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Assisted Spacecraft Demise with Exothermic reactions

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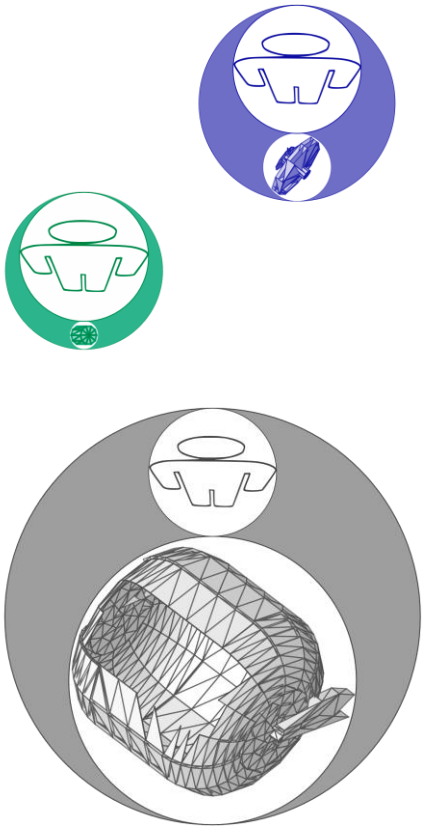
Some common spacecraft equipment pose a risk on-ground

Common critical equipment include:

- Propellant tanks
- Reaction wheels
- Solar array drive mechanisms



There is not enough heat to demise! What can we do?

- Thermite!

Thermite vs. Car
https://www.youtube.com/watch?v=rdCsbZf1_Ng&t=106s

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What is Thermite?

- Thermites are mixtures of a metal and a metal oxide, usually in powder form. Once the redox reaction is triggered, a noticeable amount of heat is released.

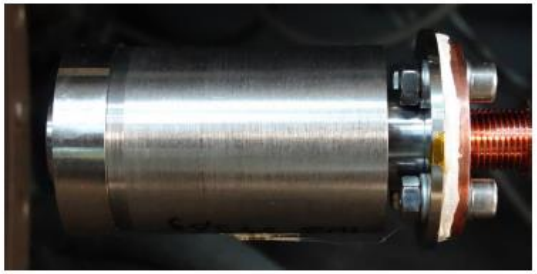
- Aluminium is the best candidate for the metallic component:
  - High energy output
  - Great availability (and low cost)
  - Non-toxic

- The metal oxides selection drivers:
  - Theoretical Maximum Density (TMD)
  - Adiabatic reaction temperature
  - Fraction of products in gaseous state
  - Specific reaction enthalpy

Exothermic reactions can aid the demise process

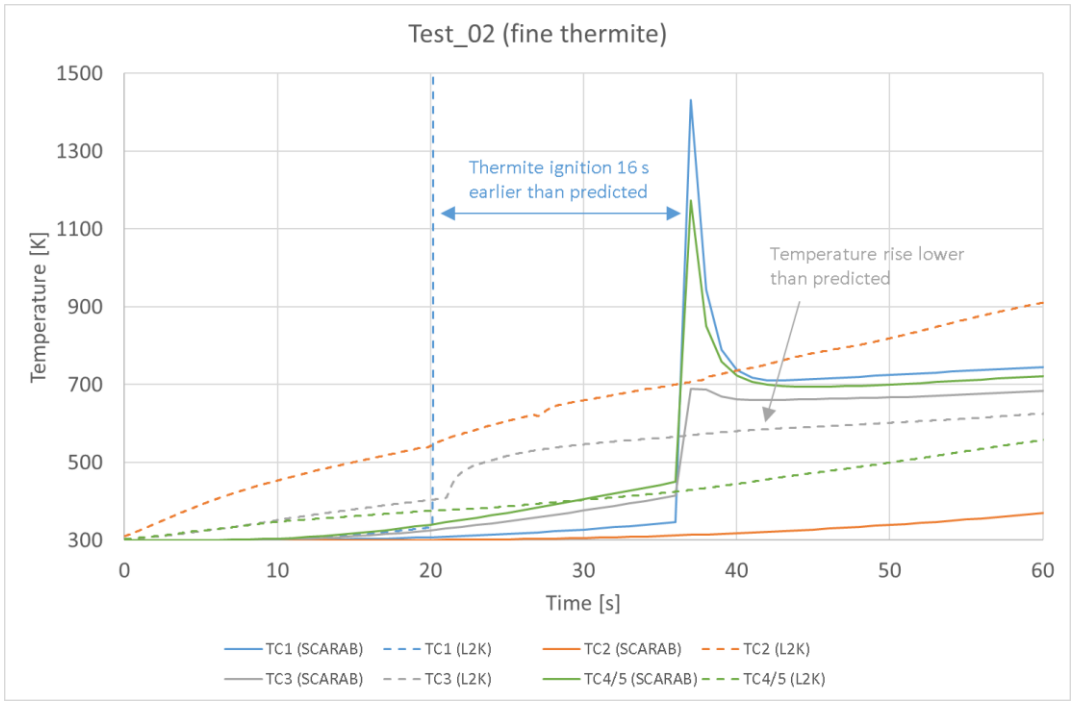
Supersonic and Hypersonic Technologies Department

