5th International Space Debris Re-entry Workshop

Design for demise applied to spacecraft structural panels and experiment for ClearSpace One platform

Alexandre A. Looten

PhD Supervisors:
Prof. Véronique Michaud (LPAC)
Ing. Muriel Richard (eSpace)

2nd of December 2020

LPAC Laboratory for Processing of Advanced Composites

eSpace EPFL Space Center

Research context

Project Partners and Objectives

1) Research context

- **ESA Network Partnering Initiative (NPI)**

Coordinators

esa

EPFL

PhD student

Partners

IRS

Belstead

Together ahead. RUAG

icotec

Bcomp®

clearspace today

Monthly meeting progress status

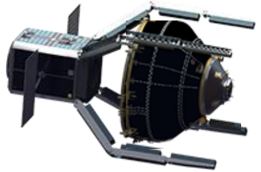
1) Research context

- **Project general objectives**

Design high demisability structural panels

Improve materials demise simulation models

Panels integration on ClearSpace-One satellite
Launch 2025



Scope of Research

Motivation and Method

2.1) Research aim

Motivation

Reduction of spacecrafts (S/C) reentry casualty risk
From components surviving **uncontrolled reentry events**

Demise environment

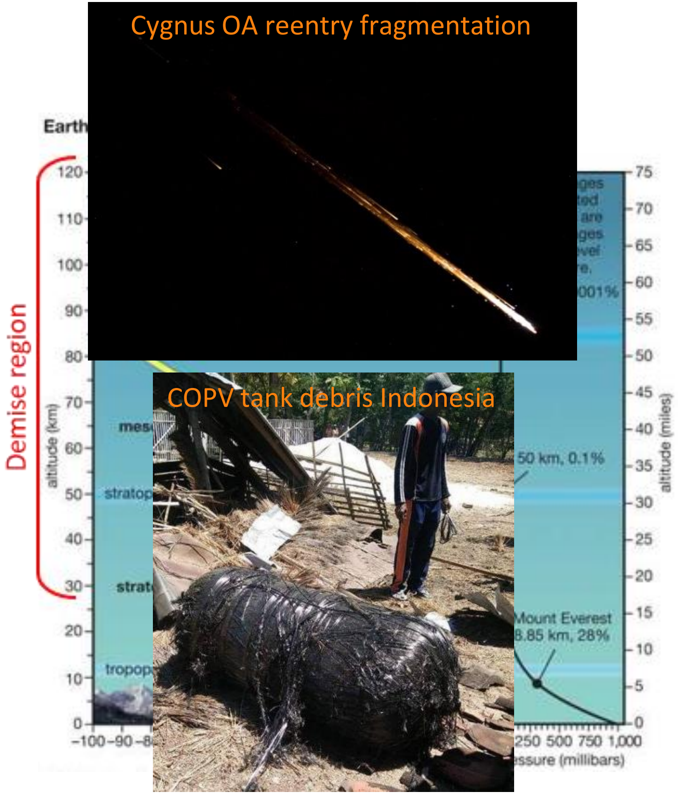
From Space to Earth => high Air/Object interactions

→ **Aero-thermo-mechanical loads**

Obstacle for D4D research

→ Difficult conditions to make in-situ measurements and to recreate artificially on-ground

→ Complex and dynamic reentry environment



britannica.com
atv5.seti.org/cygnus
reentry.esoc.esa.int/home/recovereddebris

2.2) Research method

3 main steps

- Evaluation of the demise behaviour at :
  - Material level → Composite material
  - System level → Sandwich panel

- Deal with composite material main issues:
  - Typical use of high temperature resistance fiber (carbon)
  - Convective blockage of matrix extreme outgassing [1]

- Development of complementary solutions:
  - **Natural fiber implementation (Flax fiber)**
  - **Matrix with active particulate filler**
  - **CFRP fasteners (screw, bolts)**

Project objective → **Increase overall S/C demisability by material substitution and specific design**

