Multi-Disciplinary Assessment of Design for Demise Techniques

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Introduction

- The on-ground casualty risk caused by re-entering spacecraft has to be lower than 1:10,000 for ESA missions [ESA/ADMIN/IPOL(2014)2].
- Design-for-Demise (D4D) is a technology based approach to reduce the ground casualty risk in order to avoid the otherwise mandatory controlled re-entry.
- D4D steps:
  1. Identify the critical elements in a space system design for the on-ground casualty risk.
  2. Evaluate techniques for Design for Demise at system, sub-system and equipment level.
  3. Assess the implementation of the identified techniques and evaluate their impact at system level.
  4. Apply Design for Demise techniques to actual mission designs and assess the feasibility and system impact.

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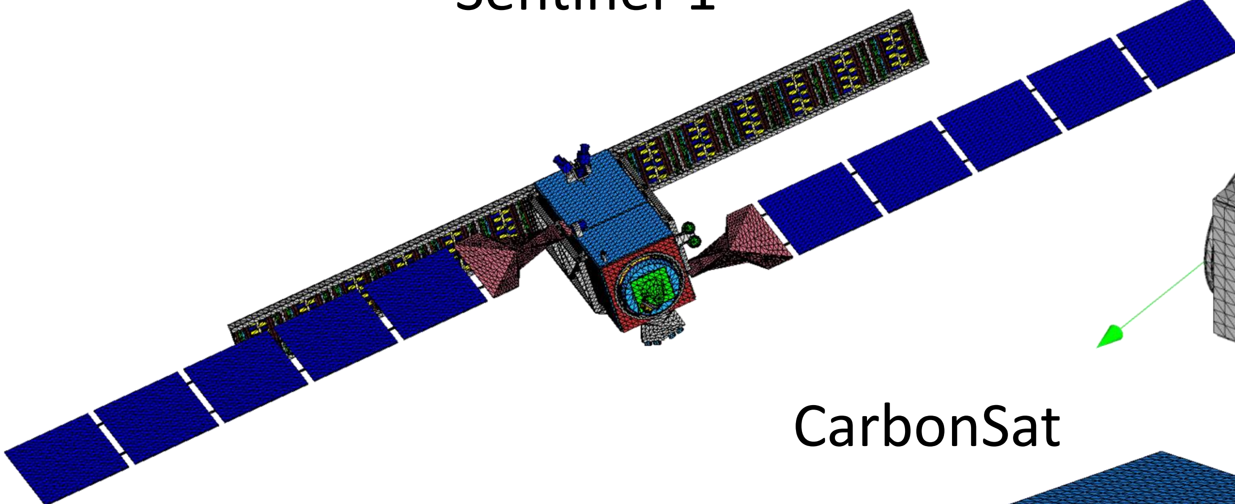
Critical Elements

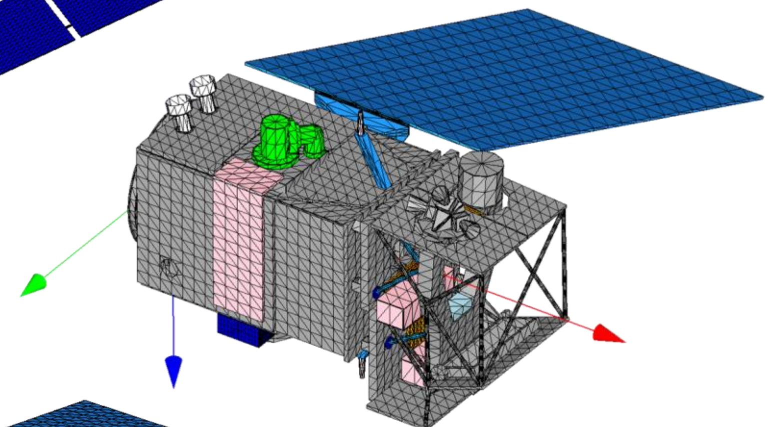
Critical elements			
	Deimos/OHB	**Airbus DS UK**	**TAS-I**
P/F	Tanks	Tanks	Tanks
	RWs	RWs	RWs
	MTQs	MTQs	MTQs
	SADMs	SADMs/Drive Mechanisms	
	Balance Masses		Balance Masses
		Batteries	
P/L	Optical Benches	Optical Benches	Optical Benches
	Instrument Frameworks		Instrument Frameworks
	Large Objects (e.g. SAR Panels)		Large Objects (e.g. SAR Panels)
	(shielded/protected) E-Boxes		(shielded/protected) E-Boxes
	Coolers		
		Pointing Mechanisms	

