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CLEAN SPACE INDUSTRIAL DAYS

Demisable Solar Array Drive Mechanism

22.09.2021

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Agenda

- Presentation of activity and objectives
- Presentation of unit under investigation
- Demisability simulations using the high-fidelity destructive reentry simulator SCARAB
- Plasma Wind Tunnel test campaign in DLR
- Lessons learned and way forward

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Abbreviations

- DLR – Deutsches Zentrum für Luft- und Raumfahrt
- HTG – Hyperschall Technologie Göttingen
- KDA – Kongsberg Defence & Aerospace
- PWT – Plasma Wind Tunnel
- SADM – Solar Array Drive Mechanism

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Demisable SADM activity

- Activity started in 2019 as part of the ESA Clean Space initiative under a TRP contract

- Goals:
  - Select a baseline KDA SADM to be investigated for which increased demisability is desirable
  - Build an analysis model of the SADM in a high-fidelity reentry simulator (SCARAB) and assess its demisability
  - Perform Design for Demise (D4D) iterations in SCARAB aiming to improve the demisability of the SADM
  - Design and build a «dummy» SADM to be tested in a PWT test campaign
  - Perform PWT test campaign on the full-scale dummy SADM, and on critical components alone
  - Perform correlation of the PWT test results with SCARAB simulations and perform potential corrections

Unit under investigation
KARMA-4 TG (Third Generation)

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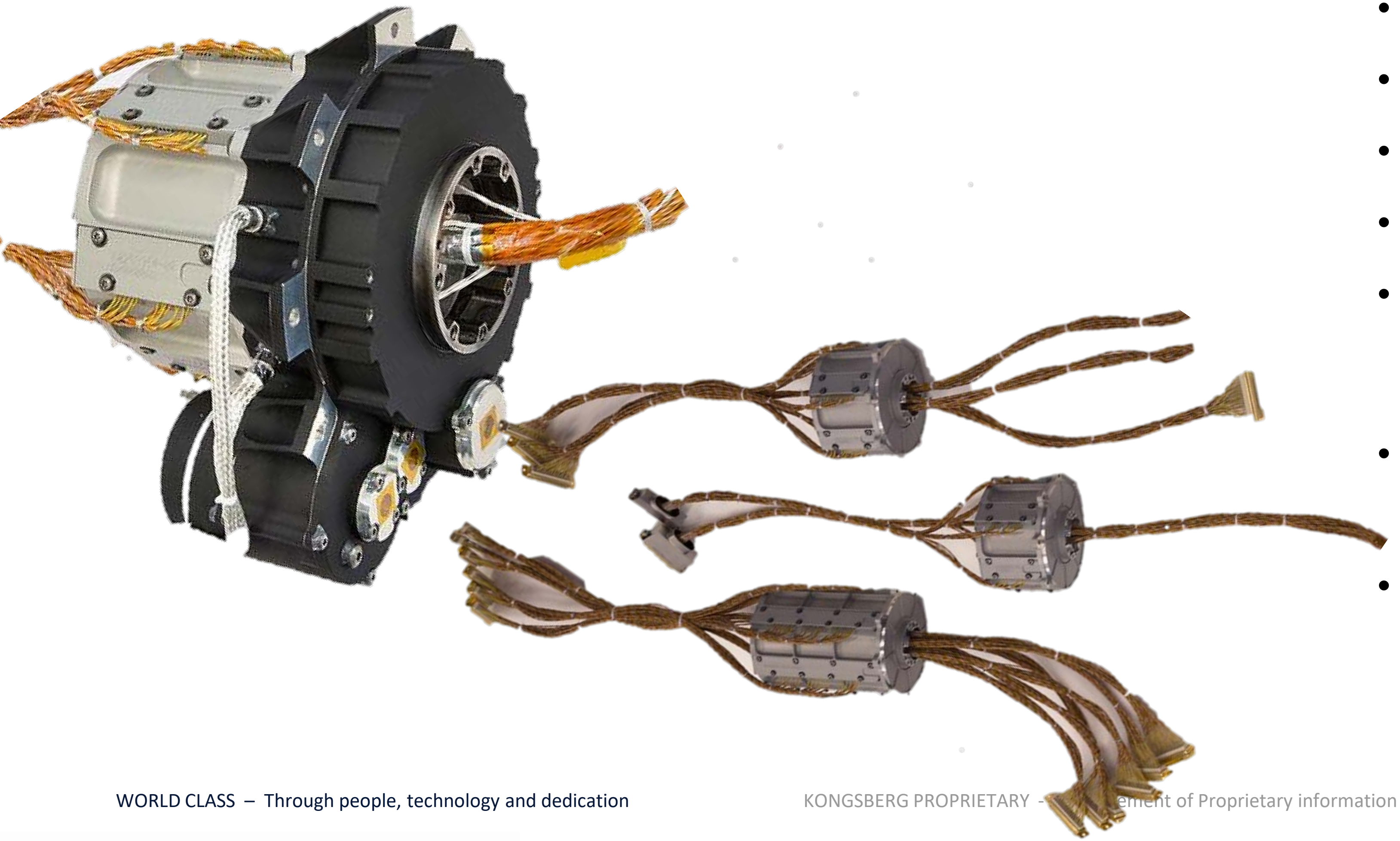

