INTERNATIONAL ASTRONAUTICAL FEDERATION

Space Traffic Management

The IAF initiative

Status of Working Group #2.7

Improving the knowledge

Hazards associated with reentry

Special Session

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Membership

INTERNATIONAL ASTRONAUTICAL FEDERATION

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This report provides insights on the current state of understanding of hazards associated with space vehicle reentry and their prediction and regulation.

Topics discussed include:

- Current regulations and guidelines that limit hazards to people from a single object reentry and describe recent desires to minimize hazards associated with reentries of multiple satellites from individual large constellations
- Tools and material data that are used to model reentries and estimate ground hazards
- Issues associated with object-oriented and spacecraft-oriented reentry prediction tools
- Uncertainties that affect the ability to predict where and when an object will decay from orbit and reenter the atmosphere
- Flight experiments that collect data to help understand reentry breakup and improve hazard prediction models

The report asks a number of questions and suggests next steps that should considered to improve models and reduce reentry hazards as new space systems emerge and evolve.

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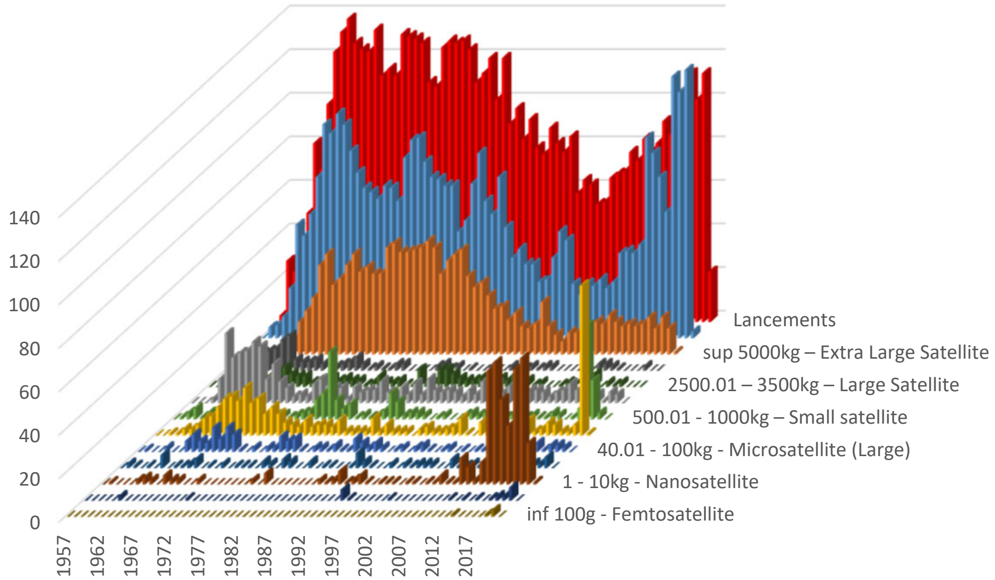
Generalities



Two types of reentries where hazards should be considered:

controlled reentry :

- reentry point is actively controlled
- large fragments do not pose an unacceptable hazard

uncontrolled reentry : object in orbit is simply allowed to reenter because of atmospheric drag. Any debris created by disintegration of the object will land somewhere on the planet along the object's orbit track.

In both cases, consideration must be given to the possibility that debris too small to be a threat to humans on the ground could be dangerous to aircraft

Reentry and the risk to human life

Reentry risk criterion is currently the 1E-4 collective risk limit commonly adopted in all documents

Issues are computations and tools associated

With large constellations and new space the notion of cumulative reentry human risk is born :

"In developing the mission profile, the program should limit the cumulative reentry human casualty risk from the constellation" (ODMSP)

need to be addressed with methodology associated

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Description of the exiting method

