Marco Santi

Study and Development of a H2O2 based Liquid Rocket Engine

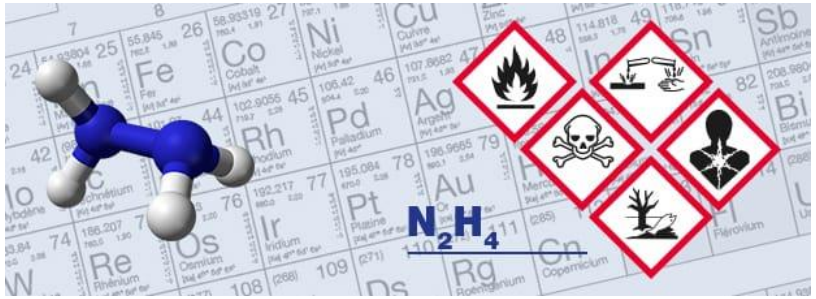
September 13th 2019

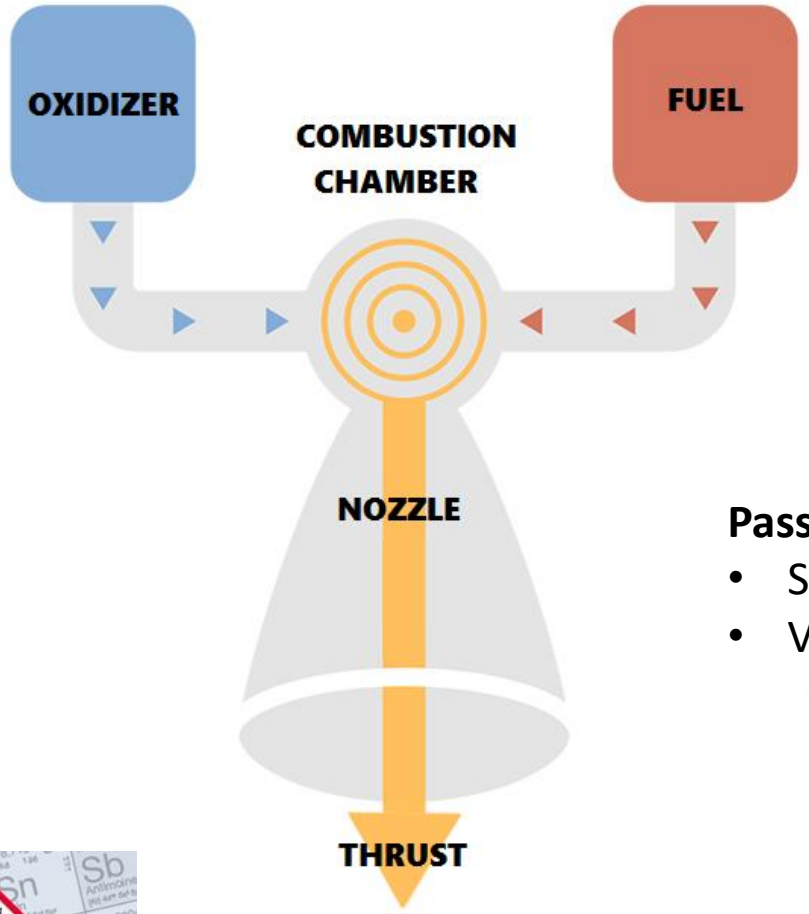
LRE-Liquid Rocket Engine

Advantages
- High specific impulse
- Two controllable feeding lines
- Operation flexibility
  - Multiple shut down & re-ignition
  - Mass flow throttling
  - Mixture ratio control
- Long burning times

Disadvantages
- High manufacturing costs
- Technological complexity

In Space Propellant:

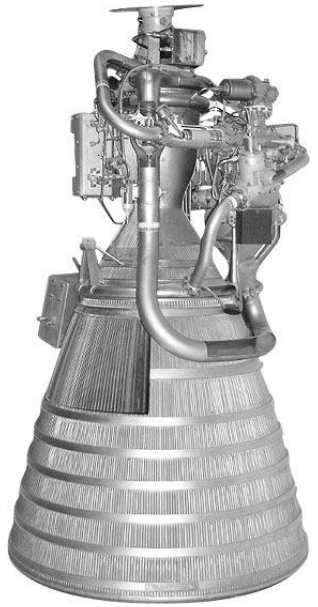




High combustion temperature

Different cooling system solutions

Passive methods
- Small scale thruster
- Very expensive materials



Active methods
- Large scale engine
- Regenerative cycle
- Technological complexity

New Space Economy

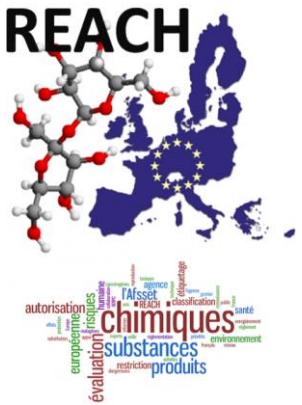
- Low cost
- Performance
- Environmental friendliness
- Controllability
- Customization capability