D4D Study Cases

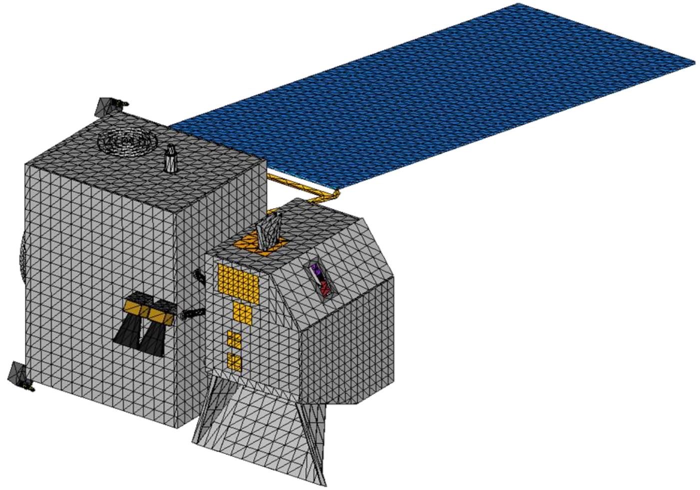
Sentinel-1



Sentinel-2



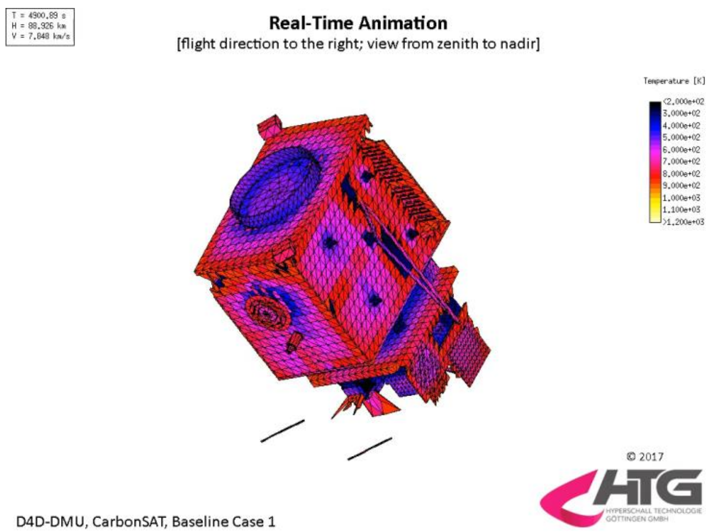
CarbonSat



D4D Study Cases – Re-entry Animations

D4D-TAS-I, Sentinel-1, Baseline scenario, CSAR panel break-up

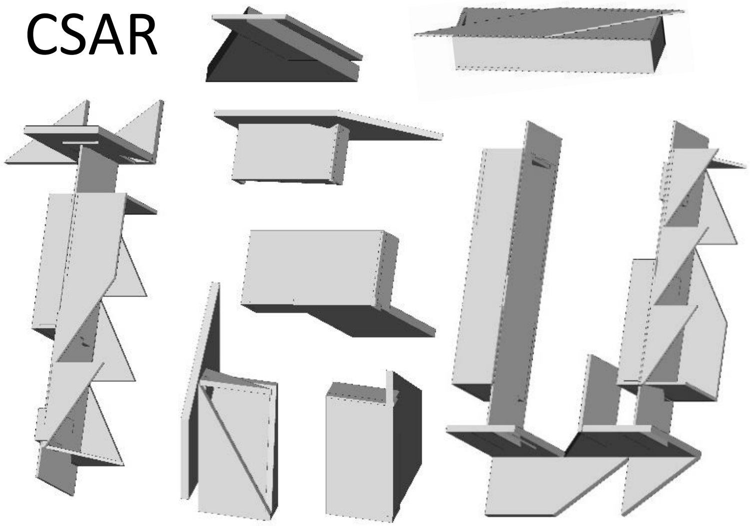
D4D-ADS, Sentinel-2, Baseline Case 1



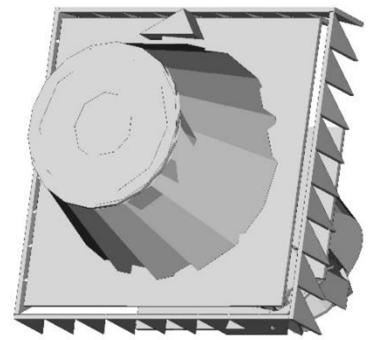
D4D-DMU, CarbonSAT, Baseline Case 1

Sentinel-1: Typical Surviving Fragments (not to scale)

