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Equipment level demise analysis with SCARAB

P. Kärräng

The casualty risk for any re-entry shall not exceed 10^{-4}

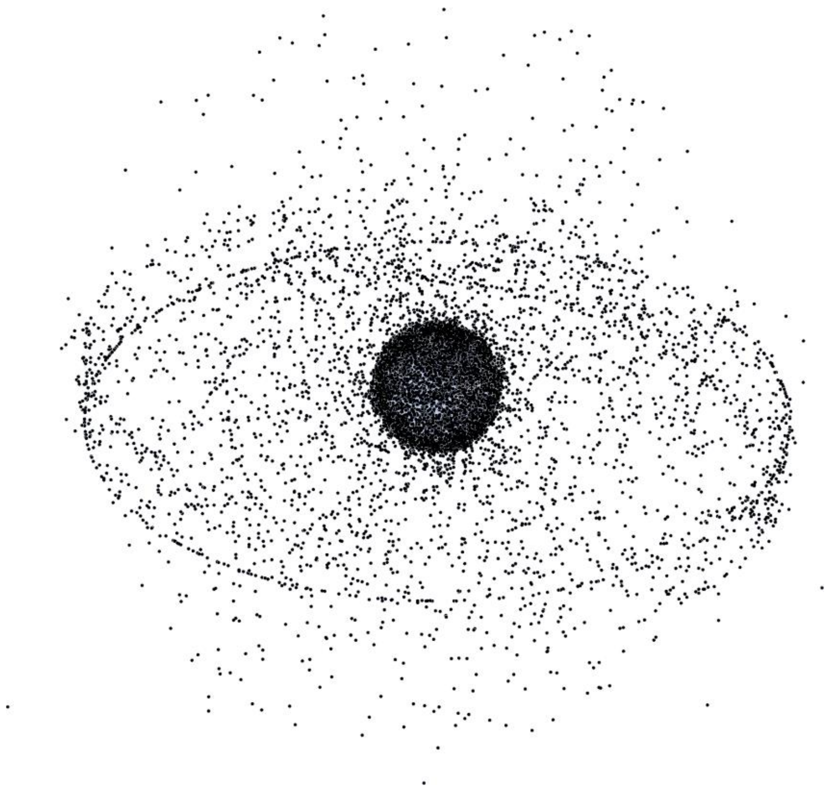


Image credit: NASA
https://eoimages.gsfc.nasa.gov/images/imagerecords/40000/40173/spacejunk_geo_2009237_lrg.png

Design for demise can significantly reduce the risk associated with re-entry.

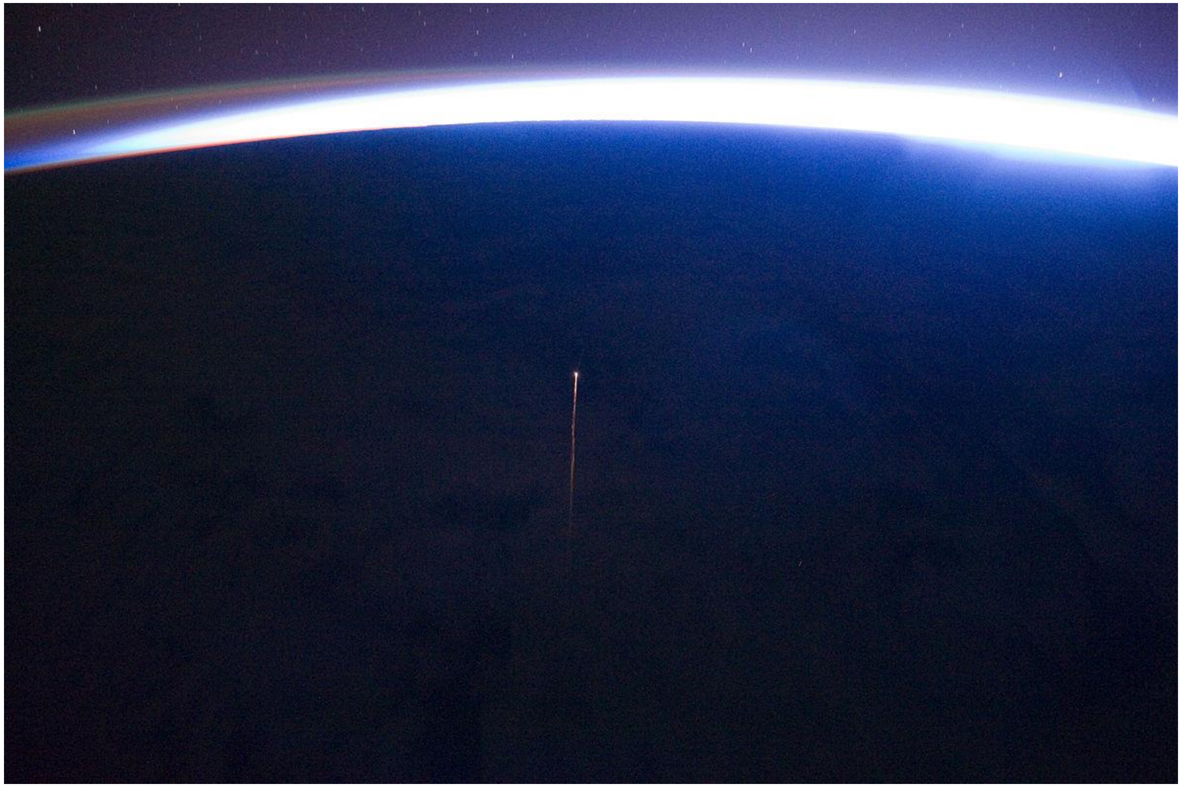
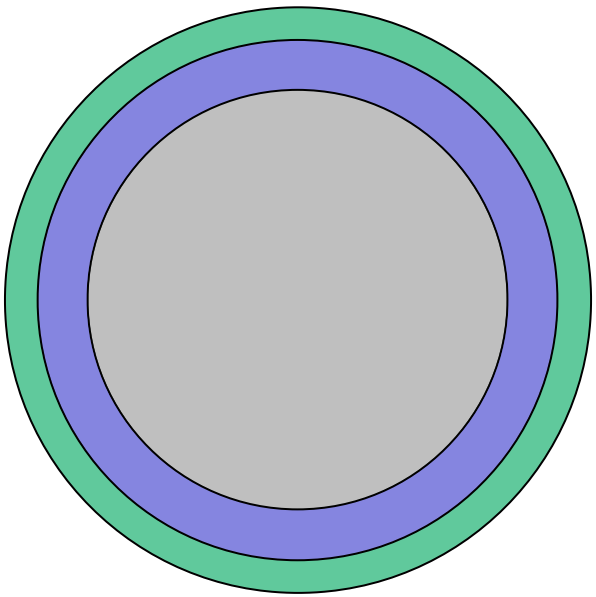


