Developing aerospace modeling tools for tomorrow's space journeys

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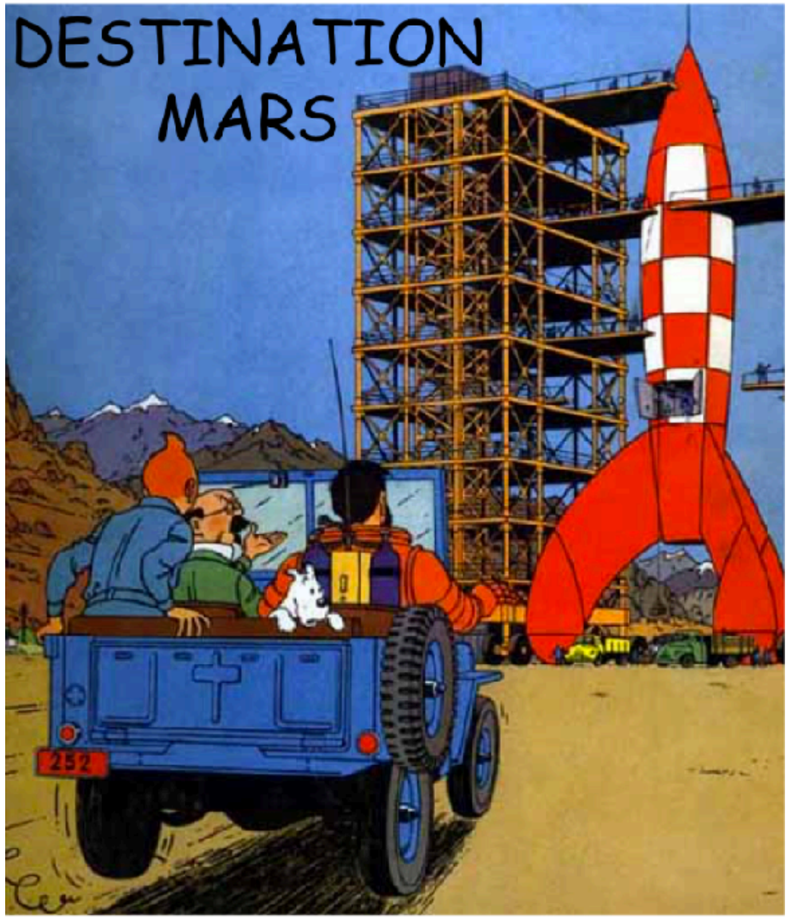
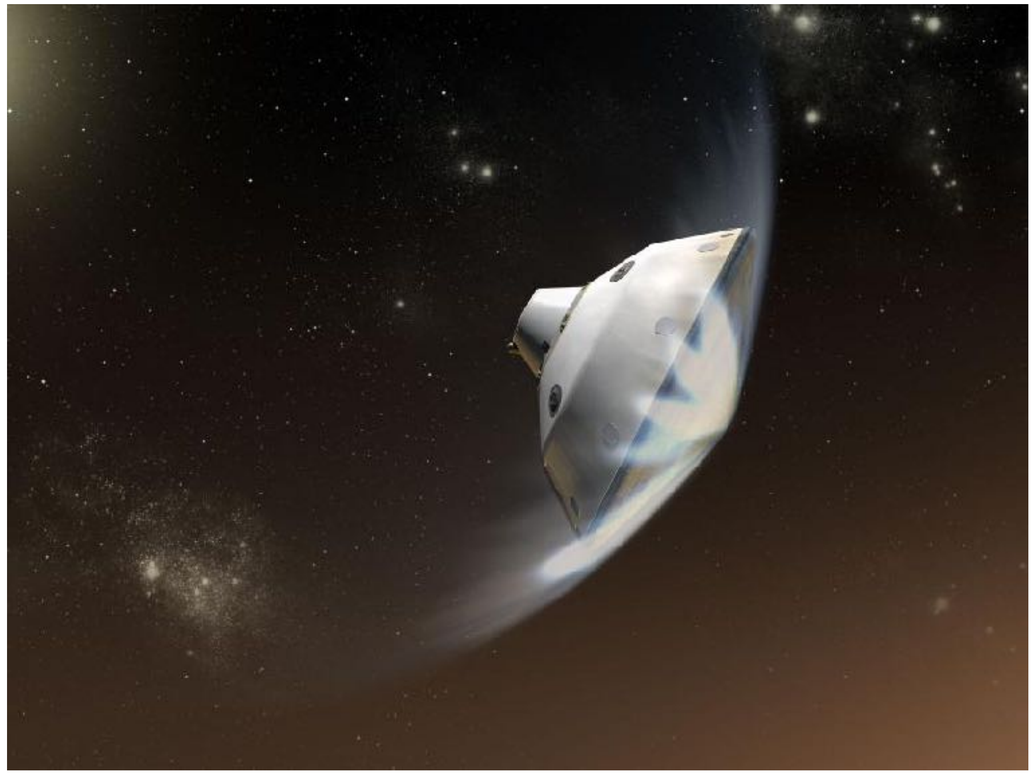
ERC Starting Grant #259354, P.I. Thierry Magin (2010-2015)

