WE LOOK AFTER THE EARTH BEAT

MULTI-DISCIPLINARY ASSESSMENT OF DESIGN FOR DEMISE TECHNIQUES

D4D System Level

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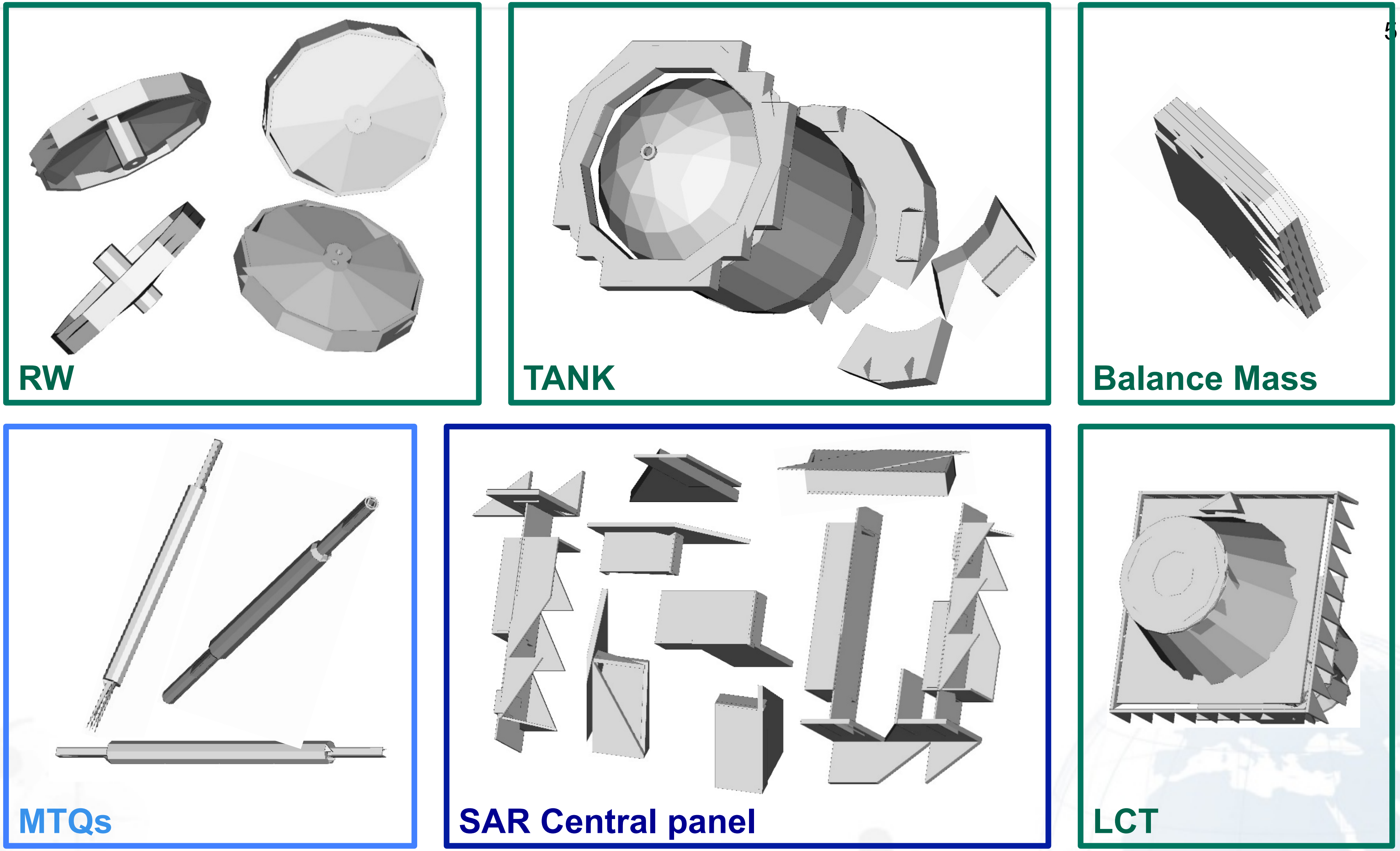
Identify D4D techniques to reduce the risk posed by re-entering satellites

Main tasks:

- Identify critical elements
- Identify the most promising D4D techniques
  - At component level
  - At system level
- Apply D4D techniques to a study case
- Estimate the CA reduction
- Derive general guidelines and potential future improvements


Study case: **Sentinel-1**
Mass: 2 tons satellite
Orbit: SSO, polar orbit
Altitude: about 693 km
Main feature: large SAR antenna

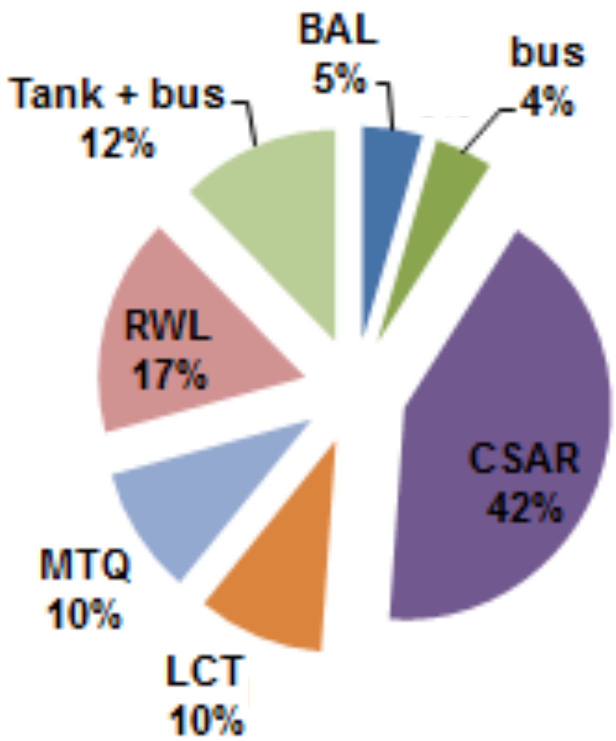
Critical components of Sentinel-1 – baseline design