Image credit: NASA
https://apod.nasa.gov/apod/ap110801.html

$$E_c = \rho_p A_c$$

The casualty area can be reduced by limiting the number, size and kinetic energy of fragments

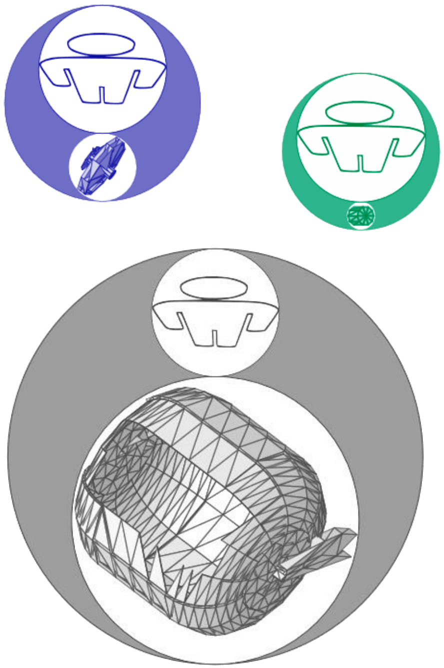
Total casualty area (A_c)



IF ($E_k > 15$J)

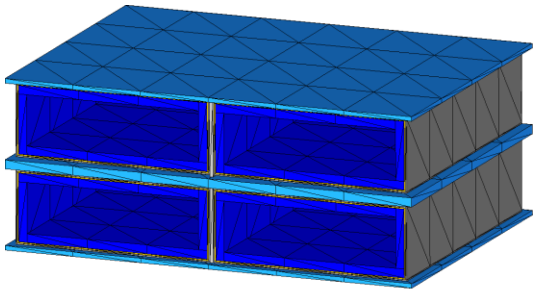
$$A_c = \sum_{i}^{N} \left(\sqrt{A_h} + \sqrt{A_{frag,i}} \right)^2$$

Surviving fragments and potential human casualties

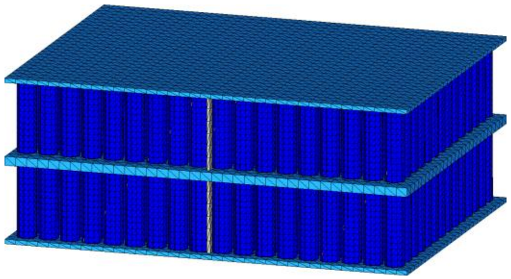


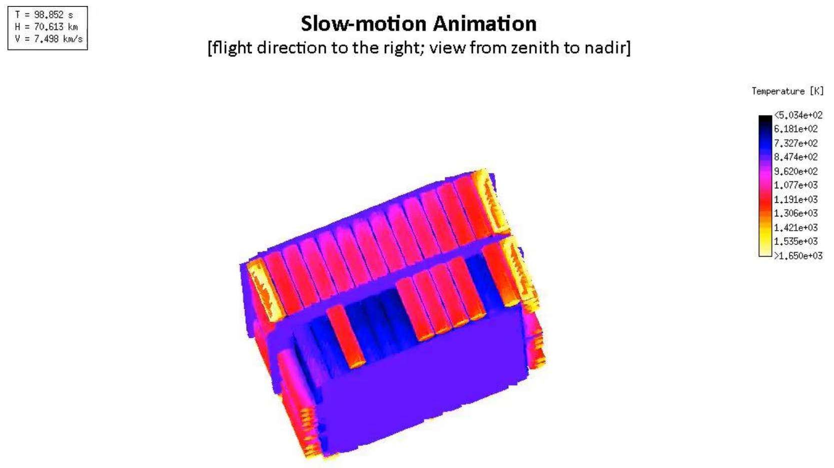
Equipment-level analysis allows for iterations which cannot be done on System-level