AEROSPACEPHYS: Multiphysics models & simulations for reacting and plasma flows applied to the space exploration program





Mars Science Laboratory landed the Curiosity rover in Mars' Gale crater on August 6, 2012

From applied research… to basic research

“Engineers use knowledge primarily to design, produce, and operate artifacts…
Scientists, by contrast, use knowledge primarily to generate more knowledge”

Walter Vincenti

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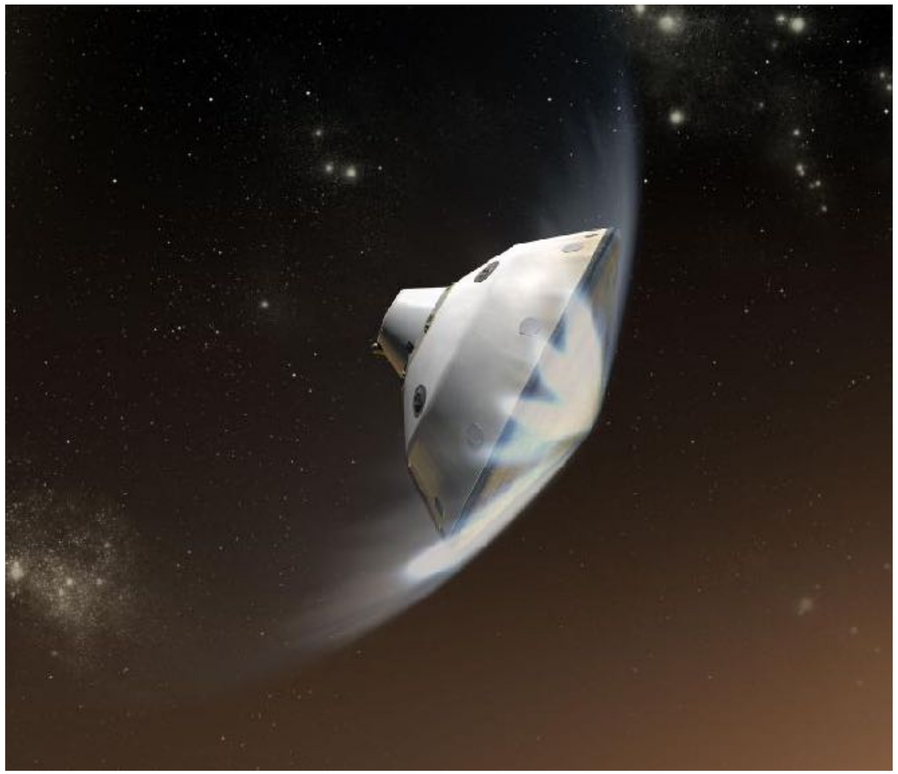