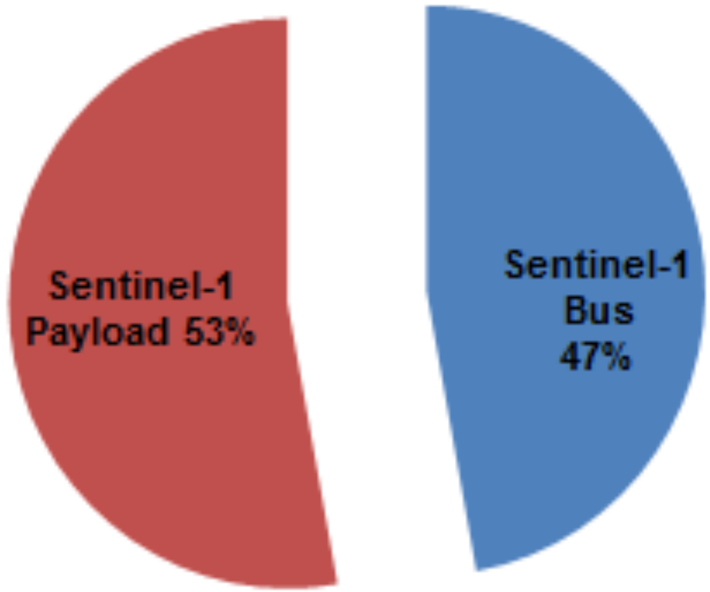


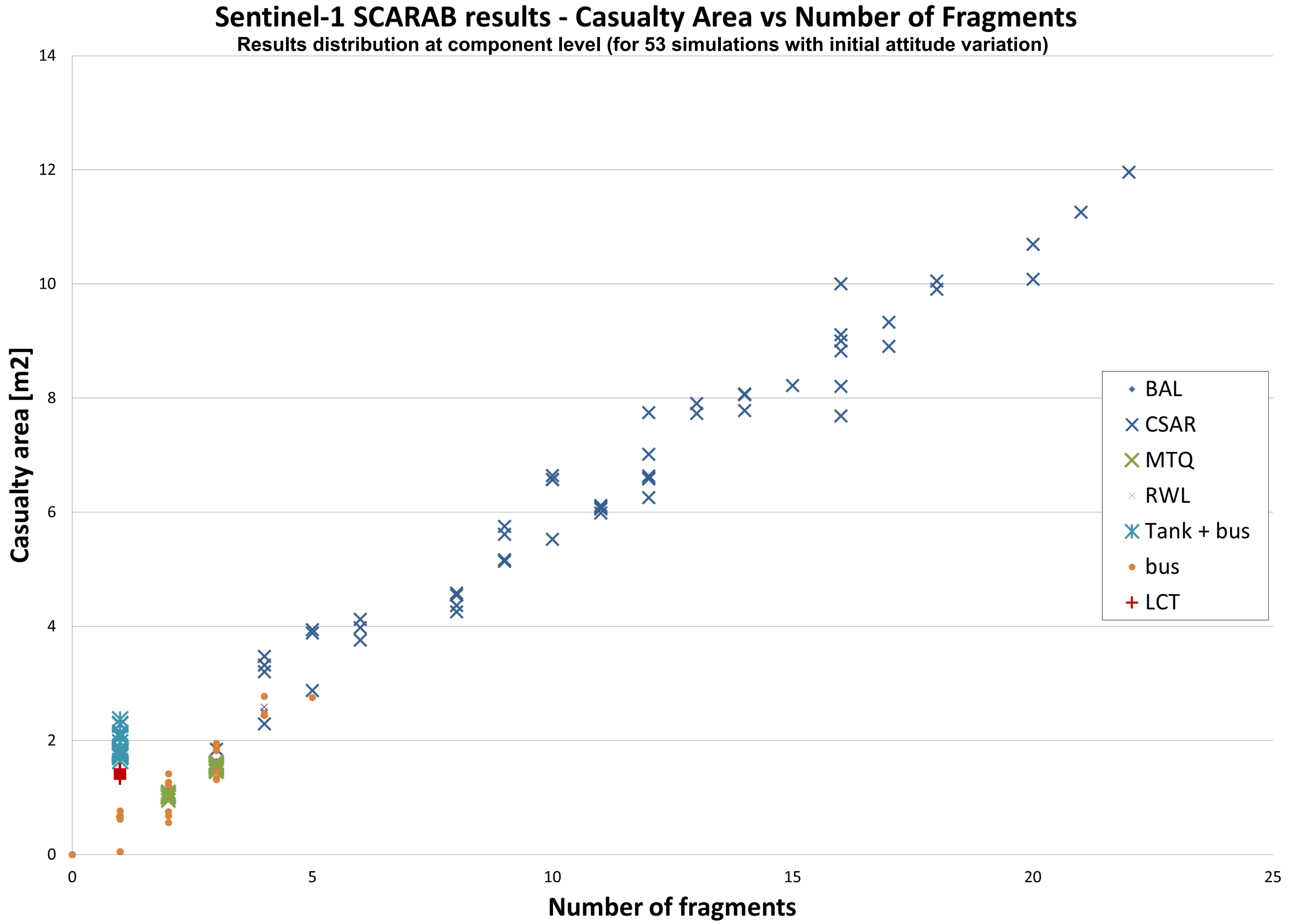
→ **Identify critical items** and define the **reason of survivability** is the first step to identify and tune D4D techniques