Traditional Battery model



Detailed Battery model





Designing for risk reduction is possible through several techniques

Limit number of fragments

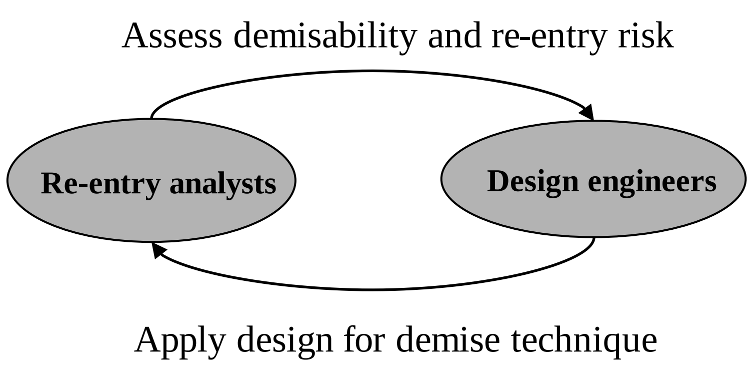
- Increase heat absorbed
- Reduce heat for complete demise
- Containment

Limit size of fragments

- Increase heat absorbed
- Reduce heat for complete demise

Lower kinetic energy at impact

- Partitioning of equipment



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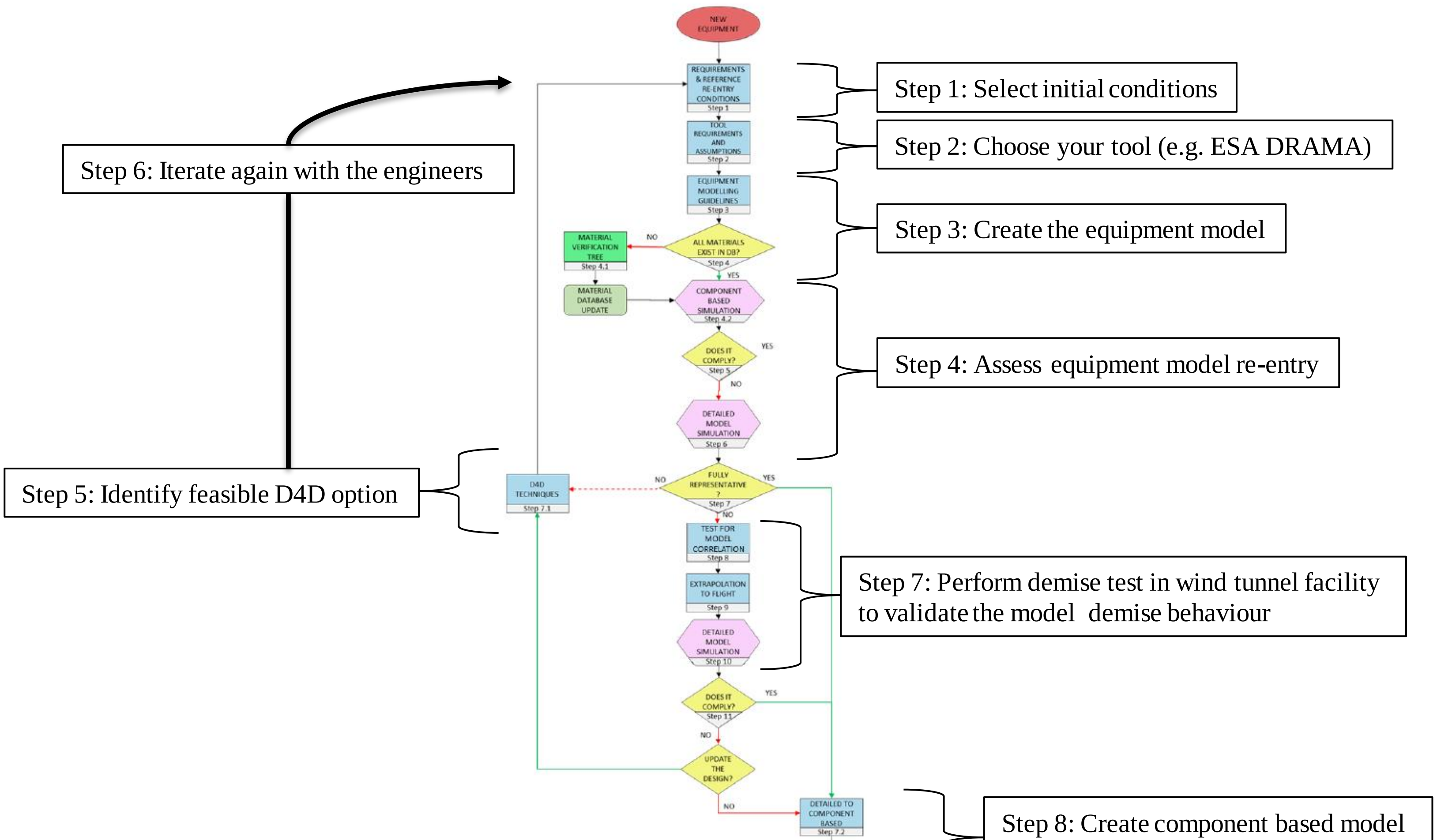
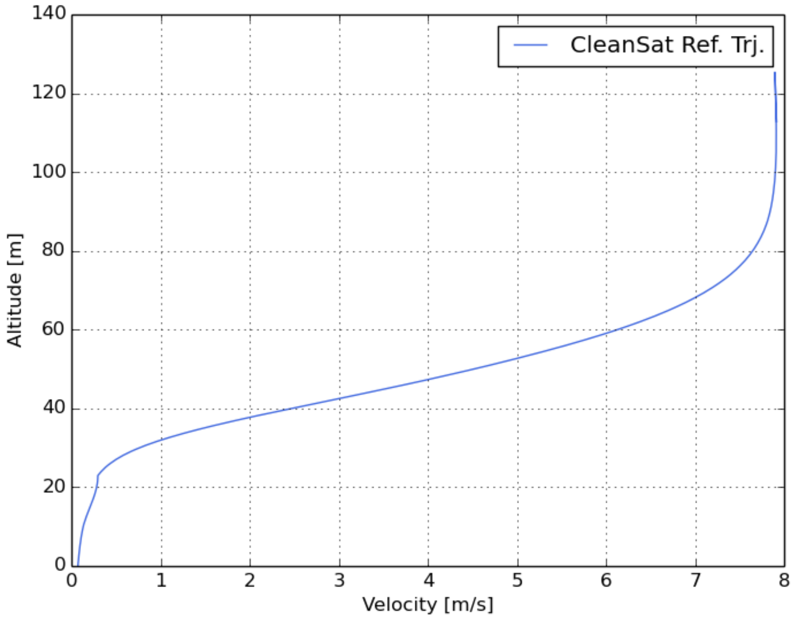
DIVE Guidelines
Equipment level Verification Tree