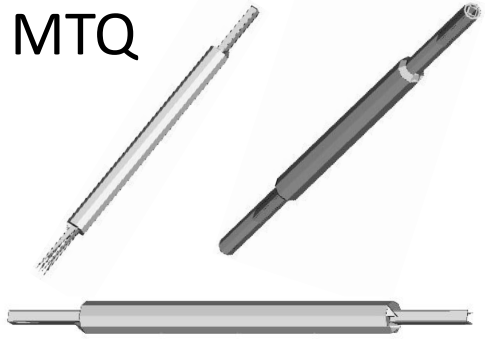
CSAR



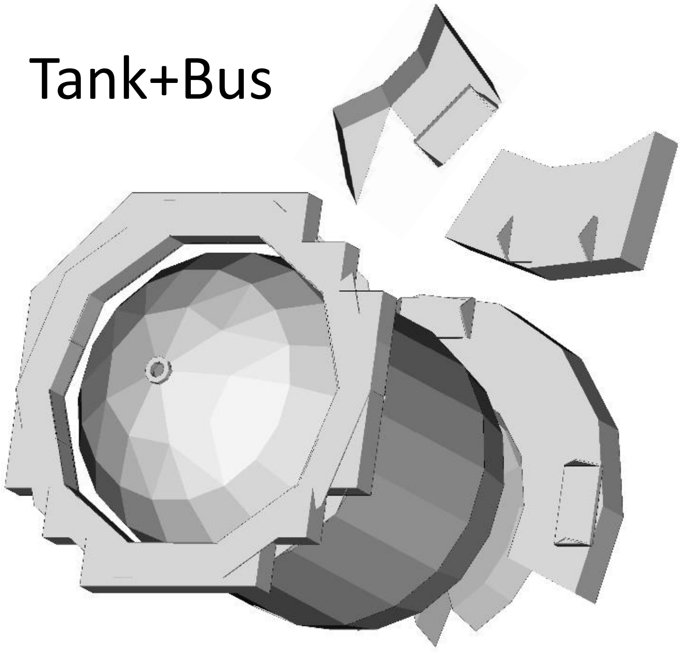
LCT



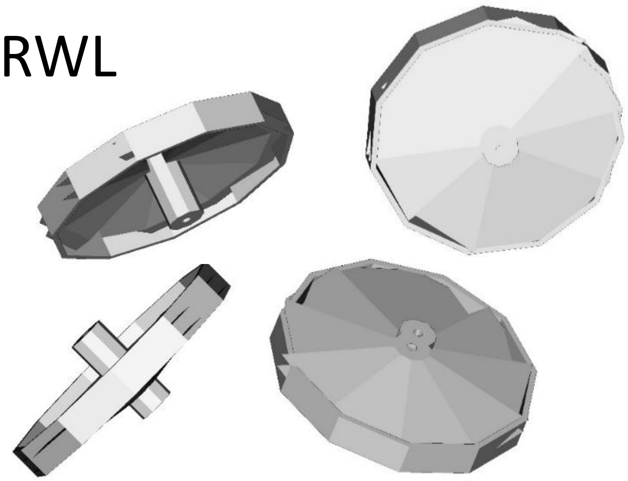