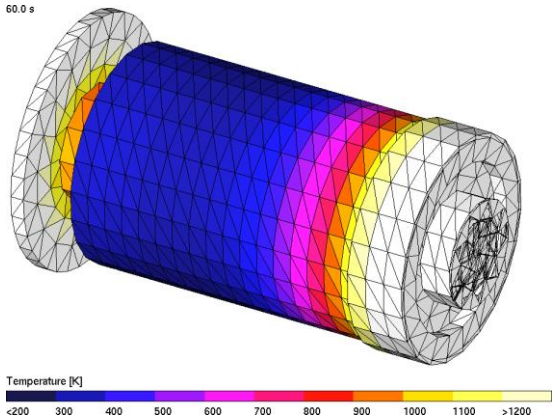
DLR

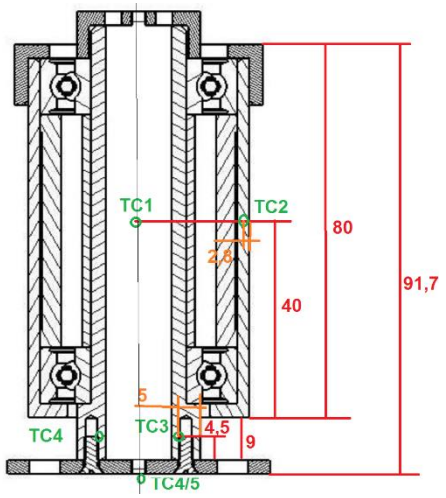


ERASD - Exothermic Reaction Aided Spacecraft Demise - Proof of Concept Testing – Final Report, Contract No. 4000126547/19/NL/AR/ig, Issue 1, Revision 2, 10/05/2019

Numerical re-building improve our understanding of the demise process







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The on-going SPADEXO project aims making exothermic reactions practical for demise purposes

- SPADEXO [HTG / PoliMi & ReActive / DLR]

- The goal of the current project is to:
  - Design, optimize and prove the concept of using exothermic reactions for demise purposes.
  - Design and verification of different fuse concepts.
  - Devise guidelines for use of the technology in various equipment

- Currently the project is in the design phase for the breadboard. The test campaign is scheduled for early 2023

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Energetic material selection

