6th International Space Debris Re-entry Workshop

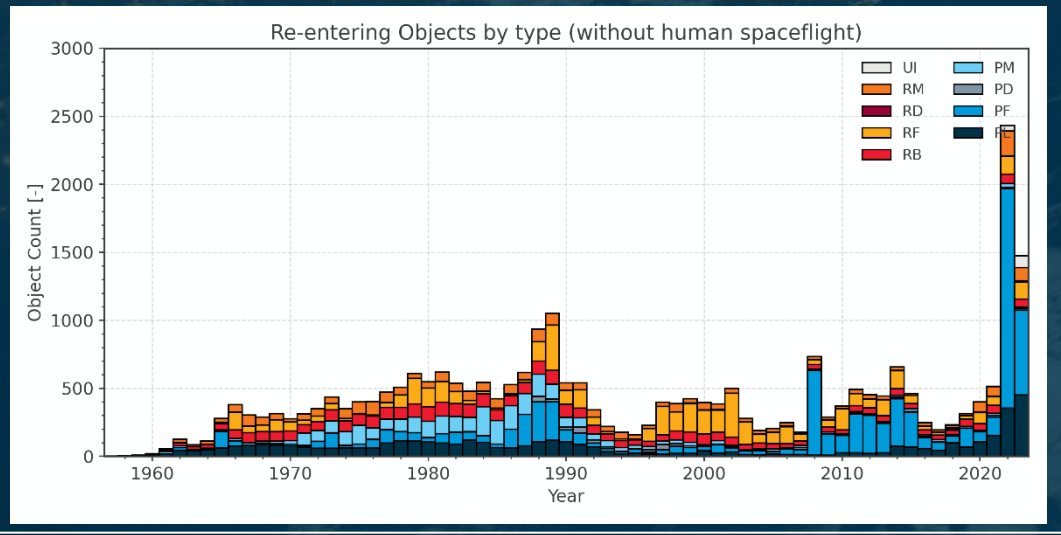
ESA Space Debris Office

15/01/2025

Context and historical background

Apollo 11 Service Module

ATV-1 Jules Verne



Space Debris Mitigation Requirements

Space Debris Mitigation Requirements

End-Of-Life Measures in Low Earth Orbit

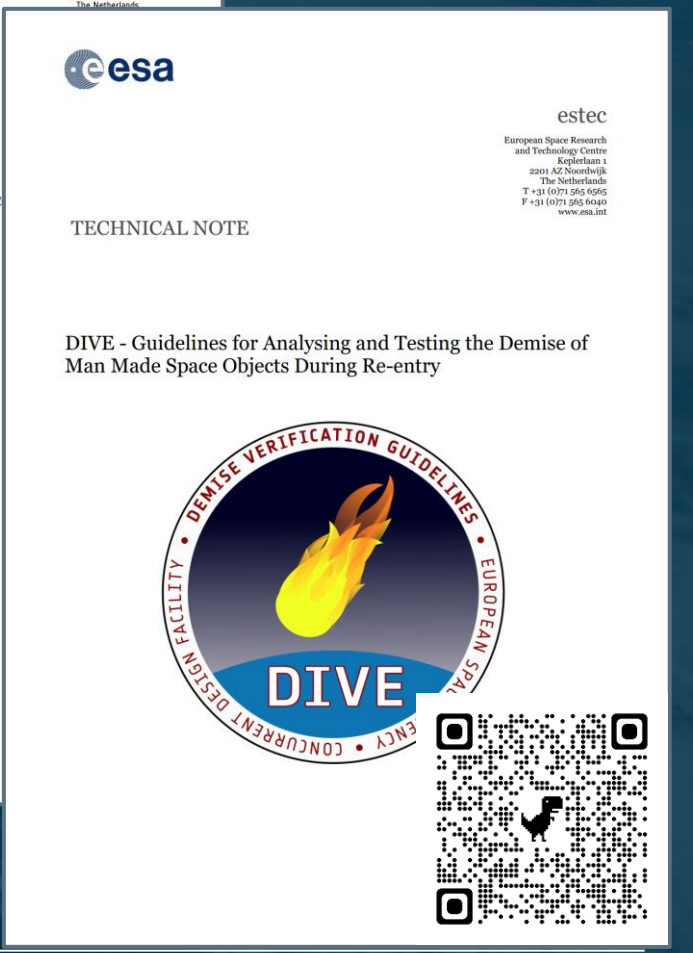
ATMOSPHERIC RE-ENTRY

Atmospheric re-entry within 5 years of mission completion.