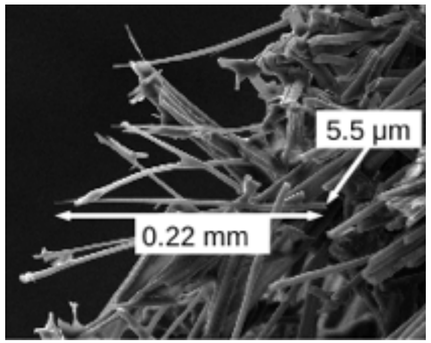

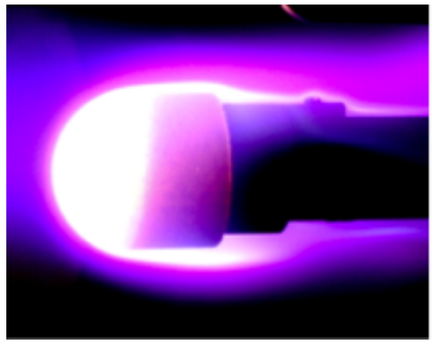

Material

Flow

Radiation

From applied research… to basic research

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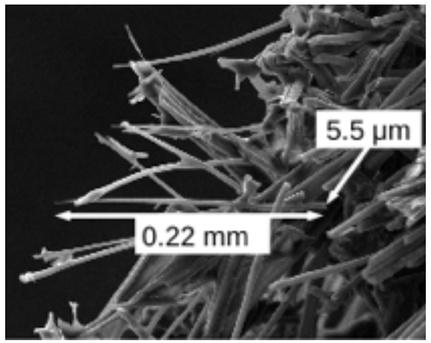
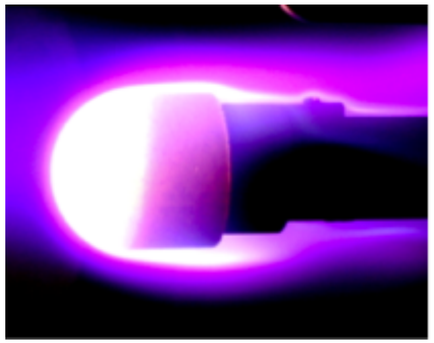
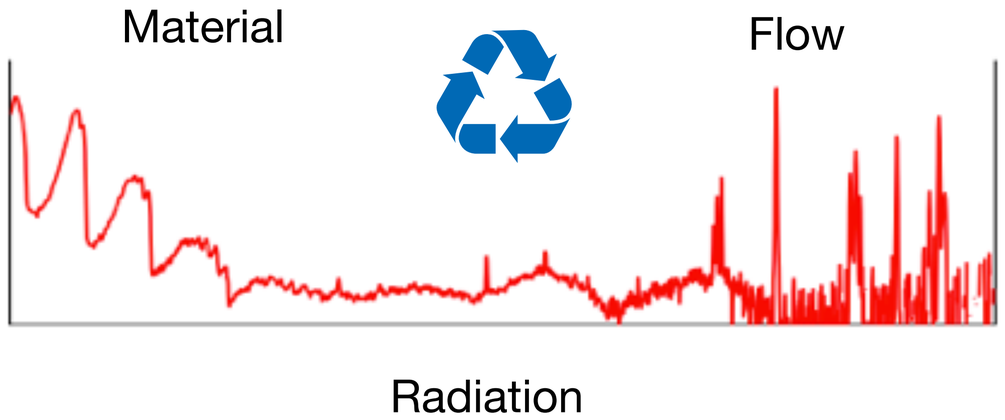
What is the coupling mechanism between the flow, radiation, & material fields?

… to accurately predict the complex degradation of innovative lightweight carbon-composite materials







How to write an ERC proposal?

Not a general recipe! My personal story…

- **Developing an innovative research program can take years**

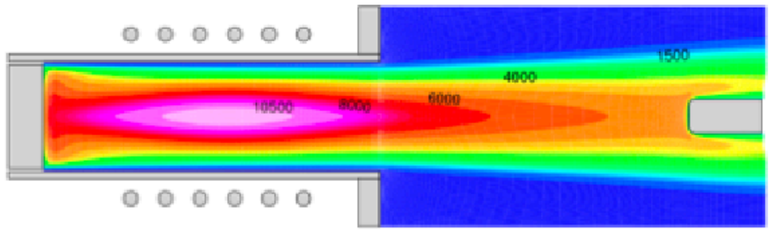
PhD (2000-2004) **Postdoc 1 (2005-2006)** **Postdoc 2 (2007-2009)**

- **Writing a proposal is usually faster**
  - Appointed Assistant Prof at VKI in October 2009
  - Writing started 11 days before the submission deadline!

- **Involve your collaborators in the writing (keep control)**

How to write an ERC proposal?

Step outside of your comfort zone



Computations

Verification

Validation

UQ

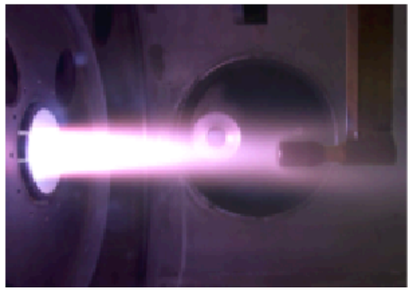
Models

Experiments

Model inference

$$\mathbf{V}_e = -\bar{\bar{D}}_e \mathbf{d}_e - \bar{\bar{\theta}}_e \partial_x \ln T_e$$

