Principali attività di ricerca in corso e possibili sviluppi

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Incontro promozione attività di ricerca DIMA
Roma, 6 febbraio 2017

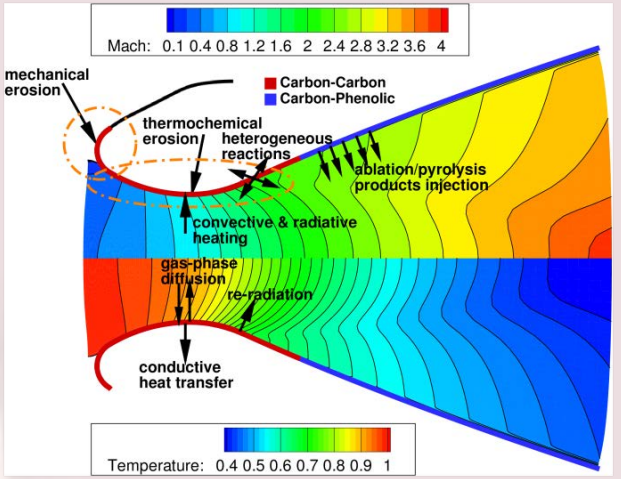
SAPIENZA
UNIVERSITÀ DI ROMA

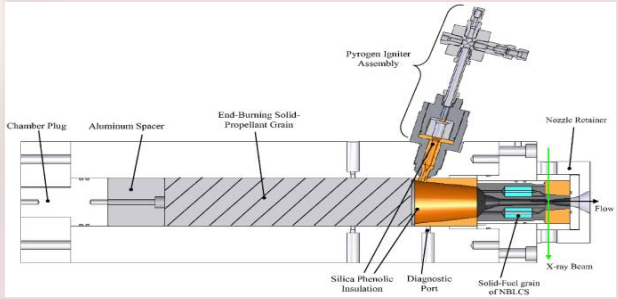
Main activities

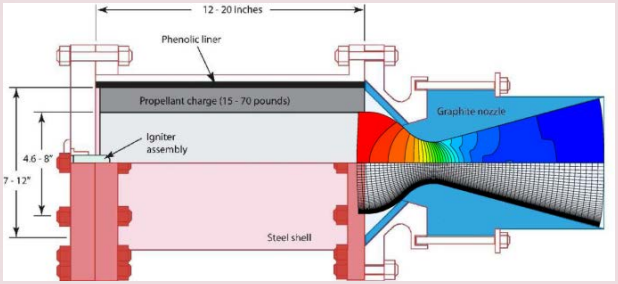
- Solid rockets:
  - Nozzle flows coupled with thermochemical ablation modeling
  - Nozzle transient heating and shape evolution due to ablation
- Hybrid rockets:
  - Modeling of motor internal ballistics and performance
  - Modeling of gas-surface interaction
    - fuel pyrolysis
    - nozzle ablation
    - liquefying fuels
- Reentry vehicles and hypersonics:
  - Ablative thermal protection systems (TPS) modeling and simulations
  - Models for ablation, pyrolysis and catalysis over TPS

