CLEANSAT industrial days
Demisable Xenon Tanks (BBO2)

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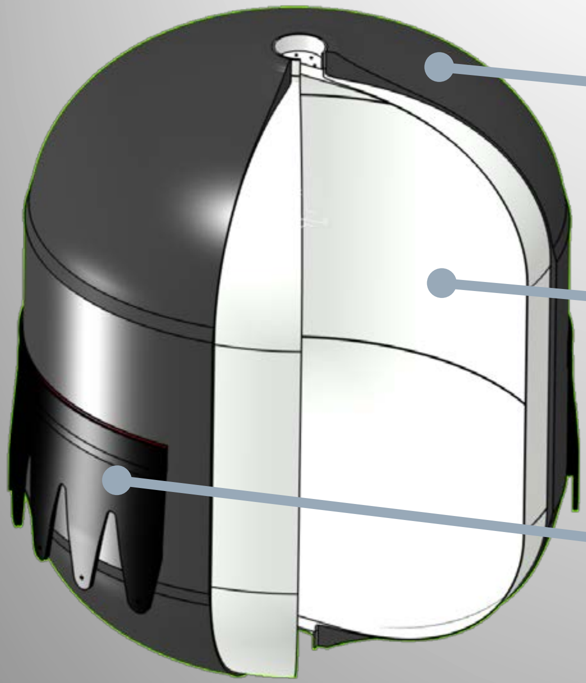
Xenon tank heritage technologies (with no demiseability specifications)



Carbon composite overwrap
- IM carbon fibers
- Thermoset epoxy matrix

Metallic liner
- Titanium (Ta6v)

Skirt mounting interface for large tank (polar mounting still baseline for small tanks)

Observation on re-entry behaviour of heritage COPV technologies

The mysterious metal ball in Calasparra, Spain. (Image: www.abc.es)

- Titanium liner is almost not affected by re-entry and keep is shape

- Composite material is not fully demised
  - Carbon fibers partially separated from burned matrix but not removed

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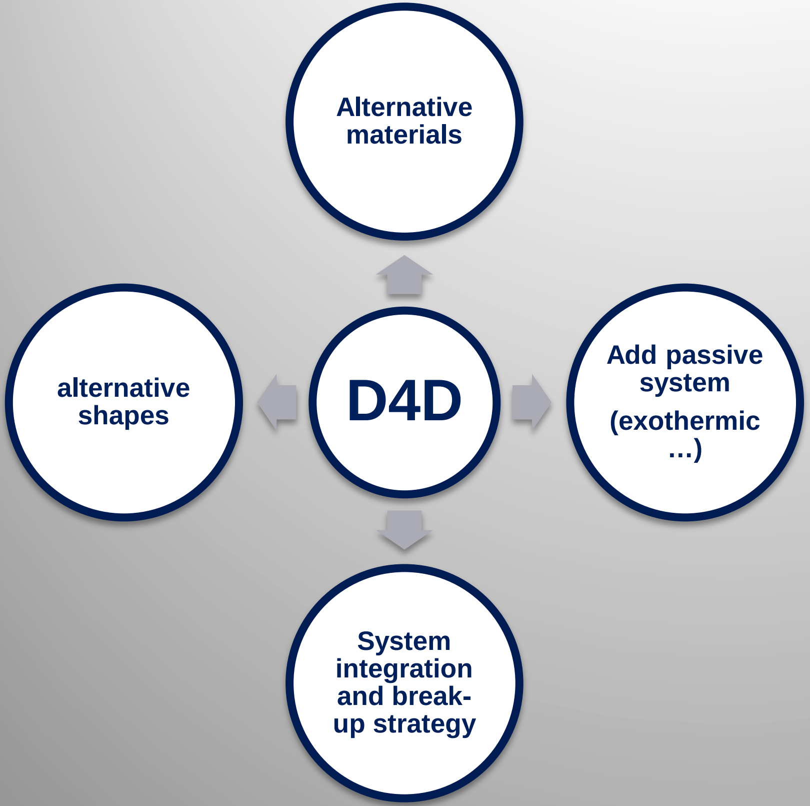
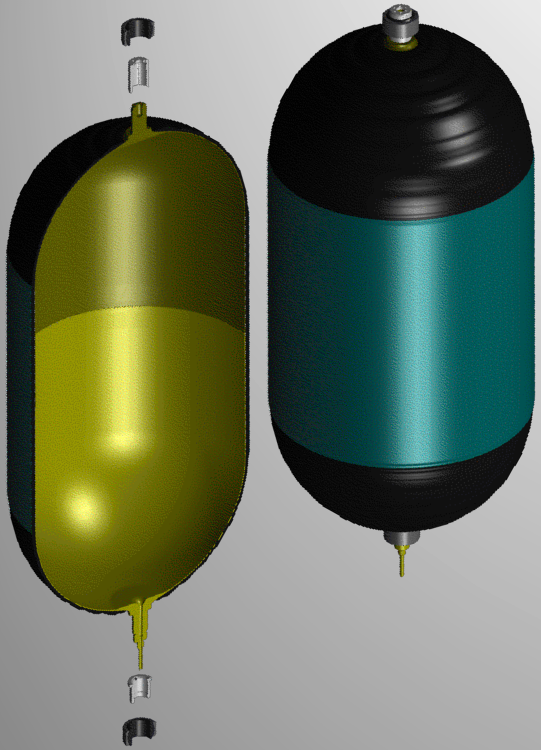
Design drivers for demisability improvements



