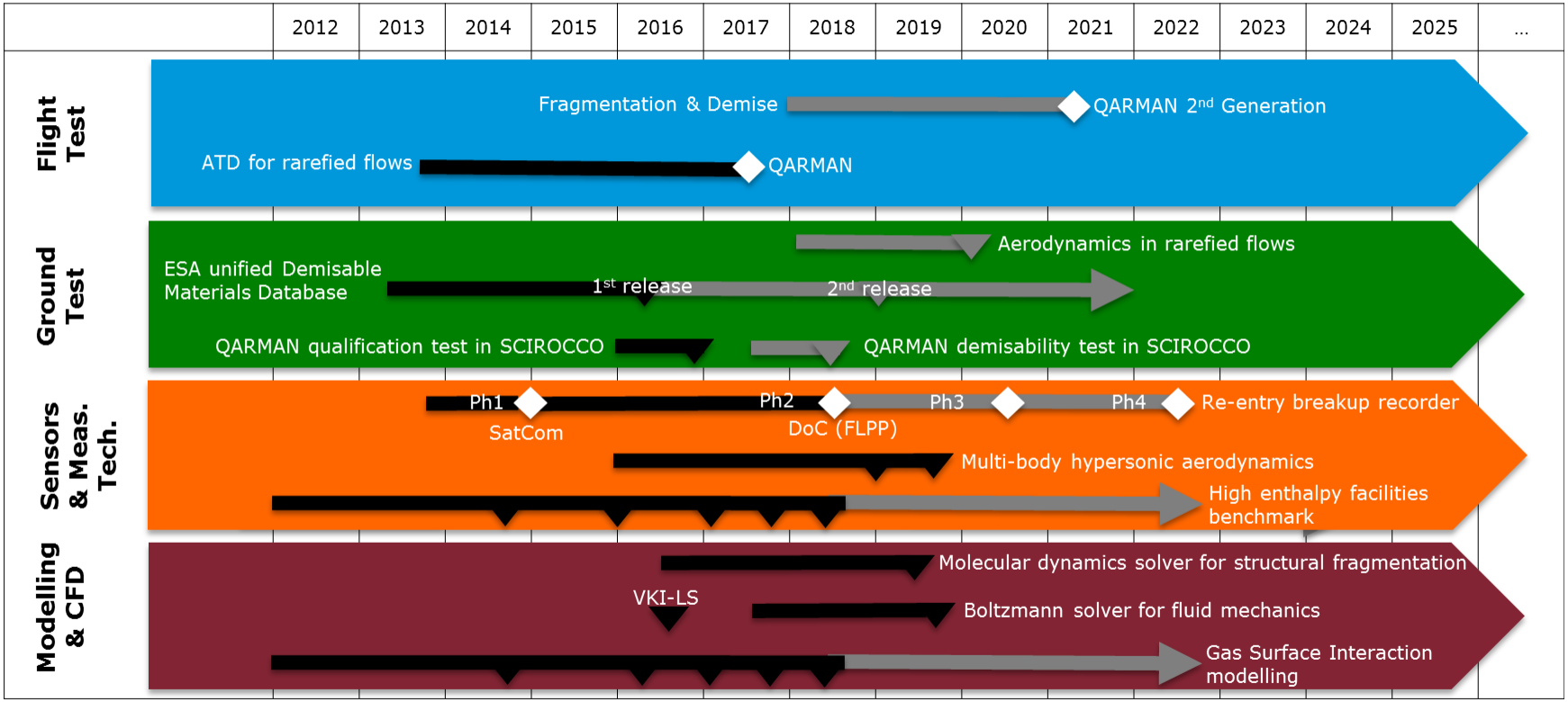
ATD Fragmentation & Demise

(black: approved; grey: planned; triangle: event; diamond: flight)