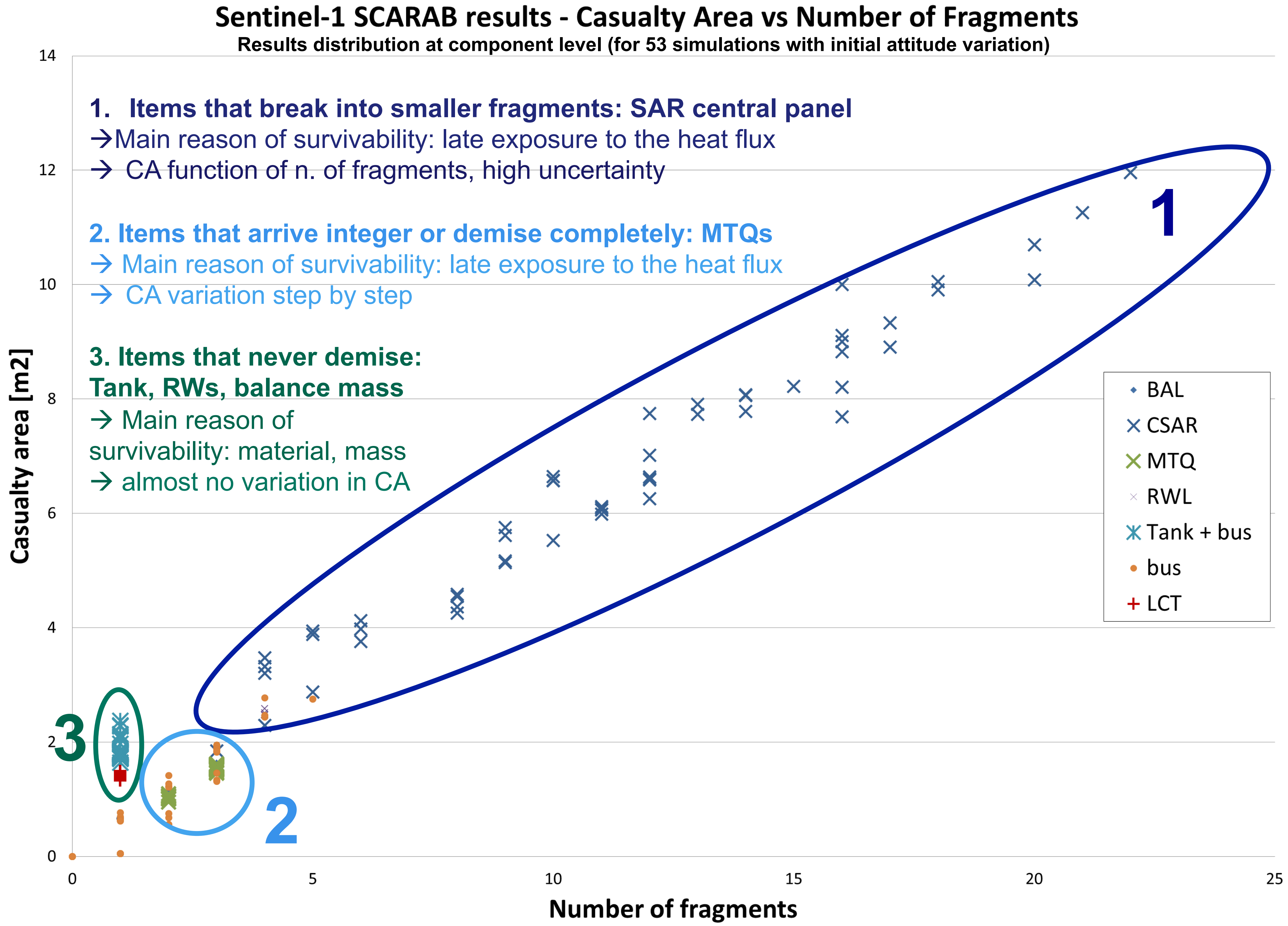
Casualty Area = 15.2 ± 2.6 m^2

Average value of 53 SCARAB simulations






Sentinel-1 SCARAB results - Casualty Area vs Number of Fragments
Results distribution at component level (for 53 simulations with initial attitude variation)
Casualty area [m2]
Number of fragments
0
2
4
6
8
10
12
14
0
5
10
15
20
25
BAL
CSAR
MTQ
RWL
Tank + bus
bus
LCT



Sentinel-1 SCARAB results - Casualty Area vs Number of Fragments
Results distribution at component level (for 53 simulations with initial attitude variation)
1. Items that break into smaller fragments: SAR central panel
→Main reason of survivability: late exposure to the heat flux
→ CA function of n. of fragments, high uncertainty
2. Items that arrive integer or demise completely: MTQs
→ Main reason of survivability: late exposure to the heat flux
→ CA variation step by step
3. Items that never demise:
Tank, RWs, balance mass
→ Main reason of survivability: material, mass
→ almost no variation in CA
1
2
3
BAL
CSAR
MTQ
RWL
Tank + bus
bus
LCT
Casualty area [m2]
Number of fragments
0
2
4
6
8
10
12
14
0
5
10
15
20
25

Critical components → D4D techniques

1. Items that break into smaller fragments
→ Main reason of survivability: late exposure to the heat flux

2. Items that arrive integer or demise completely
→ Main reason of survivability: late exposure to the heat flux

→ **Increase the heat load e.g.: Early exposure to heat flux**

3. Items that never demise
→ Main reason of survivability: material, mass

→
- **Demisable re-design**
- **Reduce kinetic energy below 15 J**
- **Containment**

→ Note that redesign can cause the change of category

D4D techniques

- Extensive investigation of D4D techniques
- Preliminary evaluation of CA reduction trough parametric analyses using low (TADAP) and high fidelity (SCARAB) codes
- Evaluation of System level impact, cost, TRL, etc.
- Ranking of solutions

