A Review of the Experimental and Numerical Activities on a Hydrogen Peroxide-based Hybrid Rocket for Small Satellites

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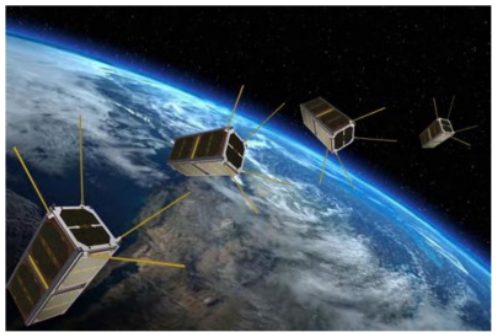
Introduction - Scenario

- Emerging market for **Nanosatellites** (e.g. Cubesats)
- Need for dedicated propulsion technologies for
  - Attitude Control
  - Drag Recovery
  - Orbit Changes
- **Chemical technologies** are suitable for relatively **high-thrust**, impulsive maneuvers at **low power consumption**
- Replacement of toxic hydrazine with greener propellants (**H_2O_2, N_2O**)
- H_2O_2 and N_2O can be employed as **oxidizer** in the case of hybrid rockets, in combination with polymeric fuel grains



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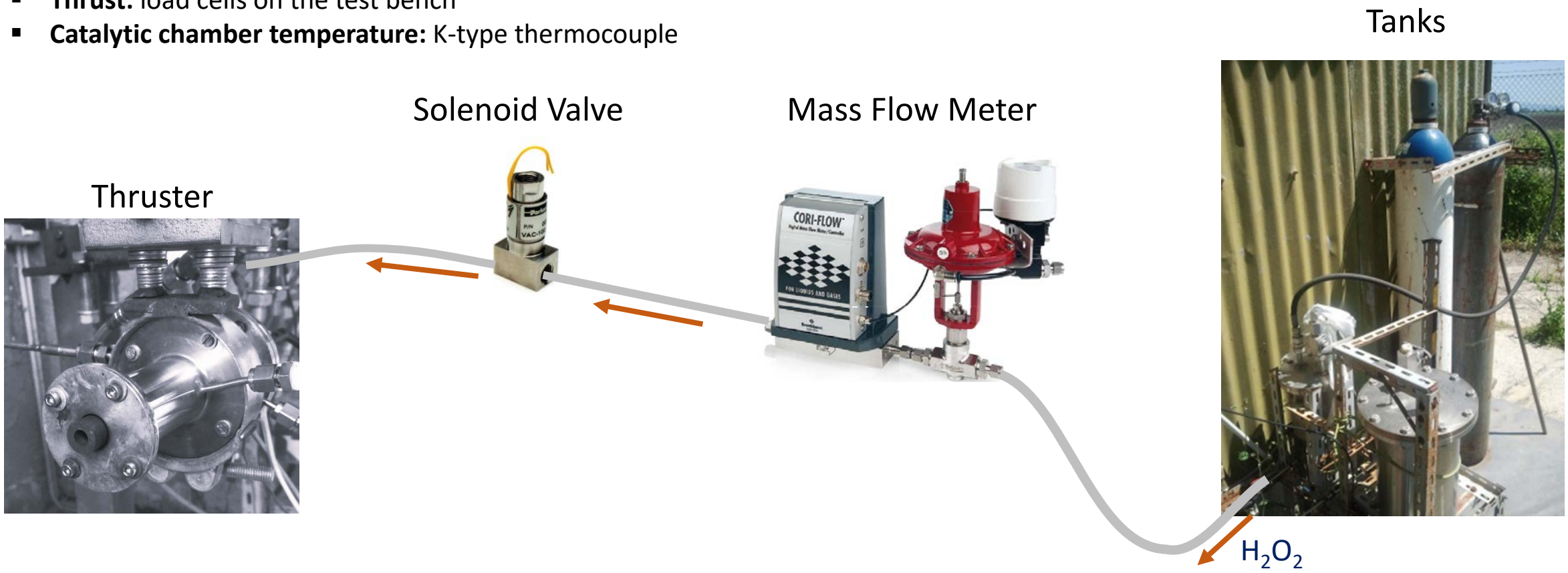
Experimental Setup

