Demisability Assessment of Reaction Wheels

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Problem Statement

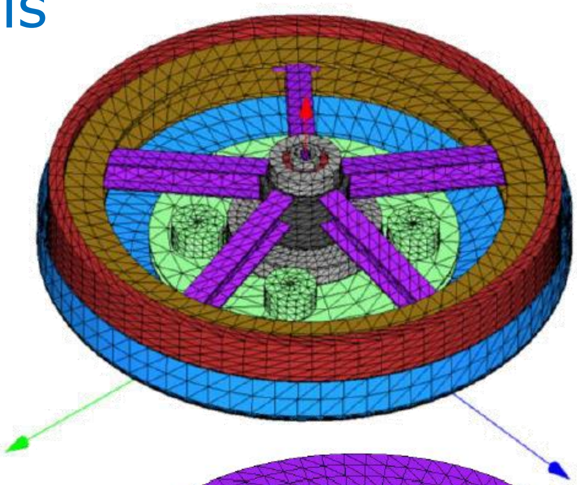
- Reaction wheels are identified as critical hardware impacting risk of casualty on ground of a re-entering satellite.
  - Typical contribution of 20-30% of spacecraft casualty area
- Existing models used in simulation considered too coarse and potentially too conservative
  - Features with low melting temperatures aiding the design not included in the models
- In the frame of ESA's activity "CleanSat: Technology assessment and Concurrent engineering in support of LEO platform evolutions", OHB subcontracted HTG. Support provided by RCD and ESA for model definition
  - SCARAB simulations to assess the break-up and demise behavior of reaction wheels
  - Identify the influence of different release conditions on the demisability of RWLs

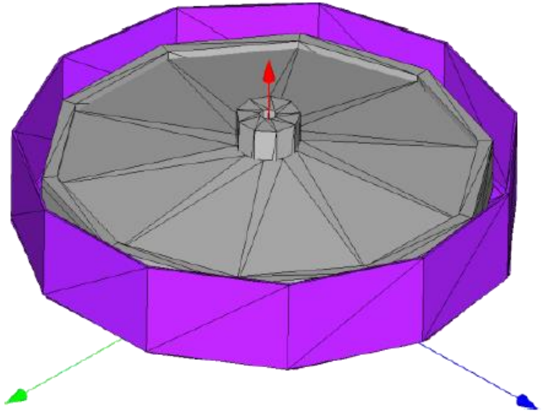
RW models

- RWLs with three different flywheel types have been analyzed:
    - Stainless Steel flywheel with brazed/bolted spokes (68 Nms) [RSI 68 SS]
    - Aluminum monobloc flywheel (68 Nms) [RSI 68 Al]
    - Aluminum flywheel with machined spokes and smaller diameter (45 Nms) [RSI 45 Al]
- All three wheel designs could have a momentum capability of 68 Nms
    - Electronics upgrade required for 3rd wheel type
- All subsystems accurately modelled using the correct material properties
    - Specific connections deemed important introduced, i.e. brazed connections with low melting temperature
- Improved model granularity
    - Average mass of 2g/panel vs 50g/panel on simple model