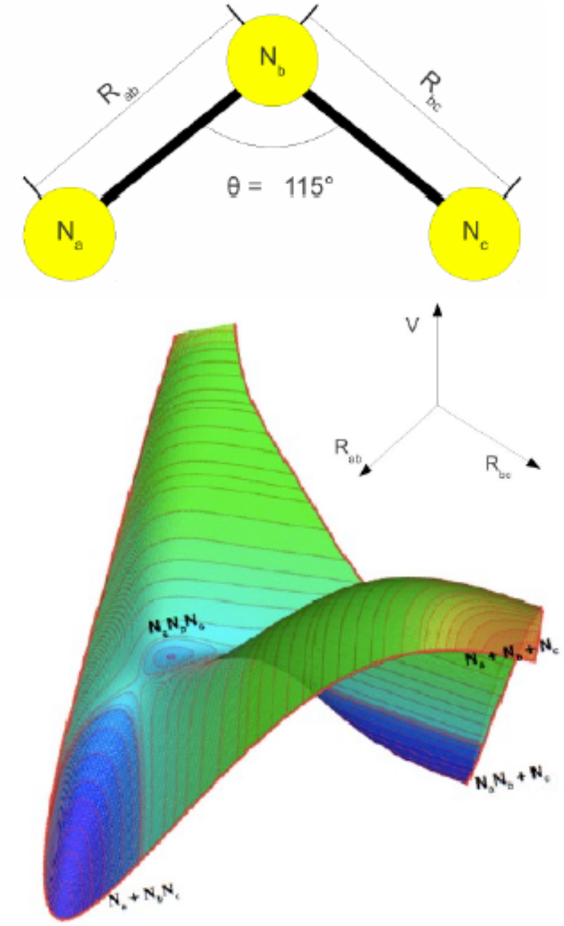
$$Q_{ij}^{(l)}(E) = 2\pi \int_0^\infty \left[1 - \cos^l(\chi)\right] b \, db$$



Predictive engineering is based on modeling / computations / experiments

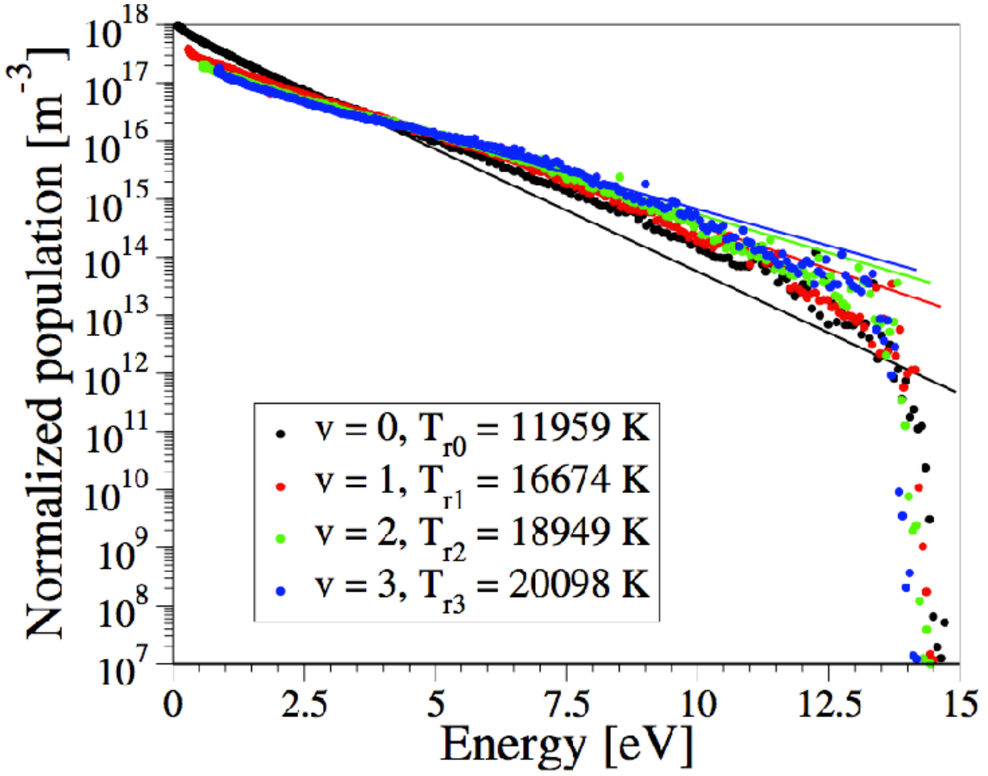
How to write an ERC proposal?

Think outside of the box



esa

2011 Fundamentals on Aerothermodynamic award



Quantum chemistry databases were first coupled to flow solvers for hypersonics about 10 years ago

How to write an ERC proposal?

Create bridges between disciplines

Developed ab initio chemistry calculations, at the interface between computational chemistry & CFD (Gordon conference)