ON-GROUND CASUALTY RISK

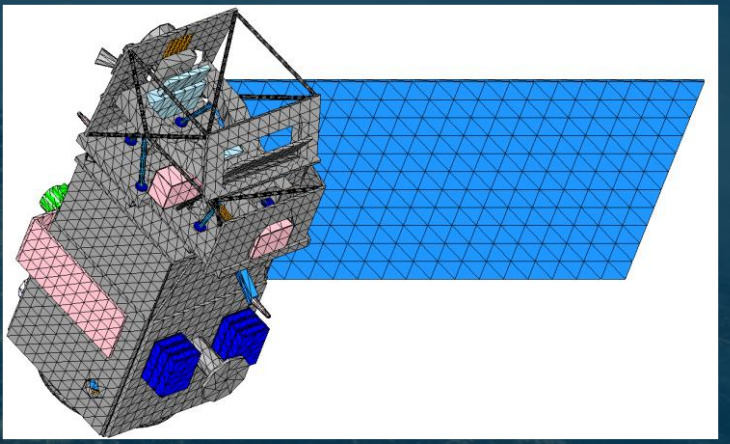
The probability of serious injury or death on ground **shall not exceed 1 in 10 000**

Design for Demise



Towards a validated re-entry model

From a satellite model to a validated re-entry simulation



Challenges

- Full-scale high-fidelity multi-physics simulations (including aerodynamic, thermal, structural and failure behaviour) is beyond computational capabilities.
- Simplified aero(thermo)dynamic and structural failure models need validation.
- Limited number of aerodynamic shapes and material properties well characterised on-ground (~ 10 qualified materials; ~5 simple shapes qualified aerothermodynamics models).
- Fragments reaching the ground only partially predictable.