[1] P.Reynier, Survey of convective blockage for planetary entries, 2012

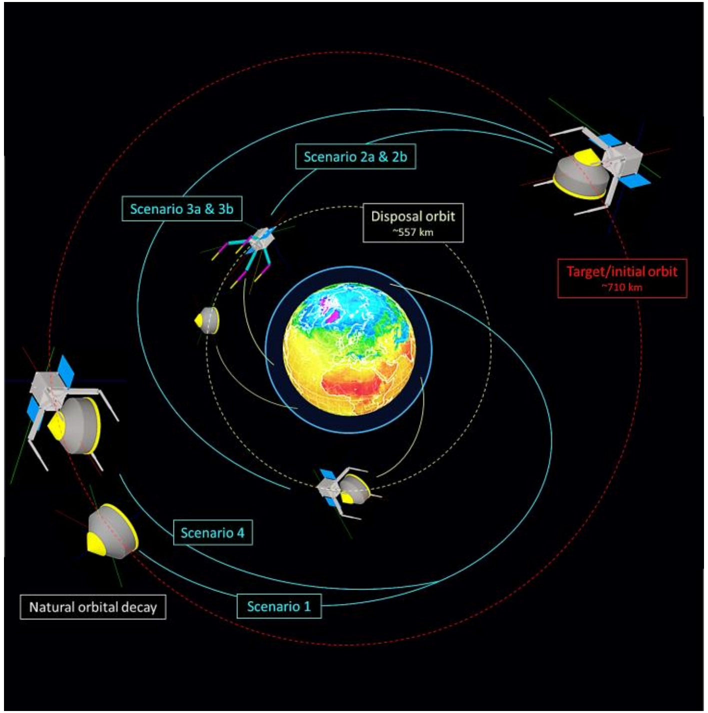
2.3) Material models improvement

Thermomechanical experiments
→ Demise properties vs Temperature
→ Demise behaviour, onsets

Reentry simulation material model update
Specific composite properties
→ Pyrolysis, charring, spallation
→ Oxidation
(DRAMA, SCARAB)

Optimal sandwich panel design
&
S/C reentry scenario selection

ClearSpace-1 reentry scenarios analysis



Novel composite design

Sandwich Panel Facesheets and Fastener

3.1) Sandwich skin selection

Evaluation of 5 skin versions for the structural sandwich panel

2 Typical designs

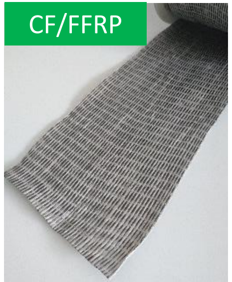
Reference - Full aluminium

Best structural properties

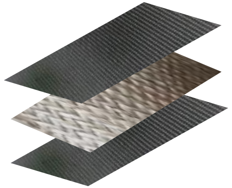
3 Novel designs

Full flax

Hybrid Carbon/Flax



Superposition Carbon-Flax



Avantages of Flax fiber:

- Demisable under typical reentry environment
- High vibration damping properties
- Hybrid reinforcement compatible

Particulate filler in composite matrix

High regression rate matrix pyrolysis to facilitate ablation/spallation of the plies

→ Aluminium micro/nano particles

3.2) Composite fastener

→ Higher overall demisability by passive earlier structural panel release

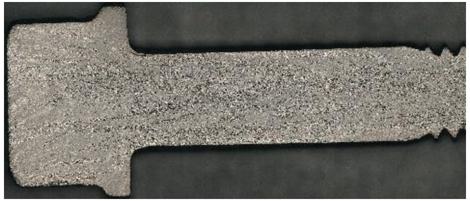
Baseline fastener materials

Stainless steel
Ti-6Al-4V
Al 7075v

Composite alternative

CF/PEEK

Icotec CF/PEEK screws M6x30



Avantages of CF/PEEK fasteners over typical material:

- Higher strength/mass ratio
- Lower loosening temperature
- High vibration damping properties