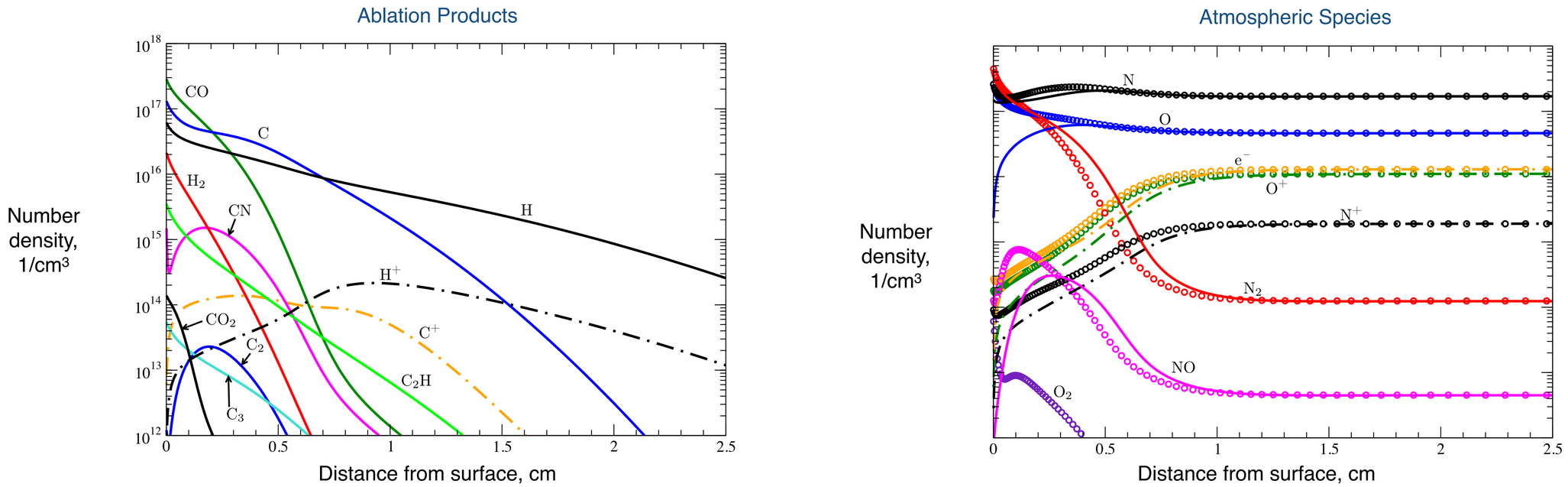
Pioneered the use of Uncertainty Quantification tools in aerospace applications (ESA TRP)

Developed kinetic theory models for plasmas with applied mathematicians (Jean d’Alembert Chair at Ecole Polytechnique)

Coupling mechanism between flow, radiation, & material fields?

Application to Apollo 4 flight data

- Low ablation rate increases convective heating through diffusion
- Radiative cooling sufficient to offset increased convective heat due to absorption in BL
- Ablation coupling decreases convective heating caused by radiation absorption



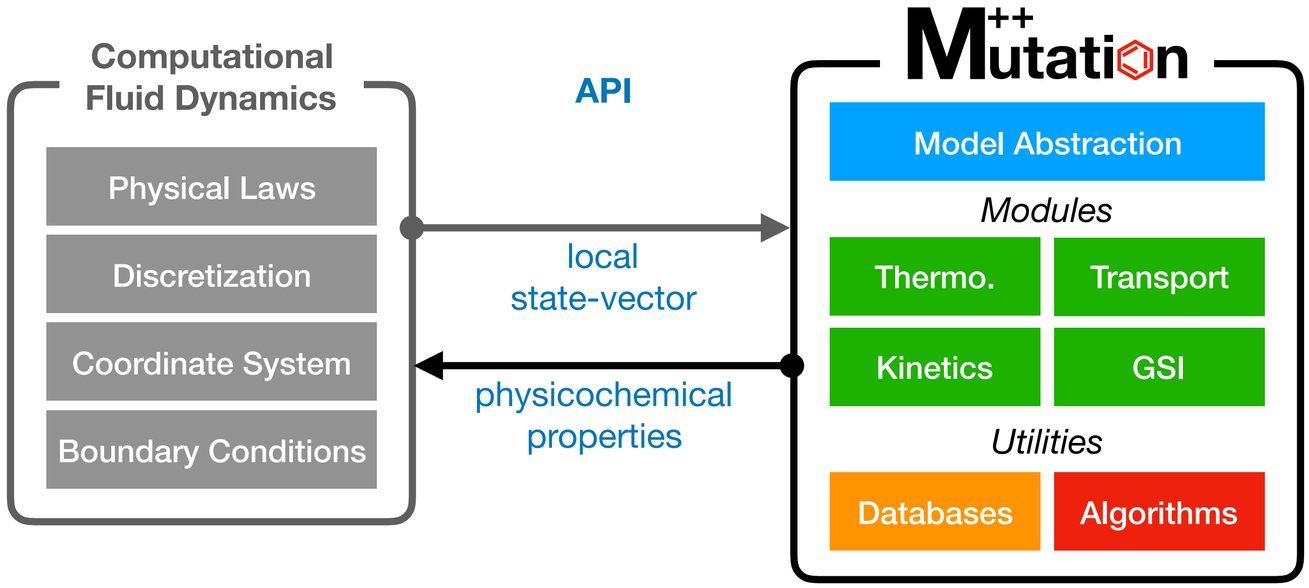
Apollo 4: 30032 s time, 59.79 km altitude, 10.252km/s velocity