- Cover 2.0-5.5 kW/unit
- Market: GEO, Constellations, EO, Science
- Commercial baseline
- Mass 4 kg (depending configuration)
- Qualification life:
  - 15 years
  - 125 000 revs(SR)/cycles(TC)
- Twist Capsule
  - Power range 62-125 Amp/unit
  - Scaleable based on modular design
- Fully qualified design

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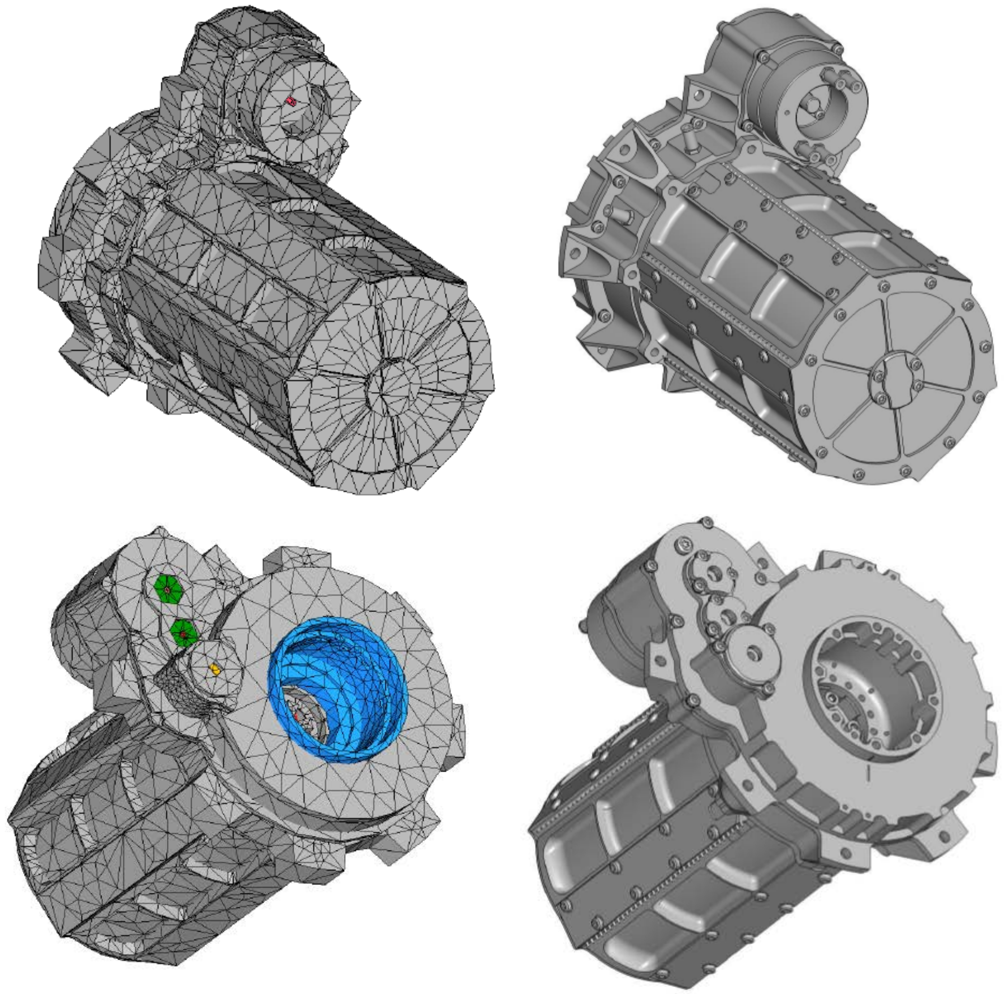
Baseline model for KARMA-4 TG in SCARAB