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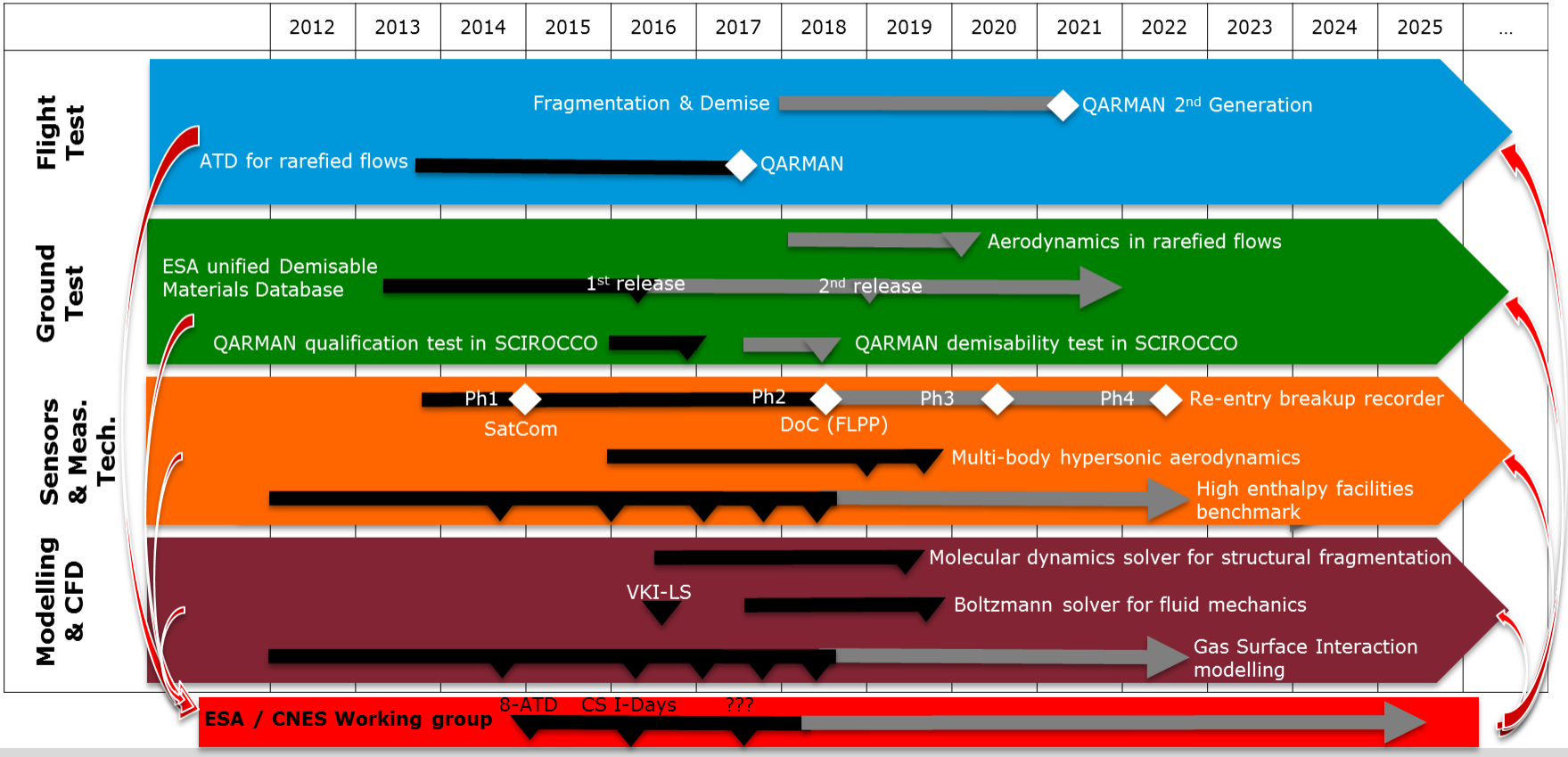
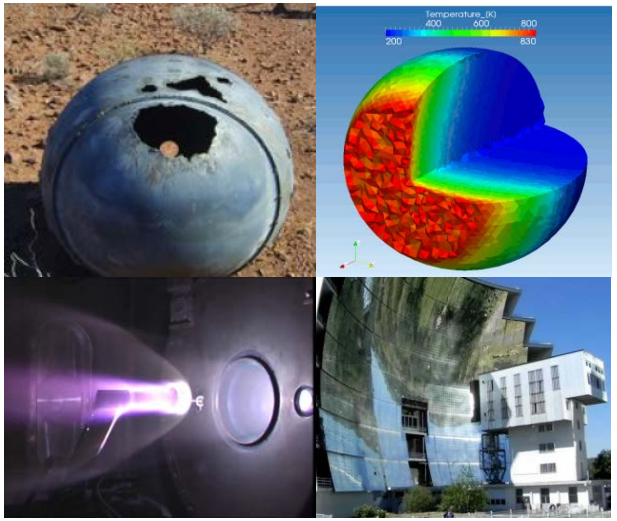