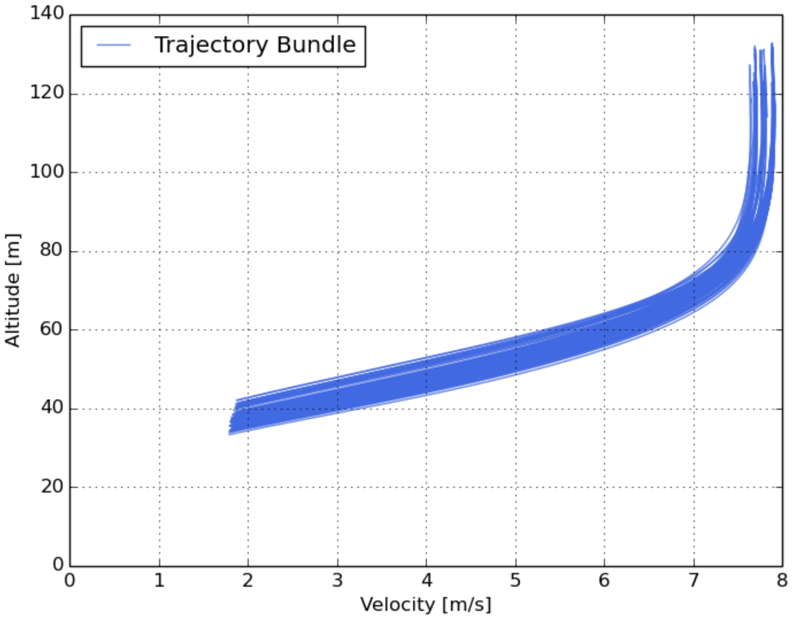
DIVE - Guidelines for Analysing and Testing the Demise of Man Made Space Objects During Re-entry, Technical Note: ESA-TECSYE-TN-01831, Issue 1, Rev. 0, Date 20/04/2020

Step 1: Release conditions for the equipment from reference trajectories

Single trajectory
(e.g. mission specific trajectory)

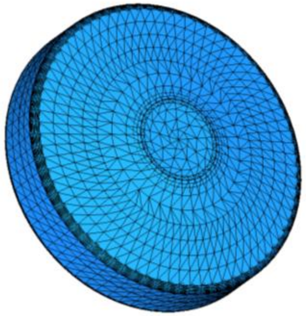


Trajectory bundle
(e.g. uncontrolled re-entry trajectory)

