R.Tech
Research & Technology

REACTION WHEEL SCARAB/PAMPERO

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November 23th 2020

PR-RW-PRES-201120-2844-RTECH

Context

The French Space Operation Act (2008) enforces the assessment of prospective risks

CNES is in charge of ensuring the right application of the law

CNES develops its own certification tool and spacecraft-oriented tools

DEBRISK and *PAMPERO*

DEBRISK®

PAMPERO

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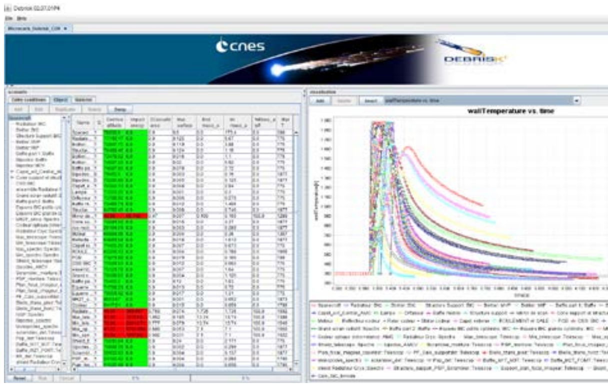
Space Debris Reentry Tools

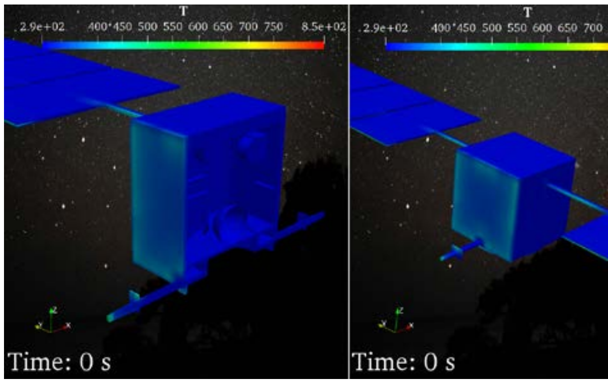
DEBRISK : French certification tool (100% CNES)
- Provided to the aerospace companies and operators
- Designed to perform **rapid survivability analyses** of fragments from space vehicles during their atmospheric reentry
- Based on an **object-oriented** approach

DEBRISK®



PAMPERO : French spacecraft-oriented tool (100% CNES)
- Validate assumptions used in object-oriented tools
- Perform computations for sensitive objects reaching the ground close to the 14J limit
- Perform computations for very **complex objects** (not available within object-oriented tools)
- Perform **D4D computations** for future missions
- Support **experts** for the **fragmentation** modelling

- Since 2020, R.TECH has an **exclusive license** of PAMPERO in order to achieve state of the art studies for customers of the industry



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PAMPERO Team

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FR — NL

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Aerothermodynamics, Meshing

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IT support, testing and quality assurance

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1 – Geometry and mesh

2 - Validation

3 – Results

4 – Discussions

Geometry

Geometry :