Nozzle thermochemical ablation in solid rocket motors

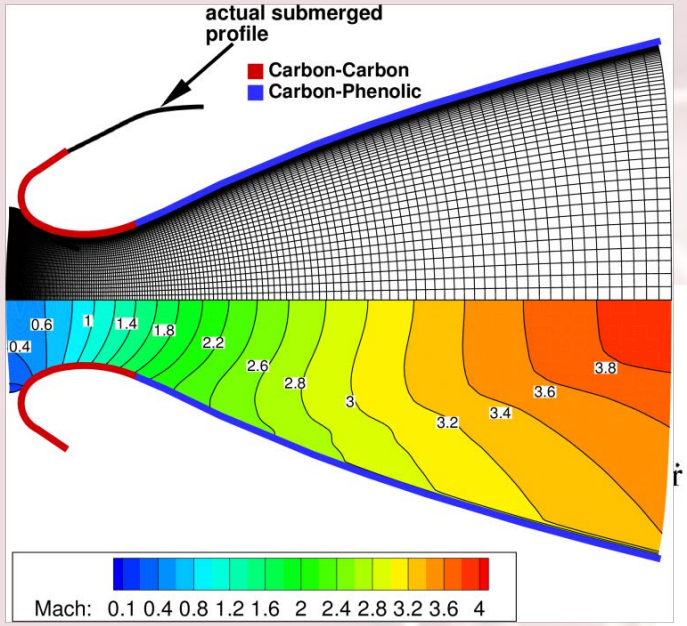
- DIMA personnel (all activities below):
  Bianchi, Nasuti, Onofri
- Collaborations: Vigor Yang (Georgia Tech)
  Kenneth Kuo (Penn State)
  B. Favini E. Cavallini (DIMA)
- Background (since ~ 2004):
  - Coupled analysis of flow and surface ablation in carbon-carbon rocket nozzles
  - Extension to finite-rate ablation modeling, shape change, and pyrolyzing materials (e.g. carbon-phenolic)
  - Effect of radiation and roughness (V. Yang), high pressure (K. Kuo), and nozzle shape
- Recent activities (ESA-ESRIN 2014/2015):
  - Study of nozzle erosion behavior of the carbon-carbon nozzles for the three solid stages of Vega launcher (P80, Zefiro 23 and Zefiro 9)



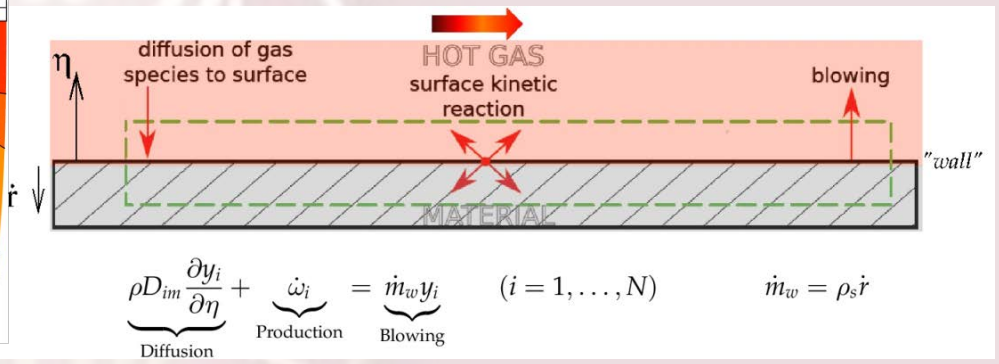




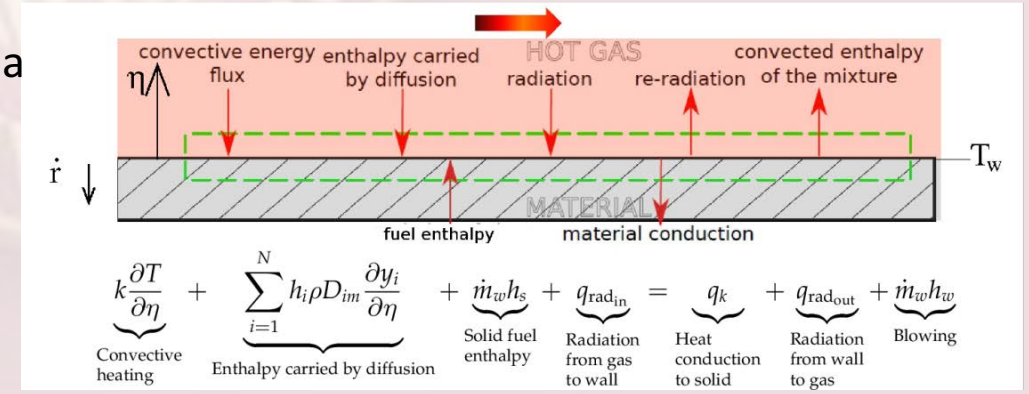
Nozzle thermochemical ablation in solid rocket motors