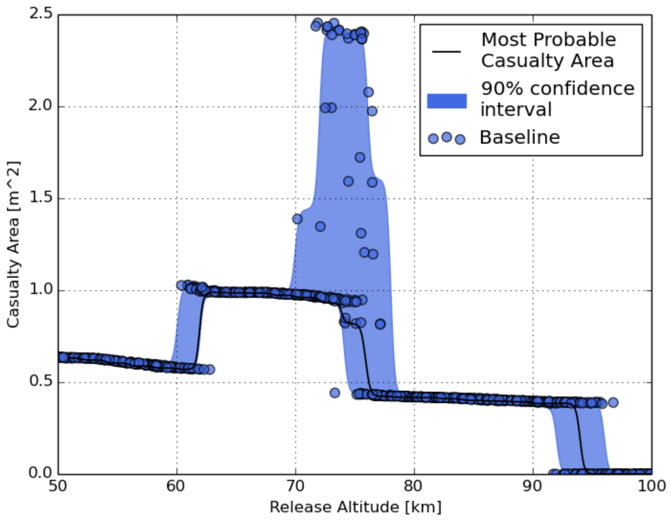


Initial temperature 300K

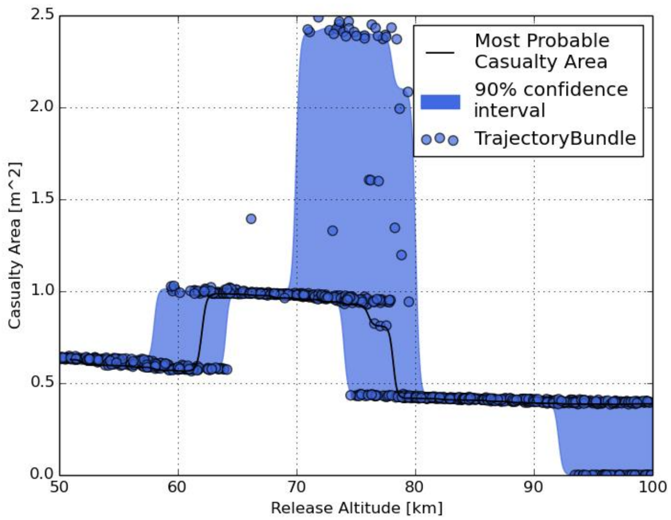
Trajectory bundle gives a larger range of initial re-entry conditions



Single trajectory, without uncertainties

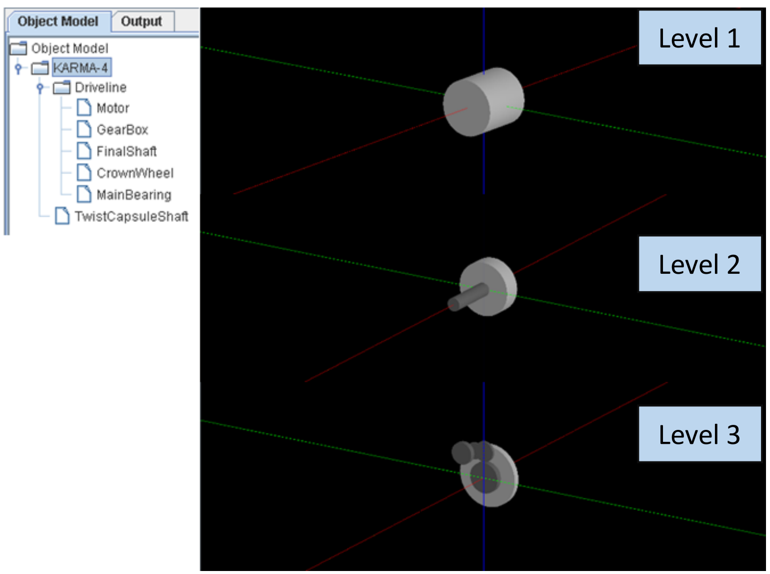


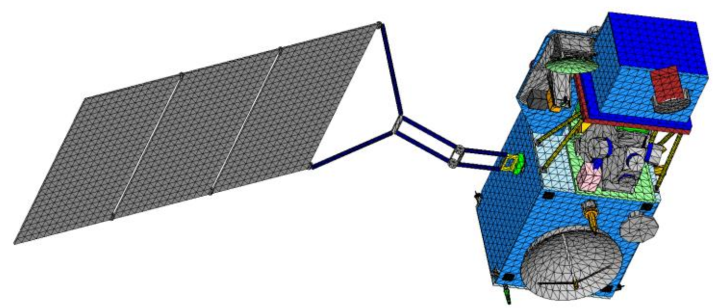
Trajectory bundle, without uncertainties



Step 2: Select your tool (e.g. ESA DRAMA / SARA)