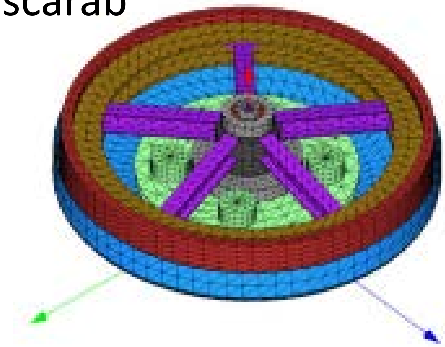
- Total mass : 7,79 kg

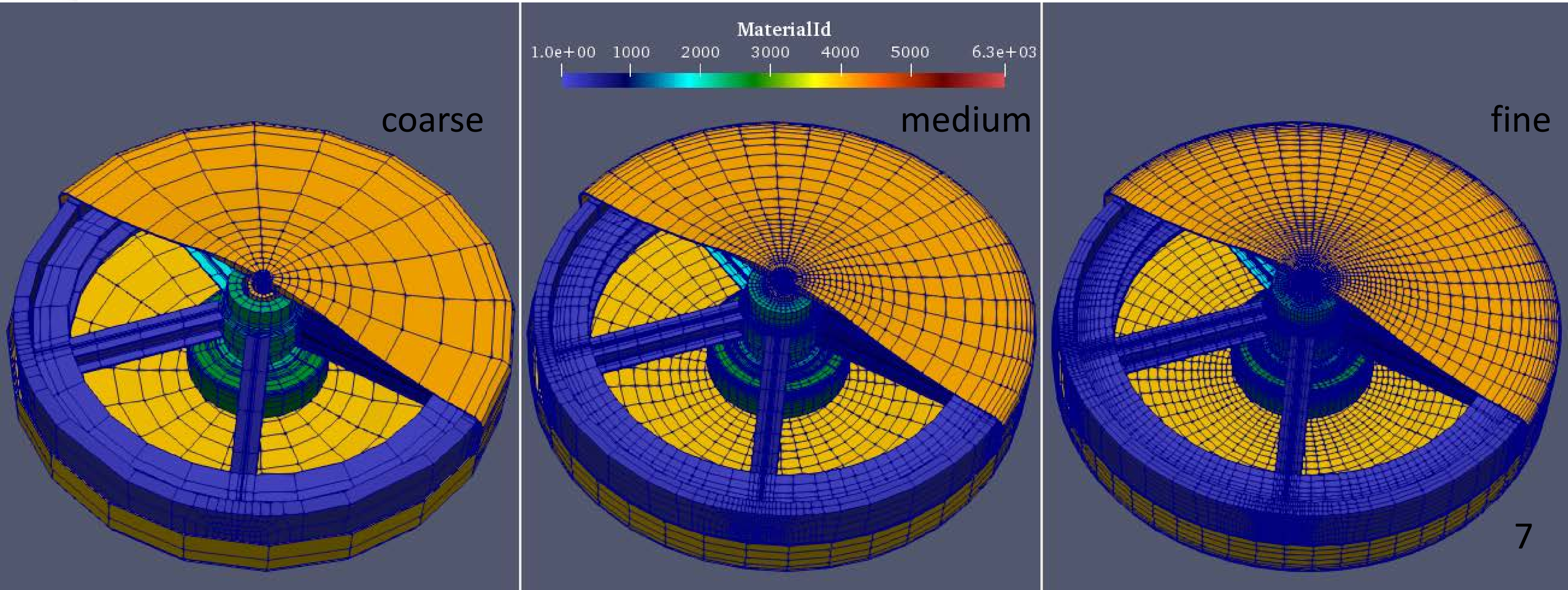
Mesh

<u>3 meshes :</u>

- coarse : 7 303 cells
- medium : 59 144 cells
- fine : 199 611 cells