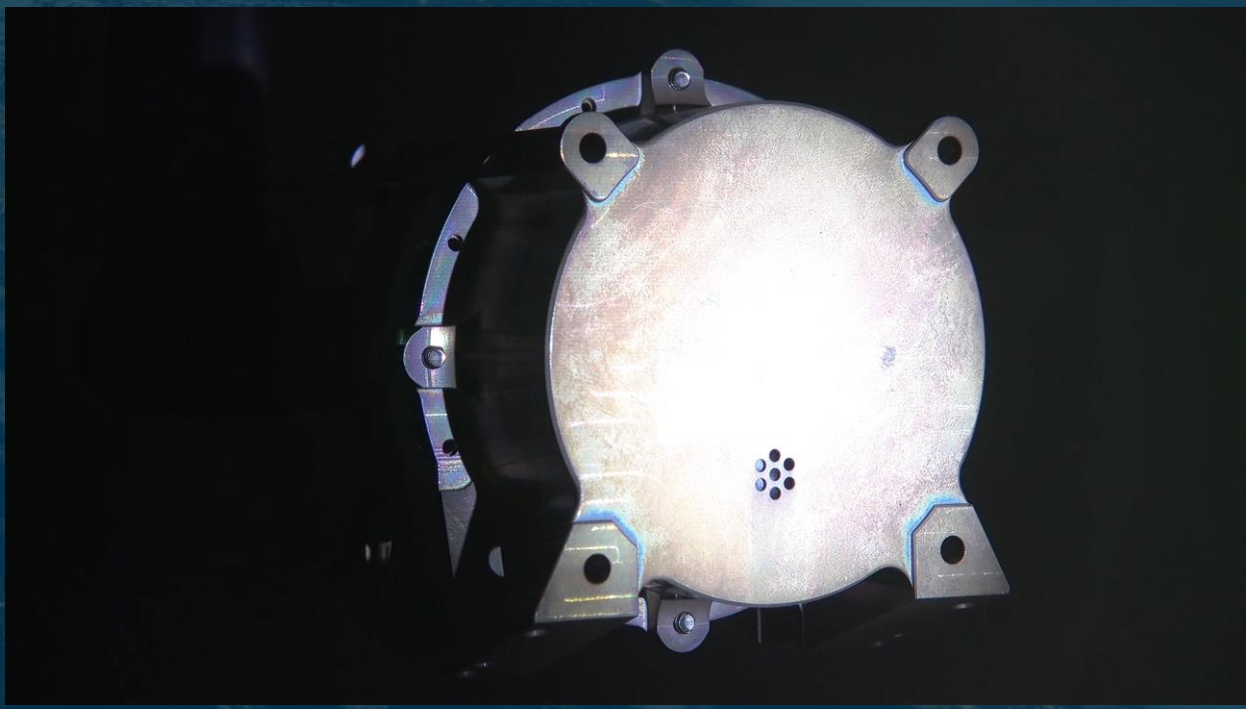
Towards a validated re-entry model

Challenges of on-ground characterisation and testing

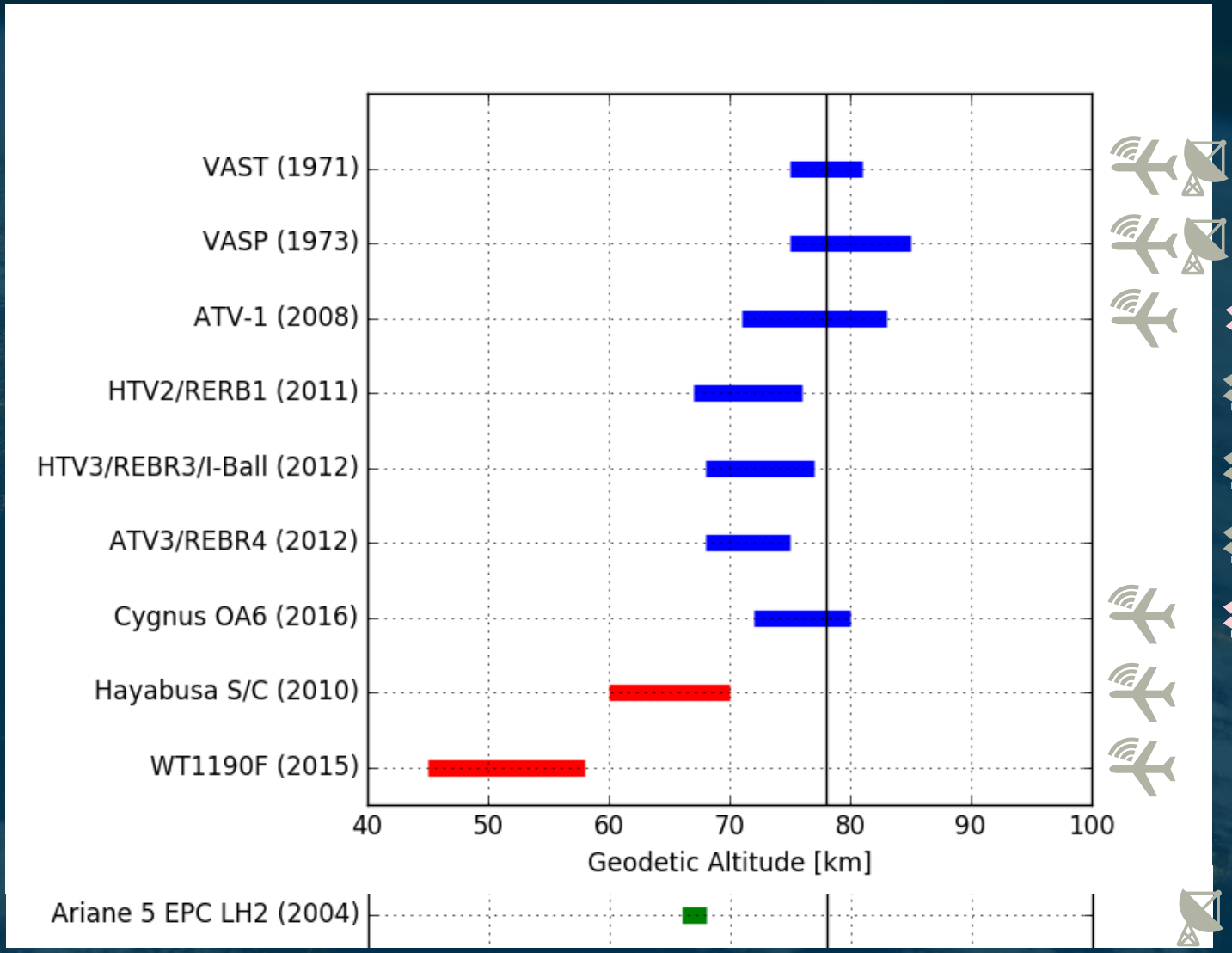
- Completely representative environmental conditions (aerodynamic and aerothermal) difficult to achieve.
- Limited to small-scale or component-level testing.
- Components are small systems themselves.

- Testing at scale of realistic structures (e.g. jointed sandwich panel structures) is not feasible on-ground.

Plasma wind tunnel test of component demise
Credits: DLR/Belstead Ltd.