Building block trade-offs



Pilot case:

- Tank volume: 30L
- Gas: pressurized Xenon
- Interfaces: Polar mounting

Trade off variable

- Liner material (aluminum grade)
- Composite shell material (carbon / kevlar, thermoset, thermoplastic)

Trade-off criterion

- Demisability
- Mass
- RC/NRC
- Development time

Tank design approach

Re-entry simulation

Composite shell sizing

Liner sizing

Elastically operating

- Limited impact on justification
- Higher mass impact

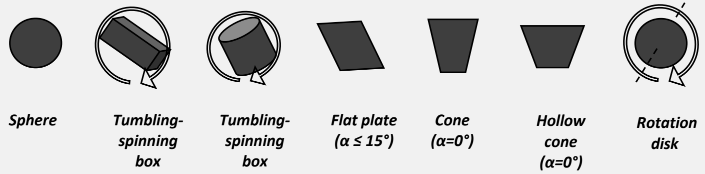
plastically operating

- Limited mass impact
- Extended justification and qualification activities vs low cycle fatigue

CLEANSAT industrial days: AIRBUS DS D4D tools

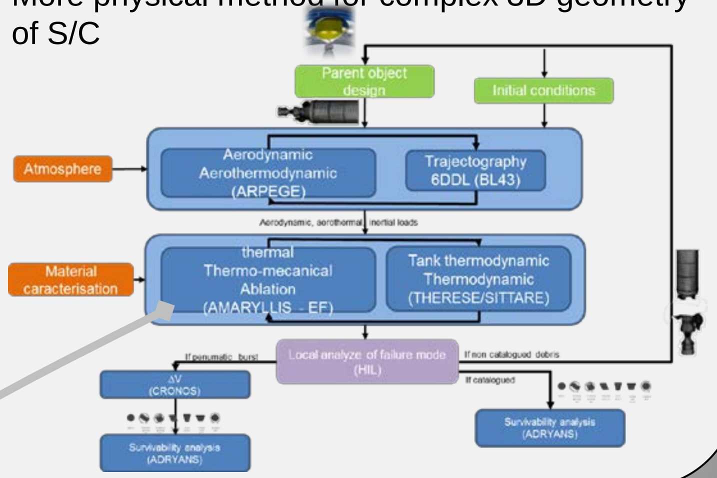
Survivability object oriented tool: ***ADRYANS***

- Computes the survivability of a space debris during its atmospheric reentry.
- Developed at Airbus Defence & Space in partnership with the French Space Agency CNES
- Predict the risk associated with an atmospheric reentry of a rocket launcher stage or component