Work performed by partner HTG

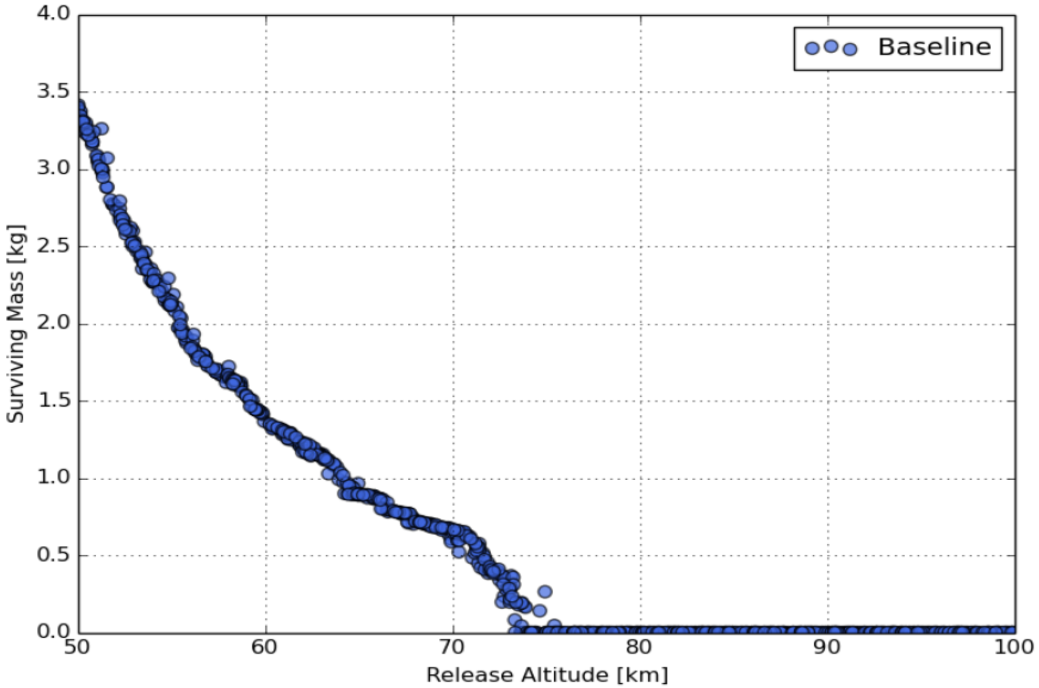
- KARMA-4 TG modelled in SCARAB with a high-fidelity (detailed bill of materials and masses used)
- Harness not included → difficulty to model flexible elements
- Excluding harness, mass difference between actual model and SCARAB model is ~1.3%