→ **Most promising techniques for the study case were selected**

D4D RECOM°	D4D DRIVERS	D4D TECHNIQUES	D4D TECHNOs	RISK Mitigat°	IMPACT System	TECHNO Maturity	TECHNO Cost	System RANKING	Techno RANKING	Overall RANKING	S1 Case
Reduce Heat Needed	DEMISE Material	Swap MATERIAL	Ti & CFRP -> **Alu High Perfo** Applications ?	6 PART DEMISE	4 E/Rho=, Vol>	7 Normal Work	7 Normal Work	24	49	1176	
			Thermoplastic High Strength PEEK,PAEK,PEKK+Fibers (C,G)	3 PART DEMISE	5 E/Rho=, Vol>	3 Delta Qual°	6 Delta Qual°	15	18	270	
			Ti -> Alloy+**Exothermic additive** DEMISE TI Alloy (if additive Mg,Li) ?	3 PARTS DEMISE	5 Mass<,Mech<	2 Feasible ?	4 Space H/W ?	15	8	120	
			Ti -> Alloy & Exothermic additive **THERMIT**	4 PARTS DEMISE	2 Mass>	1 Feasible ?	2 Space H/W ?	8	2	16	
	DEMISE Component		CFRP/Alu HC -> **GLARE, ARALL** Impacts ?	2 S/S DEMISE	4 Mass >	5 Delta Qual°	7 Delta Qual°	8	35	280	
			Cu Wires -> **Alu Wires** Applications= High PWR Harness	3 S/S DEMISE	6 Mass< Perfo<	7	7	18	49	882	
	DEMISE Equipment		**Prop Tank -** Titanium shell Alu liner-Overwrap Carbon ?	5 S/S DEMISE	9 Mass<	5	5	45	25	1125	
			RWA -Steel Rim & Motor/bearing DEMISE Rim - SURVIVE I/F+bearing	4 S/S DEMISE	5 Perfo =	4 Redesign	7 Delta Qual°	20	28	560	
		LAYERING	2 small instead of one Big **Tank ?** MTB ? RWA ?	3 DEMISE >	4 Mass> Cost>	9	9	12	81	972	
	DEMISE Process		**Sintering** Process Binder may DEMISE	3 DEMISE >	5	3 Delta Qual°	8 Delta Qual°	15	24	360	
			Added Glued path (FML, I/Fs) Added Welds (weak in Demise)	4 DEMISE >	5	8 Delta Qual°	8 Delta Qual°	20	64	1280	
	Size Impact		2 small instead of one Big **HC Panels ?**	3 DEMISE >	8	8 Delta Qual°	8 Delta Qual°	24	64	1536	
			Segmentation - Fragmentation Tank cut in several parts	5 DEMISE >	5 Device TBD	3 Device TBD	5 Delta Qual°	25	15	375	
	Mass Impact	Swap PROCESS	Normal Work Design New solution = **3D Print**	3 PART DEMISE	7 Mass = ; Cost>?	7 Normal Work	7 Normal Work	21	49	1029	
	Emissivity impact? Thermooptical impact ?		**Emissivity** Change Coating ? Treatment ? Process ?	3 PART DEMISE	8 Mass = ; Cost>?	5 Normal Work	8 Normal Work	24	40	960	
	Impact Wetted & Radiative Surface		**3D Print** Micro-Mesh Structures	2 PART DEMISE	7 Mass <	6 Normal Work	7 Normal Work	14	42	588	
	Mass Impact Size Impact	**System SELECTION** 2 small s/c replace one big	**Small - MiniSat** <500 Kg , <1000Kg	8 TBC ???	4	7	5	32	35	1120	
	DEMISE Equipements	**Equipment SELECTION** Promote DEMISE Equipts	MTB replaced by RWA ? RWA desaturation by RCS	3	3	9	9	9	81	729	

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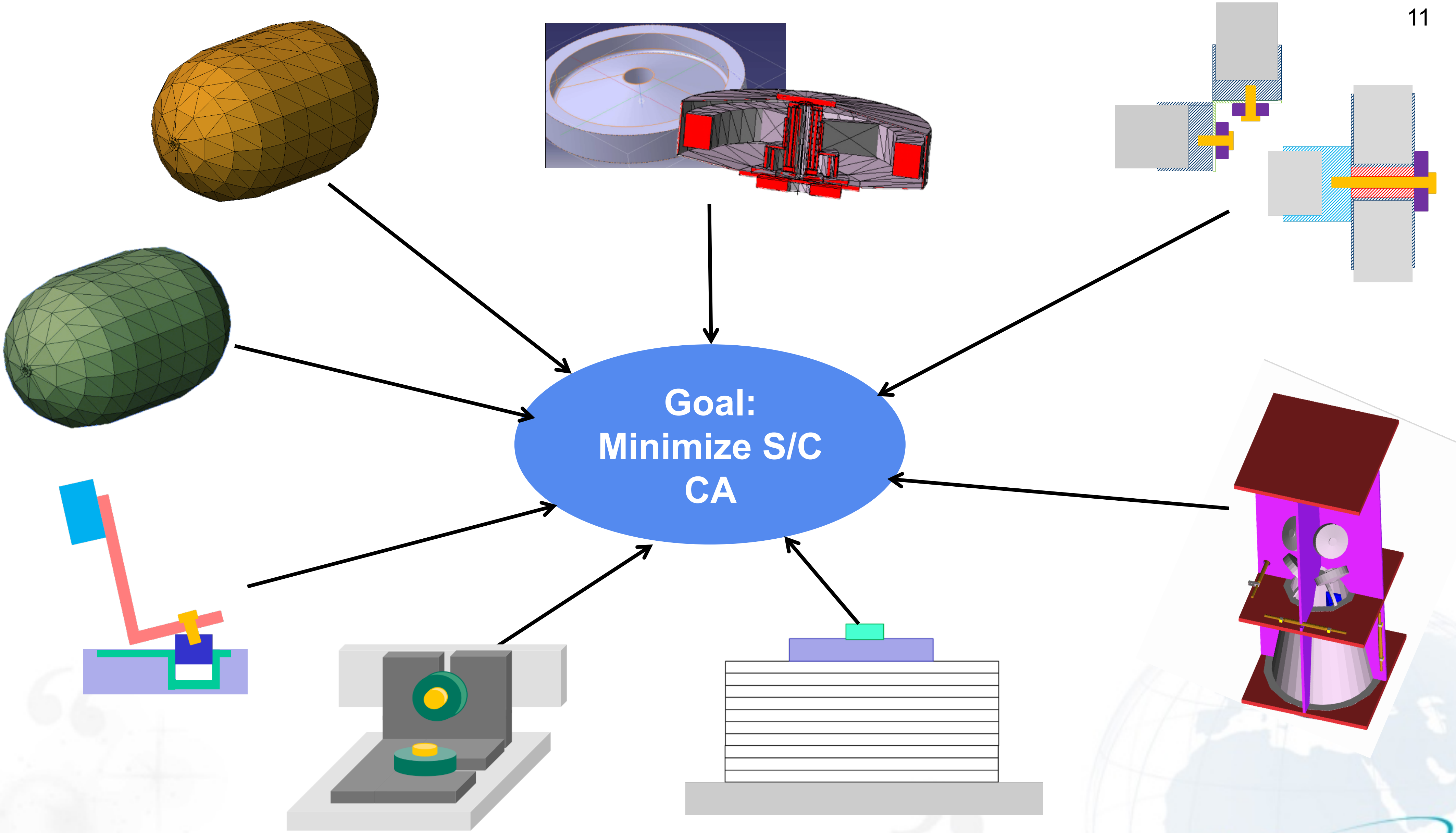
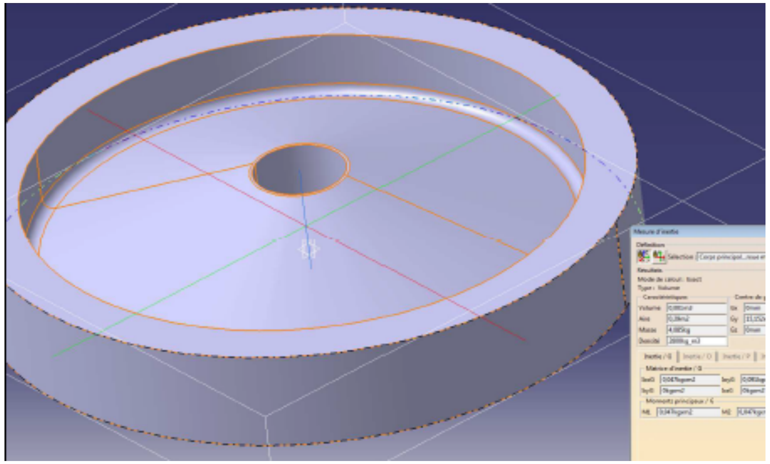
Study case: Demisable components and S/C design