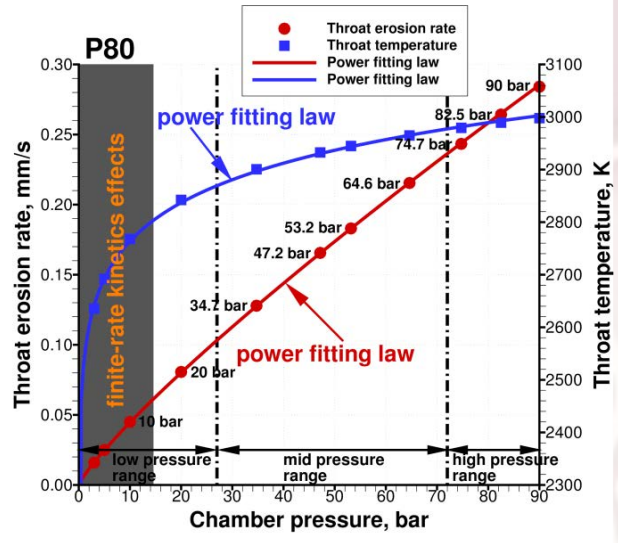
- Thermochemical erosion calculation as part of flow-field solution
- **Detailed surface mass and energy balance** at the ablating surface

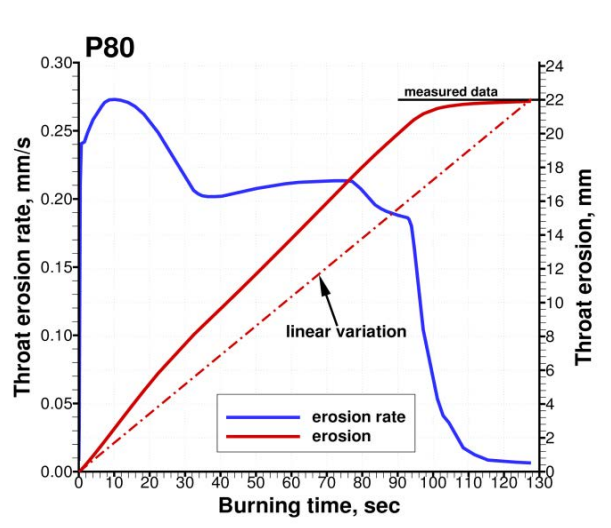


- Surface ablation modeled via **finite-rate heterogeneous reaction** mechanism
- Thermal conduction and radiation are accounted for