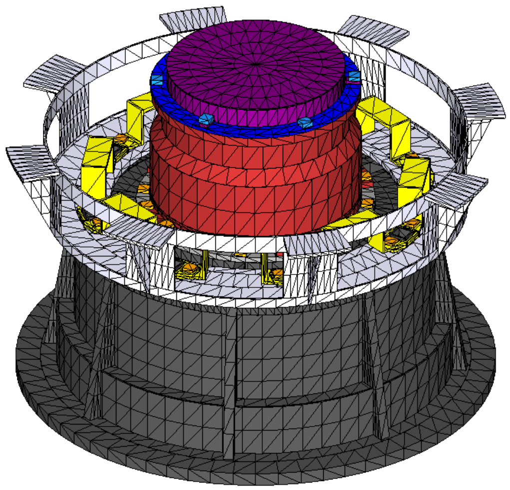
SCARAB

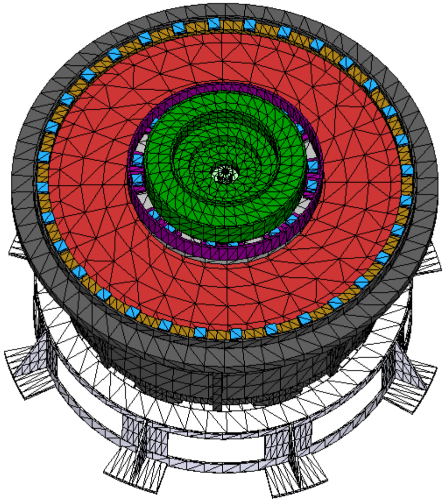




Step 3: Create a baseline model

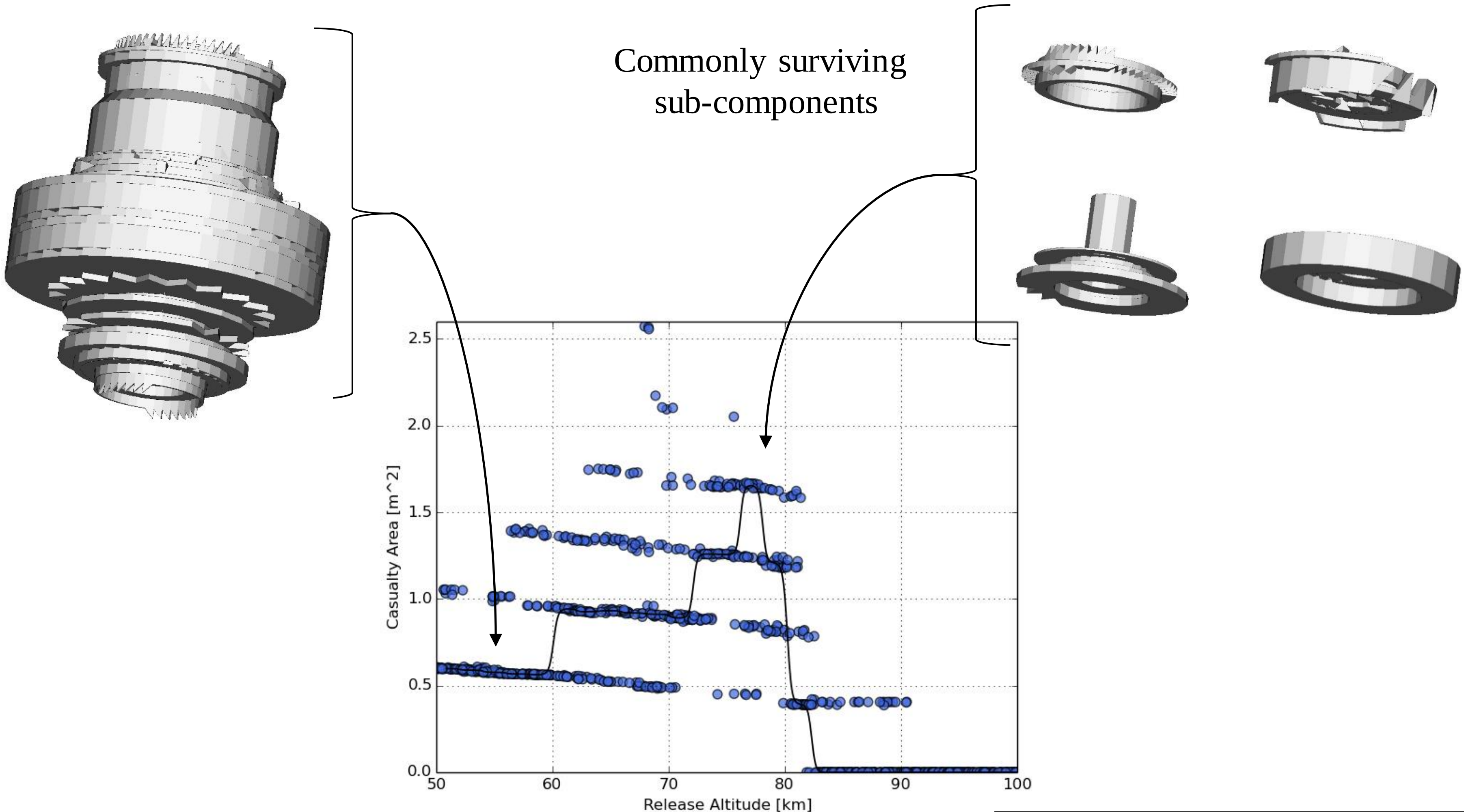
Solar array drive mechanism





High Fidelity Re-Entry Simulations on Critical Spacecraft Platform Equipment,
Demisabilty of Solar Array Drive Mechanism using SCARAB, Final report,
ESA Contract No. 4000121149/17/NL/GLC/as

Step 4: Assess initial model re-entry

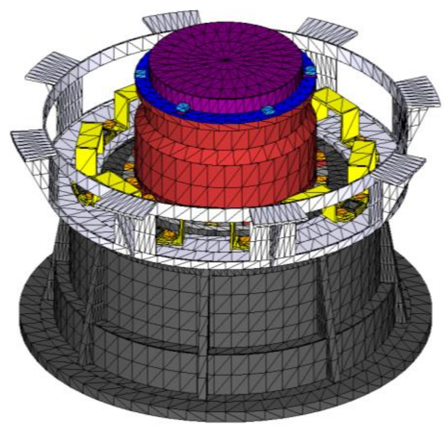


Note: Remember to apply reasonable uncertainties to the simulations when estimating the demise altitude