The ATD^3
(AeroThermoDynamic for Design for Demise)
Workshop



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Clean Space Industrial Days, 23-27 May, 2016, ESTEC, The Netherlands

Outline

I. Context: why ATD^3?

II. Aerothermodynamics: why, how

III. Workshop presentation
- Objectives
- Structure and organization
- Interests
- Test cases & previous work
- Future work

IV. Introduction of the round table discussion

Introduction

Legislation / regulation:

- **Risk mitigation** : Requirements on Space Debris Mitigation for ESA Projects. APPLICABILITY : This document shall be applicable to all ESA space systems orbiting the Earth, or re-entering the Earth's atmosphere (since 2008)

- **Risk assessment** : The new French law on Space Operations (2008) enforces the assessment of risks (The maximum allowable probability to have at least one victim) for every mission to be launched / operated from French territory
  - ✓ in case of a launch failure
  - ✓ in case of an atmospheric re-entry (controlled and uncontrolled)

Implications for the Space Agencies & industry to be compliant with regulations

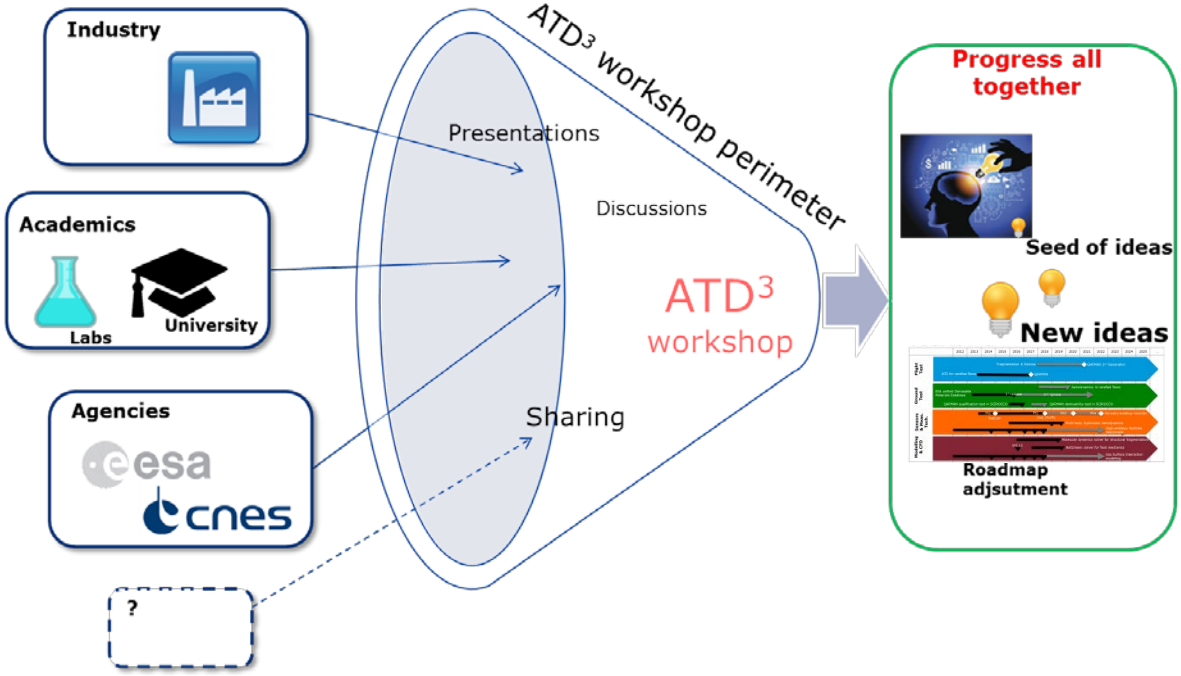
- Avoid debris generation
- D4D → **Aerothermodynamics is a key discipline to be investigated**