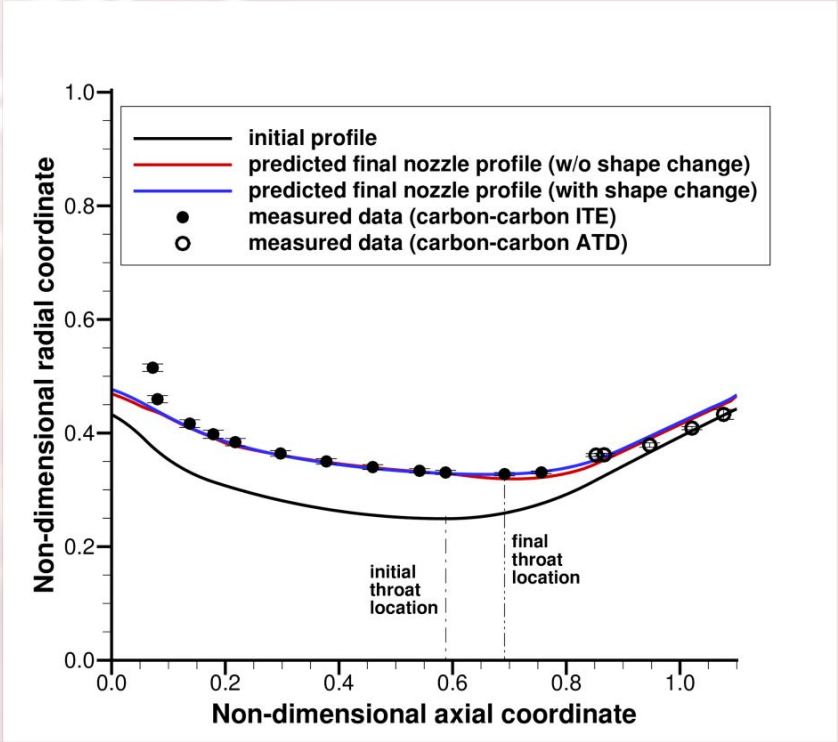


Nozzle thermochemical ablation in solid rocket motors



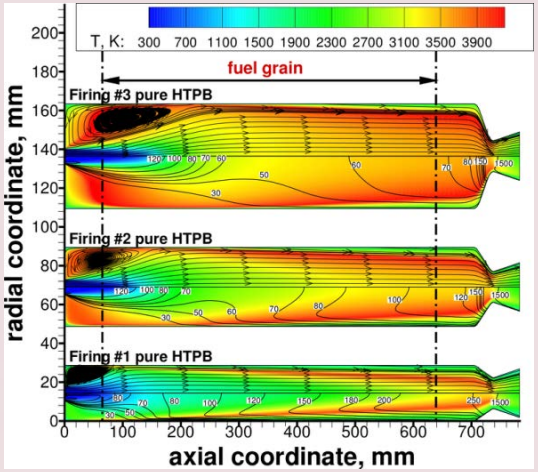


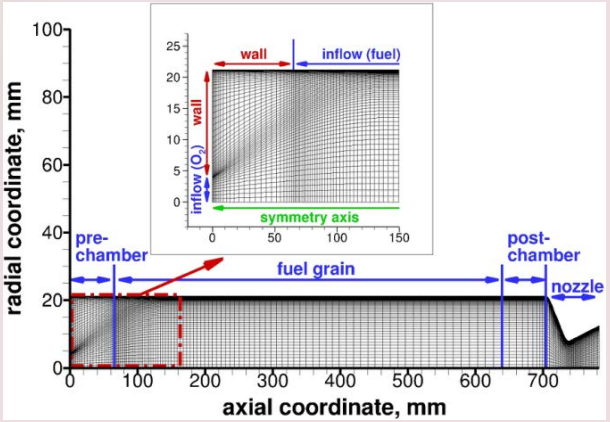
- **Thermochemical ablation characterization** in terms of nozzle **throat erosion** dependency upon motor **chamber pressure**
- Reconstruction of nozzle throat history and **time evolution** of nozzle profile

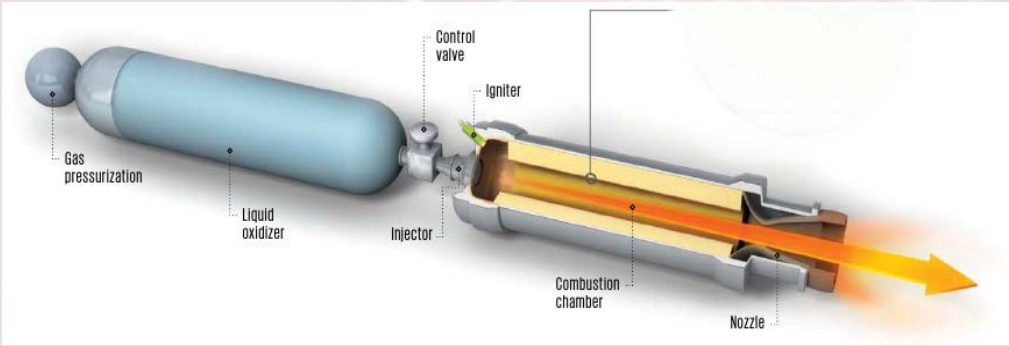


Numerical Simulations of Hybrid Rockets

- DIMA personnel (all activities below):
  Bianchi, Nasuti
- Collaborations: R. Savino, C. Carmicino (UniNa Federico II), L. Galfetti (PoliMi), D. Pastrone (PoliTo)
- Background (since ~ 2009):
  - Nozzle ablation modeling in hybrid rocket environment
  - Gas-surface interaction modeling for fuel regression
  - Extension of modeling approach to liquefying fuels
- Recent activities (PRIN 2009):
  - Development and integration of the Italian scientific expertise for the progress of hybrid rocket engines