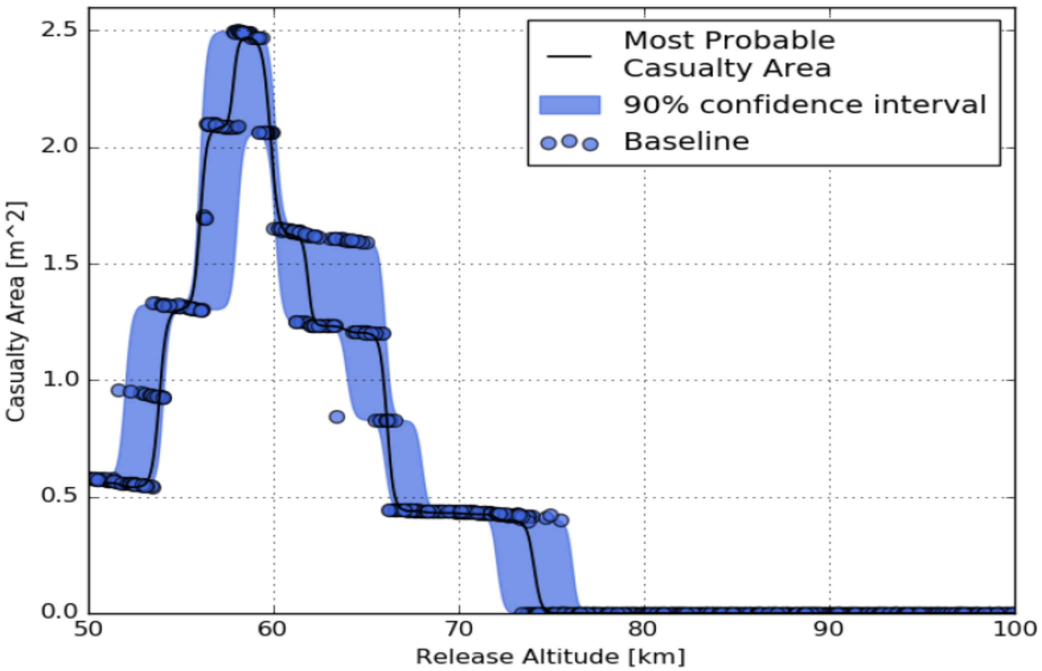


Baseline KARMA-4 demisability

- Minimum demise altitude is the lowest altitude where the component is predicted to experience complete demise. It is the first bin where the **most-probable** number of surviving fragments is zero → 74 km for baseline KARMA-4 TG

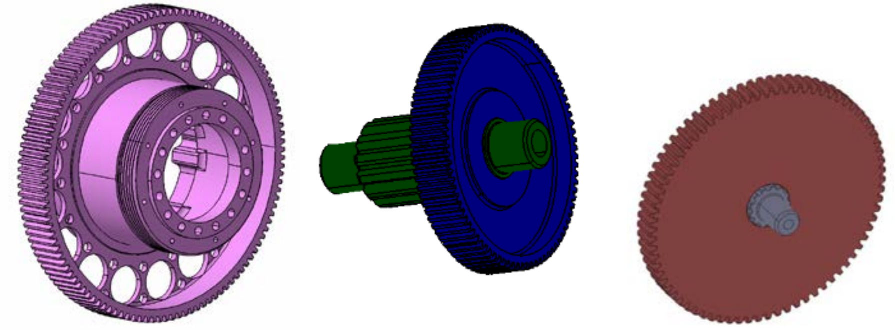
- Demise altitude is the altitude where the component is predicted to demise with a 5% significance level. It is determined by the first bin where more than 95% of the simulation cases demise → 76 km for baseline KARMA-4 TG

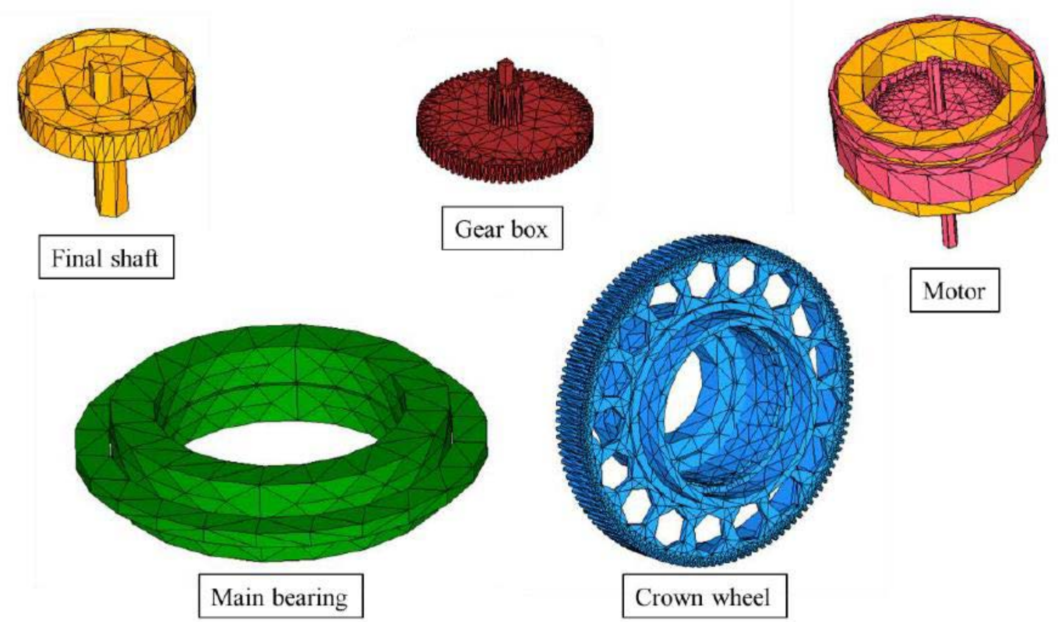




Critical components

- Inner mandrel & crown wheel
- Main bearing
- Motor
- Intermediate shaft
- Final shaft