Six modified models combining different D4D techniques

How to demise a RW

- RW reason of survivability: materials
- D4D approach:
  - Redesign of RWs
  - Improvement of model granularity

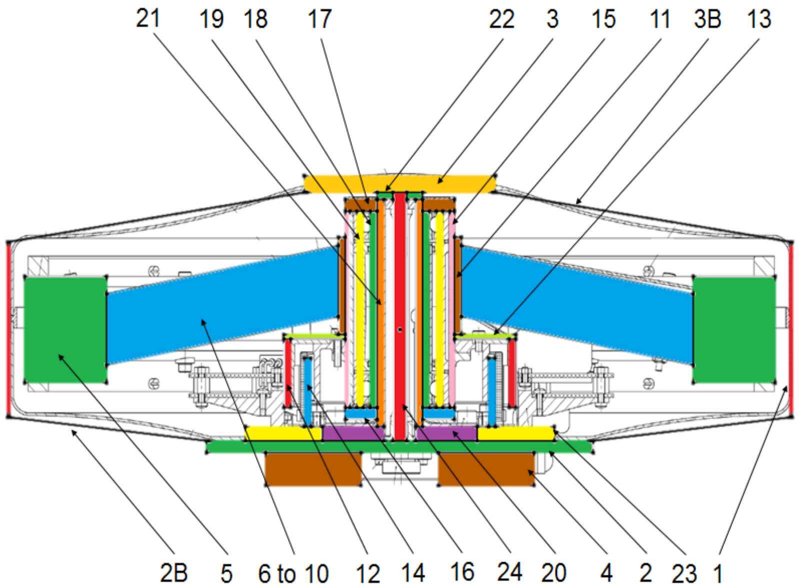


- Investigated solution:
  - Replace Stainless steel wheel with Aluminium wheel

- It is enough?

→ Needs of combing rim re-design with system level approach to be assessed

→ Two different scenario analyzed: redesigned RWs with and without early aperture of the bus

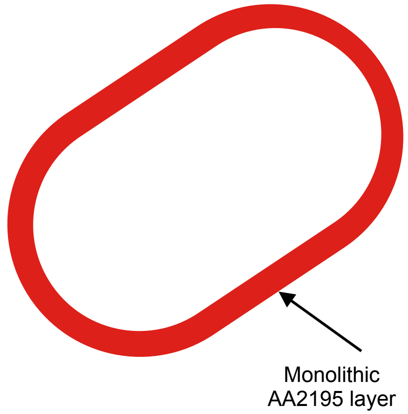


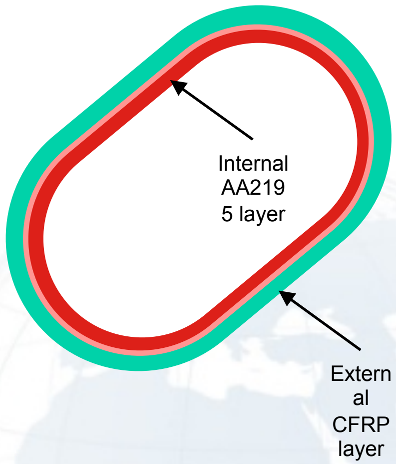
How to demise a tank

- Tank reason of survivability: material
- D4D approach: change material

- Two solutions investigated:
  - Metallic Monolithic tank
  - COPV tank → new ablation model

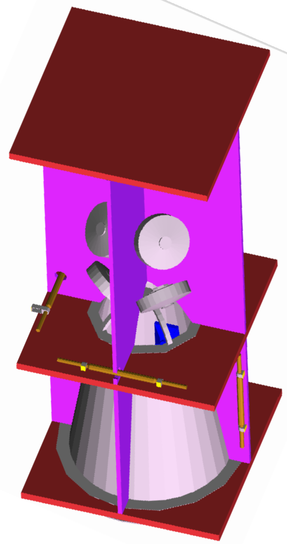
- It is enough?
  - what if the re-designed tank breaks in fragments that do not demise?
  - Two different scenario analyzed: redesigned tank with and without early aperture of the bus