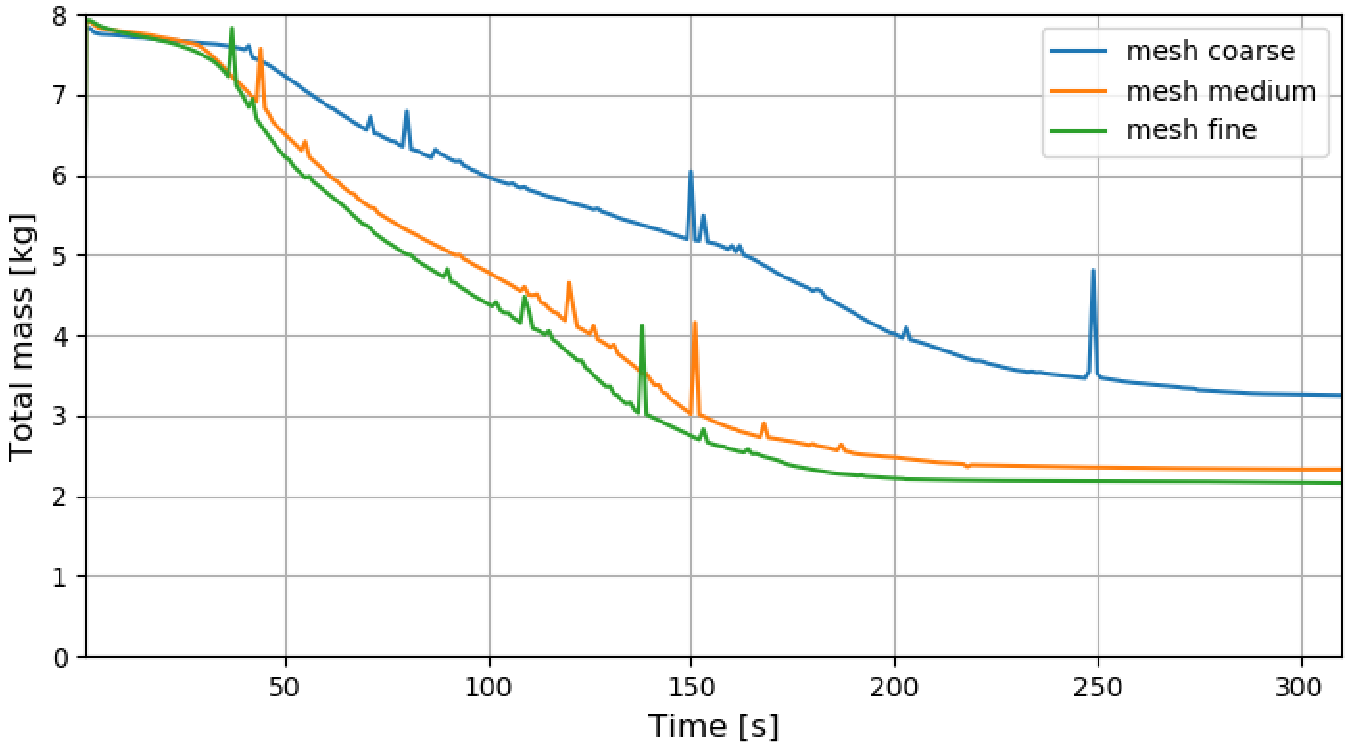
scarab





Mesh

Thermic convergence :



Mesh

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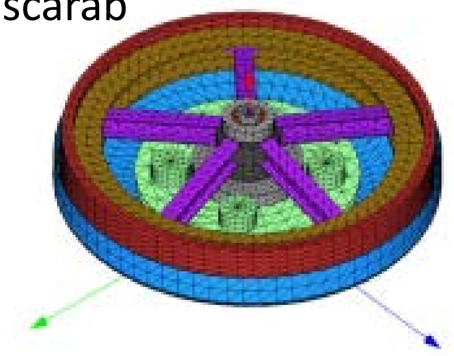