MTQ



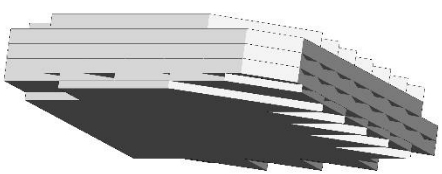
Tank+Bus



RWL



Bal. mass



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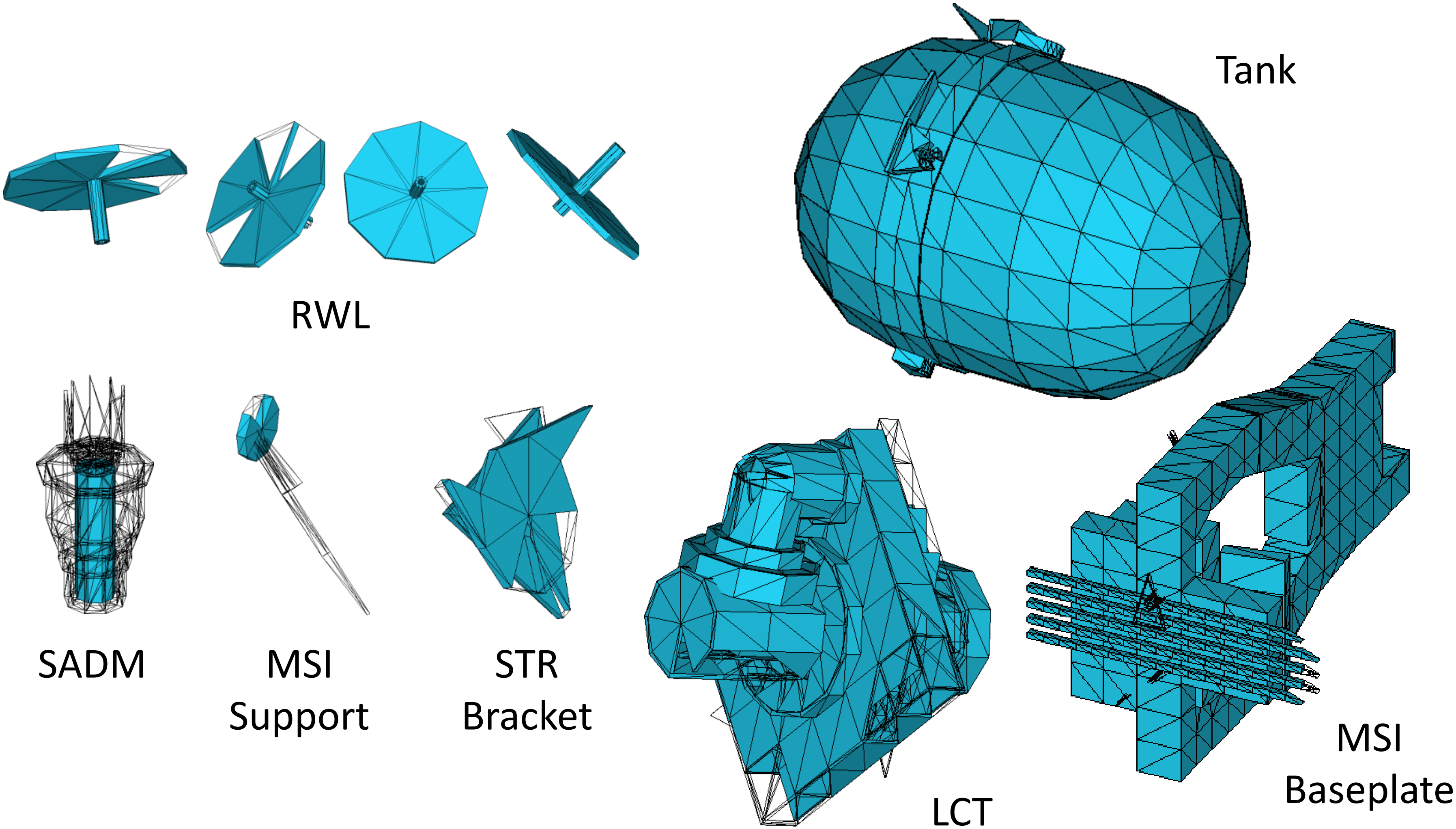
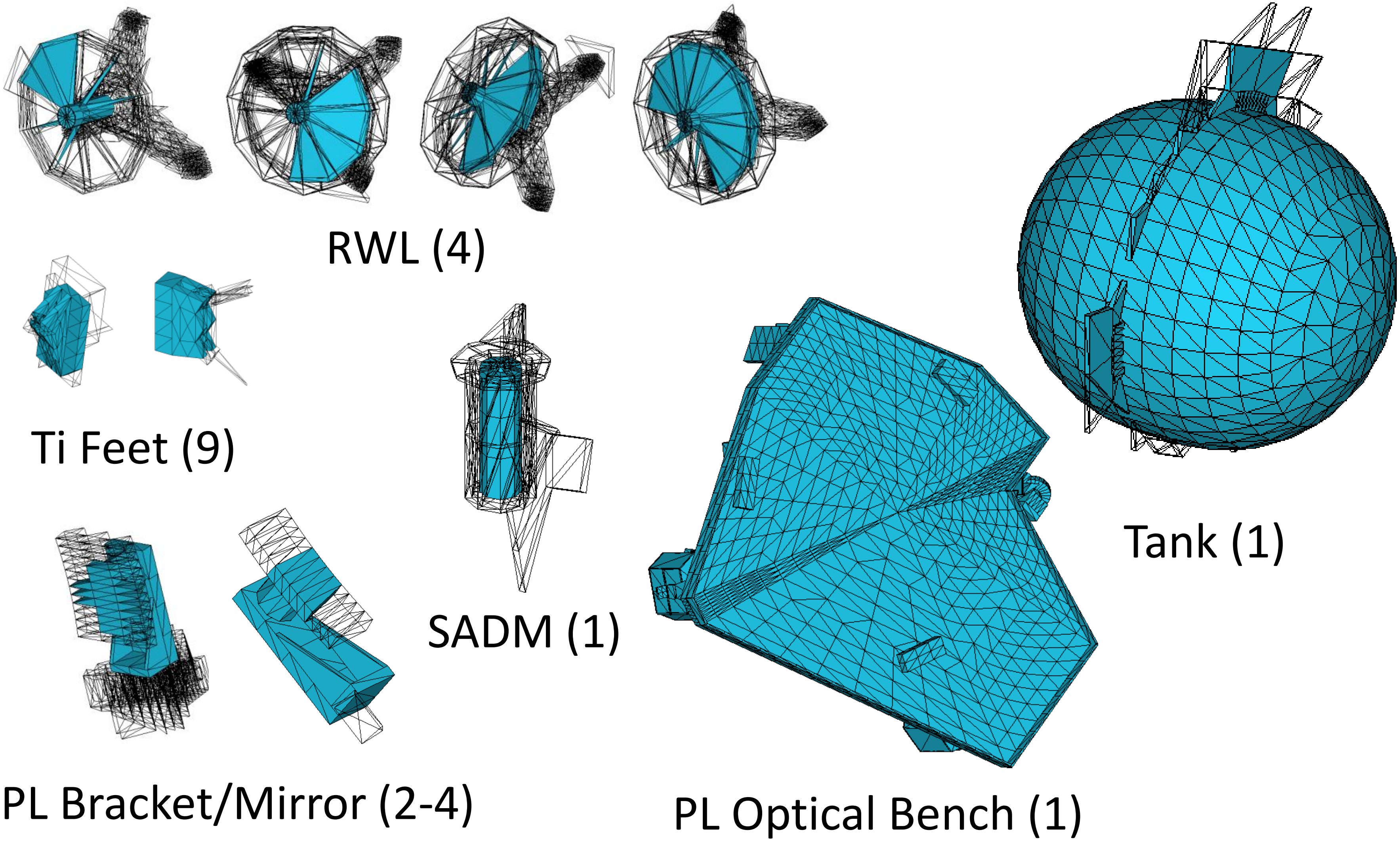
Sentinel-2: Typical Surviving Fragments (not to scale)