- Manufacturing
- Propellant

Versatility

- Monopropellant
- Bipropellant

- **Not toxic for humans**
- **Environmental friendly**
- **High volumetric specific impulse**
- **Easy storable at room temperature**



Hydrogen Peroxide

$H_2O_2 \leftrightarrow H_2O + 1/2\ O_{2(g)} + 98kJ/mol$

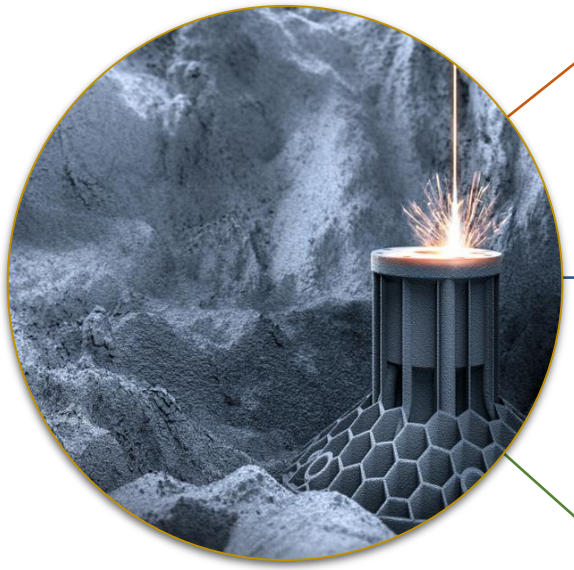
High Test Peroxide (HTP)
Mass Concentration > 80%

Performance

- Bipropellant

$ISP_{MMH/N_2O_4} \cong ISP_{HTP/RP1}$

LRE



Combustion Chamber

- Fuel injector
- Cooling system

Nozzle

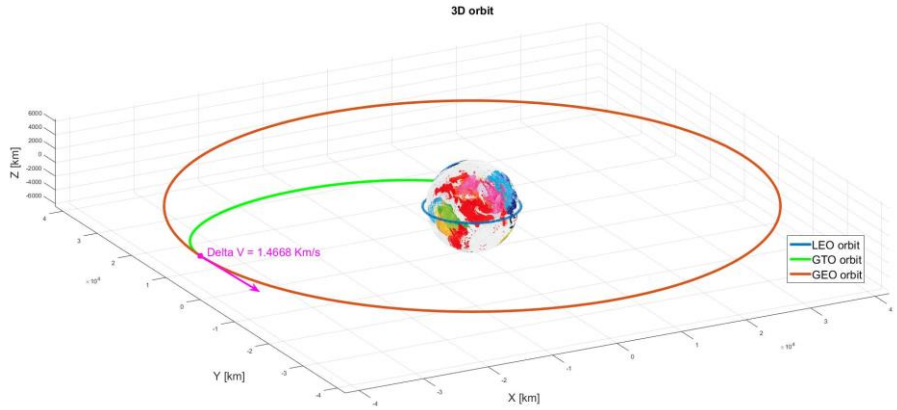
- Cooling system

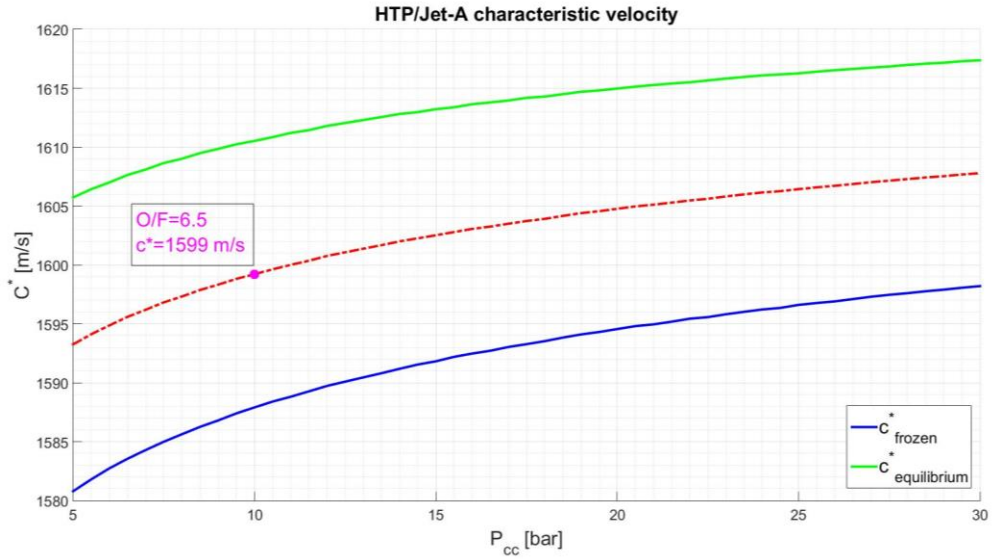
Catalytic Bed

- Volume

Additive Manufacturing?