The ATD³ (AeroThermoDynamic for Design for Demise) Workshop

According to this**, ESA & CNES** agree to initiate the **ATD³** (**A**ero**T**hermo**D**ynamics for **D**esign for **D**emise) Workshop

Every 2 years a regular European forum aiming to:

- Exchange between different communities
- Progress all together in the scope of design for demise (from the ATD point of view)



Overview of the re-entry process
(an aerothermodynamics point of view)

Fragmentation

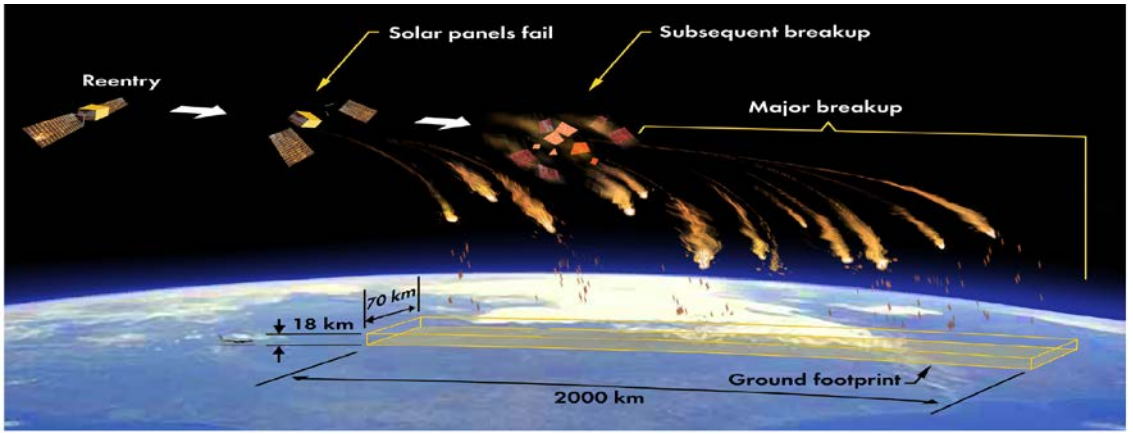
Structural mechanics

Mass loss (e.g. ablation, demise)