How to demise MTQ

- MTQ reason of survivability: late exposure to the heat flux
- D4D approach: increase heat flux



- Investigated solution: Only system level solution, no MTQ re-design
  - Relocation on the internal side of the external panel
  - increase granularity of the I/F (taking into account the glue)

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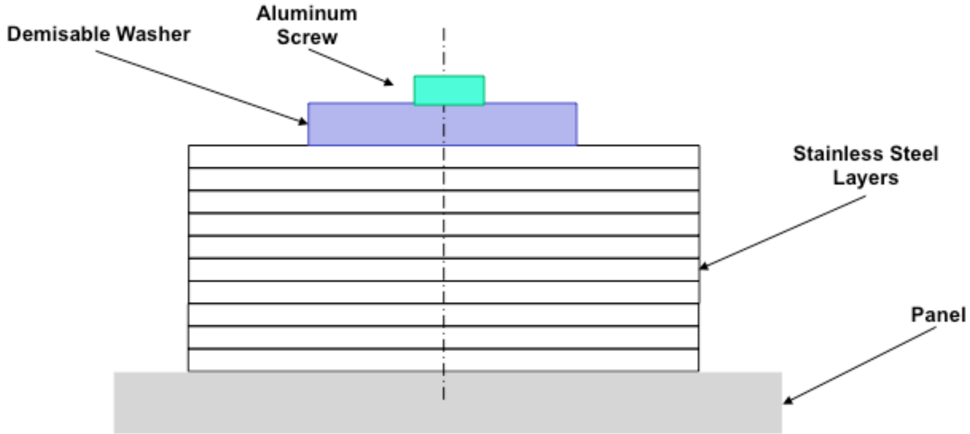
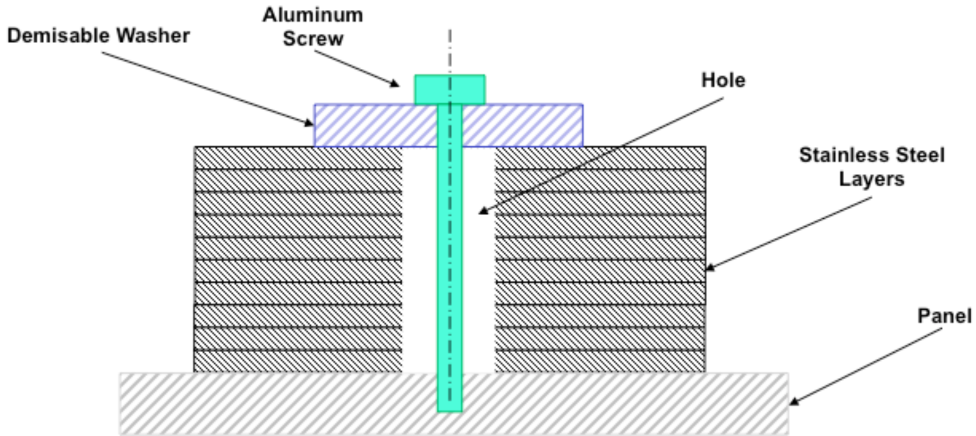
How to demise a balance mass

- Balance mass reason of survivability: material and mass
- D4D approach: layering

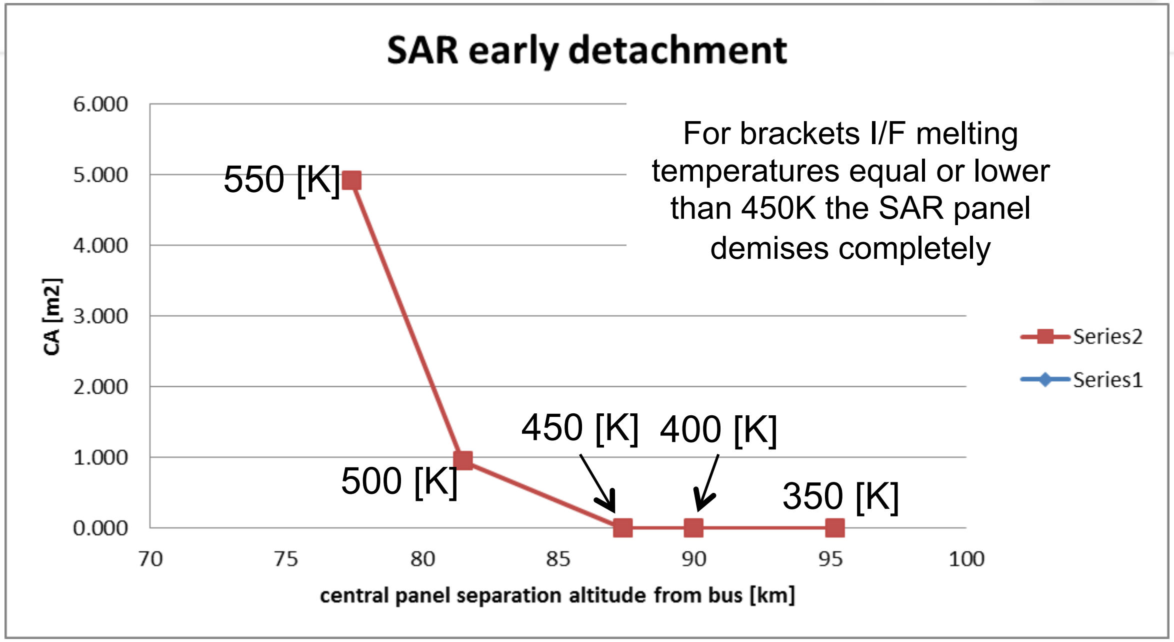


- Investigated solution:
  - Layering combined with a passive release system



- Goals of simulation:
  - Optimize number of layers
  - Define the material of the passive release system

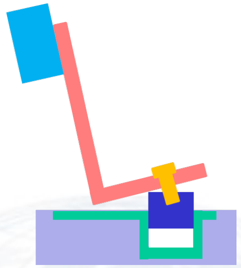
How to demise the SAR?