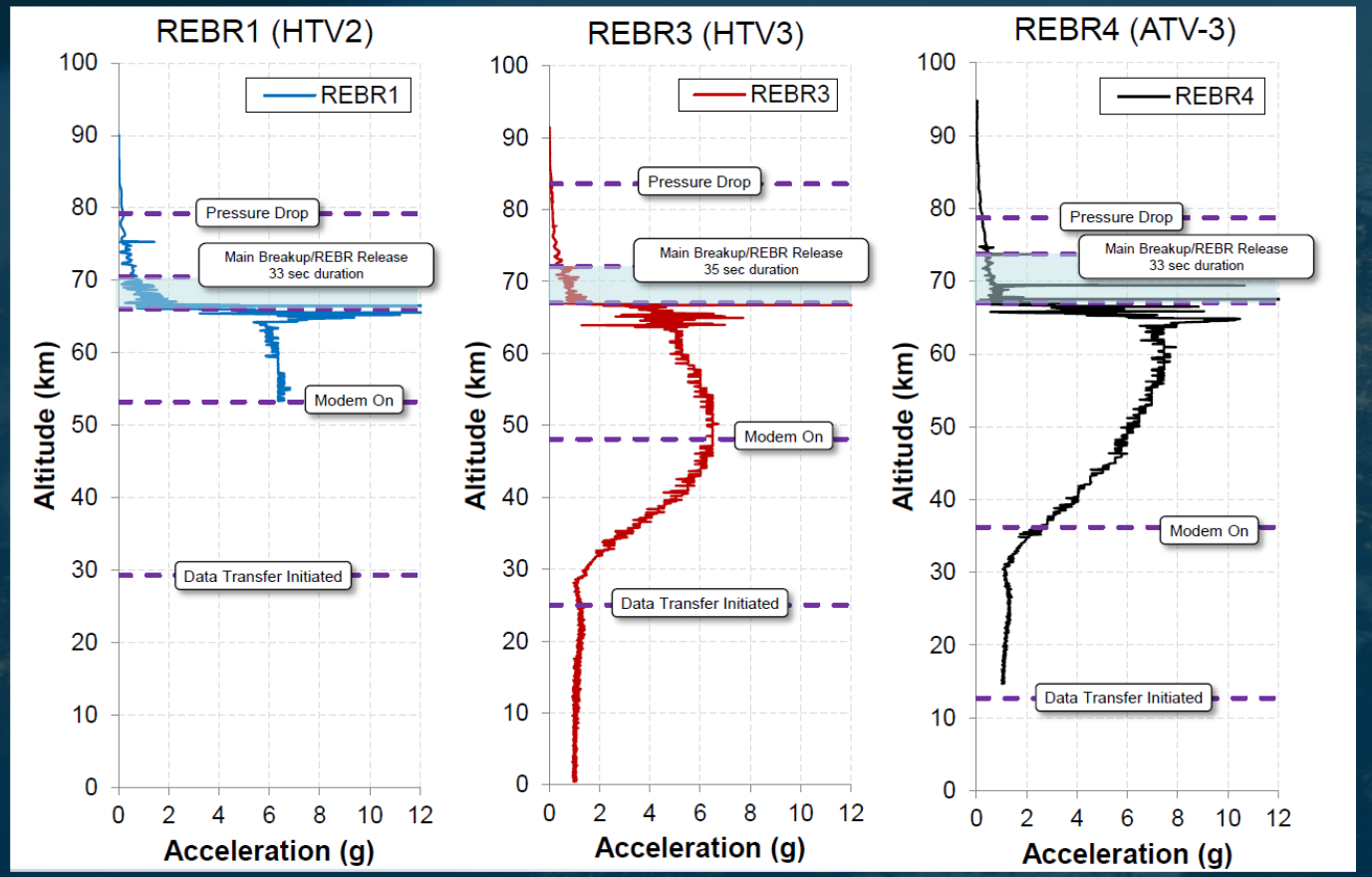
Spacecraft Re-entry observations



- Airborne observation campaign
- Ground-based observation
- **In-situ measurements & sensors**
- Tracking ships

Previous in-situ measurements

Comparison of Re-entry Breakup Measurements for Three atmospheric Re-entries.
Feistel, Weaver, Ailor. 6th IAASS Conference: Safety is Not an Option, May 2013

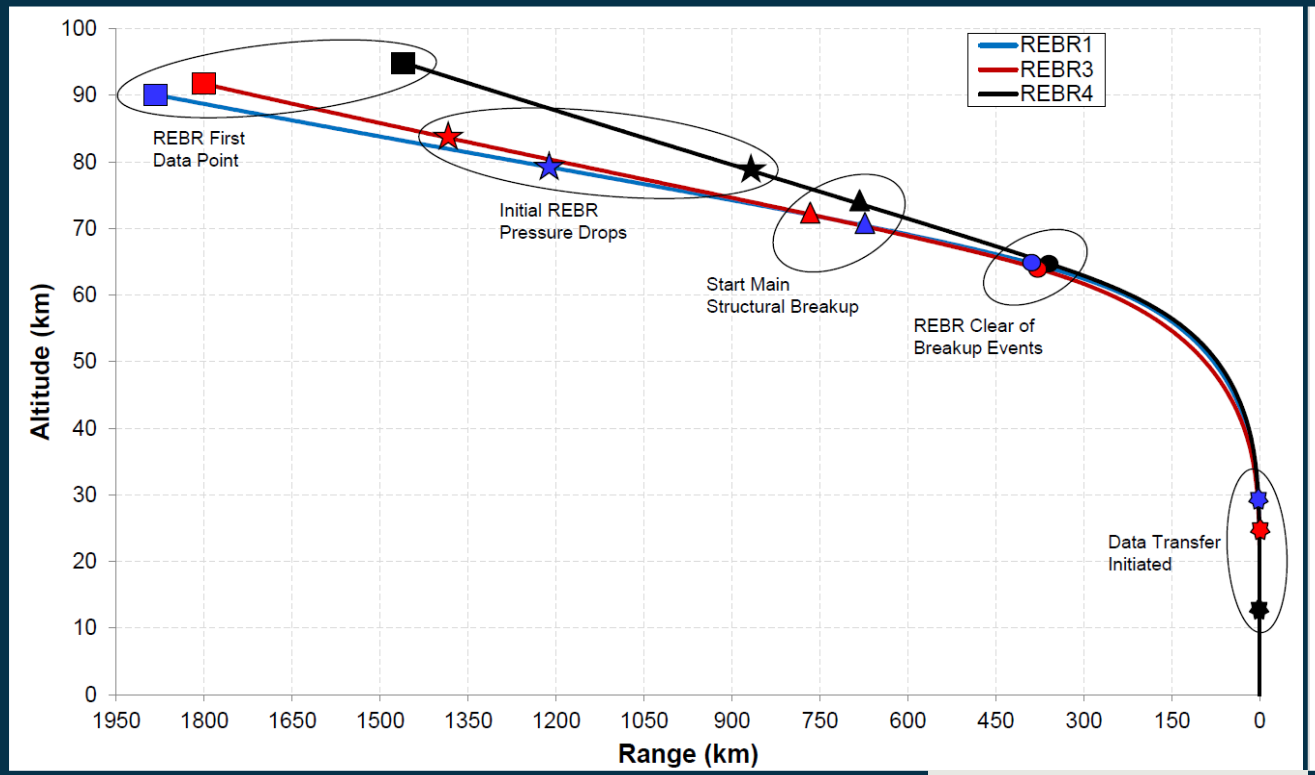


i-Ball (HTV-3) re-entry image
Credits JAXA. https://iss.jaxa.jp/en/kiboexp/theme/iball/index.html.