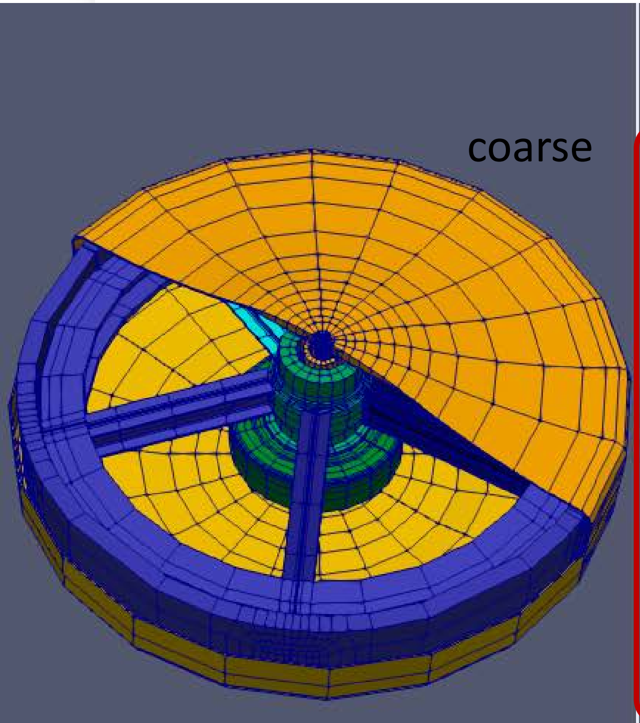

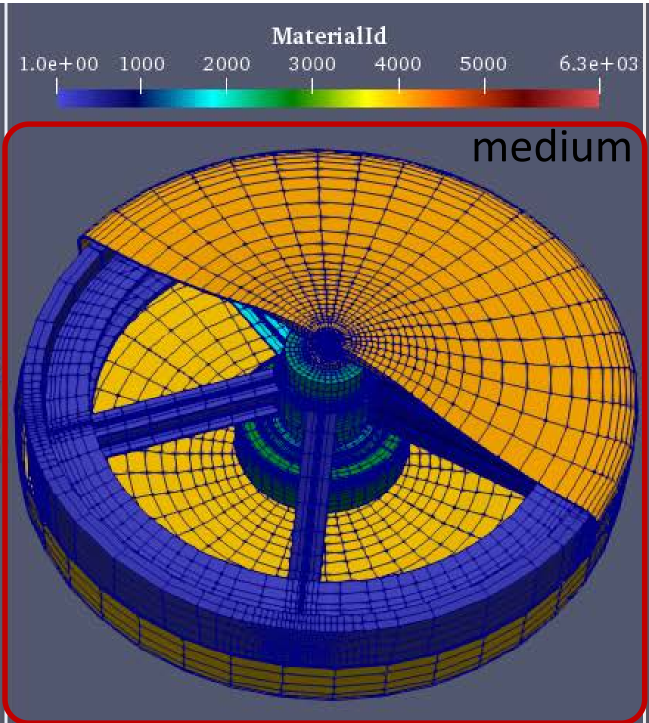

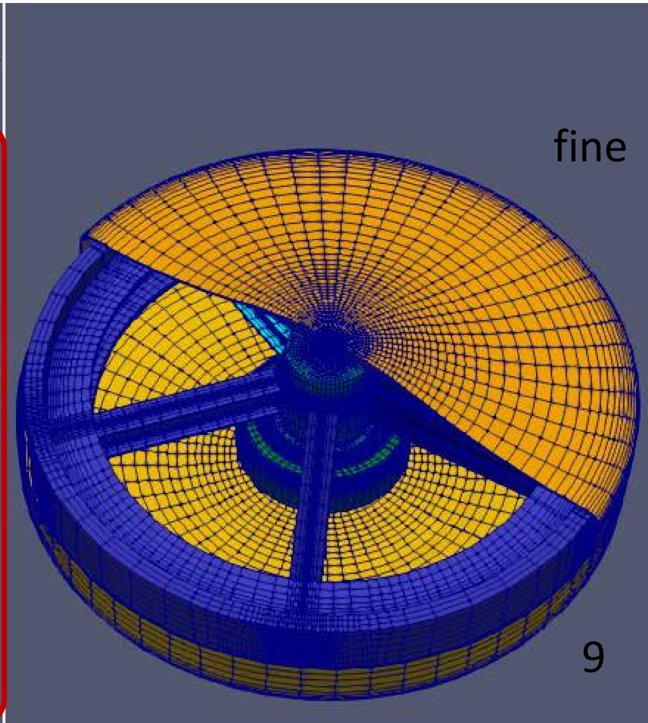

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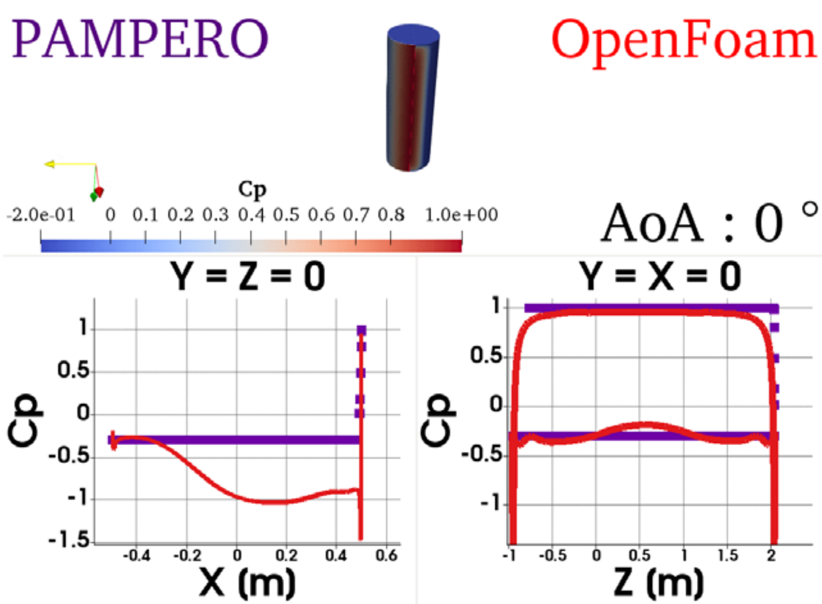
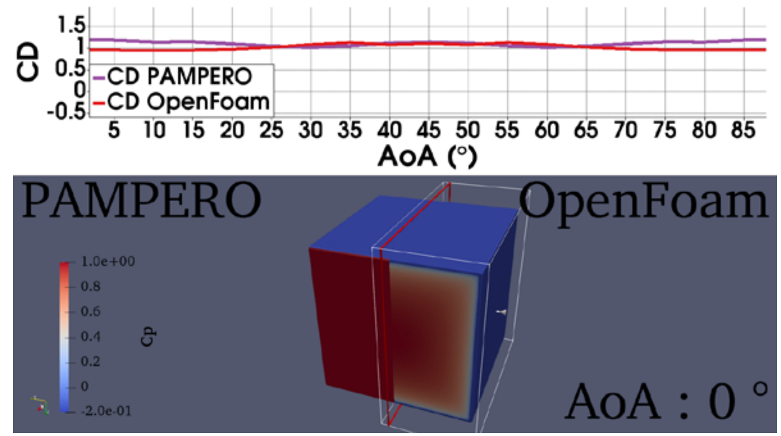
Validation Low speed

Validation of the drag coefficient/ pressure distribution capture at low speed :
Very important to **insure a great accuracy** on the **impact energy** that could influence the **casualty area** of the debris.