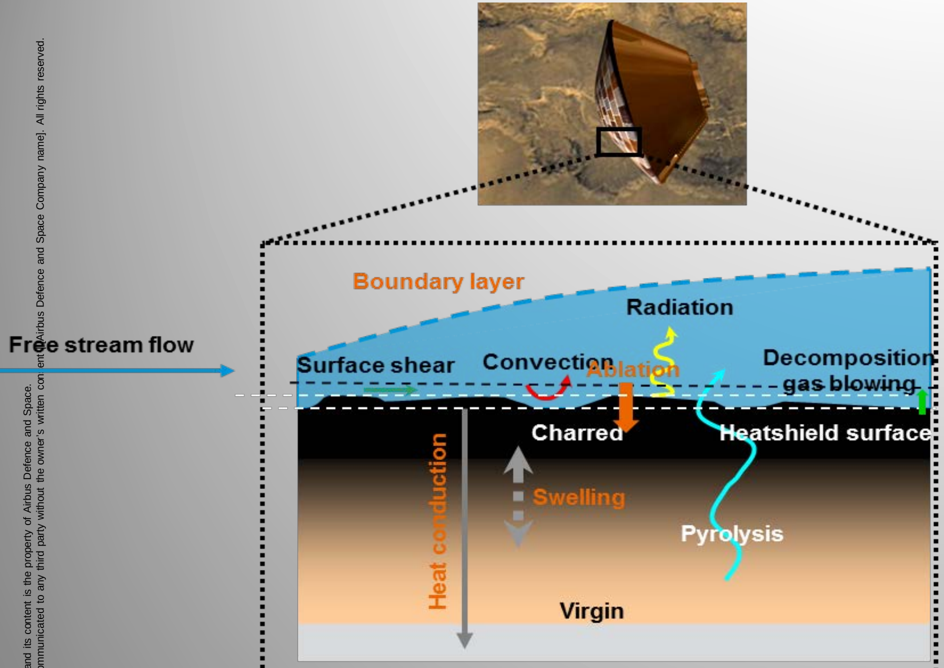
Fragmentation *– S/C oriented suite package:*

- More physical method for complex 3D geometry of S/C



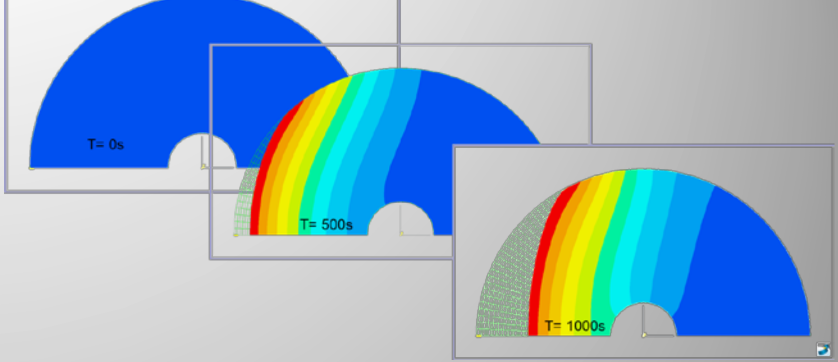
- Composite material behavior currently not available in **ADRYANS.V4** (implementation in progress in **ADRYANS.V5**)
- FE code **Amaryllis** (Samcef) is used instead (only for thermochemical analysis, no thermomechanical computation done)
- Amaryllis has multidimensional capabilities (1,2, 3D) and can simulate charring, ablation, swelling, diffusive and radiative heat transfer phenomena (initially developed for heat-shield design ad justification (cf. Huygens probe, ARD, Beagle2, Exomars Schiaparelli…)

CLEANSAT industrial days: AIRBUS DS D4D tools – model & examples

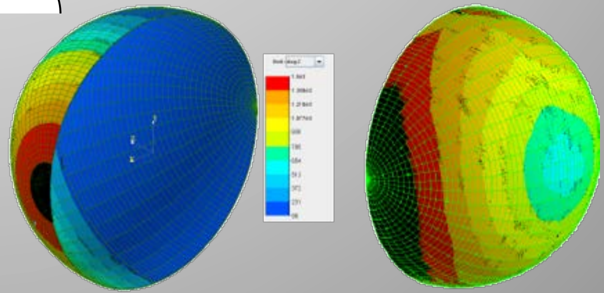


- Comprehensive thermophysic models gathered in AMARYLLIS (1,2 3D Finite Element tools software)