No direct measurements of the demising spacecraft!
Lack comparison data to validate understanding

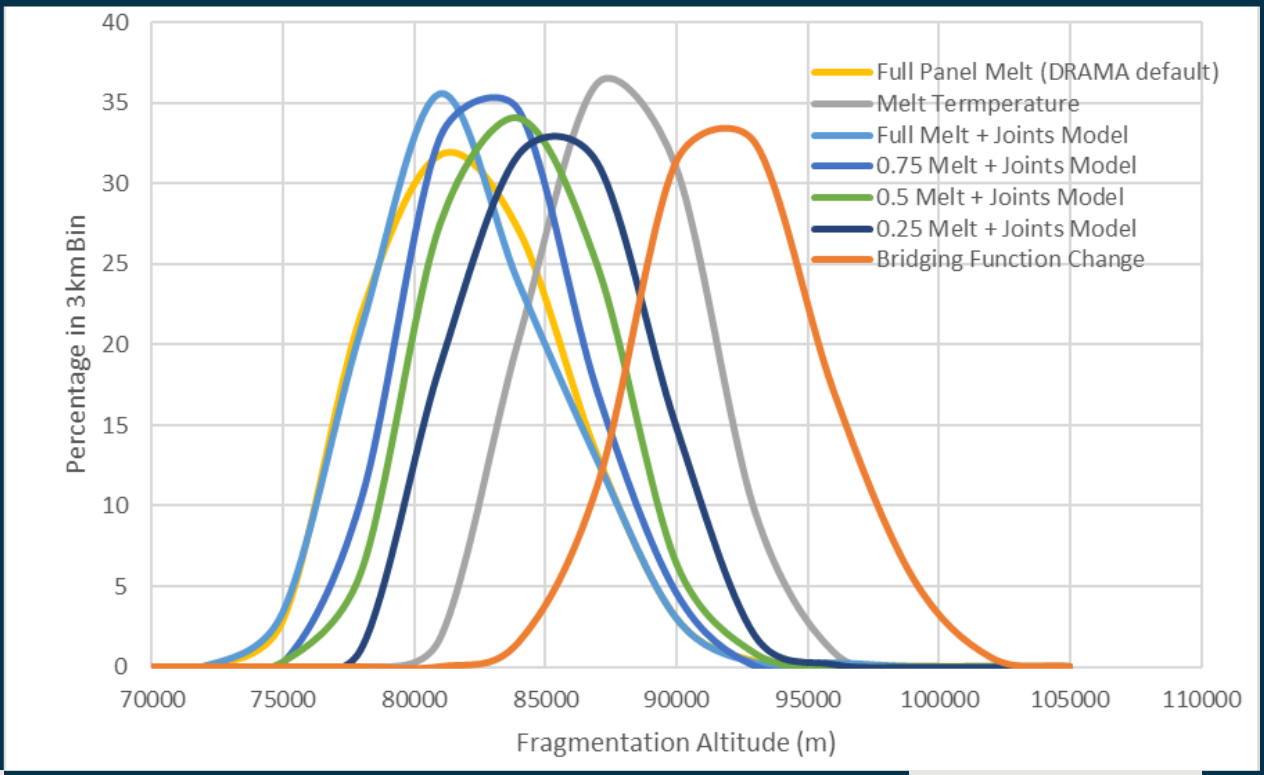
Determining the “truth” of S/C demise

RECONSTRUCTED



Credits Aerospace Corp

GROUND-TEST COMPATIBLE PREDICTIONS

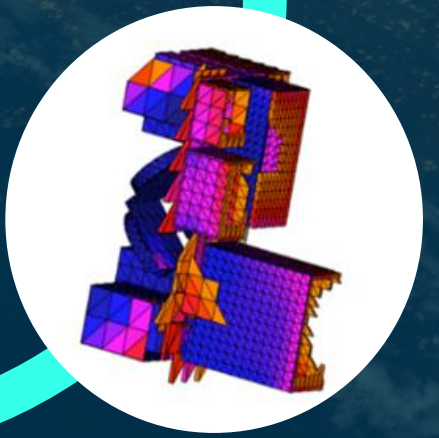


Credits BRL/ESA

Determining the “truth” of S/C demise

Data measurements and transmission

Conditions representative of full re-entry



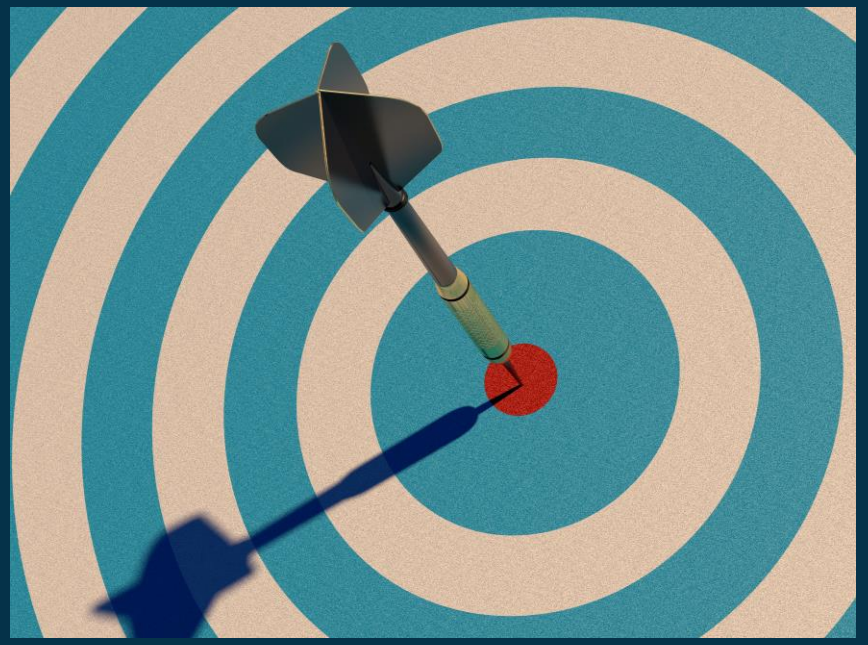
Fragmentation and behaviour of materials modelling

Topical Re-entry Prediction Workshops (at ESA)

Previous re-entry workshops (https://conference.sdo.esoc.esa.int/proceedings/list):

- Re-entry predictions during the last days prior to entry (1985)
- The Re-entry of Salyut-7 / Kosmos-1686 (1991)
- MIR Deorbit (2001)
- A Holistic View and New Avenues (2018)
- Preparing for the Race Downwards (2020, virtual):
  - How to transition from uncertainty assessment to operational products when it comes to re-entry predictions and orbital lifetimes?