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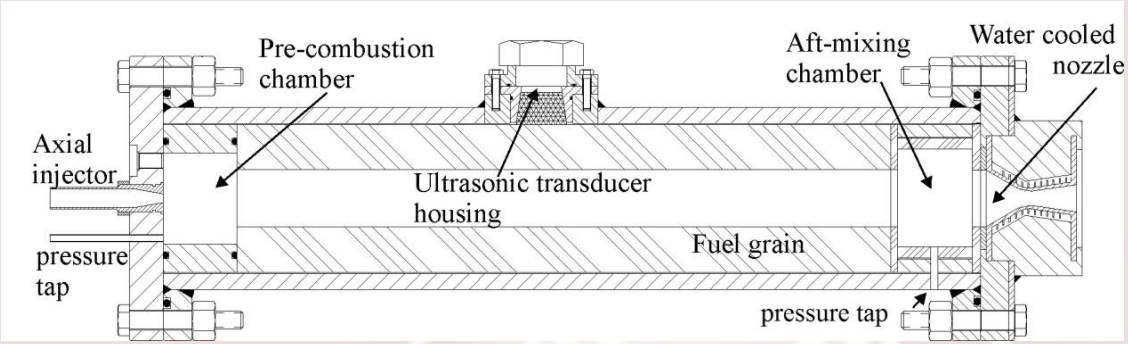
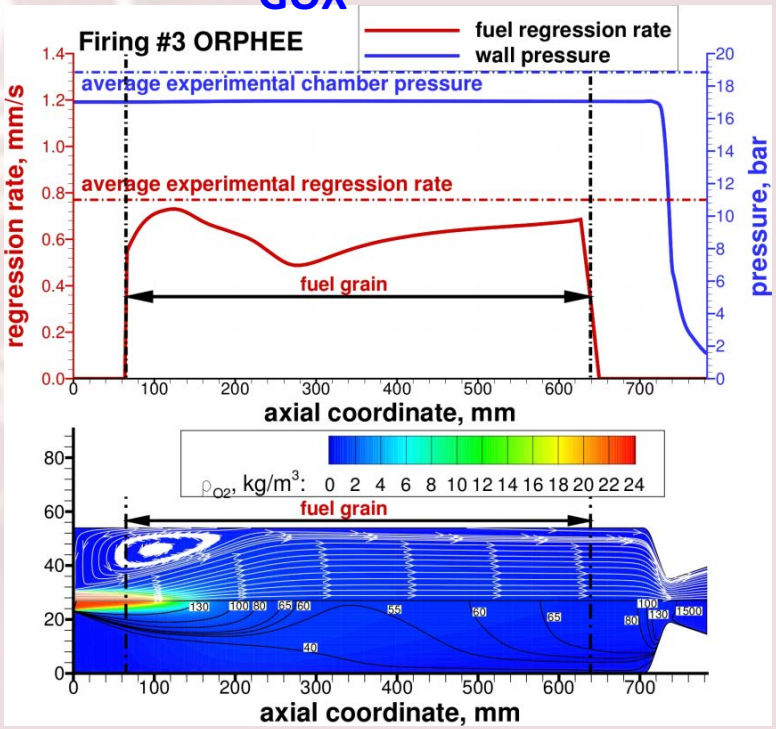


Validation Test Case

Instrumented Lab-Scale (1000N class) hybrid rocket motor (UniNa)

Fuel: **HTPB** Oxidizer: **GOX**

- Role of **injection modeling** and its influence on motor internal ballistics
  - "full inlet" vs "injector" configuration
  - Evolution of **recirculation region** inside the fuel port
  - Effect of recirculation region on **fuel regression rate** and its influence on the **motor performance**