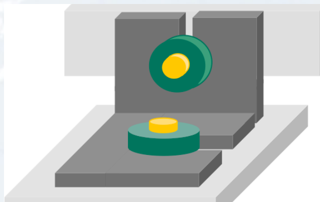


- SAR reason of survivability: late exposure to he heat flux
- D4D approach: increase altitude of separation → separation system

What we know: SAR could demise completely if is detached early enough (>86 km) (like-glue parametric SCARAB simulation results)

- Investigated solution:
  - Type 1: Material swap of the bracket upper panel inserts
  - Type 2: Design of a passive release system based on the adoption of a demisable washer





Patent system

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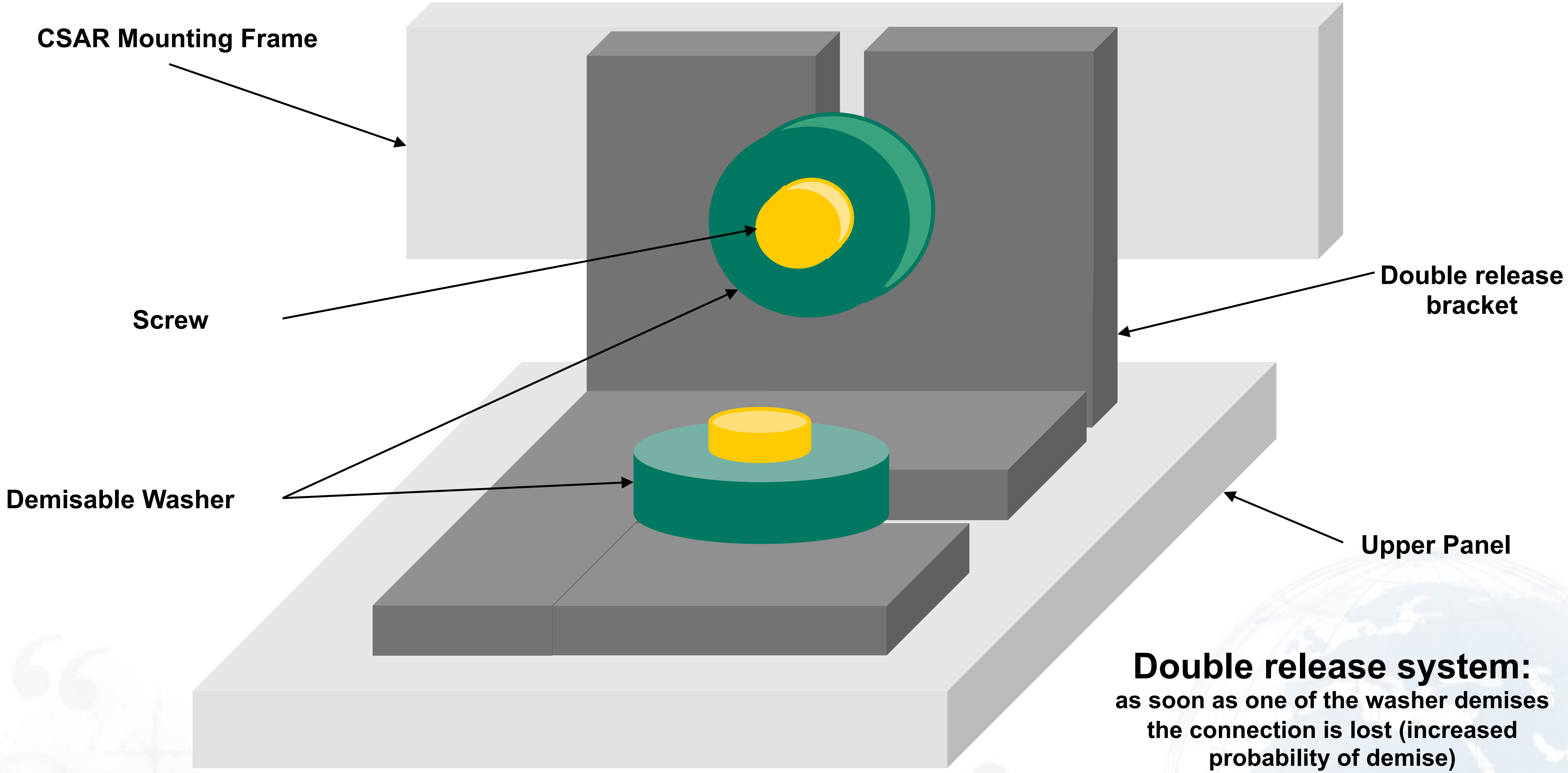
CSAR Separation System – Type 1 Design



Double release system:
as soon as one of the washer demises the connection is lost (increased probability of demise)
Patent system

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Early detachment bus external panel

Do we need early break up of the structure?

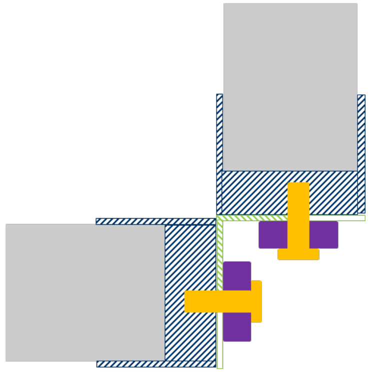
→ S/C internal components current design: components that could take benefit from an earlier aperture of the external panels of the bus are quite limited or even no-one.

- Tank and RWs would not demise in any case
- MTQs demisability can be reached in other ways. Batteries, electronic boxes and harness not critical.