  - Which multi-physics driven break-up processes produce predictions which can be verified on a macroscopic level to cause first fragmentation?

6th ISDRW objectives



1. Take stock of community activity
   - Modelers, operators, ground testing facilities, observers
   - Measurements, model validation, re-entry physics
2. Facilitate and further improve exchanges
   - Understanding others´ needs
   - Strengthening the re-entry community
3. Understand community data needs
   - Build datasets
   - Enable data sharing mechanisms and policies
   - Identify desirable missing data

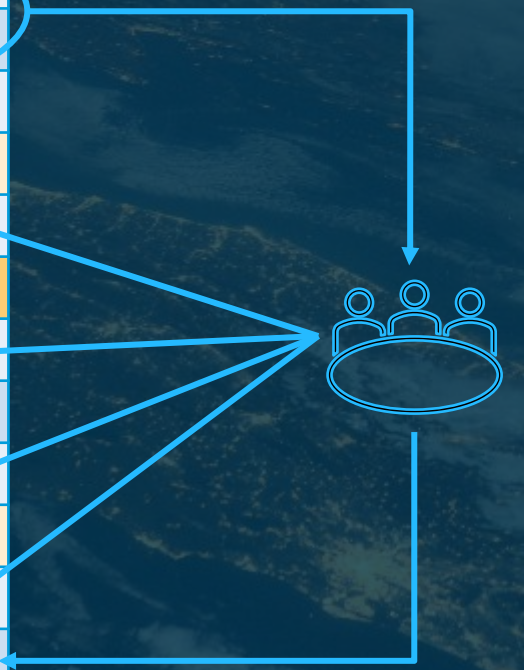
6th ISDRW objectives – sharing of data

- Some data is already available online (e.g. OPS-SAT)
- Some data can be made available through projects with ESA (including OSIP, which has an open call at the moment) (e.g. AVUM DRAMA model)
- Some data can be shared, but needs pre-processing (e.g. housekeeping data for Aeolus)
- Which data is most useful? Which data would make most sense to have online/available?

Agenda

Which data is available?