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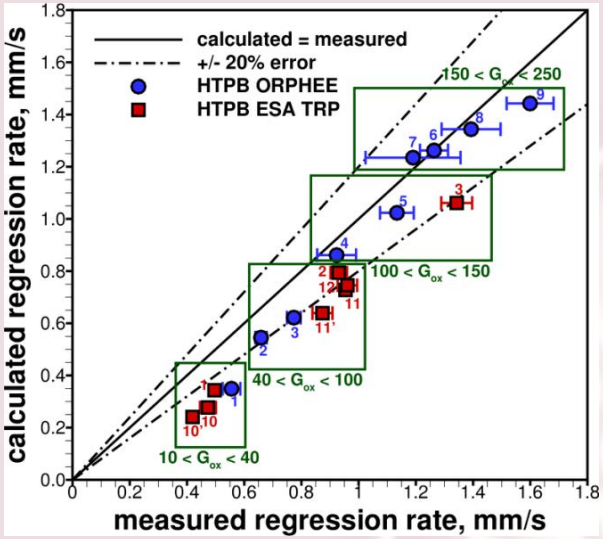
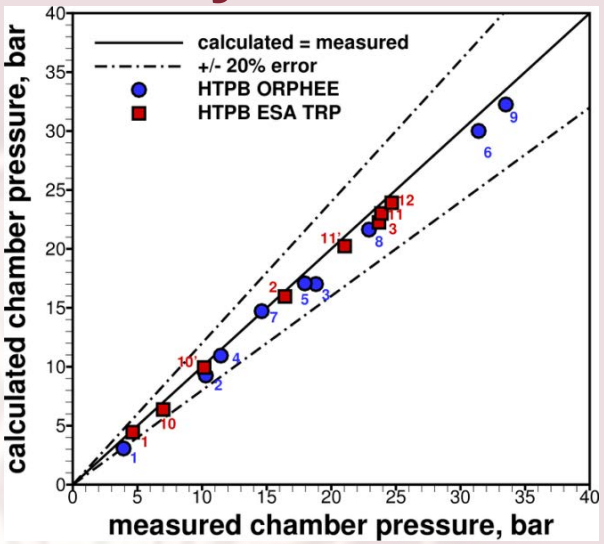
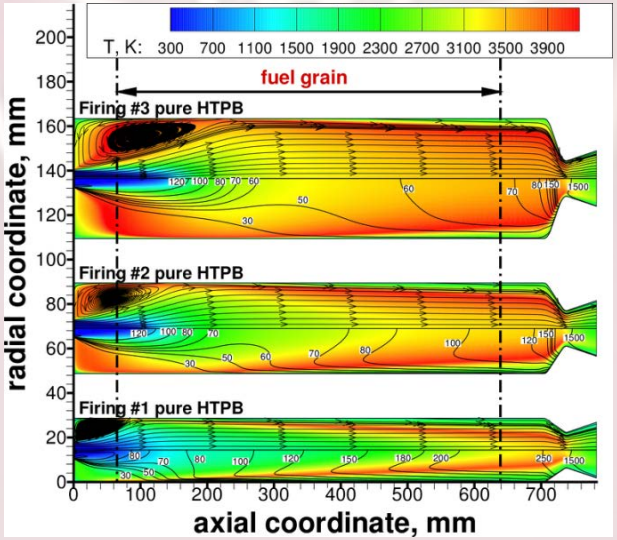
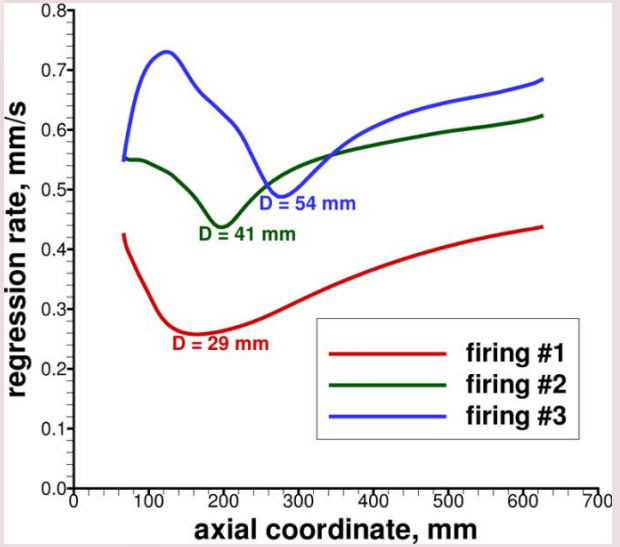