UNINA Aerospace Propulsion Laboratory, located in the F. Baracca Military Airport in Grazzanise (CE)

- **Main measurements**
  - **Propellant mass flow rate:** Coriflow M55 (re-computing needed based on compressible Bernoulli equation)
  - **Catalytic and combustion chamber pressure:** capacitive pressure transducers
  - **Thrust:** load cells on the test bench
  - **Catalytic chamber temperature:** K-type thermocouple



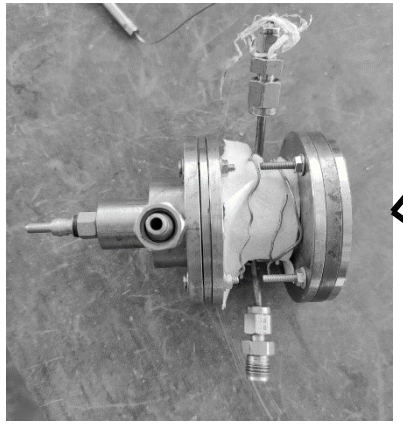
Hybrid Thruster Assemblies

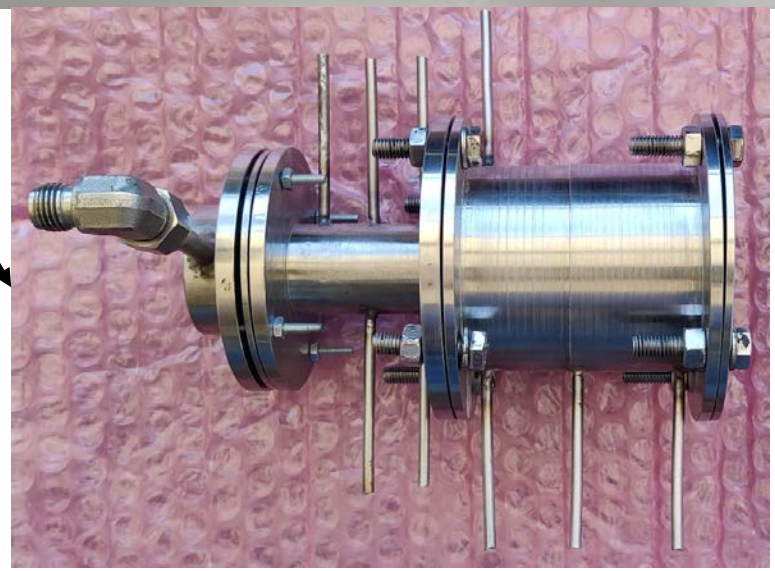
Injection System

Combustion Chamber

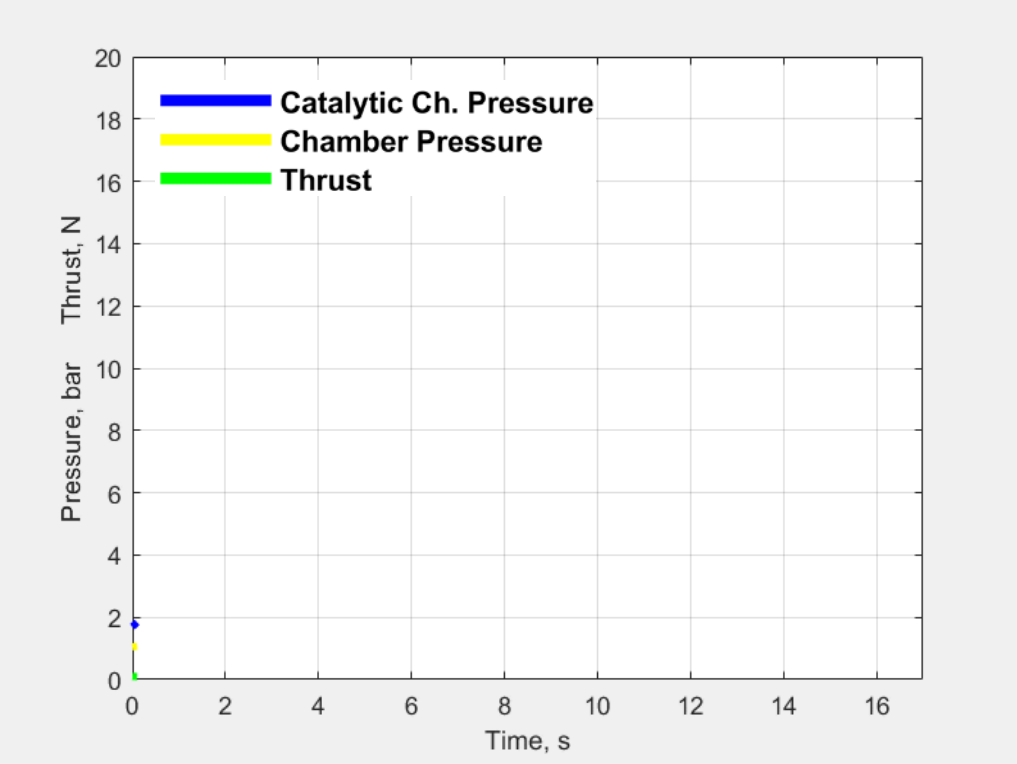
Post Chamber + Nozzle

Hybrid Thruster

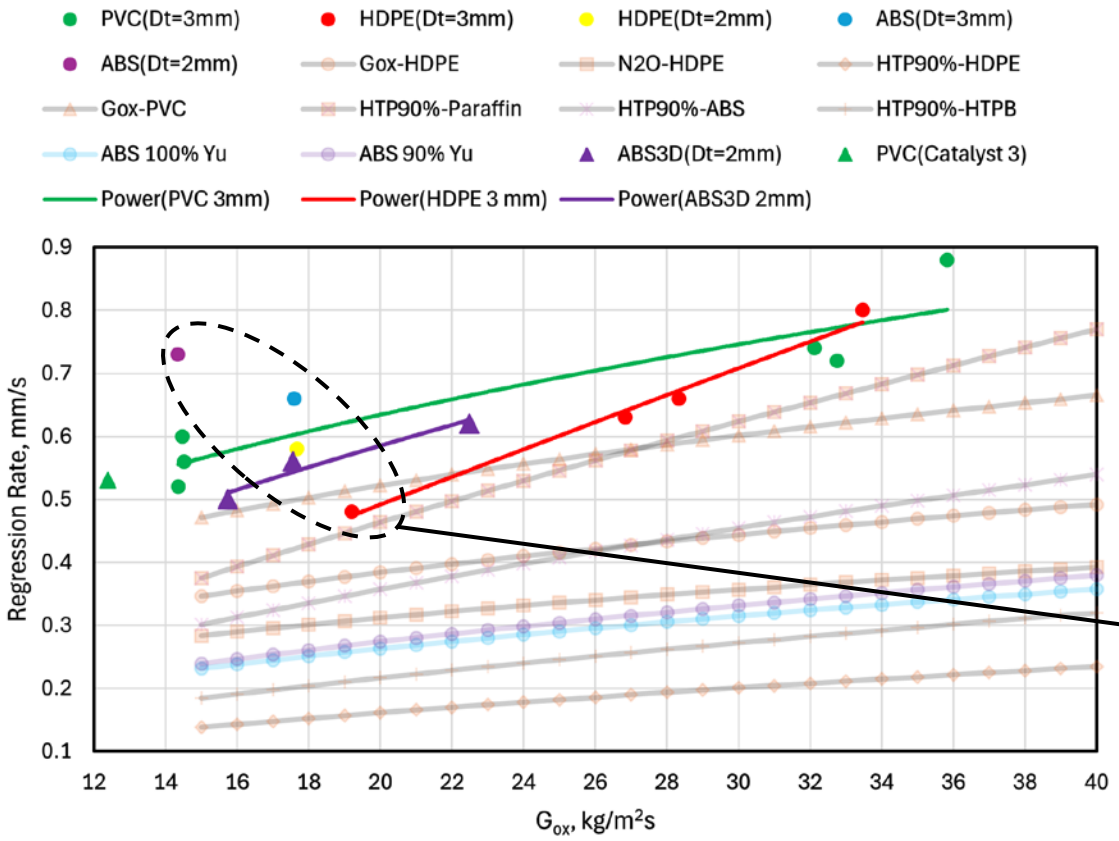




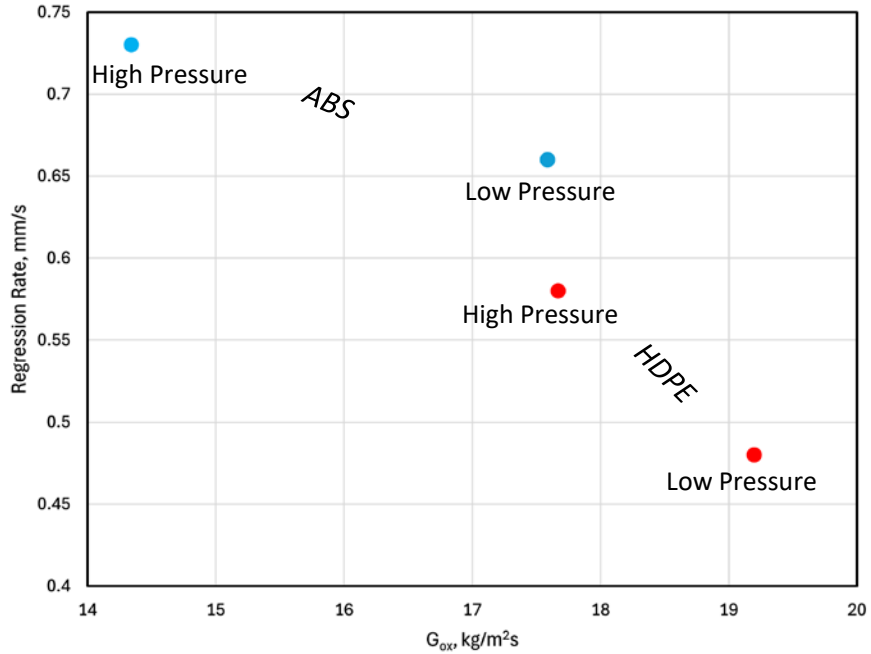
Exemplary Test