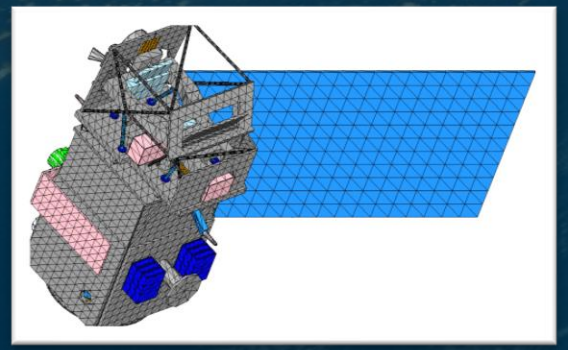
09:00 – 10:00	Welcome & Introduction
10:00 – 10:30	Aeolus and GOCE SOM (Viet Duc Tran)
10:30 – 10:45	ERS-2, AVUM, ATV-1 (SDO)
10:45 – 11:00	OPS-Sat (Tim Oerther) and BEESAT (Anton Grosse)
11:00 – 11:15	Cluster II SOM (Bruno Sousa)
11:15 – 11:45	Coffee break
11:45 – 13:00	**WS-1 Modelling**
13:00 – 14:00	Lunch break
14:00 – 15:00	**WS-2 Science of Re-Entry**
15:00 – 15:15	Near term opportunities (Stijn Lemmens)
15:15 – 16:15	**WS-3 Observation campaigns / Ground facilities testing**
16:15 – 16:45	Coffee break
16:45 – 17:30	Workshop wrap-up
17:30 – 18:00	Final remarks and future steps

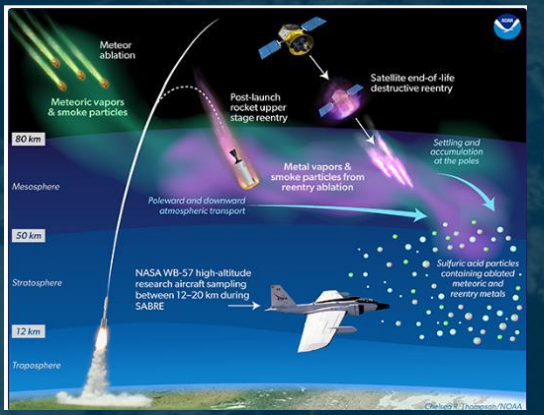


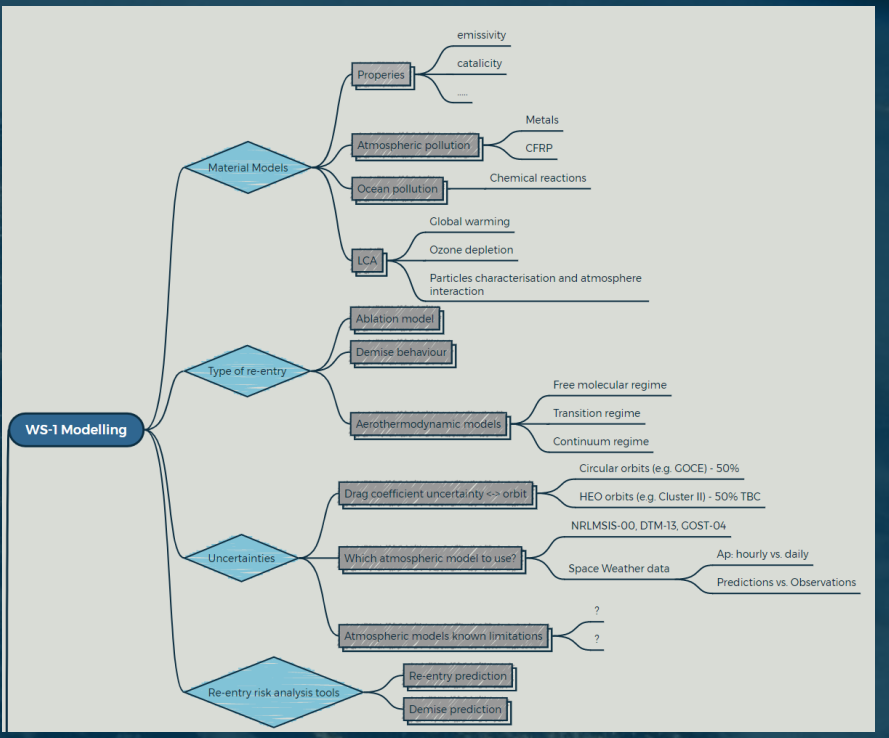
What to expect from WS-1: Modelling

Based on the State of the Art to discuss about known and identified gaps:

- Material models: properties, atmospheric pollution, ocean pollution, LCA
- Type of re-entry <-> ablation model
- Uncertainties characterisation per type of orbit <-> atmospheric models
- Risk analysis tools re-entry and demise characterisation differences