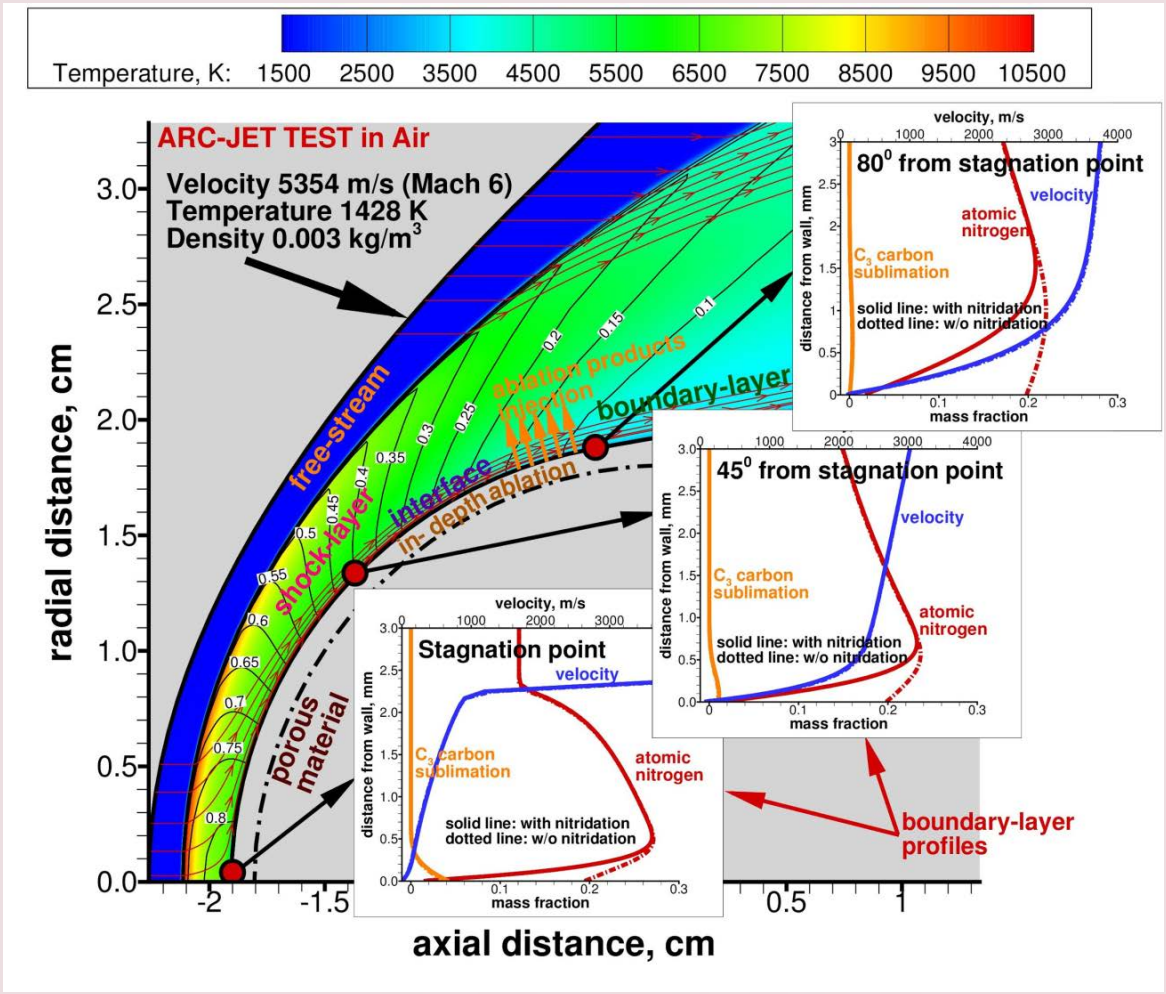
- Simulation of experimental campaign
- comparison with measurements