Simulation iterations

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- Varying reference trajectory: different ballistic coefficients for the parent object (80 kg/m^2 and 200 kg/m^2 (150 kg/m^2 used for baseline simulations) → combining results, demise altitude remains the same with a release altitude of 76 km (demise with a 5% significance level)
- Detailed main bearing: identified as critical for demisability → very similar demisability between coarse and detailed model, with slightly better demisability for the former
- Different material database ESTIMATE → demise altitude shifted from 76 km to 80 km for baseline model
- Demisable screws for SADM housings: modelled using thermal triggers (500 K and 700 K) → when applied between all housings, most probable demise altitude shifted down from 74 km to:
  - 70 km with fragments surviving up to 72 km for 500 K trigger
  - 72 km with fragments surviving up to 74 km for 700 K trigger

PWT test campaign

Two tests performed:

- Test 1 is on full-scale dummy SADM → cold wall heat flux nominal 1.8 MW/m^2, and reduced 1.1 MW/m^2 (due to recession of twist capsule)

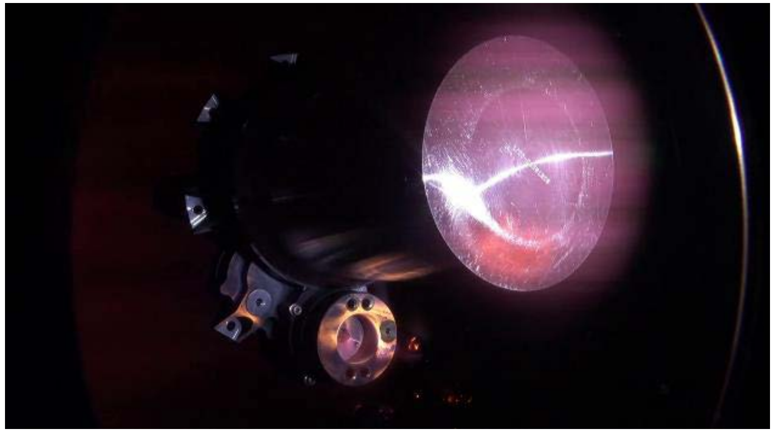
- Test 2 is on most critical elements of driveline, namely inner mandrel & crown wheel, main bearing, and preload nut → cold wall heat flux 1.1 MW/m^2

Test prediction simulations performed in SCARAB to allow comparison

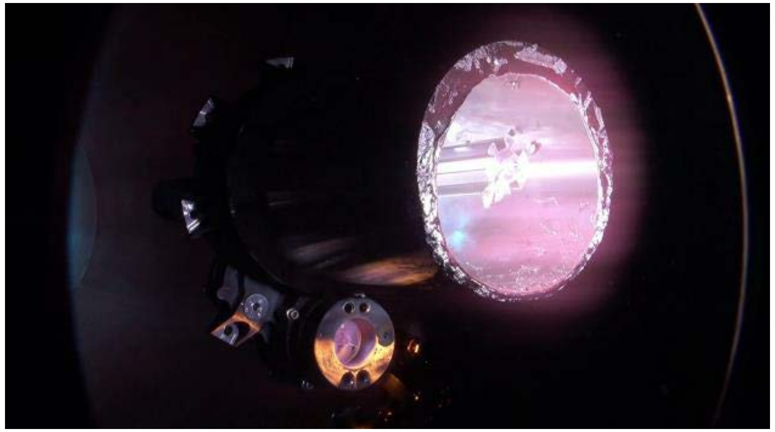
Test 1 (1/2)