Explosion

Chemical reactions

Flight mechanics



Ionisation

Heat exchange
- convection
- diffusion
- radiation

Free molecular, transitional continuum regimes

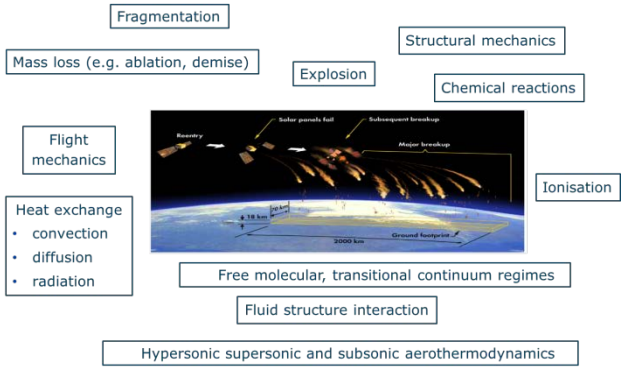
Fluid structure interaction

Hypersonic supersonic and subsonic aerothermodynamics

Aerothermodynamics : Why & How

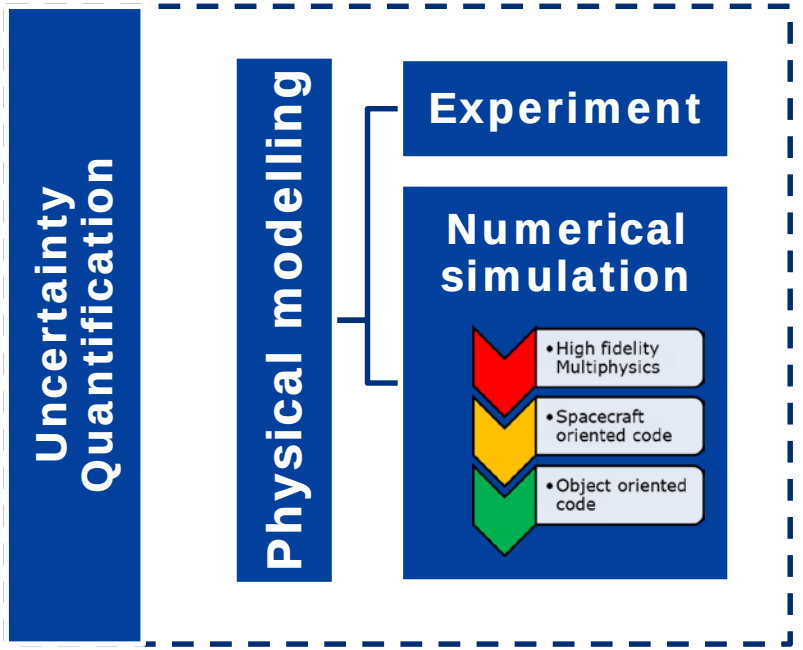
Why

In order to assess the risks associated with spacecraft re-entry that should comply with the space law regulations, a better understanding of the aerothermodynamics processes involved is necessary.



How

- Numerical tools, from low fidelity to high fidelity
- Ground facilities and measurement techniques
- Physical modelling
- Material properties (inputs for simulations)
- UQ (Uncertainty Quantification) and verification & validation process



Numerical approach

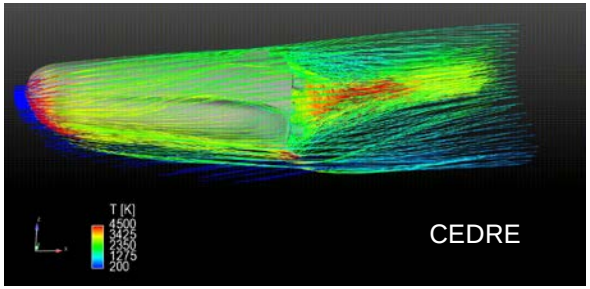
Simulation Chain

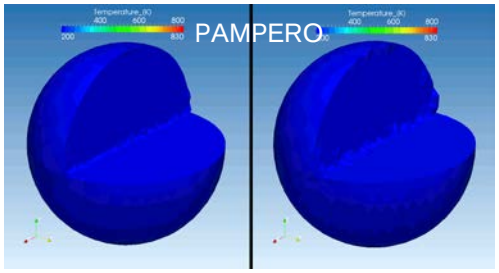
High fidelity code	***Spacecraft oriented code***	***Object oriented code***