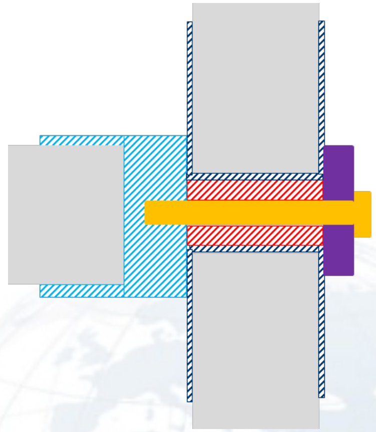
→ according to low fidelity tool results **this kind of systems/ mechanism could be necessary to ensure the demise of new demisable components to be developed.**

Goal of simulations:

- Verify the impact on tank and RWs demise of an early separation of the bus panels
- Implement a preliminary technical solution



Patent system



Patent system

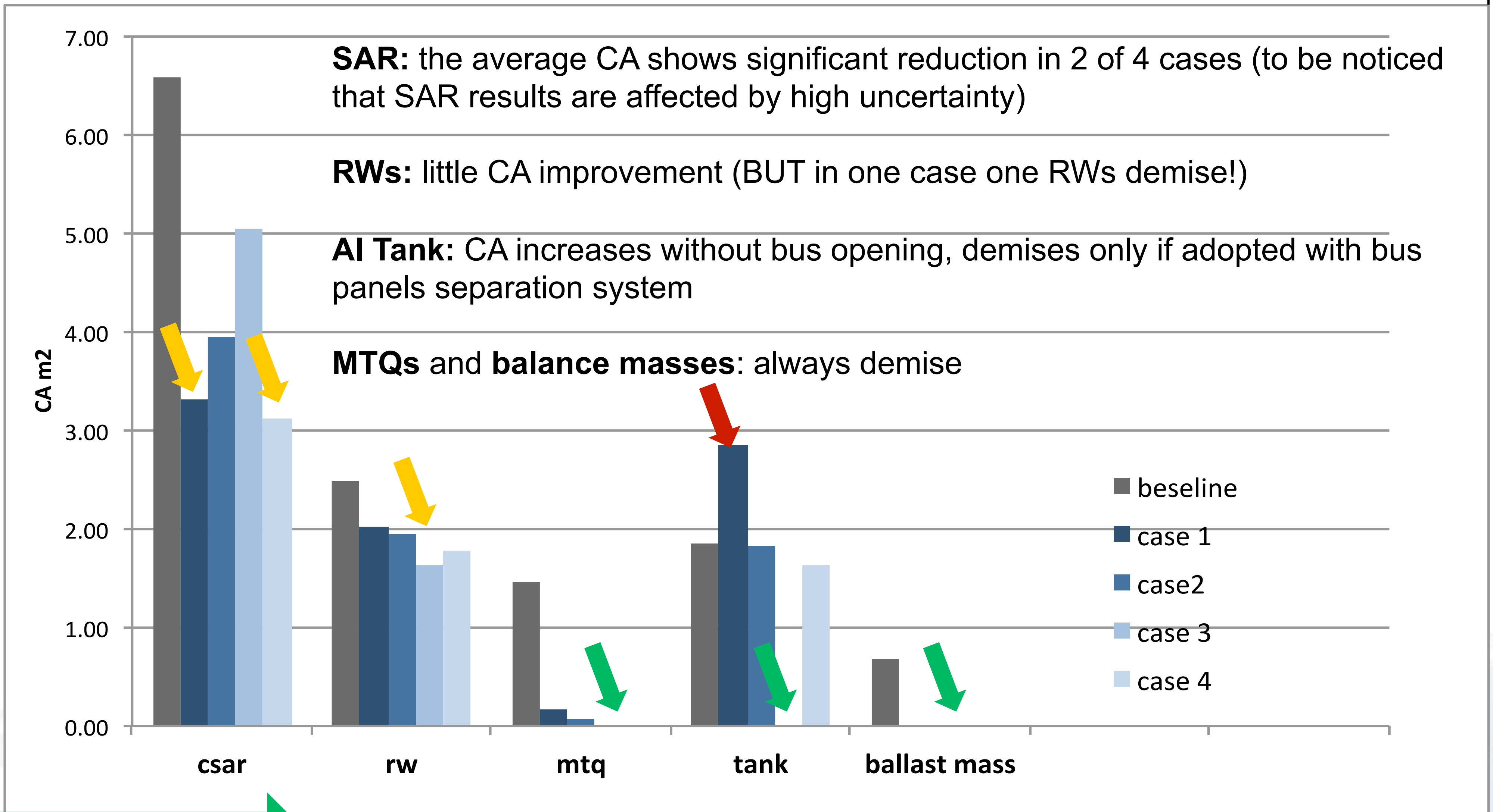
Results: Baseline vs modified cases (component level)

SAR: the average CA shows significant reduction in 2 of 4 cases (to be noticed that SAR results are affected by high uncertainty)

RWs: little CA improvement (BUT in one case one RWs demise!)

Al Tank: CA increases without bus opening, demises only if adopted with bus panels separation system

MTQs and **balance masses**: always demise



Complete demise

CA reduction (30-50%)

CA increasing

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Baseline Design

Casualty Area = 15.2 ± 2.6 m^2

Demisable Design (best combination)

Casualty Area = 6.3 m^2

Re-entry simulation results summary

	Techniques	Strategy	Needs of D4D tech combination	Achieved CA reduction	Potentially achievable CA reduction	applicability
Component level	Al li tank	Material Swap	Yes – with early aperture of bus	**100 %**		Medium term
	Al RWs	Material Swap	Yes – with early aperture of bus and possibly relocation	**35%**	Potentially 100% Relocation should lead to complete demise	Medium term
	Ballast mass layering	Layering	No	**100 %**		Short term
System level	Relocation of critical components (applied to MTQs)	Increase heat flux	No / Yes	**100 %**		Short term
	Passive system for Early separation of appendix	Increase heat flux	No	**50%**	Potentially100% Increasing separation altitude at about 85-90 km	Medium term
	BUS early separation system	Increase heat flux	Yes	**See component level impact**	increase separation altitude	Medium term

Conclusions

- D4D is an **iterative process.**
- Needs of exploiting **Synergies** among different techniques.
- **Different D4D techniques** (at component and system level) **needs to be adopted in combination** to effectively reduce the CA, and reach the compliance.

Main techniques to be developed according to study results:

- **Monolithic metallic tank**
- **Demisable RW**
- **Release systems** (for panels, appendixes, internal components)
- Etc. (see outcome of other D4D studies)

- In parallel:
  - Tests on materials
  - Improve tools

→ Optical payloads (deserve dedicated approach) → D4OP

Thank you

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