty risk 5.88×10^{-3}

Expected re-entry > 200 years

Questions