CarbonSat: Typical Surviving Fragments
(not to scale)



Casualty Area Contributions

Sentinel-1

	Mean Casualty Area Contribution m²	%
CSAR	6.593	43.3%
Tank+Bus	2.550	16.7%
RWL	2.476	16.3%
MTQ	1.462	9.6%
LCT	1.459	9.6%
Balance mass (int.)	0.691	4.5%
TOTAL	**15.231**	**100%**
Uncertainty	**2.574**	**16.9%**

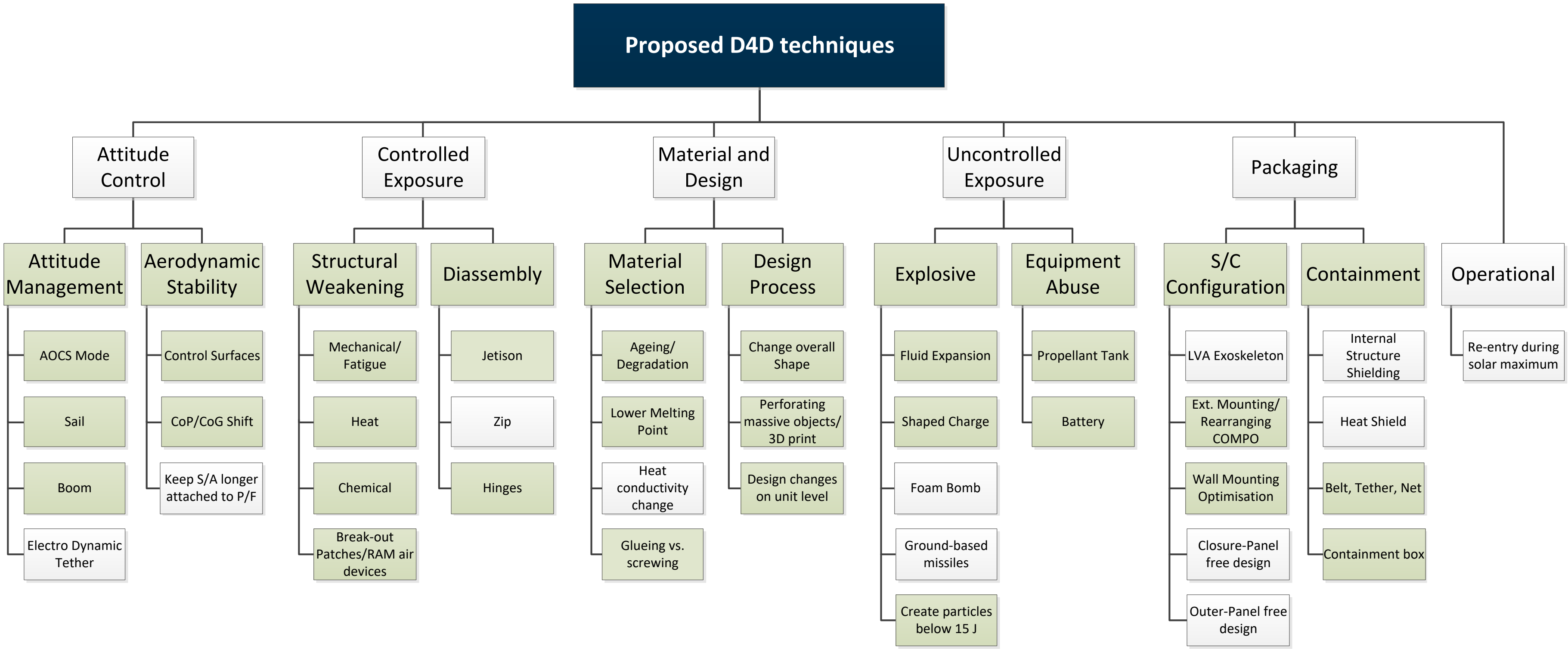
CarbonSat

	Mean Casualty Area Contribution [m²; %]	
Ti Feet	4.203	37.2%
RWL	2.304	20.4%
PL Optical Bench	1.433	12.7%
PL Bracket/Mirror	1.377	12.2%
Tank	1.273	11.3%
SADM	0.450	4.0%
PL Motor	0.178	1.6%
MTQ	0.092	0.8%
TOTAL	11.312	100.0%
Uncertainty	0.406	3.6%