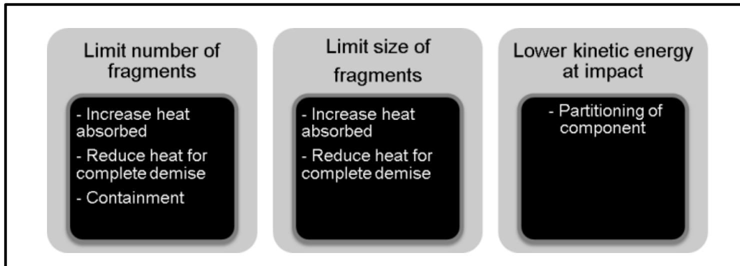
Step 5: Identify feasible design for demise options

Remove parts of the main housing?

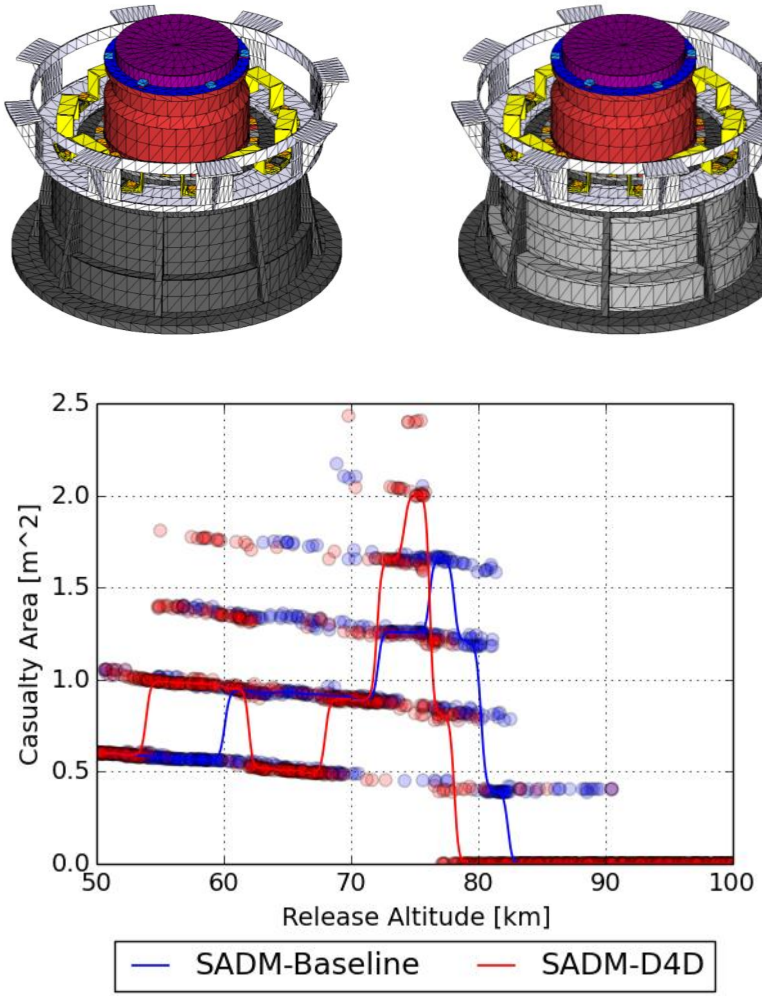
Change material of the ball bearing unit?



Weaken actuator housing to break-up earlier?



Step 6: Assess the new model



Lips, T., Kärräng, P. "Probabilistic casualty risk assessment and labelling for the re-entry of spacecraft components", *Proceedings of the 10th IAASS Conference 2019*. S01/3, Page 12.

