Activities of the AeroThermoDynamics & Design for Demise (ATD^3) Working Group

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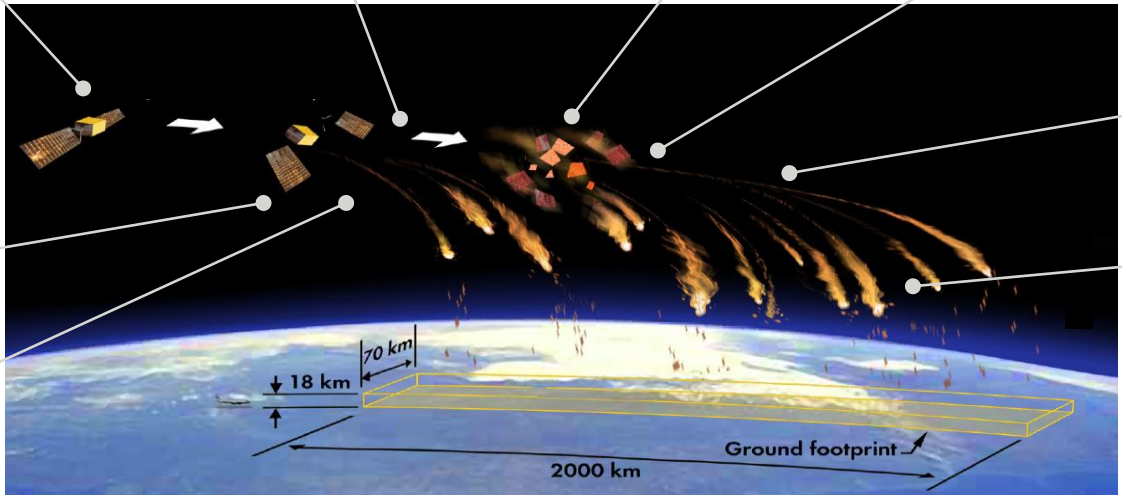
4th International Workshop on Space Debris Re-entry
28 Feb – 01 Mar 2018, ESOC, Darmstadt (DE)

Space Debris Re-entry Phenomena



Free-molecular, **transitional** and **continuum** regimes

Hypersonic, **supersonic** and **subsonic** aerothermodynamics

Aerothermodynamics: Why & How

In order to adequately assess the risks associated with spacecraft re-entry, to be compliant with space law regulations, a **better understanding** of the **complex aerothermodynamics processes** involved is necessary.