Possibility to implement simple active releasable fastening system

For high altitude panel release, to favor the demise

Thermomechanical testing

4) Thermomechanical testing

Testing steps for material selection and reentry environment simulation

- TGA
  Thermogravimetry analysis
- DMA
  Dynamic mechanical analysis

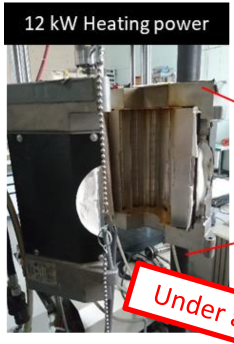
Current status

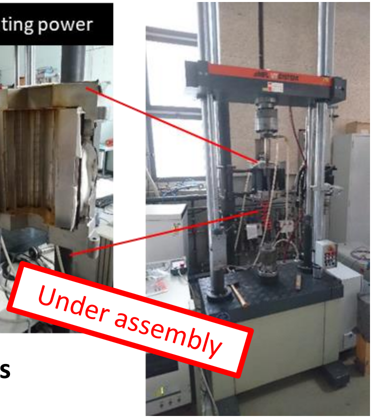
- High heat flux creep/ stress relaxation
  IR lamp heater and basic environmental chamber
- PWT (aero-thermo dynamics)
  Plasma wind tunnel @IRS (Germany)

UTM setup, F_{max} $100\ kN$

Testing parameters:

- Initial preload
- Constant displacement
- Rough vacuum, $10^{-3}\ mbar$
- Heat flux $\sim 100\ kW/m^2$

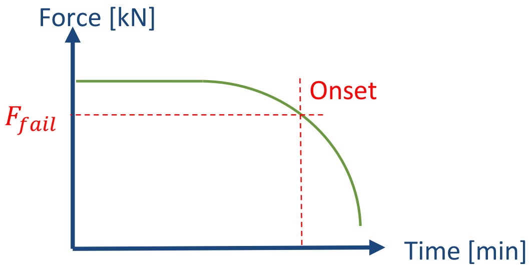




Output parameters:

- **Timing onset of the structural properties loosening at defined threshold**
- **High temperature degradation behaviour (optical/thermal camera)**

Expected results



Conclusion

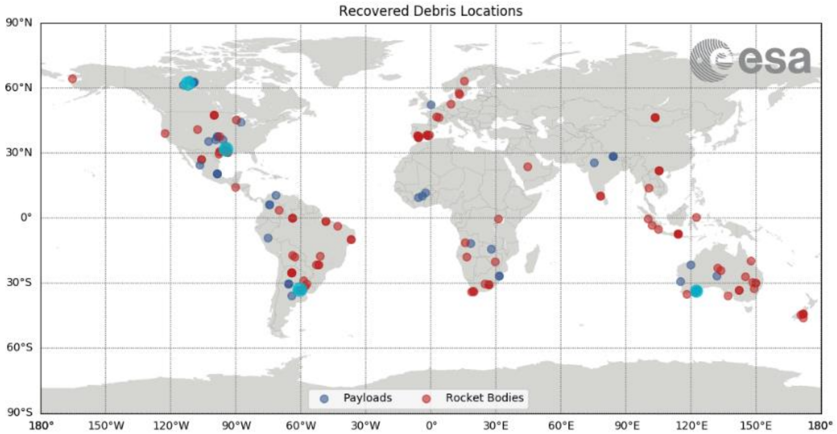
To Conclude Then

Conclusion

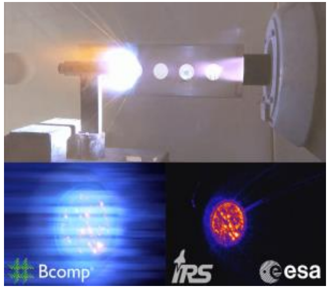
- Reentering space debris is a Worldwide problem
- Reentry conditions complex to recreate for testing

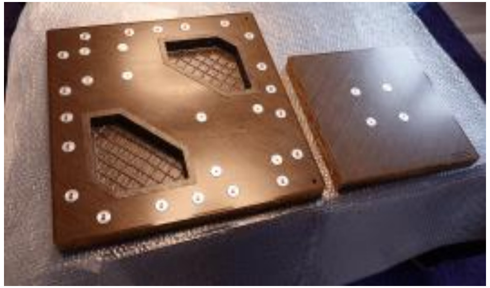
Project aims to develop:

- Scientific response to the current incomplete understanding on demise behavior at material and system level for composites
- Interconnection between experiments and demise models (DRAMA)
- Novel composite demisable structural panel and release system



Bcomp flax fiber demonstration structural panel, 2019





reentry.esoc.esa.int
bcomp.ch/news/

Thank you for your attention !

esa.int/ESA_Multimedia/

LPAC Laboratory for Processing of Advanced Composites
eSpace EPFL Space Center
clearspace today
Together ahead. RUAG
Belstead
icoset
IRS
Bcomp