Massive aluminium sphere, with non-uniform heat flux distribution

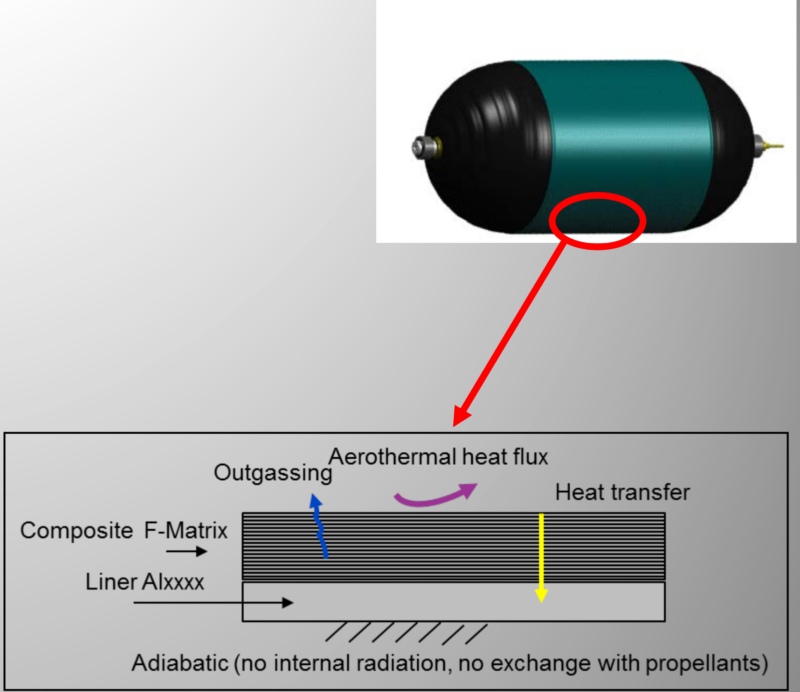


Titanium tank, motion effect



CLEANSAT industrial days: Material model and assumptions

- Conductive model assumed unchanged during pyrolysis (no data available)
- Pyrolysis kinetics built from low heating rate tests
- Theoretical approach for energetical model (specific heat, heat of pyrolysis).
- Ablation scheme based on graphite



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Demisability study : Break-up and tank assumptions

Break-up assumptions:

- tanks are fully protected during the whole reentry down to the break-up altitude
- reference break-up altitude is 78 km *(loop 1: +/-15 km sensibility was performed)*
- ESA break-up altitude is 65 km (loop 2)
- Trajectory is calculated with ADRYANS
  - Spherical shape hypothesis is compensated by increased drag coefficient
  - tumbling aerothermodynamical averaging motion

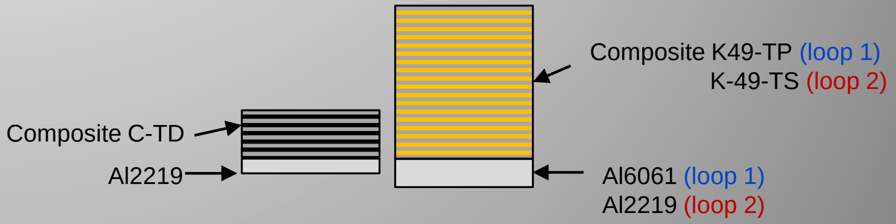
Materials assumption:

- Melting of Aluminum over given temperature
- Charring and ablation of C-TS, K-TS, K-TP is modeled with the same method

Tanks:

- *2219-T800/Thermoset* (ref. as **R1** hereafter)
- *6061-K49-TP (loop 1)* (ref. as **R2** hereafter)
- *2219-K49-TS* (loop 2) (ref. as **R2B & R2C** hereafter)

Reference	**R2B**	**R2C**
Behavior	Plastic	Elastic
Ep comp. Virole (mm)	4.4	5.72
Ep liner (mm)	1.5	2



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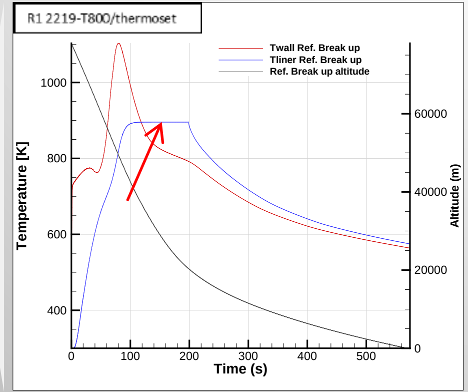
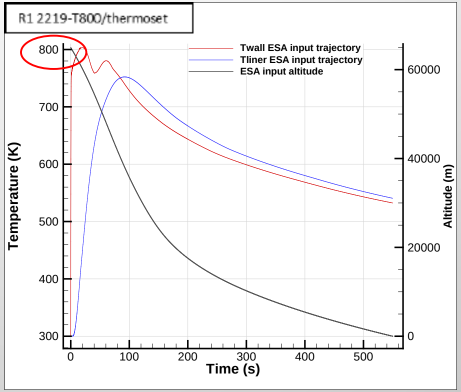
Results for *2219-C-T800/Thermoset (R1)*

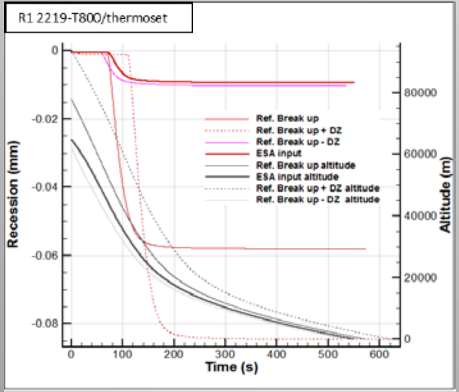
The carbon fiber goes well over 1000K, **allowing the aluminum liner to melt** for the 78 km alt. break-up trajectory. pyrolysed carbon fiber "ball" comportment during reentry is not well known.