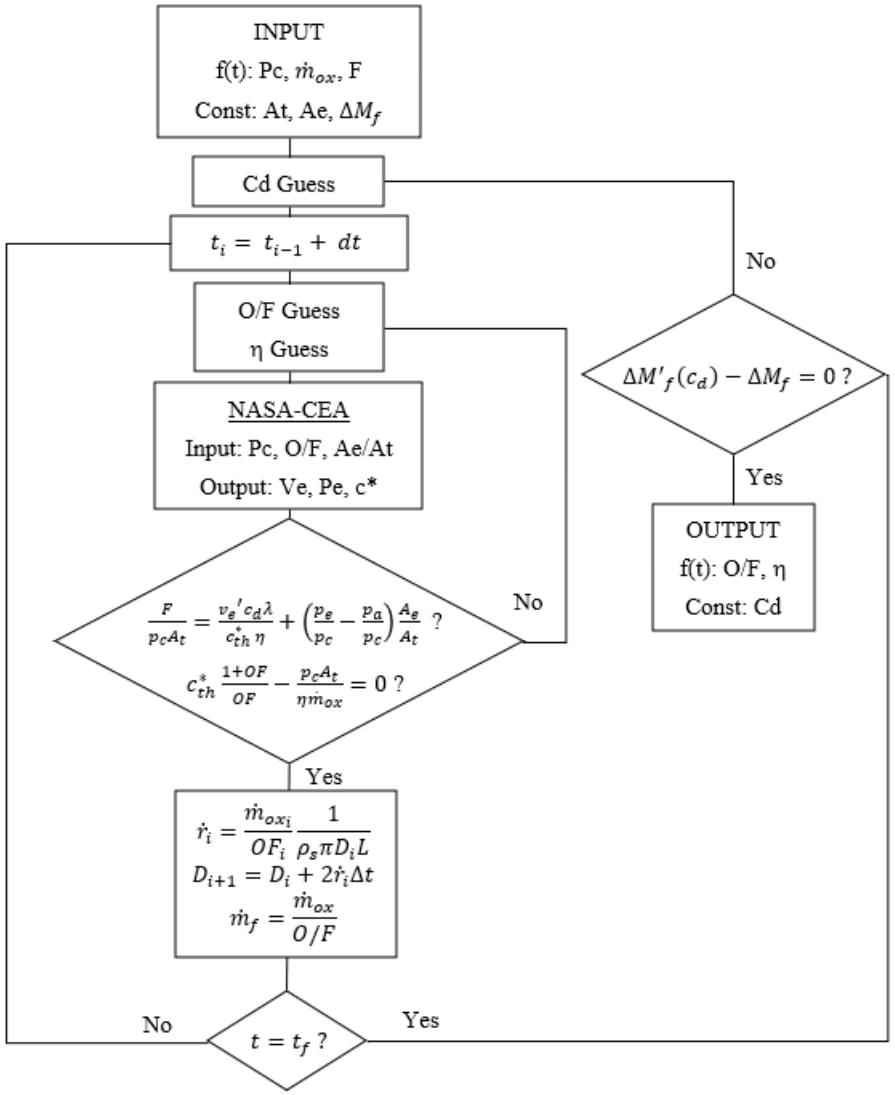
Regression Rate

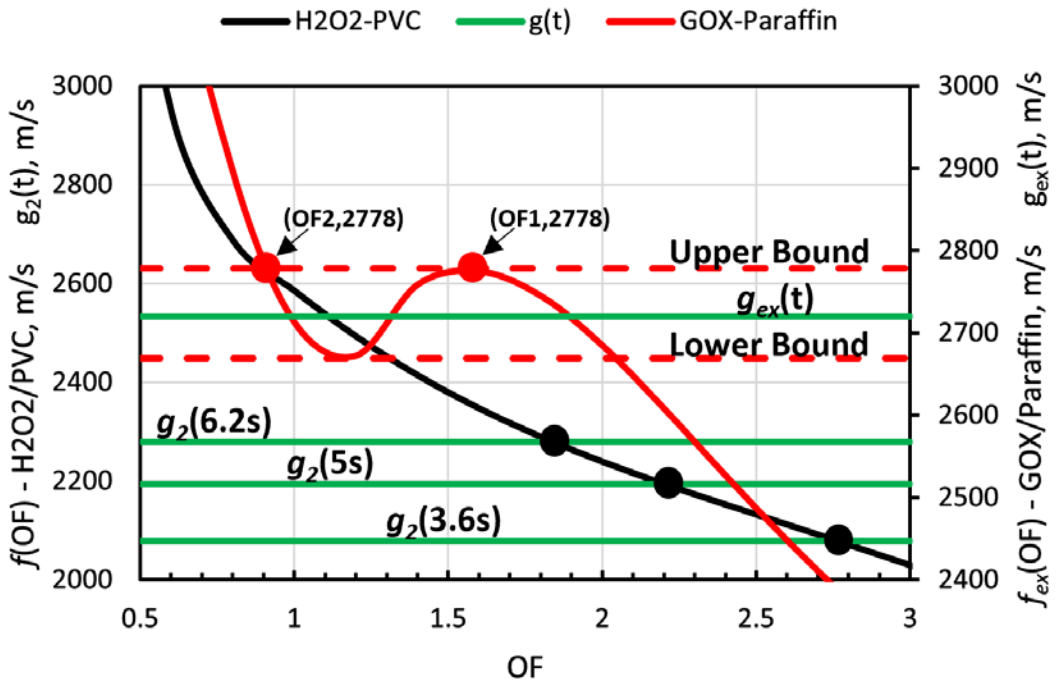


- All regression rates are higher than several correlation laws found in literature with different propellants
- Reason may be in fluid dynamics or thermal aspects