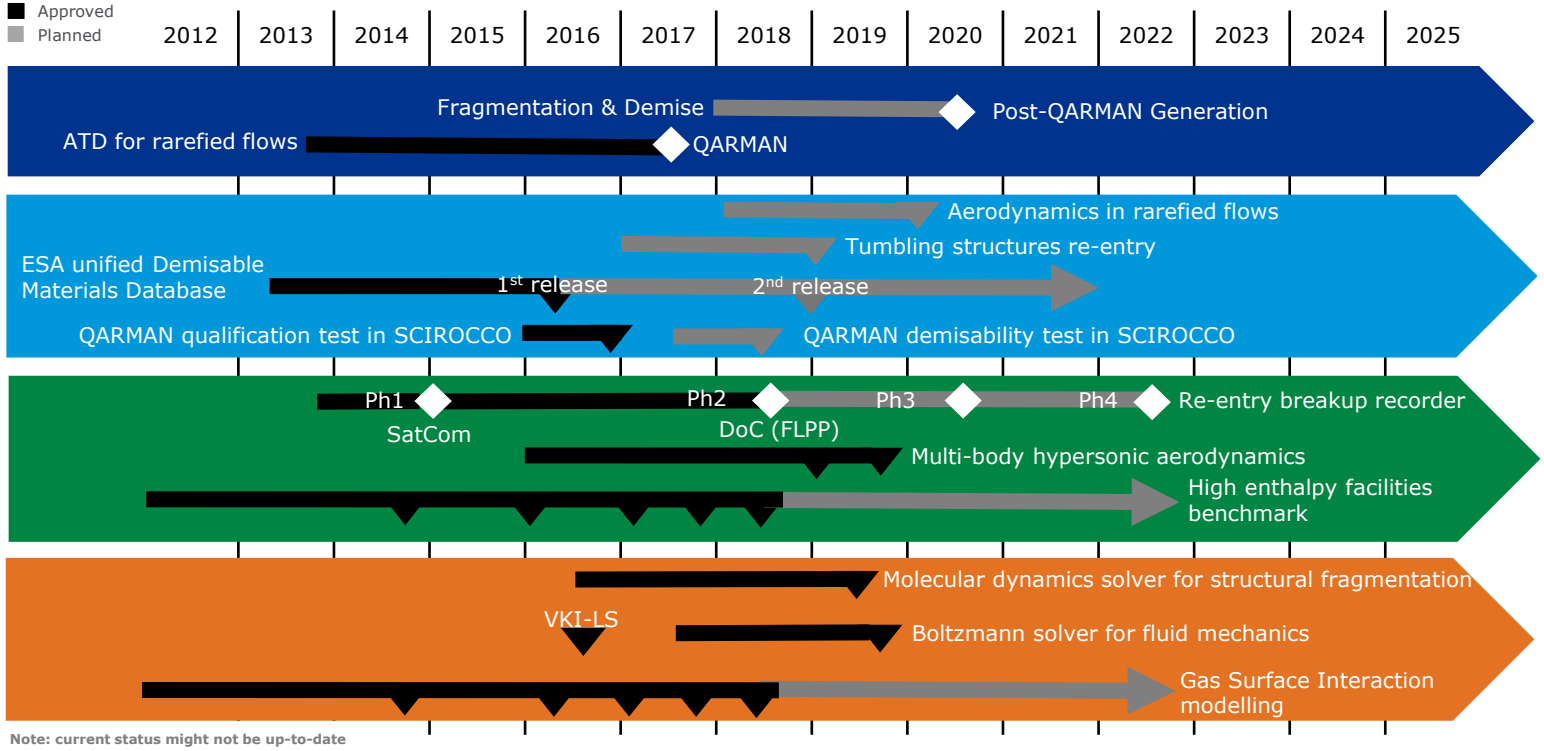
Improving the risk assessment **requires the improvement** of

- Numerical simulation tools
- Physical modelling of the phenomena
- Ground facilities and measurement techniques
- Material characterisation