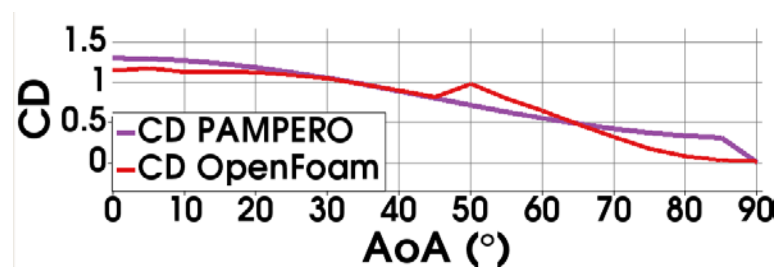
Good match between PAMPERO, the CFD code OPENFOAM and experiments for different generic debris



Pressure comparison over a cylinder at low speed with PAMPERO and OPENFOAM



Drag coefficient comparison (CD) over a cube at low speed with PAMPERO, OPENFOAM and experiments (*)



Drag coefficient comparison (CD) over a plate at low speed with PAMPERO, OPENFOAM and experiments (*)

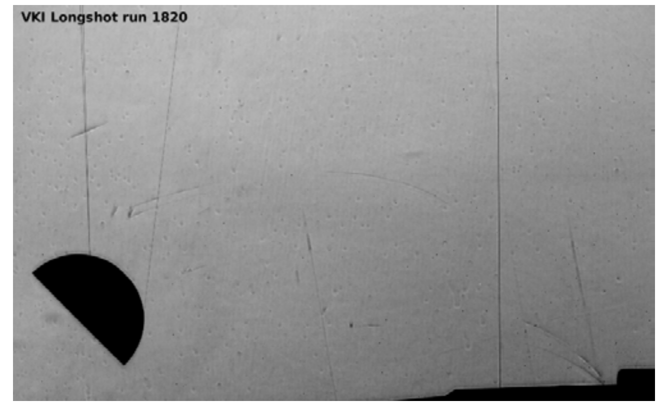
Validation
Aerodynamics for Concave Geometry

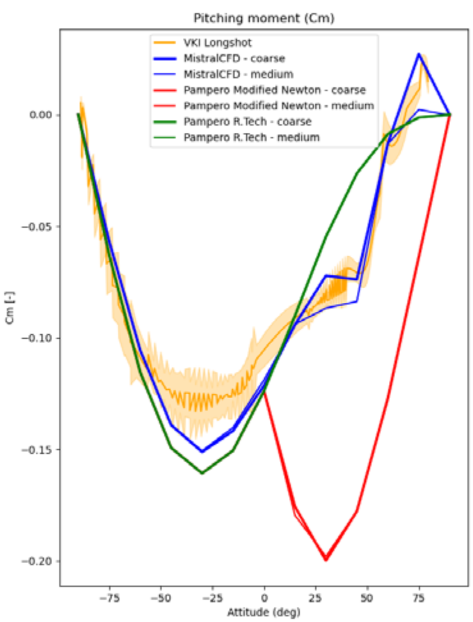
Improvement to the Modified Newton method

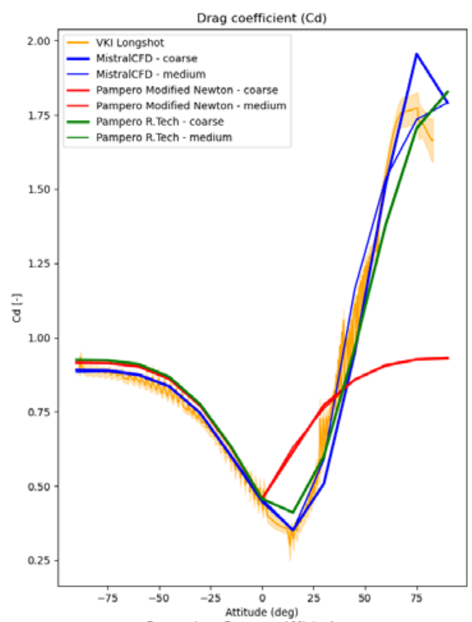
Automatic identification of concave regions

Validation of the aerodynamic coefficients on a concave shape very challenging for simplified aerodynamics softwares (concave shapes, unsteady phenomena)

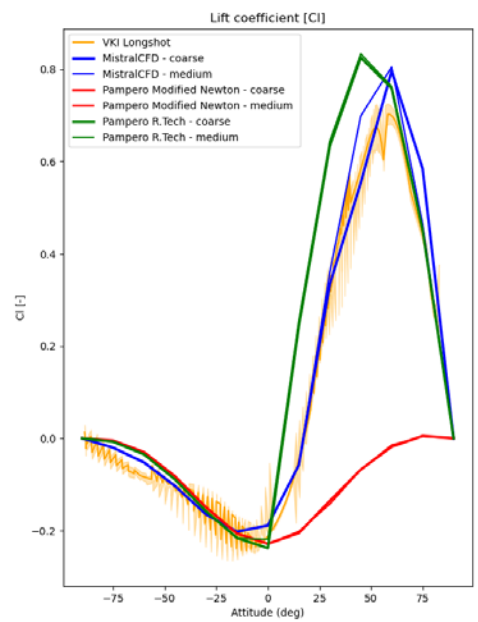
Better agreement of PAMPERO with a CFD code (MISTRAL) and experiments (VKI Longshot)







