Demisability analysis of Solar Array Drive Mechanism

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Introduction

- One way of reducing the on-ground casualty risk is by limiting the number of fragments surviving until ground.

- The fragments which survive a re-entry are often from recurring spacecraft components.
  - Propellant tanks
  - Reaction wheels
  - Solar array drive mechanisms
  - Magnetorquers
  - Balance masses
  - Optical payloads
Introduction

• Within ESA’s “High Fidelity Re-Entry Simulations on Critical Spacecraft Platform Equipment” project:
  
  ➢ Model and perform analysis of SADMs demise process during atmospheric re-entry
  ➢ Assess the impact of D4D modifications on demisability
Baseline: Model

CAD model
(provided by RUAG)

SCARAB model
Baseline: Initial conditions

CleanSat reference trajectory

Initial Temperature = 300 K

- 105 km
- 96 km
- 87 km
- 78 km
- 69 km
- 60 km
- 55 km
Baseline: Results
Surviving Mass

![Graph showing the relationship between surviving mass and release altitude.](image-url)
Baseline: Results
Casualty Area

The graph shows the casualty area vs. release altitude for different numbers of fragments (1, 2, 3, 4, 5). The casualty area is expressed in m^2, and the release altitude is in km. The data points for each number of fragments are color-coded and plotted on the graph, indicating the distribution of casualty areas for each release altitude.
Baseline: Results
Casualty Area

Casualty Area [m^2]

Release Altitude [km]

5 Frag.

4 Frag.

3 Frag.

2 Frag.

1 Frag.
Critical sub-components for 69 ±2 km

Case 2

- Actuator bearing: 100%
- Potentiometer shaft: 100%
- Harmonic drive: 100%
- Main shaft: 100%
- Solar array interface: 35%
- Front bearing: 41%
Baseline: Results
Critical Sub-components

Critical sub-components for 78 ±2 km

- Actuator bearing: 100%
- Potentiometer shaft: 100%
- Harmonic drive: 100%
- Main shaft: 63%
- Solar array interface: 33%
- Front bearing: 54%
Open SADM

Removed parts of the main housing assembly, the idea is to expose the SADM interior to the flow earlier.

Open SADM w/ aluminum actuator

Keeping the open SADM design and in addition changing some Actuator components material to aluminum (from titanium) thereby reducing the heat required for complete demise ($Q_{demise}$).

Actuator components which were changed:

- Actuator housing
- Potentiometer shaft
- Potentiometer housing

*The wall thickness of the modified sub-components has NOT been changed*
D4D: Results
Casualty Area
**D4D: Results**

**Critical Sub-components**

### Case2 (69 ± 2 km)

<table>
<thead>
<tr>
<th>Component</th>
<th>Baseline</th>
<th>OpenSADM</th>
<th>OpenSADM with Alu. Actuator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actuator bearing</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Potentiometer shaft</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Harmonic drive</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Main shaft</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
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<tr>
<td>Solar array interface</td>
<td>47%</td>
<td>47%</td>
<td>52%</td>
</tr>
<tr>
<td>Front bearing</td>
<td>41%</td>
<td>41%</td>
<td>52%</td>
</tr>
</tbody>
</table>

### Case3 (78 ± 2 km)

<table>
<thead>
<tr>
<th>Component</th>
<th>Baseline</th>
<th>OpenSADM</th>
<th>OpenSADM with Alu. Actuator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actuator bearing</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Potentiometer shaft</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Harmonic drive</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Main shaft</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Solar array interface</td>
<td>46%</td>
<td>30%</td>
<td>62%</td>
</tr>
<tr>
<td>Front bearing</td>
<td>46%</td>
<td>30%</td>
<td>58%</td>
</tr>
</tbody>
</table>

The data shows the frequency of sub-component survival for each case, with specific percentages for different components under Baseline, OpenSADM, and OpenSADM with Aluminum Actuator.
Baseline: Summary

• Release altitude **demise above 87 km**

• Release altitude **between 80 km – 55 km** result in **multiple ground fragments.**
  *(Casualty Area dependent on number of ground fragments)*

• Critical sub-components surviving:
  - Actuator bearing
  - Harmonic Drive
  - Potentiometer shaft
  - Main shaft
  - Solar array interface
  - Front bearing
D4D: Summary

- **D4D modification (1): Open SADM**
  - Complete demise for release altitudes above 87 km
  - Tendency to generate more fragments for release altitudes above 67 km. (Larger casualty area on average)
  - Similar “most probable” Casualty Area distribution to the baseline model.

- **D4D modification (2): Open SADM w/ Aluminium Actuator**
  - Tendency to generate more fragments for release altitudes below 69 km.
  - Minimum demisable altitude around 78 km.
Extended work

Am I out of time?

In that case:
Thank you for listening! 😊
Extended work

• How many simulations are enough?

  “With limited number of simulations, how do we ensure that our results are representative of the full output space?”

• Can I reduce my input space?
• When does my results converge?
Extended work

SADM - Initial release conditions:

**SADM release altitude**

*only thermal fragmentation simulated*
Extended work

![Graph showing SADM Case2 (69 km)]
Extended work
Extended work

![Graph showing casualty area vs. release altitude with error bars and shaded regions for most-probable and mean with 95% CI.](image)
Thank you for listening!

Questions?
Previous SADMs used in SCARAB

CarbonSat

Sentinel-2

Sentinel-3
Baseline example results

Surviving fragments Case3-1 (78 ± 2 km)

- Actuator bearing
- Potentiometer shaft + Actuator bearing + Harmonic drive
- Solar array interface + Front bearing
- Front bearing
Baseline: Results
Casualty Area

![Graph showing casualty area vs release altitude](image)