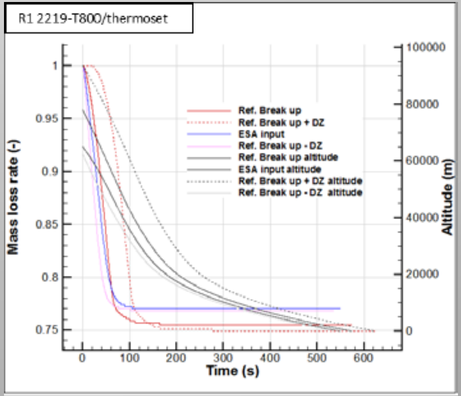




The carbon fiber does not reach 800K, the aluminum liner does not melt for the 65 km alt. break-up

Recession is more important in the 78 km alt. break-up trajectory (~0.6 mm) than in the 65 km alt. break-up (~0.01mm) due to fiber combustion and oxidation

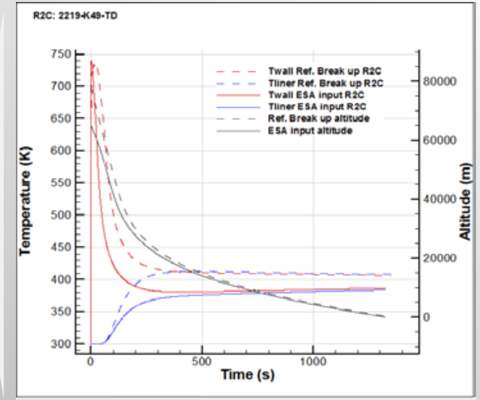


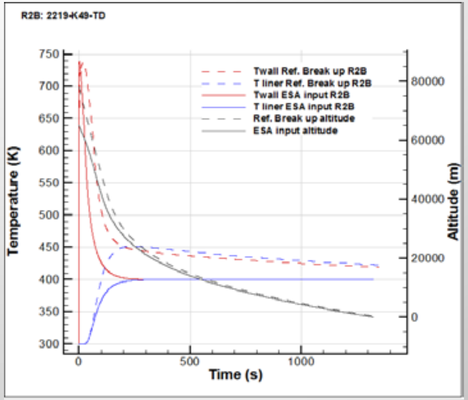


The mass loss rate is between 18% and 25%, and mainly due to resin pyrolysis during reentry, taken away by the air flow

Results for *2219-K49-TS* (R2B and R2C)

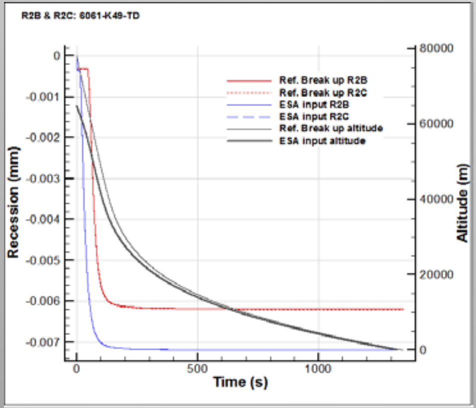
The Kevlar fiber goes up to ~750K,protecting the aluminum liner who does not goes beyond ~430 K. **The tank stays in its original shape until impact**

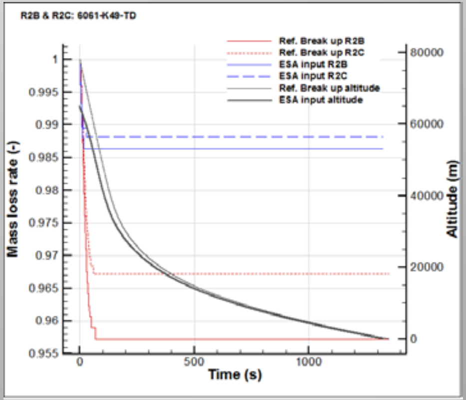




The Kevlar fiber goes up to ~750K,protecting the aluminum liner who does not goes beyond ~450 K : The tank stays in its original shape until impact