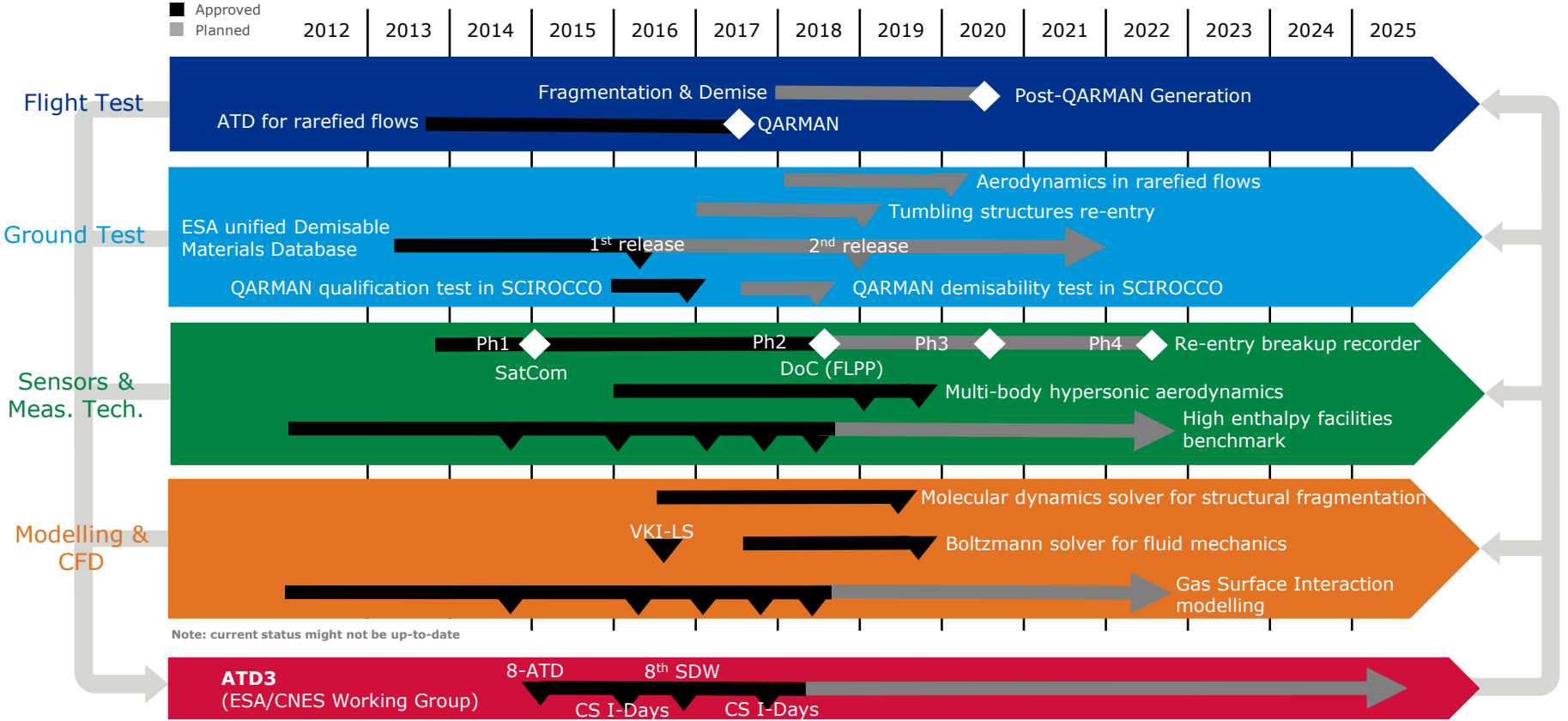
and the application of

- Uncertainty quantification
- Validation & Verification process

ESA's Aerothermodynamics Roadmap



ESA's Aerothermodynamics Roadmap



AeroThermoDynamics and Design for Demise (ATD^3)

Objective

Contribute to reducing the risk of casualties from (un)controlled re-entry by reducing the amount of debris surviving the re-entry process.

The ATD^3 Working Group is a regular forum on European level for:

- Scientific and technology discussions
- Collecting and disseminating information
- Planning (roadmap definition and coordination)

ATD^3 Working Group Support

esa cnes CENTRE NATIONAL D'ÉTUDES SPATIALES

DLR

CIRA Italian Aerospace Research Centre

ONERA THE FRENCH AEROSPACE LAB

von KARMAN INSTITUTE FOR FLUID DYNAMICS

ariane GROUP

ThalesAlenia Space a Thales / Leonardo company

OHB

deimos SPACE

IRS Institut für Raumfahrtsysteme Universität Stuttgart

HTG HYPERSCHALL TECHNOLOGIE GÖTTINGEN GMBH

bertin TECHNOLOGIES

CFS Engineering Computational Fluids & Structures Engineering

Fluid Gravity Engineering

Belstead

SENER

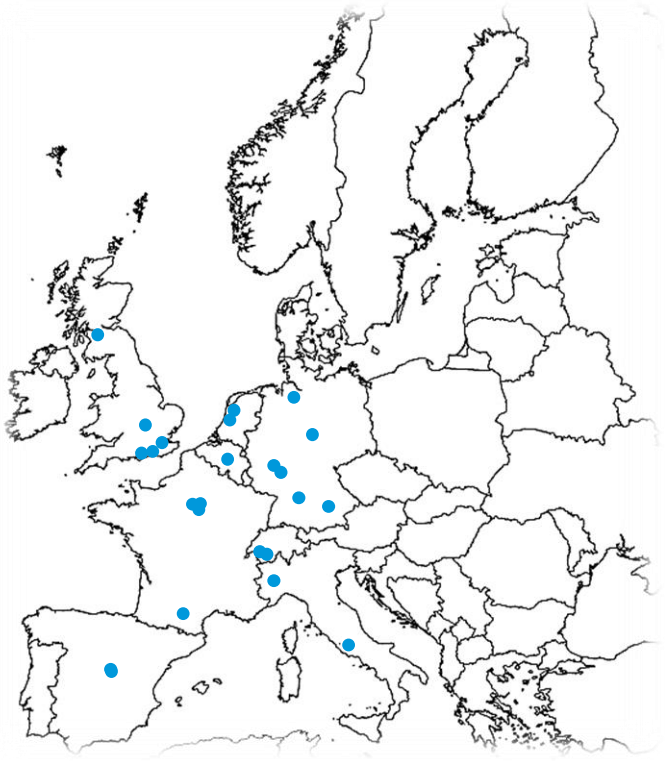
R.Tech Research & Technology

University of Strathclyde

UNIVERSITY OF OXFORD

UNIVERSITY OF Southampton

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE



ATD^3 Workshop

An ATD^3 Workshop is co-organised by ESA & CNES every ~2 years to **share results** and compare numerical simulation tools on **benchmark test cases**.