RW models

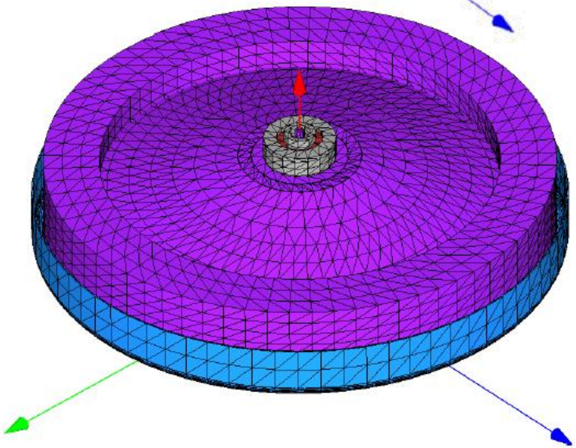
RSI 68 SS

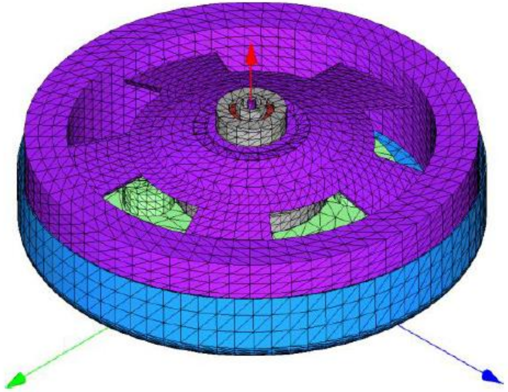




RSI 68 SS Simple model

RSI 68 Al





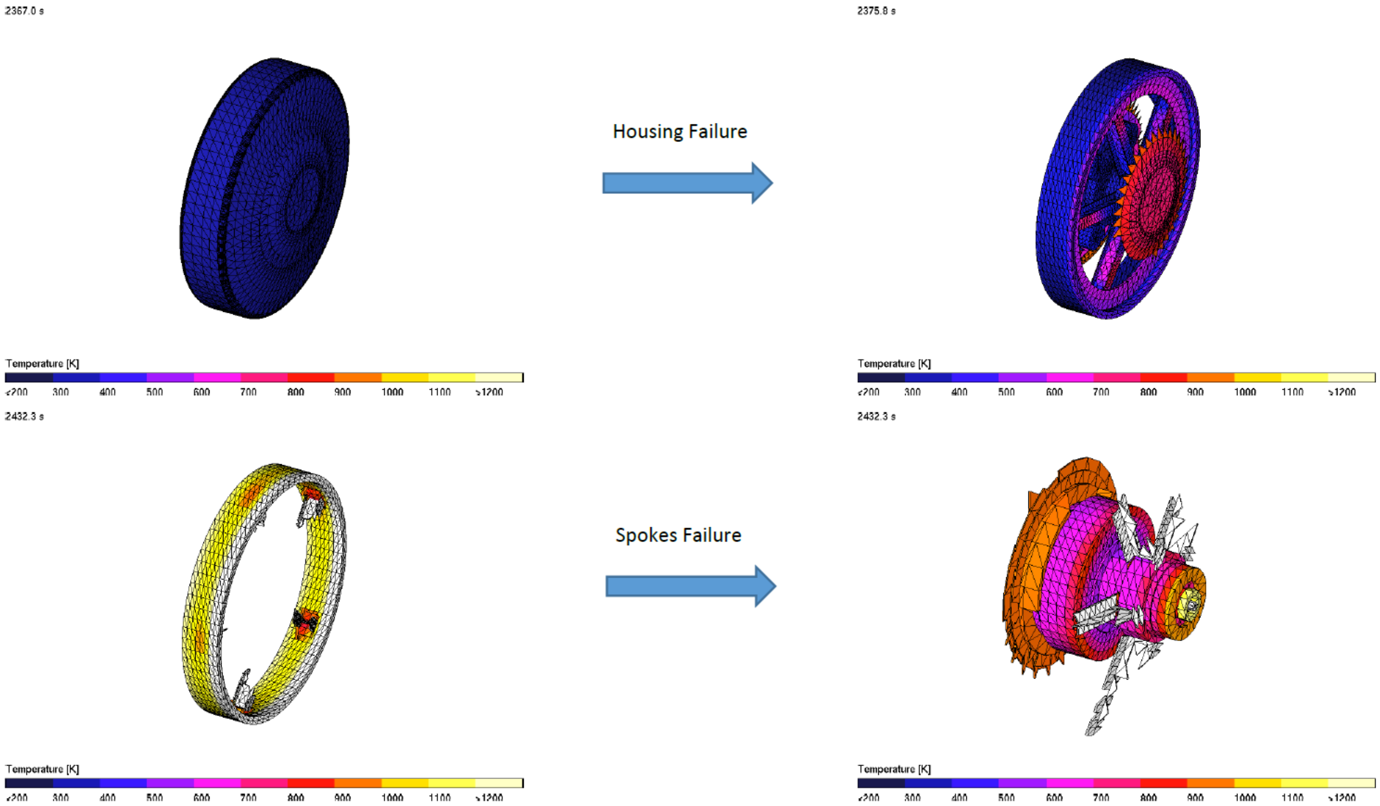
RSI 45 Al

Simulation parameters

- CleanSat Reference Trajectory used
- RW only, without connections to other hardware. Different initial attitudes used.
    - Perpendicular to the flow, upper housing in front
    - Perpendicular to the flow, lower housing in front
    - Parallel to the flow

  ➡ Not discussed as impact on results was negligible
- Fragmentation at melting temperature
- Minimum fragment mass 6g. Smaller fragments neglected.
    - Minimum panel number of 3