Object-oriented tools
- DEBRISK
- DRAMA
- DAS

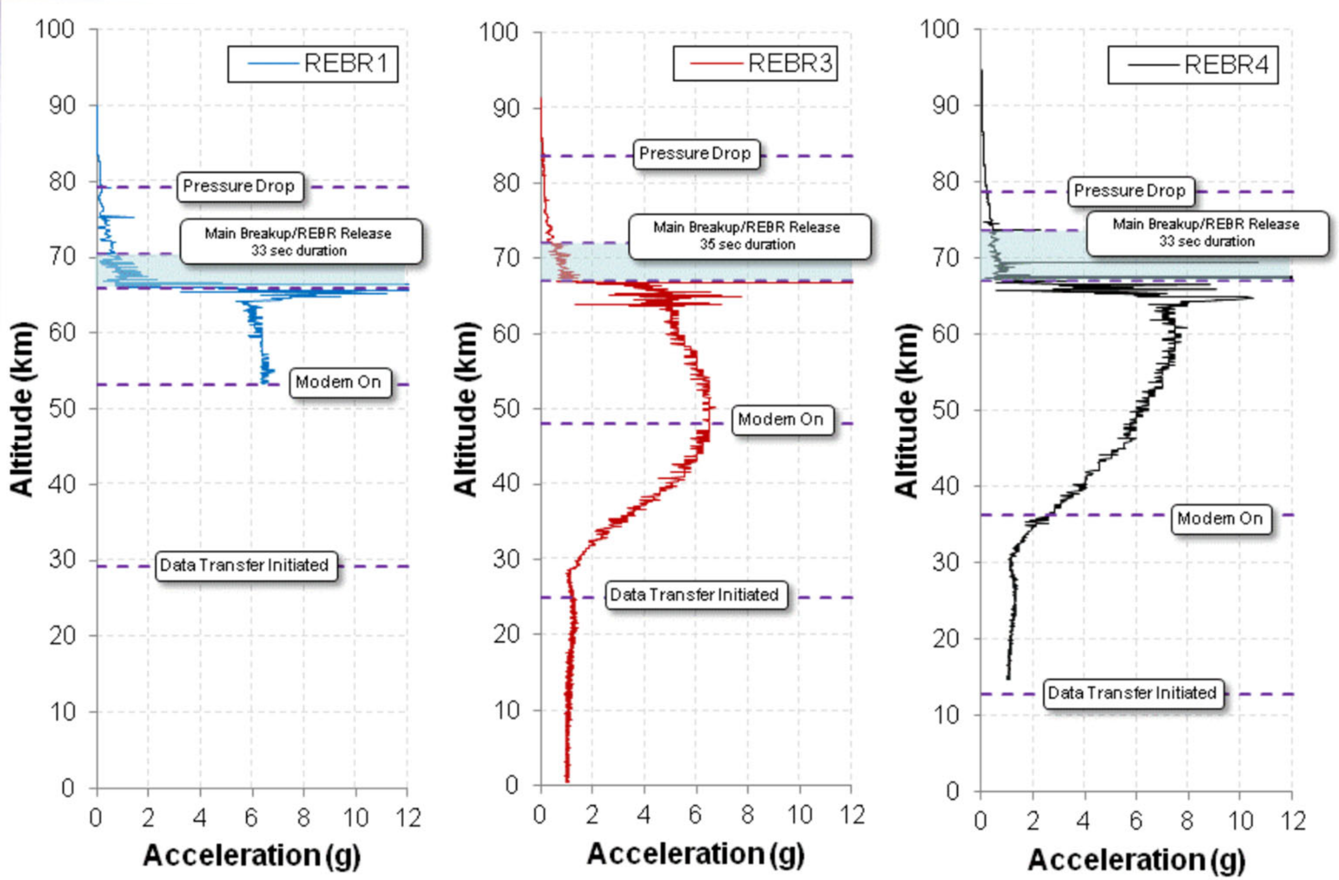
Spacecraft-oriented tools
- PAMPERO
- SCARAB

Common issues between Object-oriented tools and Spacecraft-oriented tools

- Accurate gravity model, atmospheric density model and material property data are required for survivability analysis, and lack of these will result in inaccurate results.
- Material property data (specific heat, latent heat of fusion, thermal conductivity, melting point) easy to obtain
- However, emissivity is more difficult.(metal :simple, composite materials :complicated) and more generaly Optical properties of material .
- Oxidation reaction between oxygen contained in the atmosphere and falling objects.
- Science is not well known specially aerothermodynamics (uncertainty about heat fluxes are not less than 30%)
- Break-up behavior of complex structures implies complex behavior that is difficult to capture in single physical parameter (e.g., other factors such as viscosity, creation of a oxidized layer, material ejecta deposit, etc., seem to also play a role)
- Mechanical properties are not well characterizing at high temperature

Uncertainties affecting reentry predictions on mass on ground and on the location

We need Flight experiments



- REBR or a similar device could collect data to better understand those differences and help validate results of breakup and hazard prediction tools.

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Relevance of random reentries and review of the 1E-4 hazard threshold

Based on what has been observed over the last 11 years (2010-2020), it was found that:

- On average, approximately 100 metric tons of artificial space objects reenter without control in the Earth's atmosphere every year.
  - About 80% of this mass is associated to spent orbital stages,
  - while the remaining 20% belongs to spacecraft;
- Objects with a mass exceeding 500 kg reenter uncontrolled almost every 8 days;
- Objects with a mass greater than 5 metric tons reenter once or twice, per year.
- Considering that, in most cases, a returning dry mass between 500 kg and 700 kg might correspond to a casualty expectancy of the order of 1E-4, uncontrolled reentries potentially at risk could be very frequent, likely representing more than 70% of the total number of reentering intact objects.

The reentry risk cannot be neglected since it could only increase with the intensification of space activities and the growth of the world population density.