Back to applied research…

Mutation++

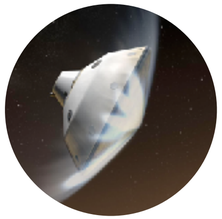
MUlticomponent Thermodynamic And Transport properties for IONized gases in C++

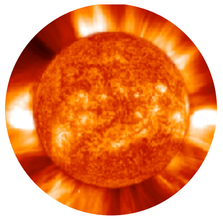
https://github.com/mutationpp



- Accurate property evaluation
- Efficient
- Extensible
- Interface to CFD
- Self documenting DBs
- Open source community

Scoggins, Leroy, Bellas-Chatzigeorgis, Dias, Magin, SoftwareX 12 (2020)

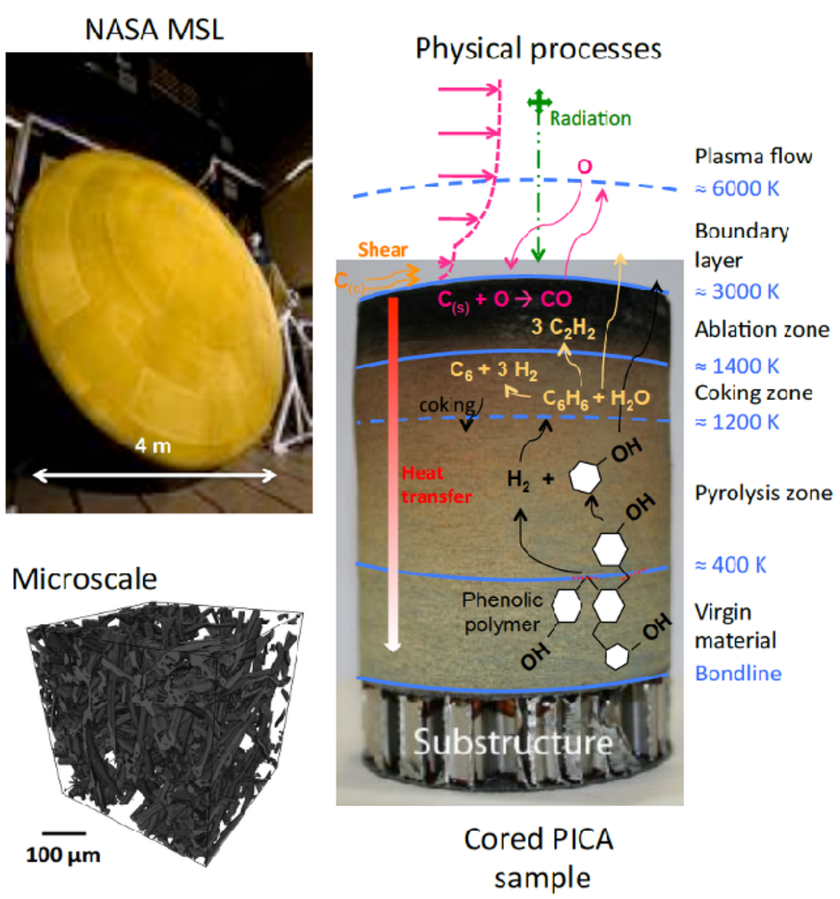


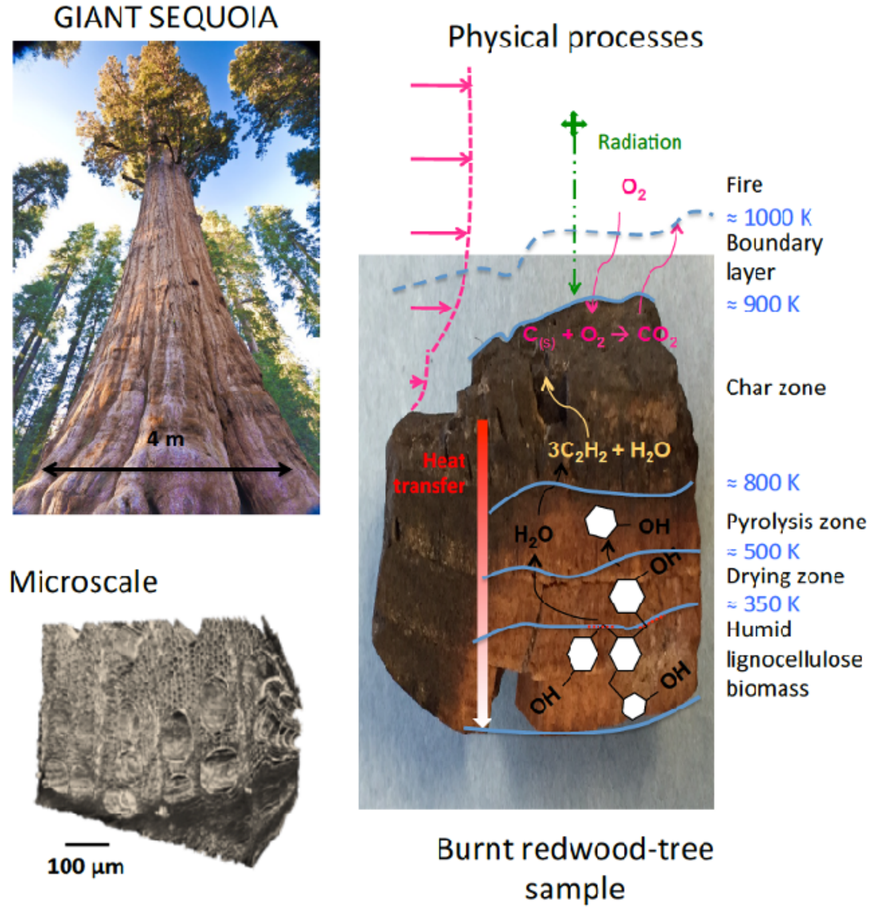




ERC Proof of Concept Grant #713726 (2016-2017)

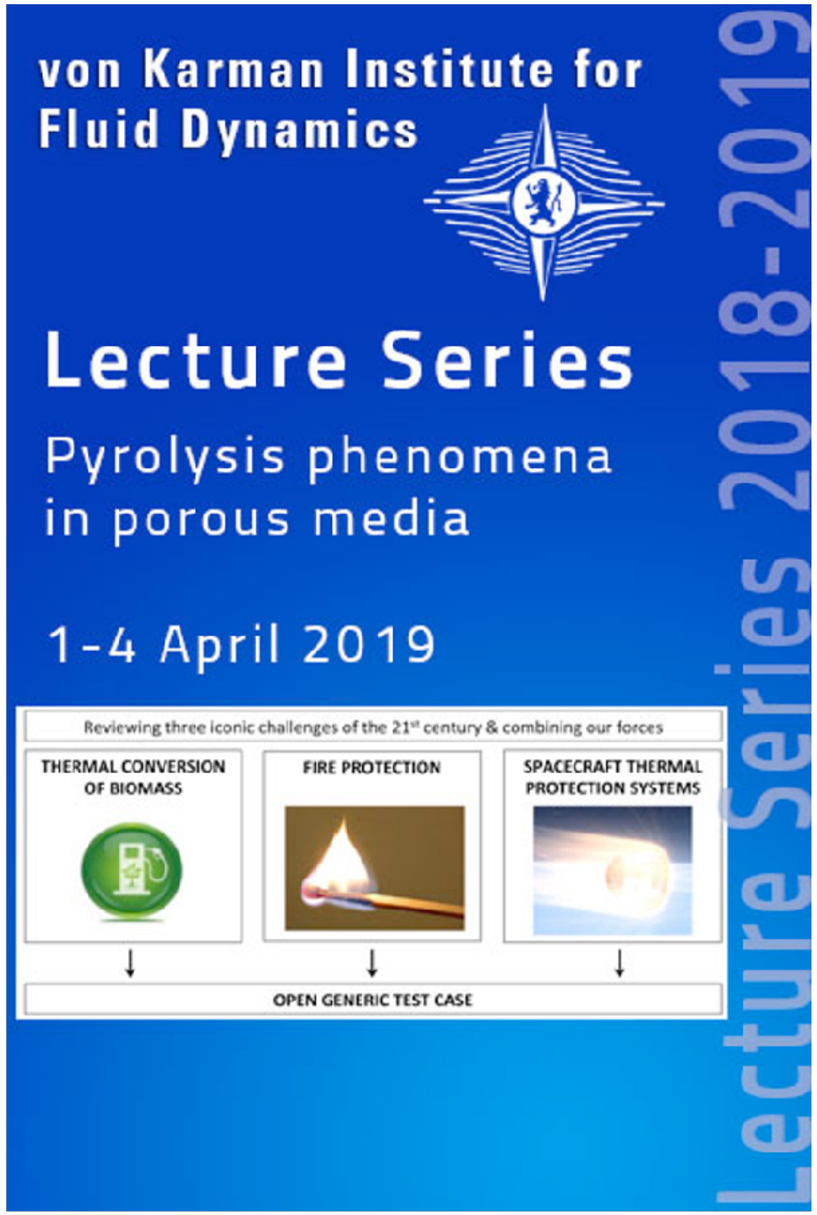
MUTX: MUTATION++ library, technology transfer from atmospheric entry plasmas to biomass pyrolysis

Collaboration with Jean Lachaud, NASA Ames (U Bordeaux)