Results – Fragmentation process



Results – Surviving Mass vs Release Altitude

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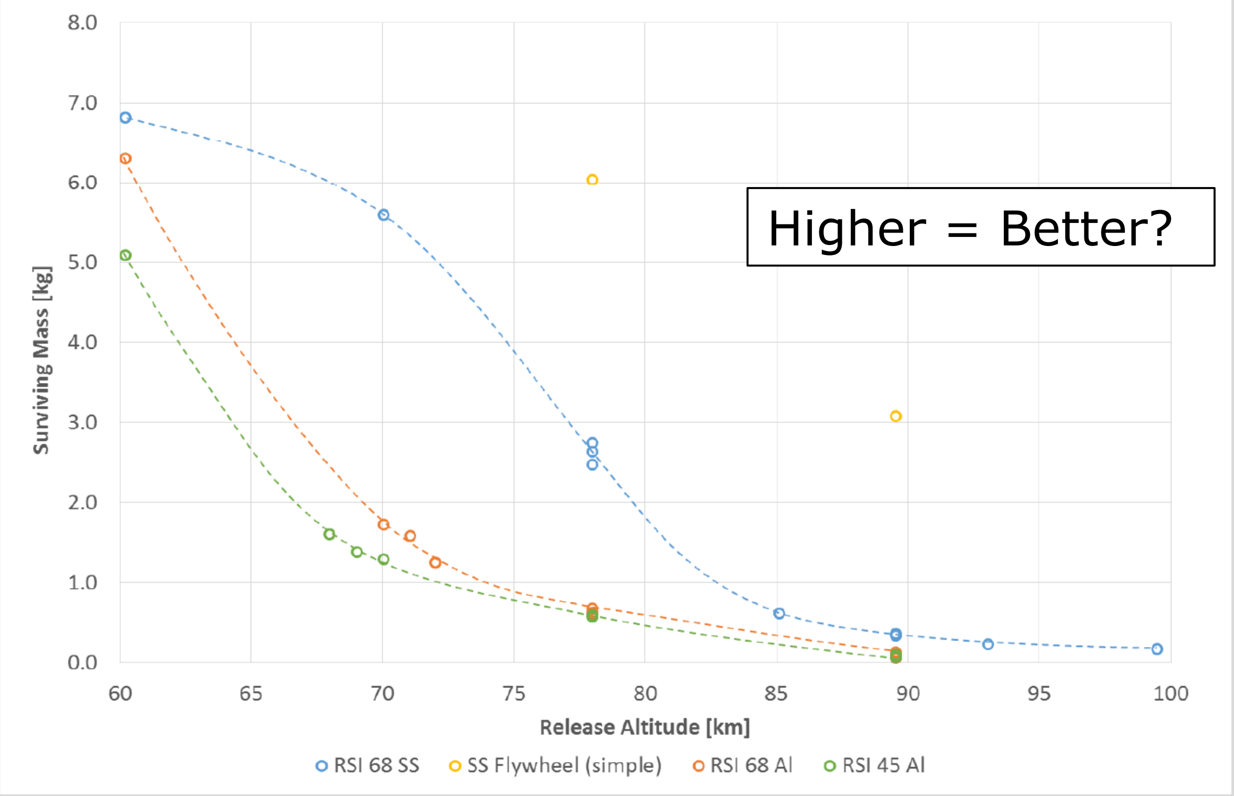
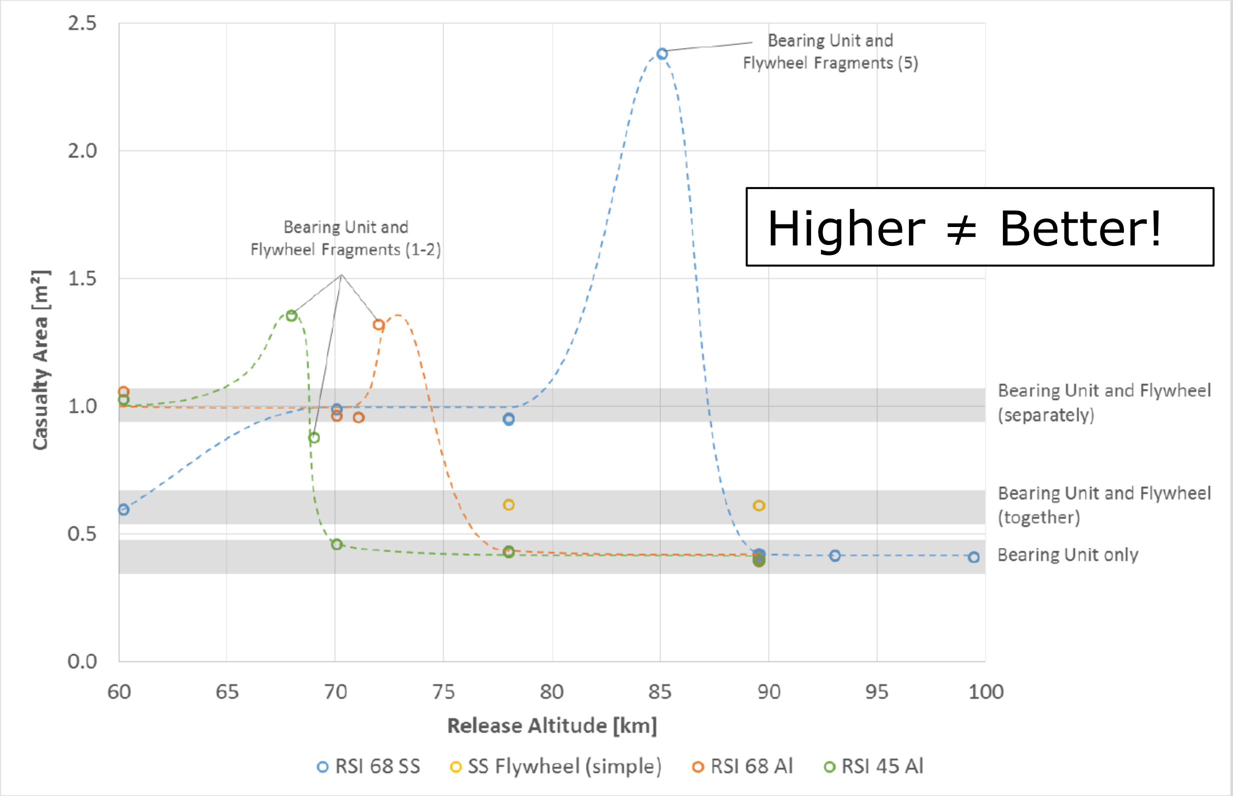