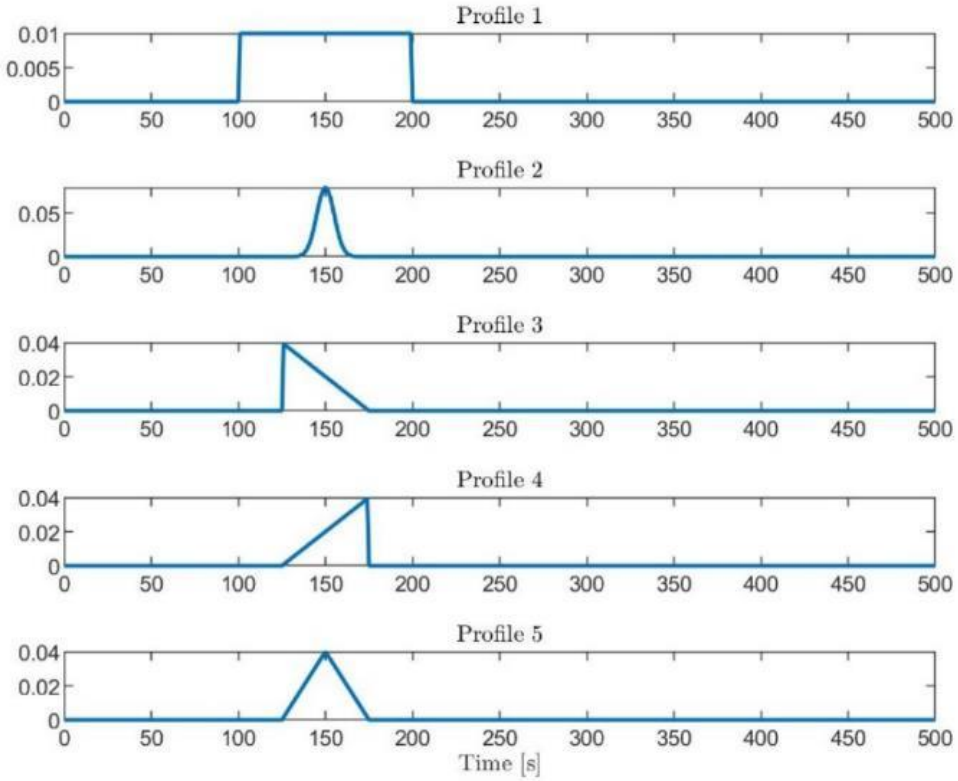
- Al-Fe_2O_3 has been selected as the main formulation to be investigated.

- It is important to have the possibility of tuning the ignition temperature of the charge:
  - Use of other thermite formulations as primer
  - Mechanical activation

- Mechanical activation can be used to increase powder reactivity, while maintaining the benefits typical of micrometric powders:
  - High active metal content
  - Safety

Update to the thermite model in SCARAB

- A new thermite model will be implemented and based on thermite theoretical available heat.



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Practical test cases will be tested in wind-tunnel

- Ball Bearing Unit and Solar Array Mechanism simplified geometry

- Wire bundle cutter

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Conclusion

- Exothermic reactions has the potential to facilitate demise for many common spacecraft equipment.

- Several on-going activities are working on making exothermic reactions for demise purposes practical.

- Exothermic reactions can in the future be a method to help space systems be compliant with the re-entry risk requirements

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Thank you for listening!