Recession is very small in both cases, between 0.006 mm and 0.0072 mm (< 1 deposit layer), it is due to fiber combustion and oxidation: the outer layer of the fiber is little impacted by reentry





The mass loss rate is between 1.2% and 4.5%, and mainly due to resin pyrolysis during reentry, taken away by the air flow

Demisability global results

Tank	R1 (2219-Carbon)		R2 (6061-Kevlar)	R2B (2219-Kevlar) plastic behavior		R2C (2219-Kevlar) elastic behavior	
Break up altitude	78 (Ref)	65 (ESA)	78 (Ref)	78 (Ref)	65 (ESA)	78 (Ref)	65 (ESA)
Tmax	850 K	750 K	400 K	450 K	400 K	420 K	390 K
Liner	100% melted	Not melted but soft : loss of mechanical properties	Not melted not softened (partial loss of mechanical properties)	Not melted not softened (partial loss of mechanical properties)	Not melted not softened (partial loss of mechanical properties)	Not melted not softened (partial loss of mechanical properties)	Not melted not softened, little loss of mechanical properties
Composite	25% mass loss Resin entirely charred	23% mass loss Resin entirely charred	8% mass loss Resin not completely charred (2.4 mm: 21%)	4% mass loss Resin not completely charred (1 mm: 22%)	1.2% mass loss Resin not completely charred (0.4 mm: 9%)	4.2% mass loss Resin not completely charred (1 mm: 17%)	1.4% mass loss Resin not completely charred (0.4 mm: 7%)

- Aluminum liner could improve demisability in the studied case : it can be melted during re-entry if the composite overwrap does not act as a thermal protection
- Carbon composite has a better conductance than Kevlar
- Kevlar composite overwrap thickness, determined by mechanical sizing, impacts negatively the global conductance of the layer, thus creating a thermal protection behavior of the composite overwrap

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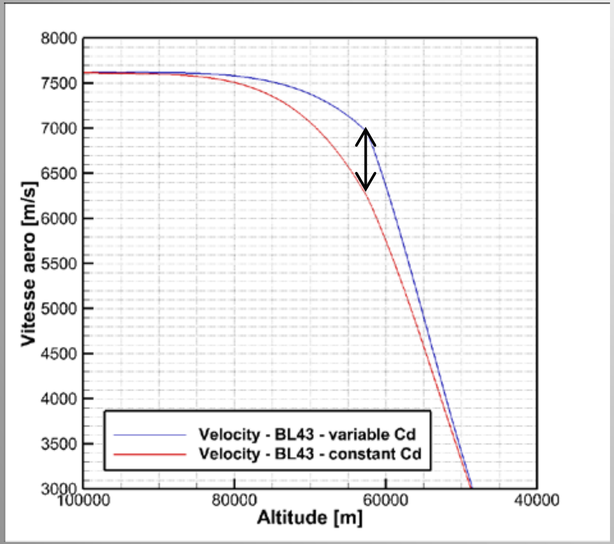
Impact of various drag coefficient hypotheses on the trajectory before break-up



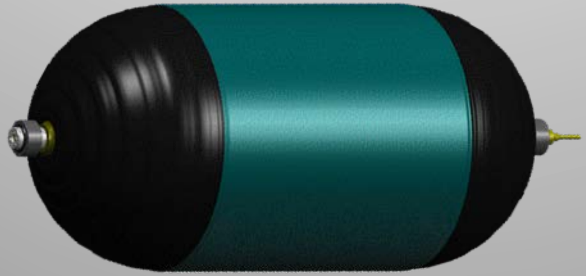
In this case, a maximum speed difference of ~800 m/s (at iso-altitude) has been computed

- 2 trajectories were calculated depending on different drag coefficient Cd:
  - One with constant Cd
  - One with Cd coefficient calculated with bridging functions between free molecular flow and continuous flow

The constant Cd hypothesis can lead to important velocity differences
In our case, the Cd calculated with a bridging function will let the tank at a higher velocity than the constant Cd. The atmospheric drag is more important on the constant Cd trajectory.

- Aluminium liner is confirmed as a good candidate to improve demisability of xenon tanks

- CFRP composite overwrap is still baselined but additional work has to be performed to show compliance with demisability requirements:
    - Behavior of a free falling hollow composite tank after matrix pyrolysis (shape/speed/trajectory…)
    - Ground impact of an almost dry fiber "ball"



Thank you

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