International contributions and participation desired!

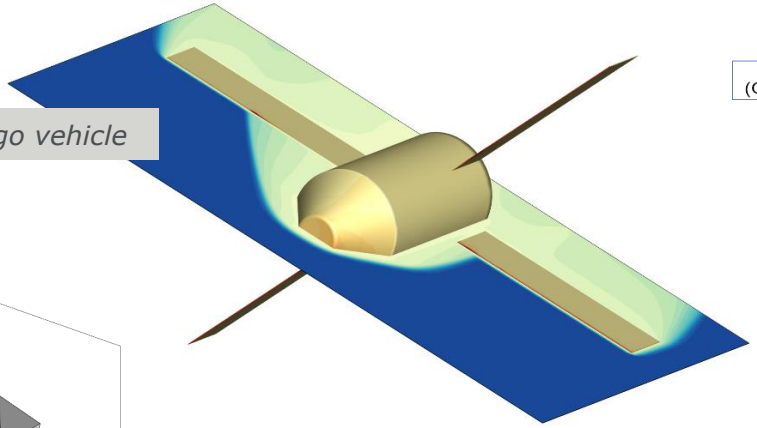
These test cases are defined with different levels of complexity and, when feasible, experimental activities are used to generate data to validate computations.

The subjects of interest are:

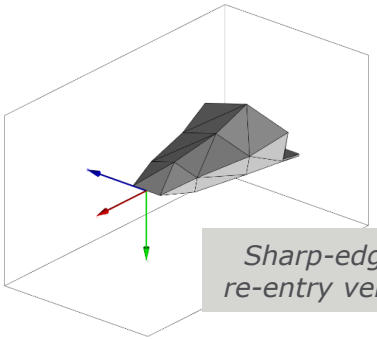
- Free molecular and transitional regime
- Fragmentation, ablation phenomena
- Shock-shock interaction, wake effects
- Experimental capabilities/measurement techniques
- Material and flow characterization
- ...

ATD^3 Test Cases

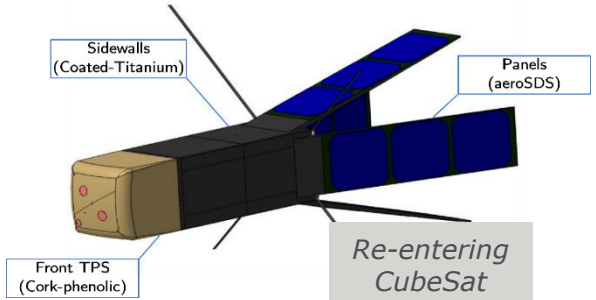
1. **Aero**(thermo)**dynamic** model validation
   Aerodynamic and heat flux coefficients for a fixed re-entry condition.