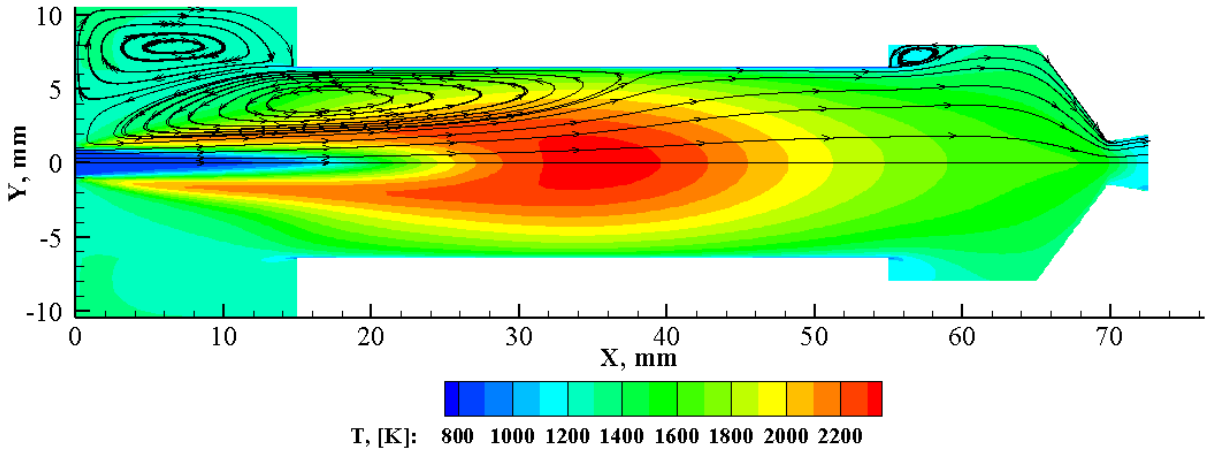
Ballistic Reconstructions





- Thermodynamics properties of couple H_2O_2-PVC allow to avoid the multiple solution region
- Complex Solution Method has been used for PVC
- Simplified Method has been used for HDPE and ABS
- Ballistic reconstructions allow to obtain regression laws by taking hundreds of points into consideration
- The reconstructed laws permit to design experiments with errors lower than 10% on the main parameters

CFD Simulations (HDPE)



- CFD simulations are performed for HDPE and ABS fuels
- The studied configuration generates a large recirculation zone, leading to a relatively high regression rate
- Grain heating plays a crucial role in regression rate
- Simulated regression rate profile along the grain shows good agreement with experimental findings

Test n.	T_i (K)	Exp $\dot{r}$ (mm/s)	CFD $\dot{r}$ (mm/s)
8	300	0.48	0.448
8	400	//	0.464
8	500	//	0.486
9	300	0.80	0.730
9	500	//	0.80
10	300	0.66	0.610

Conclusions

- A 10N H2O2-based hybrid rocket was successfully tested, based on catalytic ignition of the mixture
- Regression rates were consistent and always higher than literature
- Experimental tests were reconstructed applying different principles to reduce the data scattering
- Regression rate results to be affected by combustion chamber pressure and grain heating, which may be crucial in such small-scale thrusters

- Further developments will include
  - Tests in different conditions and with other fuels
  - Unsteady simulations to better match experimental regression rate distribution along the grain
  - Experimental and Numerical investigations of the geometrical configuration impact on the internal ballistics

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