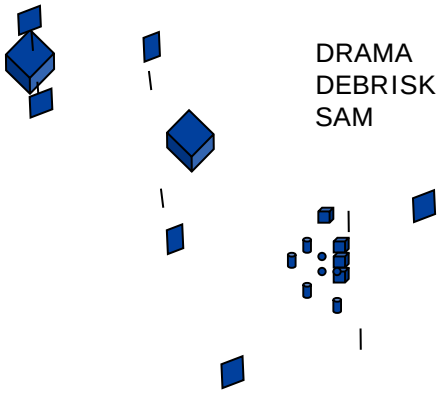
Accuracy ←

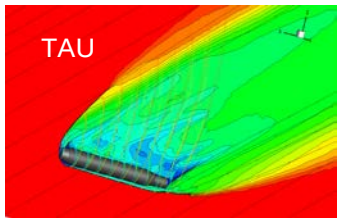
Cost ←

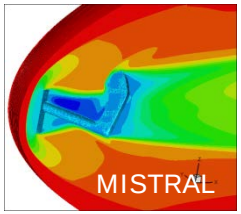
Validation →

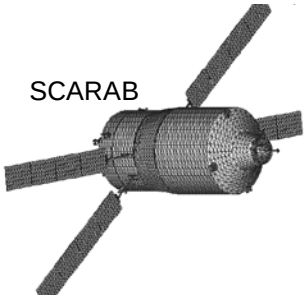








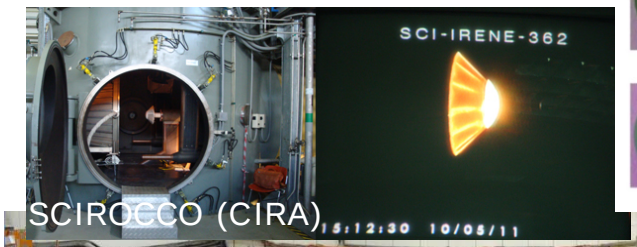




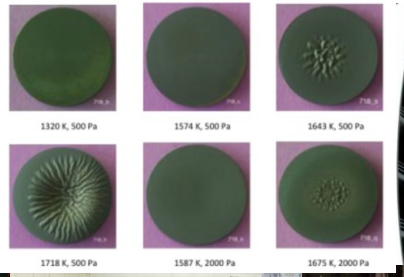
Experimental approach 1/2

Experiments for the validation of model & codes

❑ Facilities

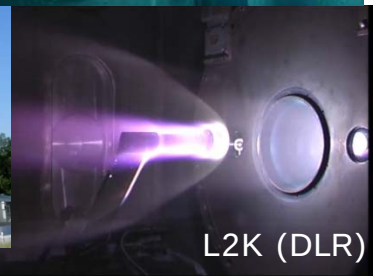


SCIROCCO (CIRA)

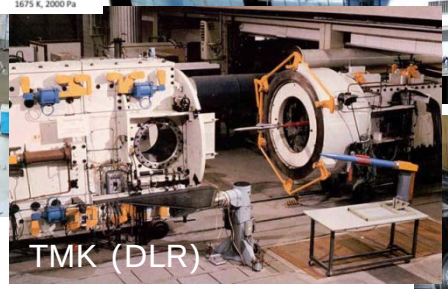



Solar Furnace (CNRS)

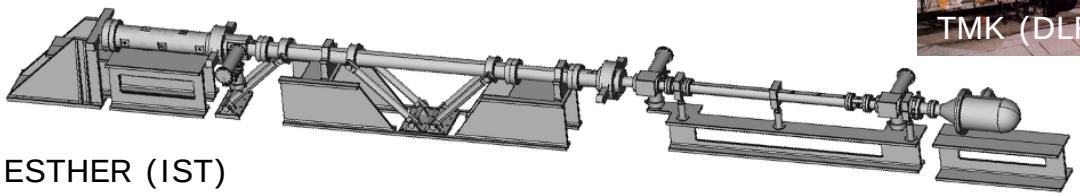

Plasmatron (VKI)


L2K (DLR)


High enthalpy facilities (IRS)


TMK (DLR)

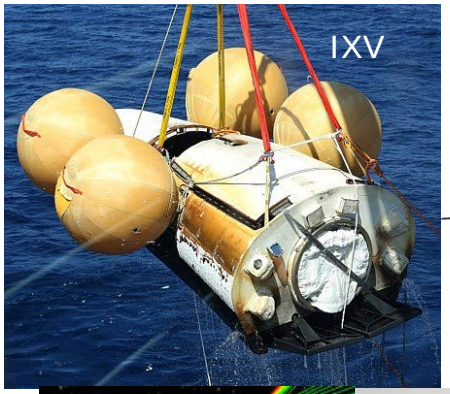

H2K (DLR)

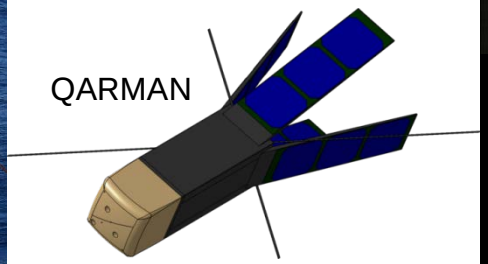

ESTHER (IST)