Duration 194 s

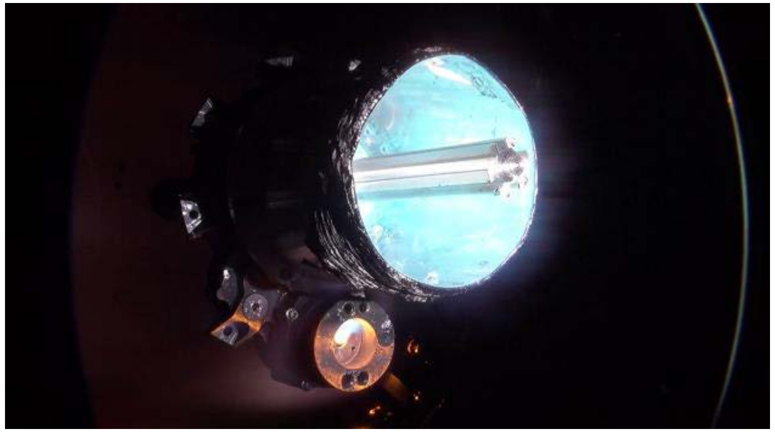
T = 0 s



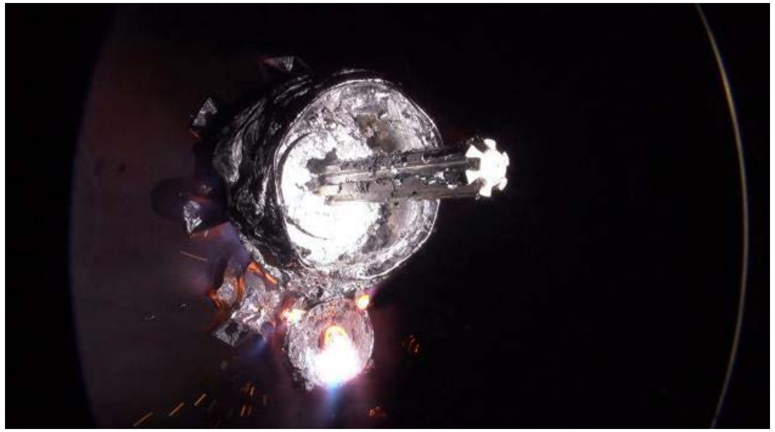
T = 1 s



T = 5 s

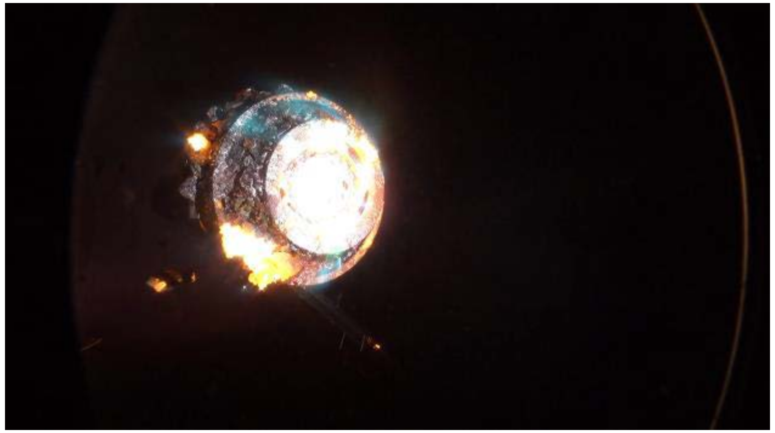


T = 10 s



T = 25 s

T = 50 s

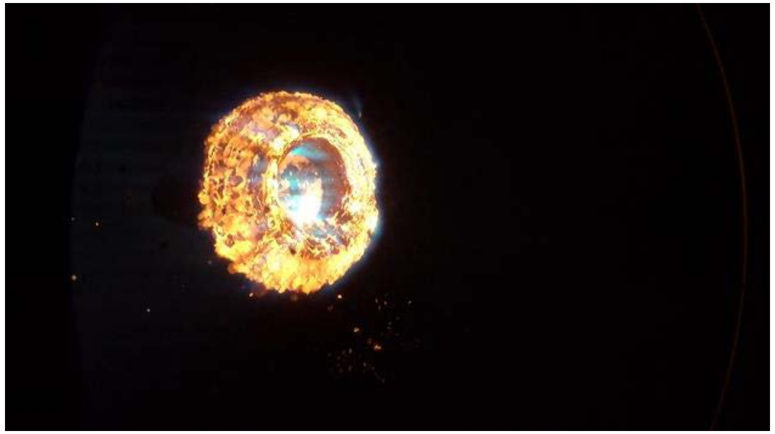


Test 1 (1/2)