VKI Lecture Series on “Pyrolysis phenomena in porous media



Broad variety of high-temperature applications

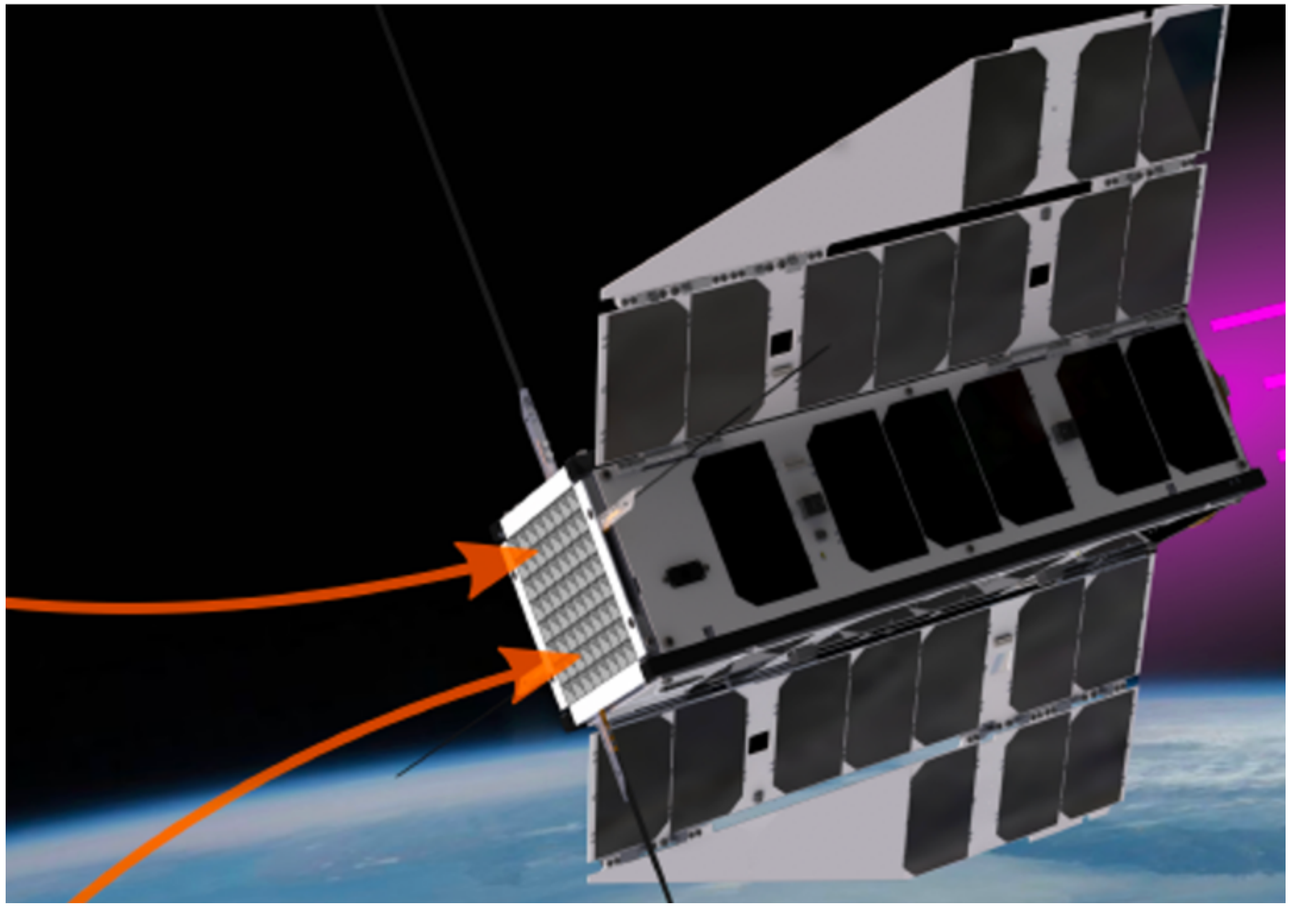
- Thermal conversion processes
- Fire protection
- Spacecraft thermal protection systems

Despite strong similarity between these disciplines for their intrinsic physical problem, transfer of ideas, as well as comparison of simulation tools are still scarce…

Research groups with different background worked together and shared ideas

Today’s new challenges for the VKI team

- Understanding gas-surface interaction in the rarefied regime
- Coupling air plasma flow & chemistry &EM field



Air-breathing electric propulsion concept for VLEO applications

- Tue 28 June (FLIPHY)
  - Pietro Parodi
  - Diana Luis
  - Giuseppe Gangemi
- Fri 1 July (FLIPHY)
  - Pedro Jorge
  - Matthias Geratz
  - Eszter Dudas

Take home message for writing your proposal

- Communicate your enthusiasm

- It’s your dream project!