Sentinel-2

	Mean Casualty Area Contribution [m²; %]	
RWL	1.904	21.8%
MSI Baseplate	1.667	19.1%
Tank	1.511	17.3%
LCT	1.340	15.4%
SADM	0.493	5.7%
MSI Support	0.459	5.3%
STR Bracket	0.395	4.5%
PCDU	0.282	3.2%
MSI VNIR	0.221	2.5%
MSI VCU	0.192	2.2%
RWL Support	0.126	1.4%
Rate-MU	0.068	0.8%
GFU Bracket	0.037	0.4%
MTQ	0.029	0.3%
TOTAL	**8.723**	**100%**
Uncertainty	**±1.332**	**15.3%**

Proposed D4D Techniques



Analyzed D4D Techniques

- Reduce casualty risk, either by
  - material changes (lower melting temperature → demise → less fragments), or
  - improved exposure (increase heating → demise → less fragments), or
  - fragment containment (less fragments).

Sentinel-1	Sentinel-2	CarbonSat
AlLi Tank CFRP/Al Tank	AlLi Tank	AlLi Tank
Lateral Panel Separation	Baseplate Assembly Jettison/Separation	Titanium Feet Tethering
SAR Panel Separation	Lateral Panel Opening	Breakout Patches
External Al RWL Mounting	External RWL Mounting	Closure Panel Free Design
Balance Mass Layering	Payload Assembly Separation	External RWL Mounting
MTQ Relocation		

D4D Techniques – Effectiveness

Sentinel-2	Risk Reduction
AlLi Tank	~30%
Baseplate Assembly Jettison/Separation	~20% (if separation high enough; >90 km)
Lateral Panel Opening	~30% (±5% depending on opening scenario)
External RWL Mounting	~10-30% (the weaker the mounting brackets, the better)
Payload Assembly Separation	~15% (optimal separation altitude hard to find)
AlLi Tank + Baseplate Assembly Jettison/Separation	~50% (if separation high enough; >90 km)

D4D Techniques – Effectiveness

CarbonSat	Risk Reduction
AlLi Tank	~10%
AlLi Tank + Titanium Feet Tethering	~40% (~10% by AlLi tank, ~30% by Tethering)
AlLi Tank + Breakout Patches	~10% (no effect by Breakout Patches)
AlLi Tank + Closure Panel Free Design	~10% (no effect by Closure Panel Free Design)
AlLi Tank + External RWL Mounting	~10% (no effect by External RWL)

D4D Techniques – Effectiveness

Sentinel-1	Risk Reduction
AlLi Tank + Al RWL + MTQ Relocation + Balance Mass Layering[1] + SAR Panel Separation[1,3]	35-45%
CFRP/Al Tank + Al RWL + MTQ Relocation + Balance Mass Layering[1,2] + SAR Panel Separation[2,4]	40-50%
AlLi Tank + Al RWL + MTQ Relocation + Balance Mass Layering[1] + SAR Panel Separation[2] + Lateral Panel Separation	50%
AlLi Tank + Al RWL external + MTQ Relocation + Balance Mass Layering[1] + SAR Panel Separation[2] + Lateral Panel Separation	70%

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D4D Techniques – Summary

Sentinel-1	Sentinel-2	CarbonSat
AlLi Tank	AlLi Tank	AlLi Tank
CFRP/Al Tank		
Lateral Panel Separation	Lateral Panel Opening	Breakout Patches
		Closure Panel Free Design
SAR Panel Separation	Payload Assembly Separation	
	Baseplate Assembly Jettison/Separation	
		Titanium Feet Tethering
External Al RWL Mounting	External RWL Mounting	External RWL Mounting
MTQ Relocation		
Balance Mass Layering		

Conclusions

- **D4D works!**
  - ➢ It is an effective and practical method to reduce the on-ground casualty risk caused by re-entries. Even a 2-ton class satellite like Sentinel-1 can reach compliance with the 1:10,000 casualty risk limit.
- **D4D is an iterative process!**
  - ➢ Combinations of various techniques might be necessary to achieve needed risk reduction, as well as optimizations of these techniques.
- **D4D is target dependent!**
  - ➢ There are no "develop once, apply everywhere" recipes. Each satellite needs its own "customized" solution.
- **D4D has a non-negligible system/component impact!**
  - ➢ It has to be considered as early as possible in projects. Specific component developments (e.g. demisable tanks and reaction wheels) are necessary.

Thank you!

Questions?

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