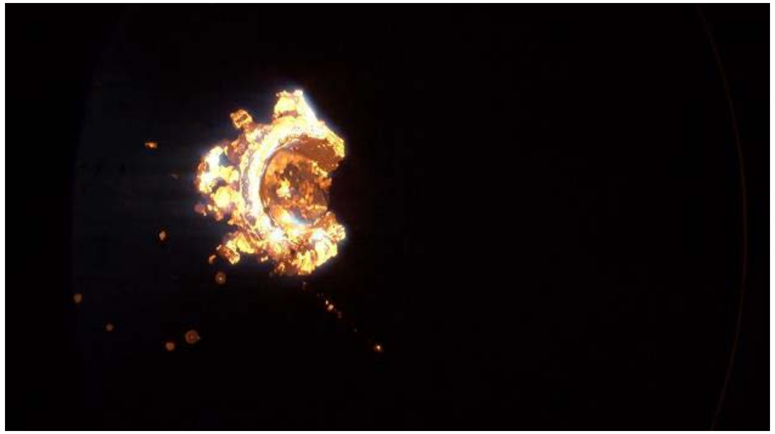
Duration 194 s

T = 80 s

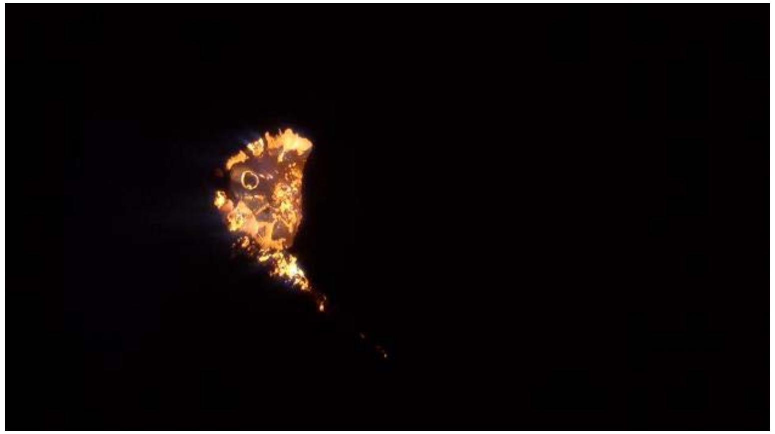
T = 110 s



T = 140 s



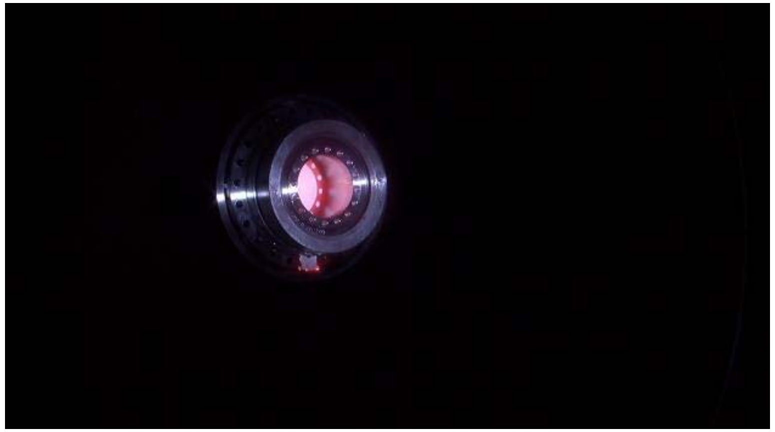
T = 190 s



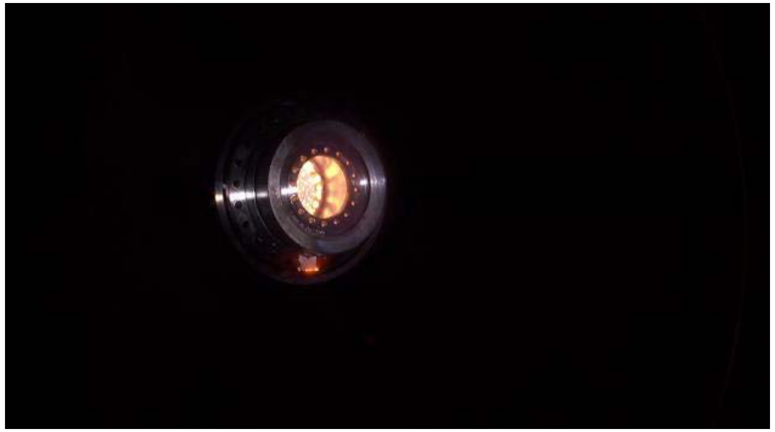
Test 2

Duration 154 s

T = 0 s

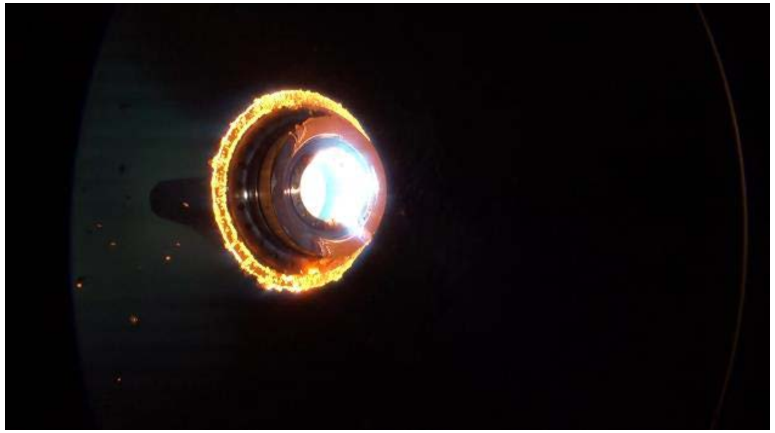


T = 5 s

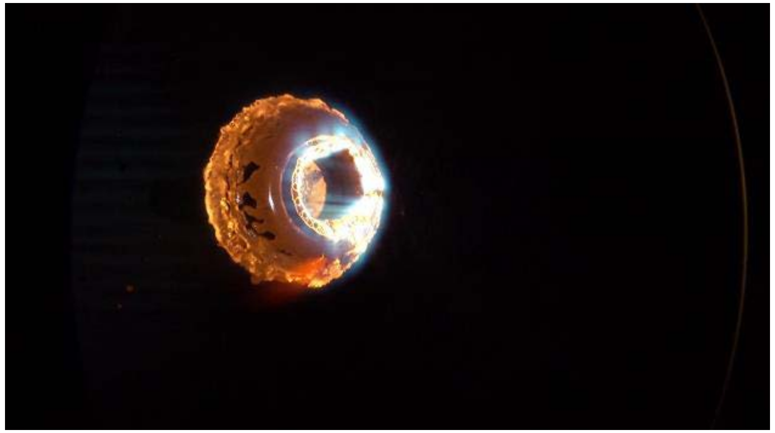


T = 15 s

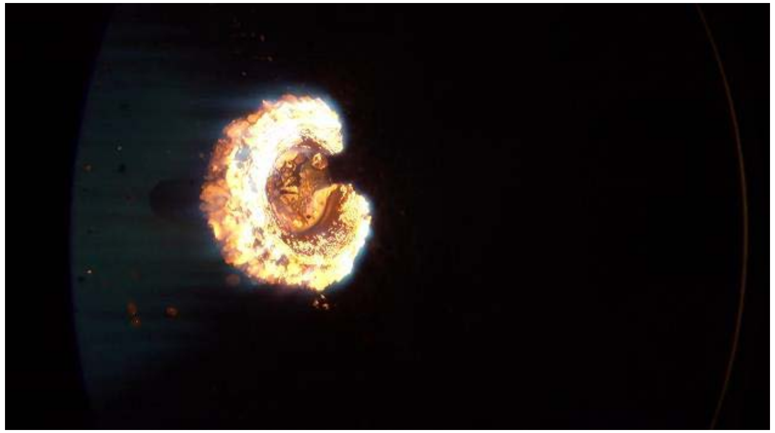
T = 30 s



T = 50 s



T = 100 s



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Simulations vs. PWT tests

- Fragmentation phenomenology predicted in SCARAB accurately corresponds to demise observed in test
- However, the fragmentation occured faster in the test than predicted → simplifications made compared to actual design seem to decrease demisability

Conclusions and lessons learned

- The baseline SADM using multiple entry trajectories has been determined to be demisable from 76 km release altitude with a 5% significance level.
- The baseline SADM using the ESTIMATE material database with uncertainty variation has a demisable from 80 km release altitude with a 5% significance level.
- The dummy SADM seems to have provided conservative results, but the impact of some simplifications is unknown and should be studied in the future (e.g. test an actual motor instead of simplified one, include flexible PCBs)
- Potential contract on the horizon to assess demisability of larger KARMA-5 TG SADM → higher fidelity aimed at for test dummy, as well as more actual D4D iterations in simulations

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Thank you for your attention!

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