Comparison Pampero / Mistral
SPHCAP (16/9/2020) 2.0



J Annaloro, S. Galera, C Thiebaut, Martin Spel, Pierre Van Hauwaert, G G, S P, O C, P O Aerothermodynamics modelling of complex shapes in the DEBRISK atmospheric reentry tool: Methodology and validation, Acta Astronautica, Volume 171, 2020, Pages 388-402

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Results
Released conditions

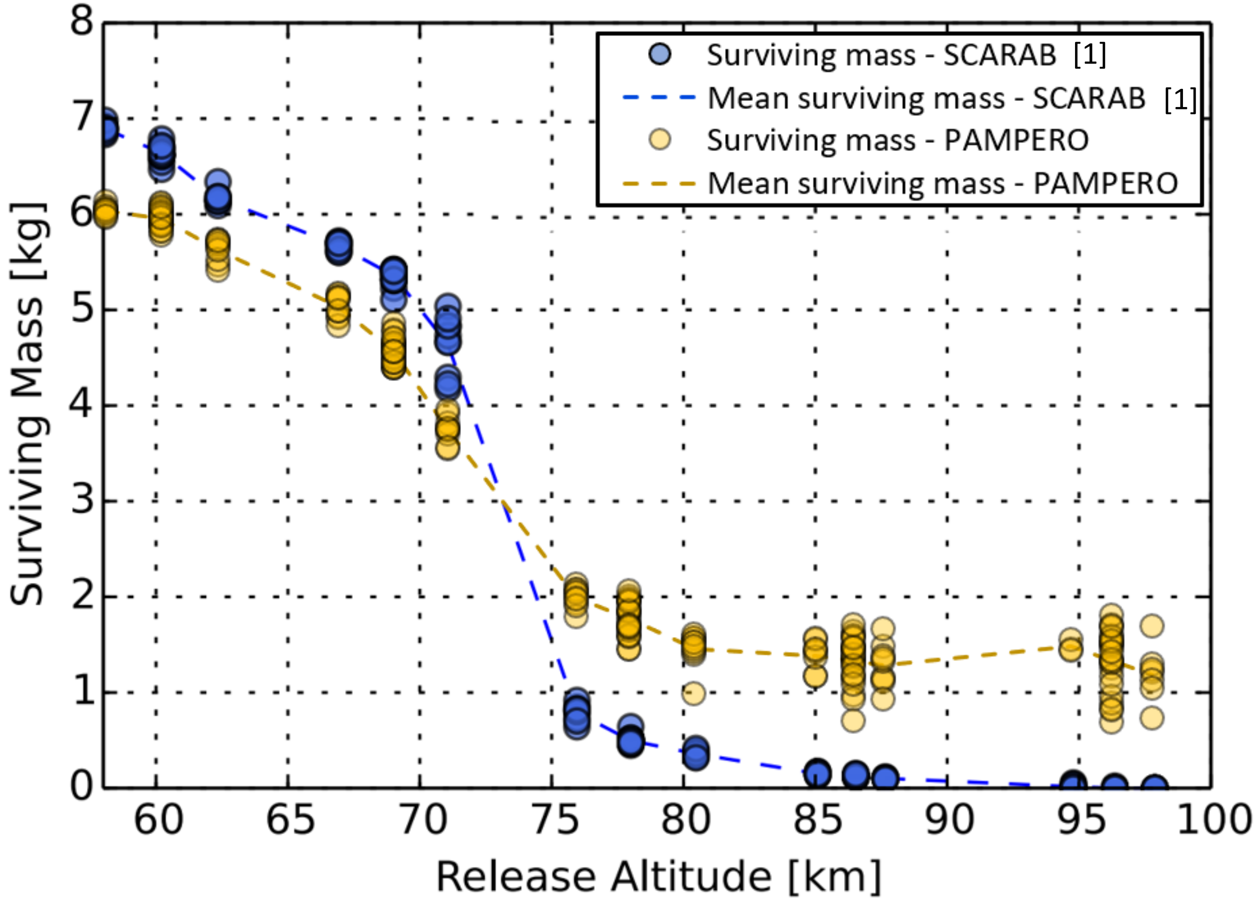
<u>Released conditions :</u>

5 main altitudes with 25 attitudes
For each altitudes, 2 secondary altitudes with 10 attitudes each