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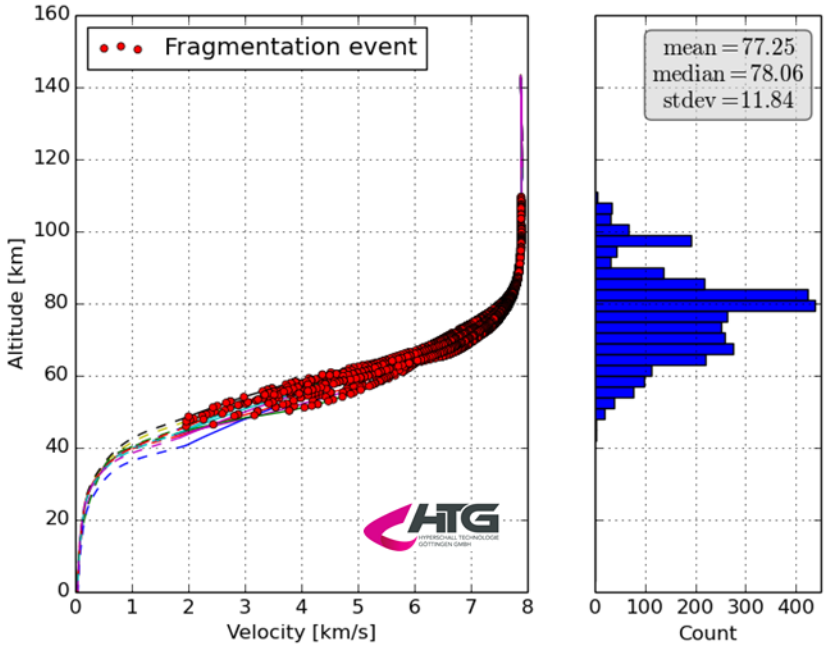
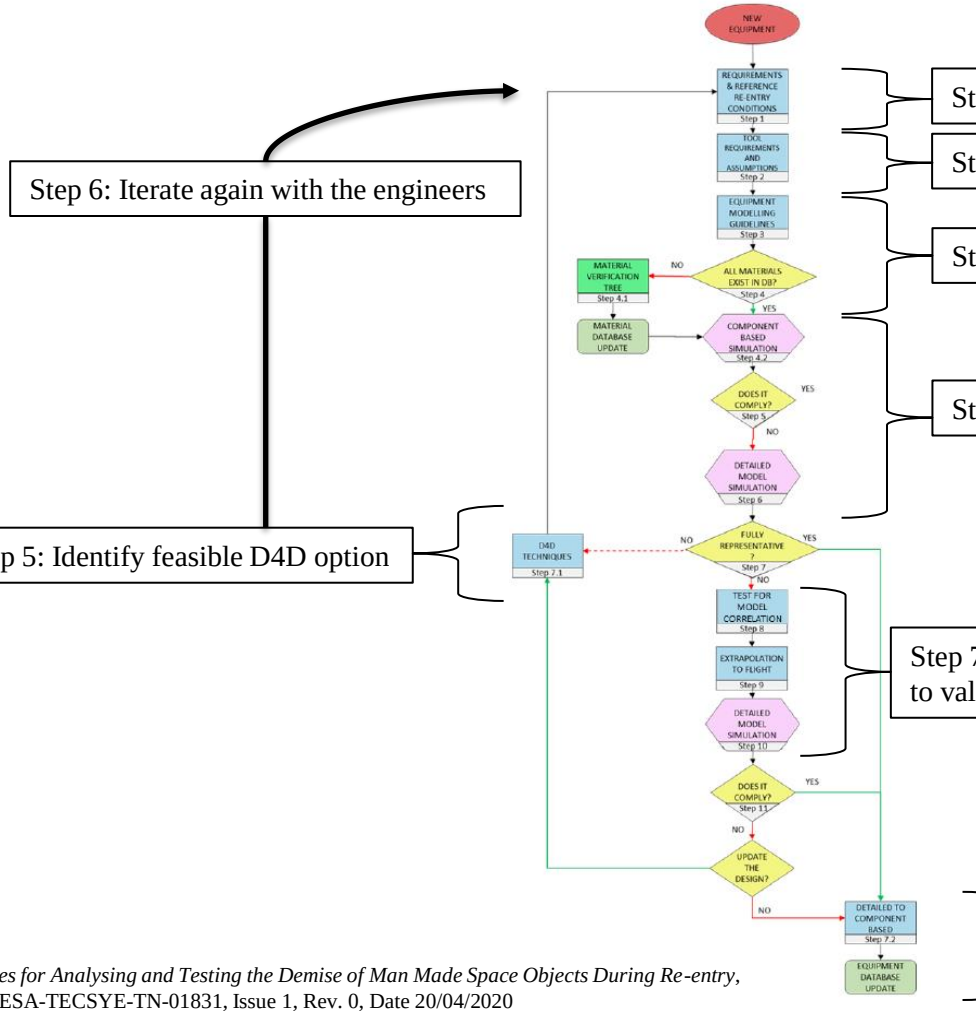
Release altitude from a “typical” spacecraft

Fragmentation data from 16 simulations of a generic “typical” spacecraft, extracted from SCARAB.



DIVE Guidelines
Equipment level Verification Tree



Step 1: Select initial conditions

Step 2: Choose your tool (e.g. ESA DRAMA)

Step 3: Create the equipment model

Step 4: Assess equipment model re-entry

Step 5: Identify feasible D4D option

Step 6: Iterate again with the engineers

Step 7: Perform demise test in wind tunnel facility to validate the model demise behaviour

Step 8: Create component based model and add to equipment database

DIVE - Guidelines for Analysing and Testing the Demise of Man Made Space Objects During Re-entry, Technical Note: ESA-TECSYE-TN-01831, Issue 1, Rev. 0, Date 20/04/2020