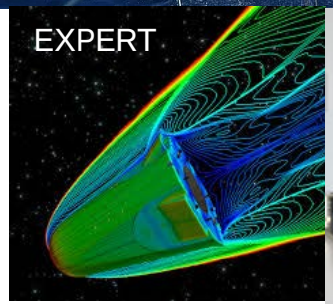
- ✓ Wind tunnels (different regimes) for aerodynamic load
- ✓ Plasma wind tunnels (arc-jet, inductively-coupled plasma WT) for heat load
- ✓ Shock tunnel (plasma radiation of high speed)
- ✓ Material characterization

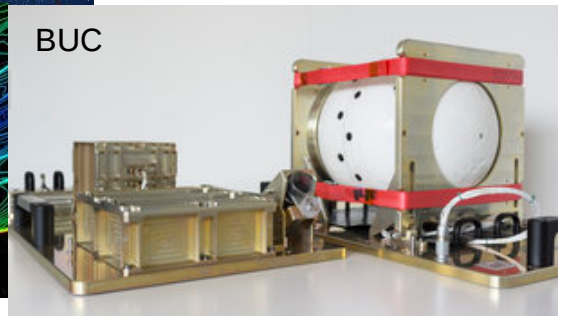
Experimental approach 2 / 2

- Flight (experiments)

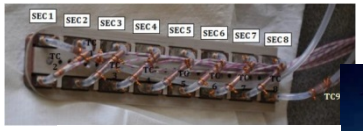


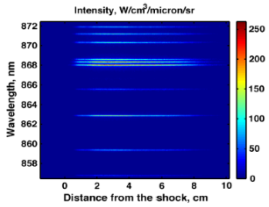


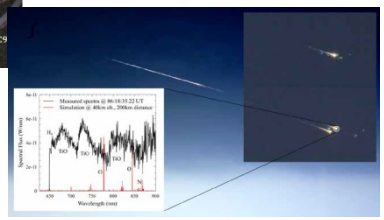




- The measurement techniques in aggressive environment (plasma, high temperature, pressure gradient…)





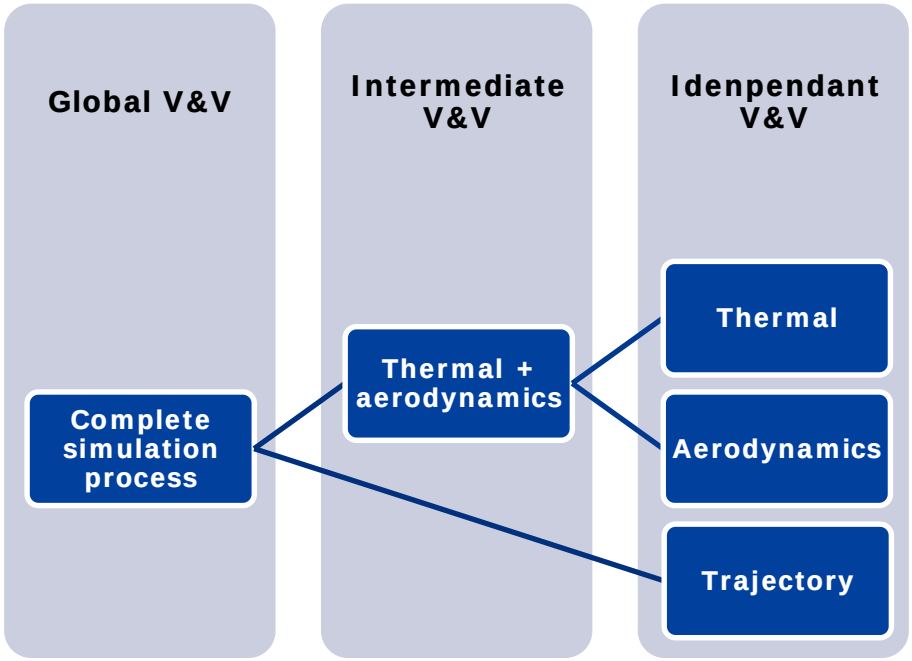


An incremental verification and validation approach

Verification & Validation process

The multidisciplinary aspect and the complexity of the process make the validation and verification a very challenging task

Example



How

Verification

- Benchmark with codes of same complexity.
- Comparison with theory.

Validation

- Comparison with flights and experiments.
- Comparison between codes
  - of same complexity,
  - of higher accuracy & complexity.