Main altitude	Secondary altitude		Cases	Total
	97,9 km	----------	10 cases attitudes varying	
96,4 km		--------------------------	25 cases attitudes varying	
	94,8 km	----------	10 cases attitudes varying	
	87,7 km	----------	10 cases attitudes varying	
86,5 km		--------------------------	25 cases attitudes varying	
	85,1 km	----------	10 cases attitudes varying	
	80,5 km	----------	10 cases attitudes varying	
78 km		--------------------------	25 cases attitudes varying	225 cases
	76 km	----------	10 cases attitudes varying	
	71,1 km	----------	10 cases attitudes varying	
69 km		--------------------------	25 cases attitudes varying	
	66,9 km	----------	10 cases attitudes varying	
	62,3 km	----------	10 cases attitudes varying	
60,2 km		--------------------------	25 cases attitudes varying	
	58,1 km	----------	10 cases attitudes varying	

Results
Global results

Surviving mass :



[1] P. Kärräng, T. Lips, T. Soares, Demisability of critical spacecraft components during atmospheric re-entry, 69th International Astronautical Congress, 2018

Results
Global results

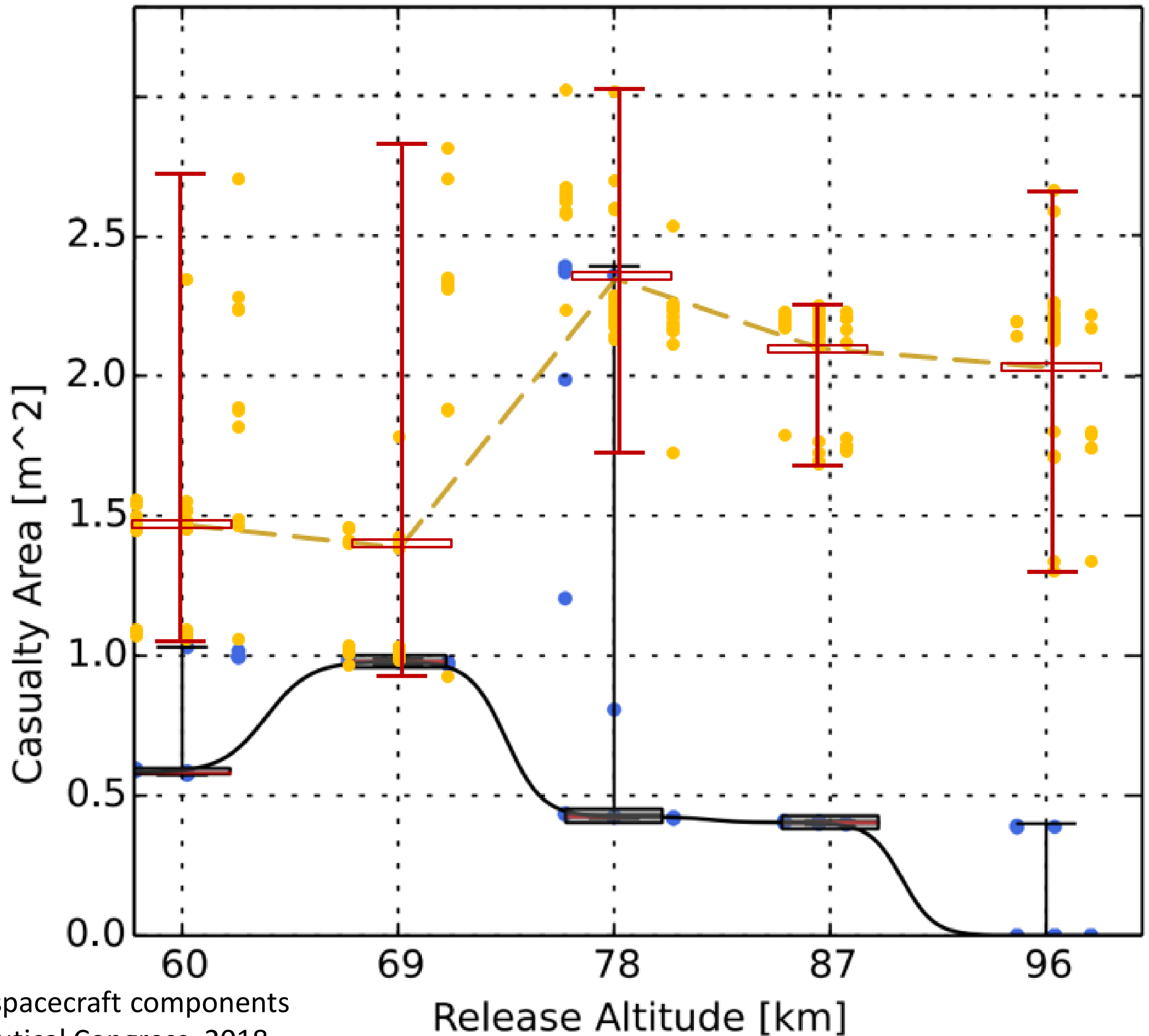
Casualty area (CA) :