Results – Surviving Mass vs Casualty Area



Conclusions – Reaction Wheels

- Details of the design included in these models impact the break-up process
  - Break up does not occur at the expected points (e.g. brazed connections) due to local shielding effects
  - Remnants of demised parts can affect break-up (e.g. impact of spoke ends on flywheel break-up)
- None of the wheels demise completely, regardless of design, regardless of release altitude
  - The BBU (Ball Bearing Unit) always survives. Only release of BBU+motor alone at unrealistically high altitudes can demise the BBU.
- Fragmentation and incomplete demise of fragments of all wheel designs can lead to a significant increase in casualty area, depending on the release altitude

Conclusions – Reaction Wheels

- The more demisable versions of the reaction wheel (Al flywheel) have lower surviving mass, but equal casualty area, albeit at lower release altitudes
- Need for a simpler model which accurately captures the break-up process
    - Detailed models not suitable for system level analysis
    - Coarse models do not accurately cover break-up behaviour
- Current assumptions of fragmentation at melting temperature only is insufficient to prove the demise of the BBU
    - Some forces within the BBU may help break up the unit

Reaction Wheels – Future Activities

- TRP 'Assessment of design for demise approaches for RWs' KO imminent
  - Further assessing break-up processes of the BBU
  - Investigating design changes to the BBU and surroundings to optimise demisability, assessing their effectiveness through analysis and simulation and proposing a development plan **OR** preparing a test campaign to verify RW demise by test
  - Developing a generic simplified model of the reaction wheel for use in future spacecraft level simulations
- Goal: Eventually achieve a large, up to 68Nms, reaction wheel design that is fully demisable when released from the spacecraft at altitudes ≥78 km
  - Leveraging existing heritage of the current reaction wheel design in order to minimise redesign and requalification time and cost where possible

Further Considerations

- Demisable equipment
  - More detailed modelling at equipment level strongly recommended to verify break-up process is accurately simulated in order to provide simplified models for system level analysis which represent the correct break-up behaviour
- System level
  - Early break-up, **BUT** some equipment may have 'undesirable' release altitudes where fragmentation with incomplete demise of the separate fragments occurs, effectively increasing the casualty area
  - Coarse models are not necessarily conservative, even if the surviving mass is higher then more sophisticated models
  - System level analysis may currently underestimate the casualty area
  - Release altitude vs casualty area results at RW level are not directly transmittable to system level as influence of connecting equipment is not represented

Thank you for your attention

Questions?