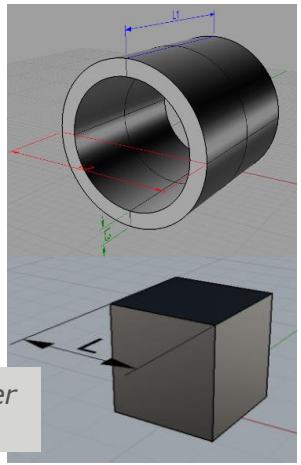
Cargo vehicle



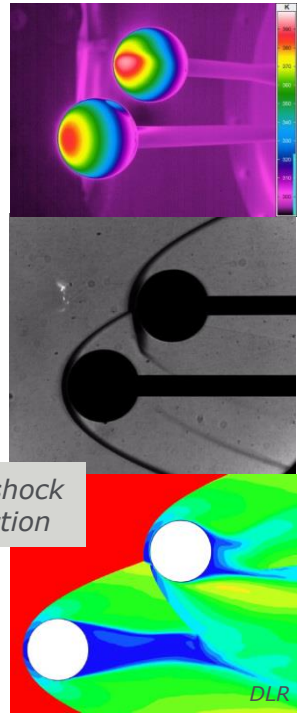
Sharp-edged re-entry vehicle



Re-entering CubeSat



Hollow cylinder and cube

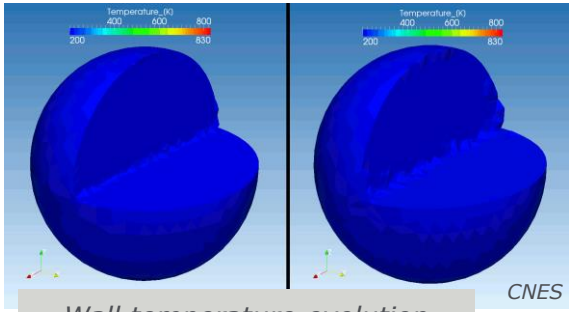


Shock-shock interaction

ATD^3 Test Cases

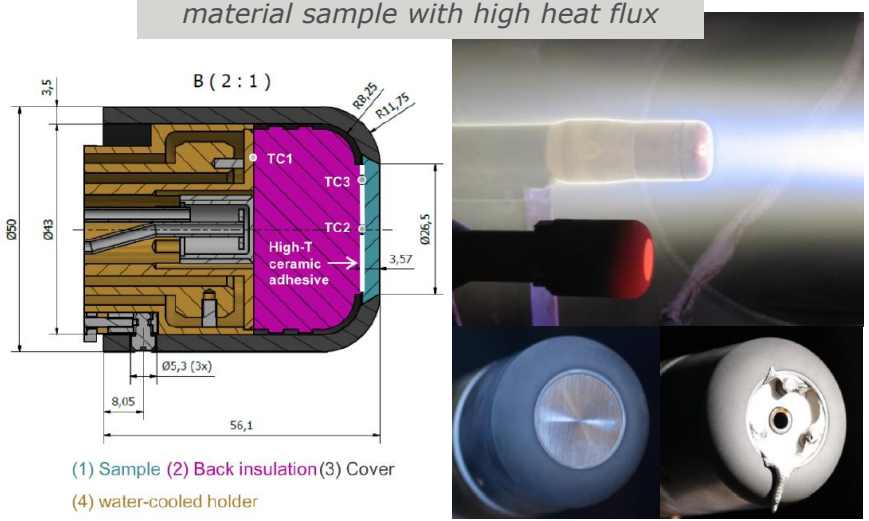
2. (Aero)**thermodynamic** model validation

Internal thermal evolution and ablation for imposed heat fluxes.



Wall temperature evolution and ablation of a solid sphere

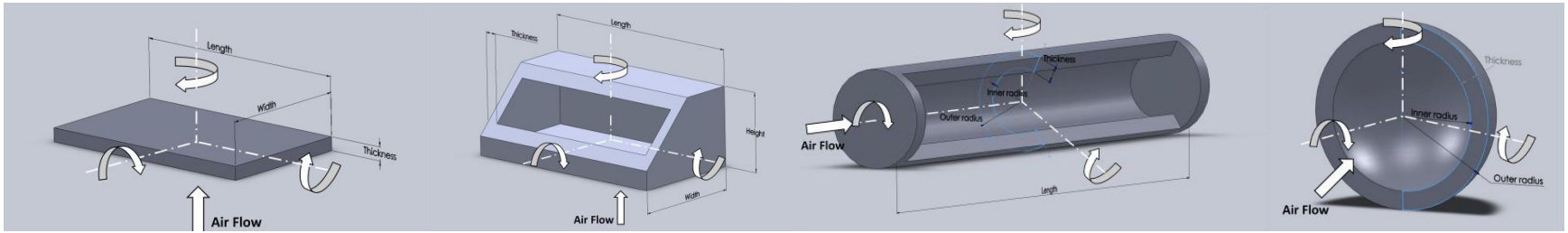
Internal temperature evolution of a material sample with high heat flux