- Casualty area – SCARAB [1]
- Mean casualty area – SCARAB [1]
- Casualty area – PAMPERO
- Mean casualty area – PAMPERO

Results for 45 cases of the main and secondary altitudes :

SCARAB : [1]
Maximal CA
Mean CA
Minimal CA

PAMPERO :
Maximal CA
Mean CA
Minimal CA



[1] P. Kärräng, T. Lips, T. Soares, Demisability of critical spacecraft components during atmospheric re-entry, 69th International Astronautical Congress, 2018

Results
Altitude 96km results

<u>Ground fragments for 25 cases :</u>

- Altitude = 96,4 km
- Variable : attitude

	A	B	C	D	E	F	G	H	J	K	L	M
	How many times (out of 25) these parts are found on ground ? Mean surviving mass [kg, % of initial mass] ?											
Impact probability	0	25 %	1	100 %	0	0	0	0	4 %	4 %	4 %	0
Surviving mass [kg]		$1.89\ 10^{-3}$	$1.16\ 10^{-5}$	1,306					$8.84\ 10^{-2}$	$1.39\ 10^{-1}$	$9.81\ 10^{-4}$	
% of initial mass		12 %	0 %	32 %					49 %	65 %	0,6 %	

- Most popular on ground :
  - D in steel (initial mass = 4,1 kg)
  - B in titan (initial mass = 16 g)

Results
Altitude 87km results

<u>Ground fragments for 25 cases :</u>

- Altitude = 86,5 km
- Variable : attitude

	A	B	C	D	E	F	G	H	J	K	L	M
	How many times (out of 25) these parts are found on ground ? Mean surviving mass [kg, % of initial mass] ?											
Impact probability	0	40 %	0	100%	0	0	0	0	0	0	0	0
Surviving mass [kg]		$5.34\ 10^{-4}$		1,342								
% of initial mass		3 %		33%								

- Two parts on ground :
  - D in steel (initial mass = 4,1 kg)
  - B in titan (initial mass = 16 g)

Results
Altitude 78km results

Ground fragments for 25 cases :

- Altitude = 78 km
- Variable : attitude

	A	B	C	D	E	F	G	H	J	K	L	M
	How many times (out of 15) these parts are found on ground ? Mean surviving mass [kg, % of initial mass] ?											
Impact probability	0	**0**	0	100 %	0	0	0	13 %	0	0	0	20 %
Surviving mass [kg]				1.747				0.003				0.006
% of initial mass				43 %				0,4 %				2 %

Results
Altitude 69km results

<u>Ground fragments for 25 cases :</u>

- Altitude = 69 km
- Variable : attitude

	A	B	C	D	E	F	G	H	J	K	L	M
	How many times (out of 24) these parts are found on ground ? Mean surviving mass [kg, % of initial mass] ?											
Impact probability	4 %	**0 %**	0 %	100 %	0 %	100 %	0 %	100 %	79 %	83 %	87 %	100 %
Surviving mass [kg]	0.022			3.830		0.123		0.375	0.007	0.025	0.013	0.115
% of initial mass	5 %			94 %		27 %		49 %	4 %	12 %	8 %	42 %

Results
Altitude 60km results

Ground fragments for 25 cases :

- Altitude = 60,2 km
- Variable : attitude

	A	B	C	D	E	F	G	H	J	K	L	M
	How many times (out of 25) these parts are found on ground ? Mean surviving mass [kg, % of initial mass] ?											
Impact probability	52 %	100 %	36 %	100 %	28 %	100 %	56 %	100 %	100 %	100 %	100 %	100 %
Surviving mass [kg]	0.022	0.015	0.029	4.075	0.017	0.158	0.043	0.747	0.165	0.154	0.168	0.264
% of initial mass	5 %	94 %	4 %	100 %	7 %	35 %	18 %	98 %	92 %	72 %	97 %	96 %

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Conclusions

Conclusions

- Good agreement between SCARAB and PAMPERO results of the surviving mass evolution
- Differences more important for the casualty area
- Influence of the attitude more important with PAMPERO, results more dispersive
- Emissivity could be one of many causes of differences and more generally material data