Step 7: Perform wind tunnel tests and model correlation

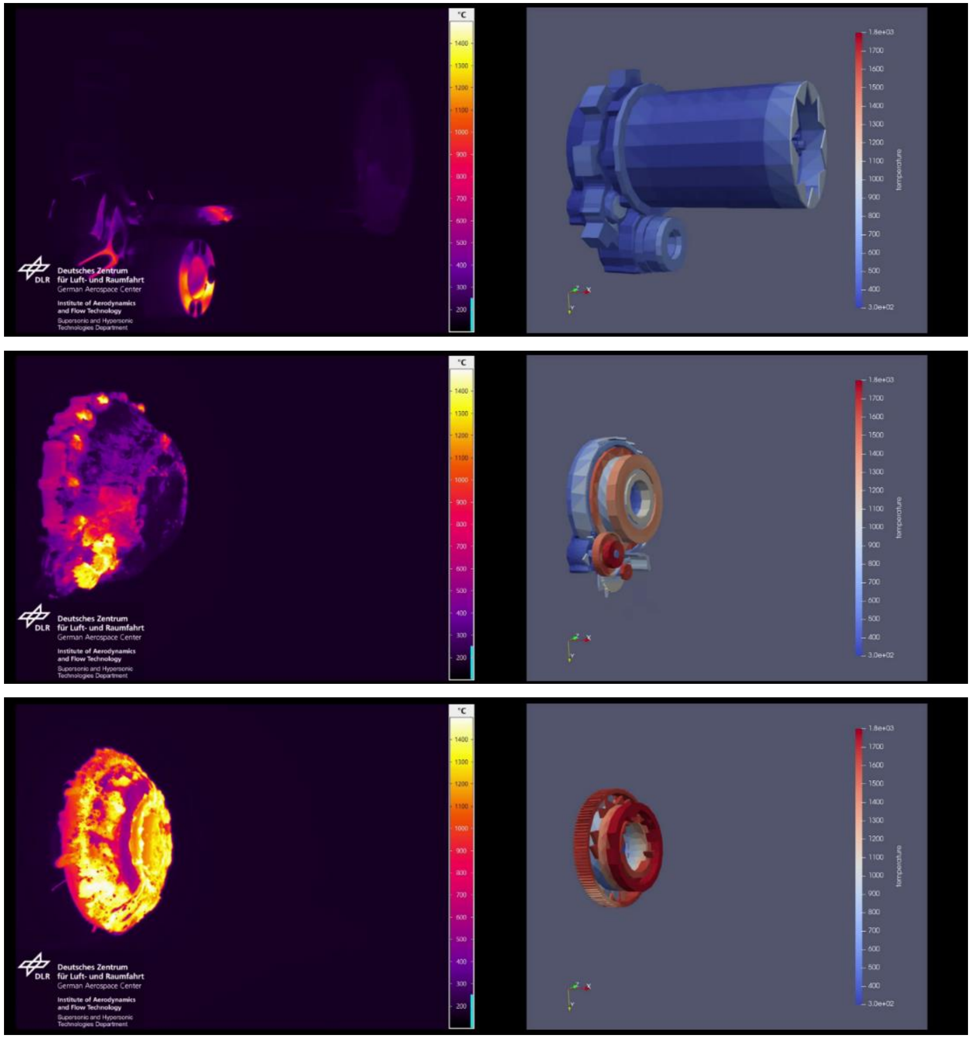
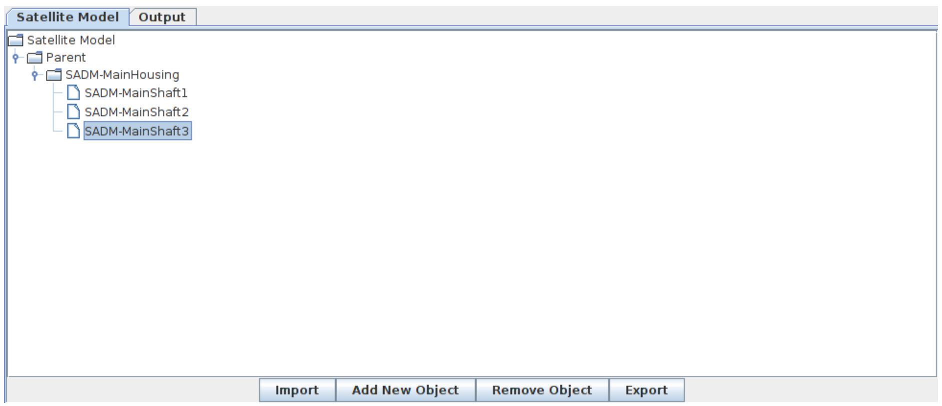


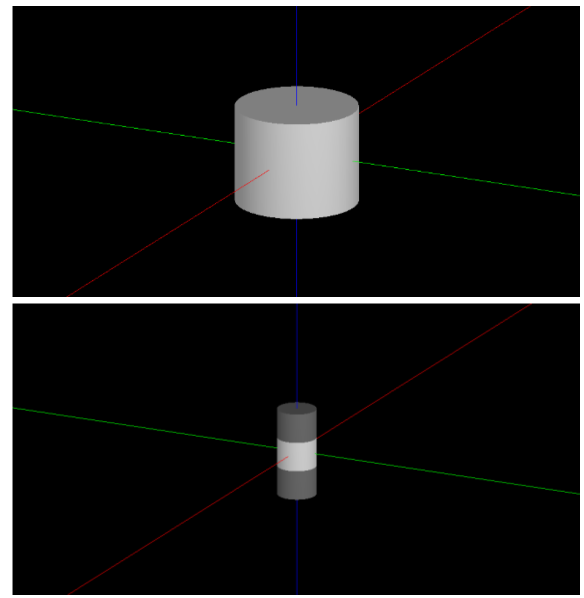
Image credit:
Demisable SADM - Final Report Public,
ESA Contract No. 4000129245/19/NL/AR/ig,

[NOTE: This image is from another project than previous results shown.]

Step 8: Create component-based model

- Detailed equipment model to component-based





High Fidelity Re-Entry Simulations on Critical Spacecraft Platform Equipment, Demisabilty of Solar Array Drive Mechanism using SCARAB, Final report, ESA Contract No. 4000121149/17/NL/GLC/as

Conclusions

Design-for-demise on equipment level …

- is an iterative process
- require individually tailored solutions
- can significantly reduce the risk and cost of a re-entry

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.