ATD^3 Test Cases

3. **Integration** simulation

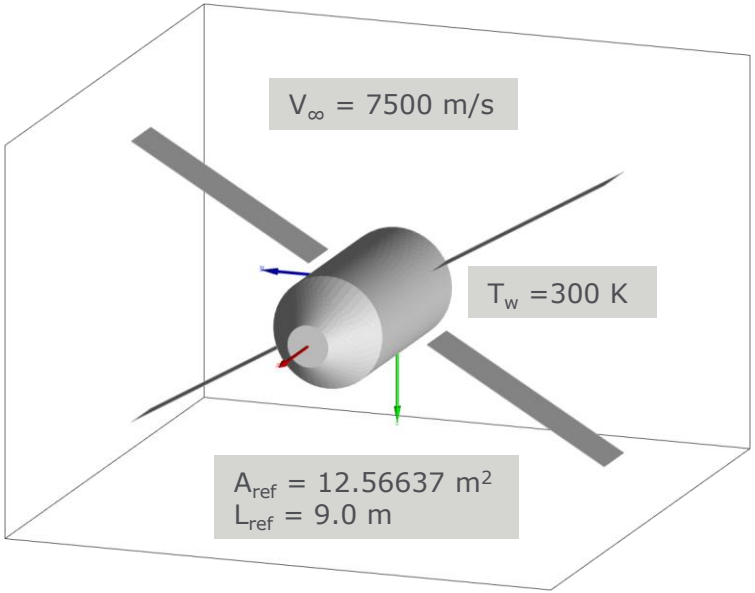
Simulation of complete re-entry process, computing the surviving debris mass, impact location, casualty area, etc.



CARGO Test Case – Description

- Altitudes ranging from 120 km to 70 km, from **free-molecular to continuum** regime
- Angles-of-attack and angles-of-sideslip **between -15° and 15°**
- **Aerodynamic** coefficients and **heat flux** distribution

How well can we predict these flows with engineering and/or high-fidelity tools?

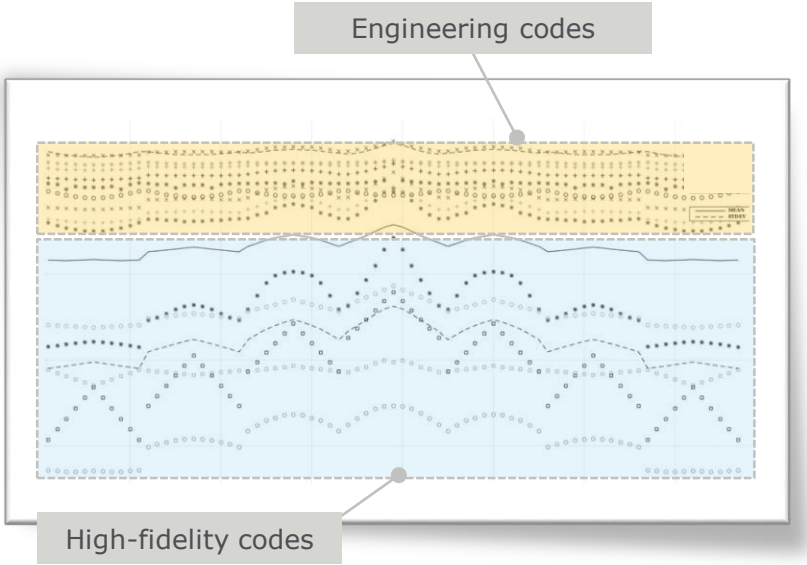


CARGO Test Case – Results

- Consistent **differences** between **engineering** codes and **high-fidelity** codes

- Large **scatter** of results, particularly in the transitional regime
  ($\sigma_{std} \approx 44\%$ for C_x)

- Effects of **shock impingement** and main body **wake** are usually not included in engineering codes