ATD^3 Workshop objectives / scope

The **ATD^3** (**A**ero**T**hermo**D**ynamic for **D**esign for **D**emise) **Workshop** is a regular forum at European level for:

- technology and scientific discussion on:
  - ✓ Physical modelling
  - ✓ Aerothermodynamics tools
  - ✓ Experimental capabilities / results
  - ✓ Measurement techniques
  - ✓ Material properties/characretization
  - ✓ Validation and verification
  - ✓ Uncertainties quantification
- collection and dissemination information
- planning (roadmap definition and coordination)

The ultimate goal is to contribute to reduce the risk of casualties from (un)controlled re-entry reducing the amount of debris surviving re-entry.

The organization

- The Workshop is co-organized by ESA-CNES with the support of the whole community
- The Workshop is organized every 2 year in a different location in Europe
  - to be combined every 4 year with Aerothermodynamics symposium
  - the first edition will be in 2017
- Three committees:

Programme Organizing Committee (POC)
- Selected people from the ATD sections of ESA and CNES

International Technical Committee (ITC)
- TBD ensure cohesion & continuity of the work.

Local Organizing Committee (LOC)
- Composed by the organizer(s).

- A dedicated working group will be created to prepare the workshop (convenes few times each year)
- Dedicated website and/or share point (TBD)
- No fees are foreseen

Foreseen interests

- **For agencies :**
  - Get inputs from the community to adjust their roadmaps.
  - Disseminate R&D results.
  - Get comments, ideas, exchange information
  - …
- **For academics & industry :**
  - Benchmarking (numerical and experimental) activities
  - Inject new proposals/highlight gaps (new area of research)
  - Increase the D4D know-how to face Agencies regulations
  - Access to the presentations of some agencies activities
  - Networking
  - …

Exchange, discuss, improve and progress all together

Test Cases & previous work

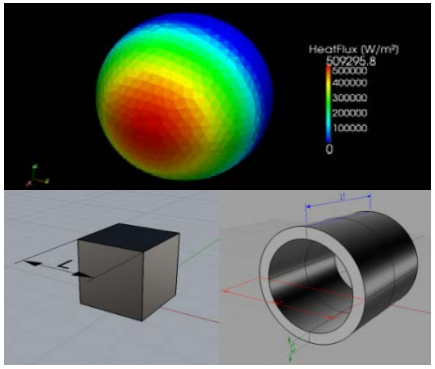
Test cases

- In the frame of the workshop, a limited number of test cases will be validated with respect to efficiency and accuracy of different methods.
- Experimental activities (when feasible and affordable) will be used to compare facilities performance and generate results to validate computations.

Previous work

In the SCDW few numerical test cases were defined with different level of complexity:

- ✓ Aerodynamic models validation: Hollow Cylinder, box to study the heat fluxes and aerodynamic coefficients for a fixed re-entry condition
- ✓ Thermodynamic models validation: 1, 2D test case to study the thermal evolutions for imposed heat fluxes



SCDW

- ✓ Integration simulation: Sphere (different masses and material) to compare between different codes the complete process of entry

Potential future (new) activities

Objectives : Address more complex numerical test cases, other physics and new experimental activities.

Subjects of interest

- More complex geometries
- Free molecular and transitional regime
- Fragmentation, ablation phenomena
- Shock-shock interaction, wake effects
- Experimental capabilities / measurement technique
- Inputs for simulation codes:
  - ✓ Characterization of material
  - ✓ Chemistry, plasma, etc…
- Development/improvement of physical modelling

How

- Discussion/interaction among experts
- Benchmarking activities (numerical and experimental)
- Thesis, Post-doc
- Dissemination of results

To be discussed with the working group attendances

The round table

The round table with all the European actors is dedicated to

- Introduction: the Workshop/Working group
- Consolidation of the Workshop objectives
- Supporting the definition of the Technical Committee
- Discussion and definition of the test cases: previous work and ideas for the future
- Initial organization of the first edition in 2017 (call for candidates).
- AOB (collection of data, storage...)

WORKSHOP

ATD workshop on Reentry simulation and testing

09:30 - 12:00 Erasmus building - NA213