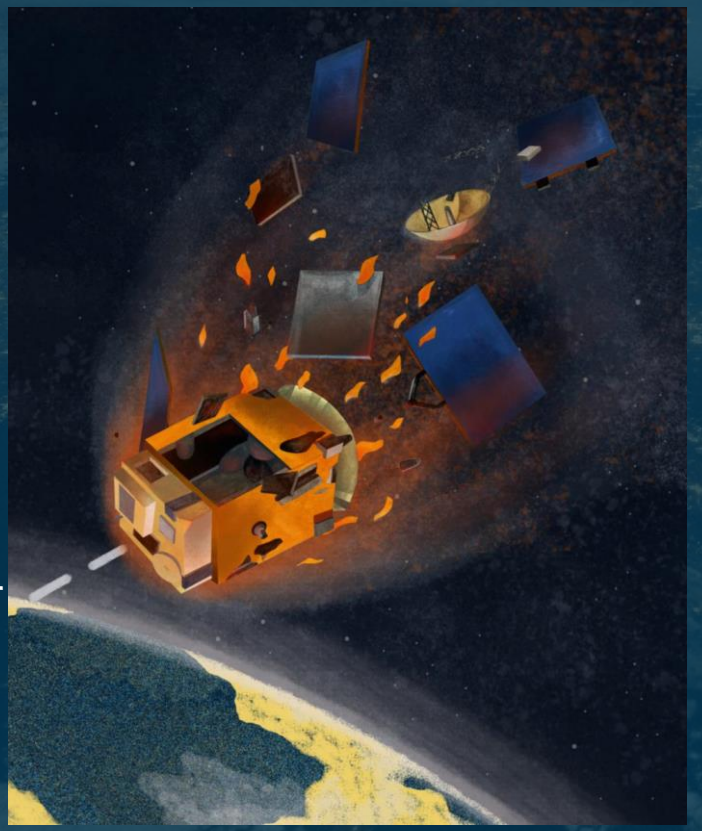


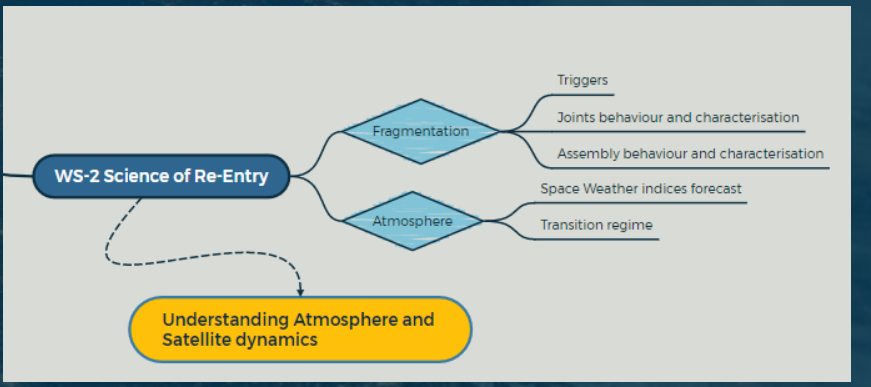


What to expect from WS-2: Science of Re-Entry

Re-entry phenomena characterisation and big picture understanding:

- Fragmentation process trigger: small vs. big SCs, type of re-entry…etc
- Joints and assembly behaviour and characterisation
- Atmosphere characterisation: space weather indices forecast
- Transition regime between free molecular and continuum aerothermodynamics



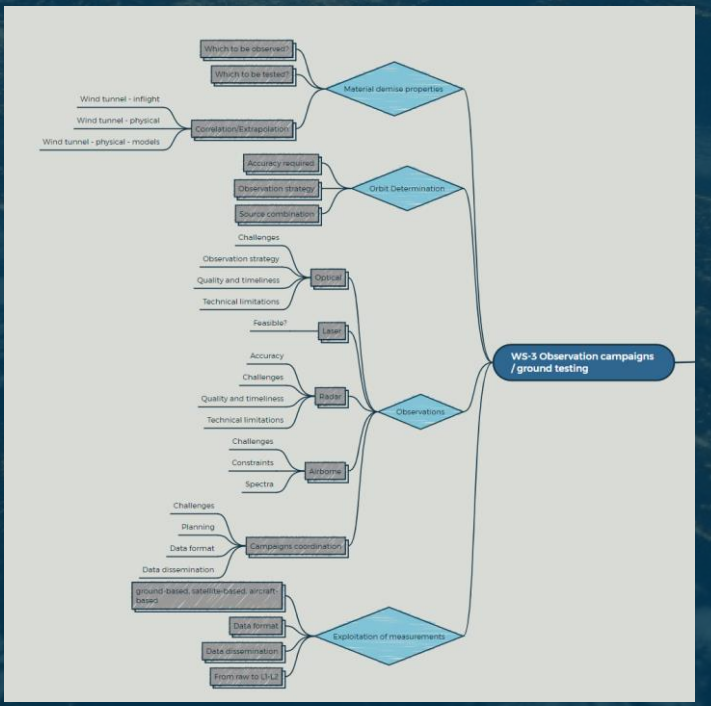


What to expect from WS-3: Observations & Ground Testing

What to test and how to observe:

- Observation techniques and coordination
  - Optical passive telescopes
  - Tracking and imaging radars
  - Airborne campaigns
- Orbit determination from observations measurements
  - Required precision for re-entry predictions
  - Required number of measurements

- Wind-tunnel tests and what can address
  - Material characterisation
  - Small length scale demise characterisation



IADC re-entry campaign

- The IADC was formally established in 1993 to:
  - promote the exchange of information on space debris research activities between member space agencies,
  - to facilitate opportunities for cooperation in space debris research,
  - to review the progress of on-going cooperative activities,
  - and to identify debris mitigation options.

- The IADC Terms of Reference request that at least one annual re-entry prediction exercise shall be conducted to verify the functionality of prediction tools.
  - Full re-entry campaign or re-entry test campaign

- Campaign administration, web-based front-end hosting and maintenance by ESA/ESOC by Space Debris Office
  - Exchange of orbital elements, predictions, observations,… within members in an easy and secure way