The port diameter can yield a direct regression rate dependence





Ablation/Catalysis modelling for high speed flows



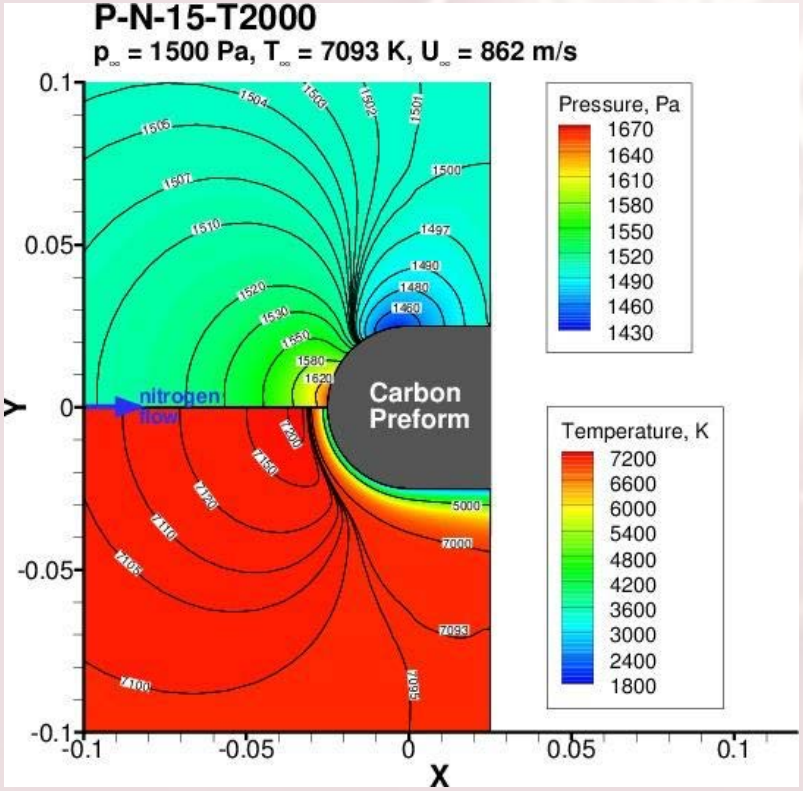
The availability of CFD tools with integrated **Gas Surface Interaction (GSI) capabilities** is fundamental in order to perform testing and evaluation of ablation and catalysis models:

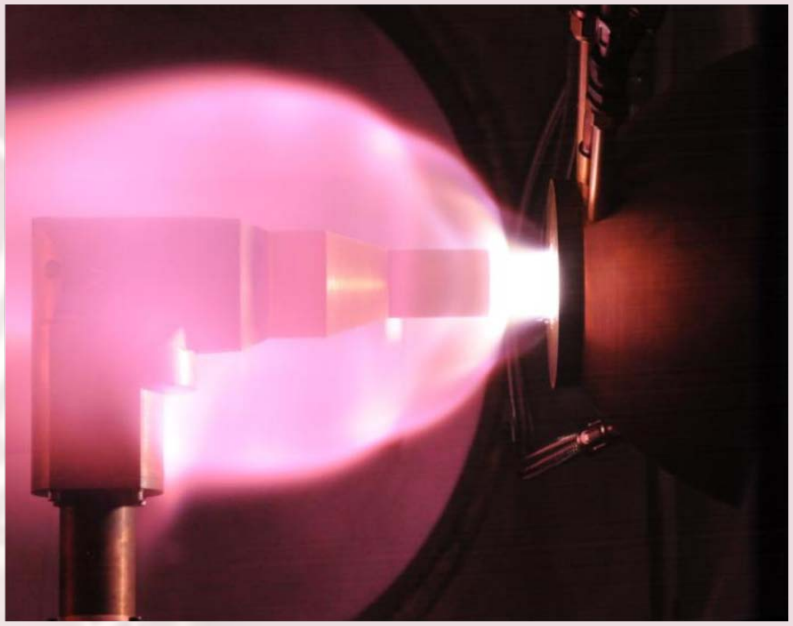
the gas interacts with the surface in such a way to **alter** the **gas-phase solution** through **chemical changes** and/or **surface blowing**

Ablation/Catalysis modelling for high speed flows

Catalytic properties of ablators ESA ITT AO/1-7664/13/NL/RA

UniRoma (IT), **VKI** (BE), **CFSE** (CH), **CNRS-LCTS** (FR), **Astrium ST** (FR)





Goals:

- Material **ablation** and **catalycity** phenomenological and physical models implementation, testing and evaluation
- models refinement, verification, and **validation with PWT data**