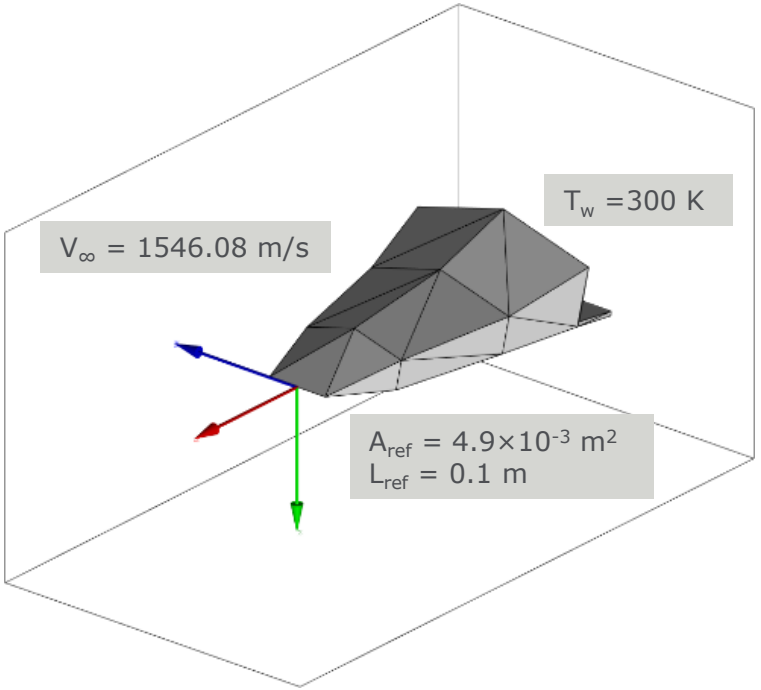


Force coefficient C_x at 90 km from all participants of the Space Debris Mitigation Workshop, VKI (BE) in 2016.

SHARP Test Case – Description

In order to benchmark the various tools against a less conventional vehicle, a **sharp-edged** case was proposed.

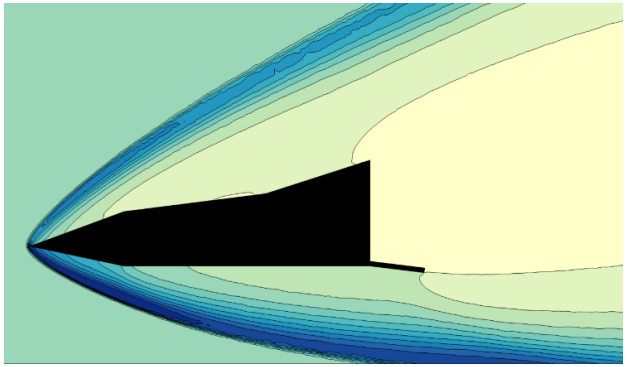
Wind tunnel tests were performed by the DLR, which allow the codes to be compared with **experimental data**.

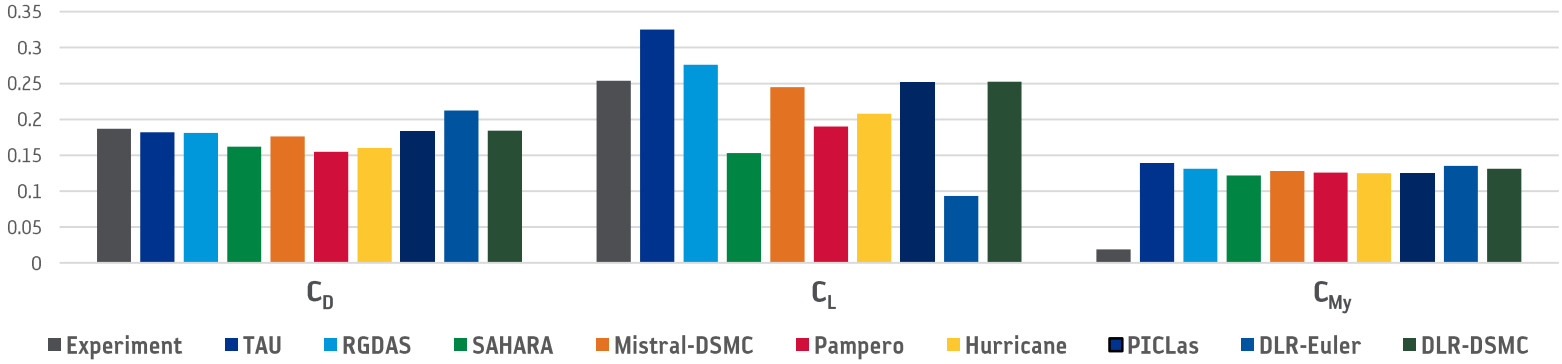


SHARP Test Case – Results

Overall the agreement is **reasonable** for **drag** and pitching moment coefficient.

Larger **discrepancies** exist for the **lift** coefficient, which needs some more investigation.





Conclusions

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