Experimental Investigation of Space Debris Fragmentation During Re-entry

Ph.D. Candidate:
Dániel Gábor KOVÁCS

Promoter
Prof. Gaëtan KERSCHEN

Supervisor
Prof. Olivier Chazot
Advisor
Dr. Guillaume GROSSIR

March 3, 2021

Framework

Space debris accumulation

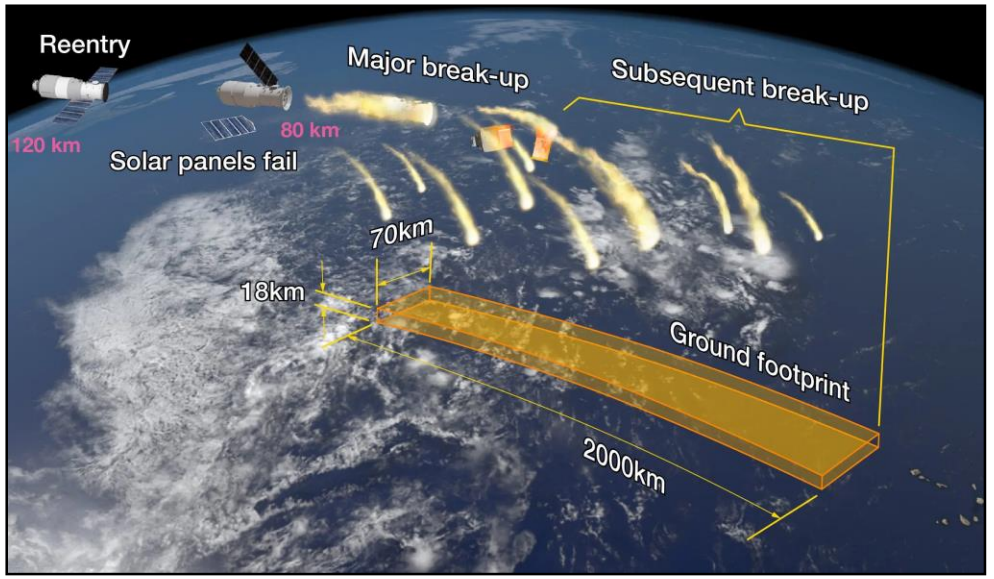
- Environmental & safety problems
- Mitigation strategy ⟶ promote reentry & **Design for Demise** (D4D)
- Re-entry is a risk for ground population ⟶ to be evaluated

1,000,000 debris > 1cm by 2021 [1-2].

[1] European Space Agency, “Distribution of space debris around Earth”, 2019
[2] European Space Agency, “Space debris by the numbers”, 2021.

Fragmentation Phenomena During Re-entry

- Trajectory
- Thermal load
- Aerodynamic load
- Thermal and mechanical stresses
- Ablation
- Peridynamics
- Breakup at weak points
- Separation and interaction of fragments
- Individual fragment trajectories



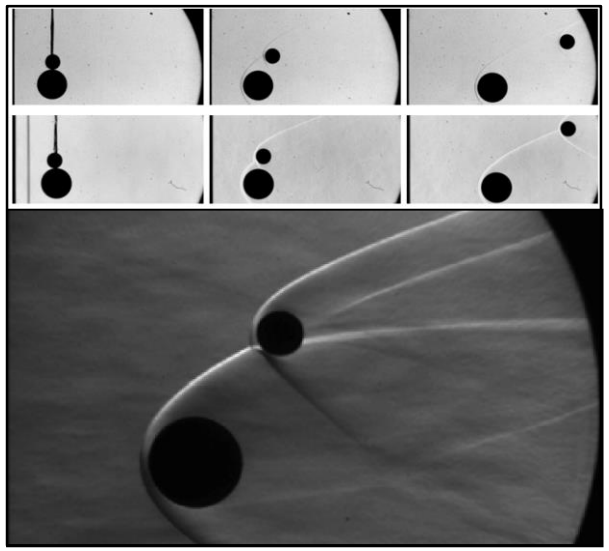
Conceptual illustration of the Tiangong-1 space station's re-entry. [3]

[3] The Aerospace Corporation, "Re-entry illustration of the Tiangong-1", 2018

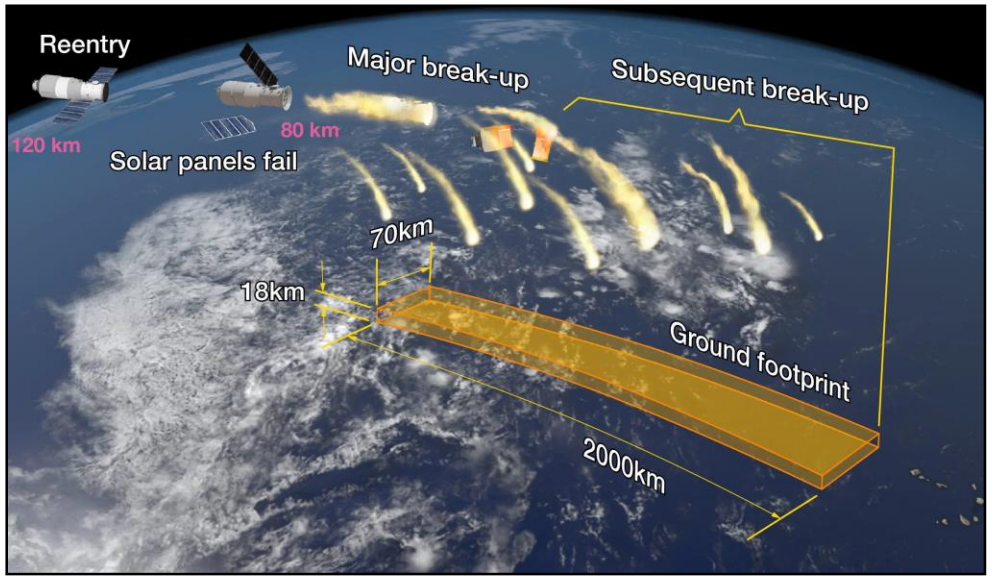
Motivation

Minimize on-ground risk

- Trajectory predictions of enhanced accuracy are required
- Fragmentation impacts the demiseability and on the ground footprint
- Literature of fragmentation is incomplete
- Lack of experimental tools



Free-flight of proximal spheres [4]



Conceptual illustration of the Tiangong-1 space station's re-entry. [3]

[3] The Aerospace Corporation, "Re-entry illustration of the Tiangong-1", 2018
[4] Laurence et al., "Dynamical separation of spherical bodies in supersonic flow", Journal of Fluid Mechanics, 2012

Research Objectives

Process leading to breakup

- Trajectory analysis and wind tunnel tests ⟶ aerodynamic and thermal loads

Effects on the structure

- Structural analysis, weak points, mechanical scaling

Breakup dynamics and fragment interactions

- Wind tunnel testing methodology with free-flight and stationary models

Limitation of testing and extrapolation to flight

Improved fragmentation altitude prediction

Illustration of ATV's fragmentation [5]

[5] European Space Agency, D. Durcos, "Artist's view of ATV-5's destructive reentry into Earth's atmosphere", 2007