Preliminary design

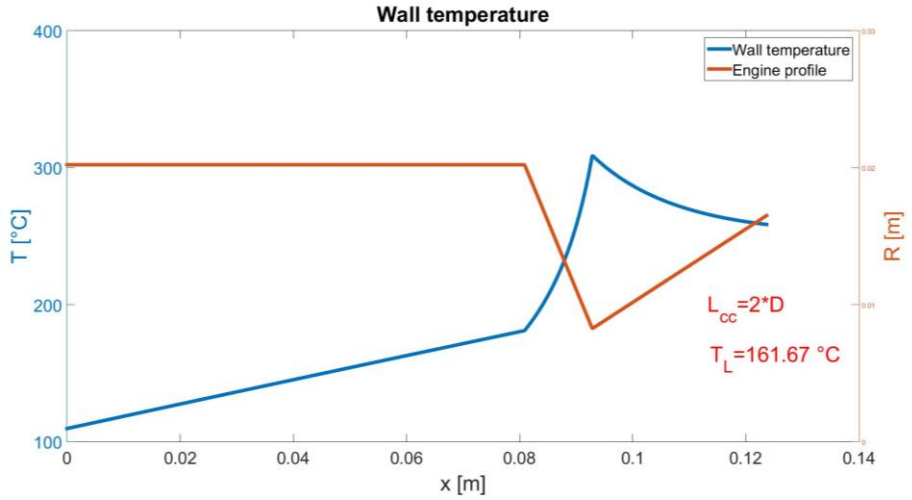


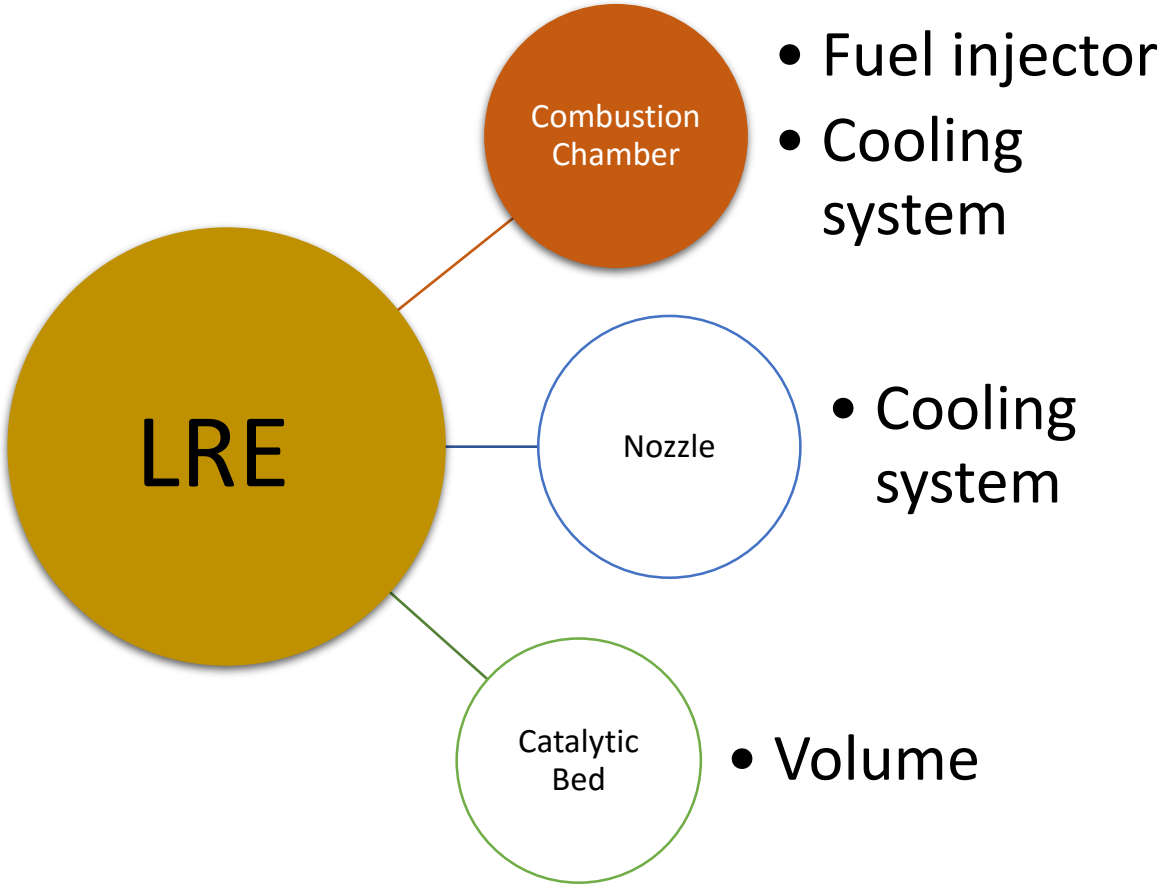


Kick Apogee Motor

m_dot	120 [g/s
OF	6.5
Oxidizer	HTP 91.5%
Fuel	Kerosene
MEOP	10 [bar
ε	220 – 330
T	420 – 440 [N
Isp	310 – 330 [s
ΔV	1.4888 [km/s
tb	1.456 [hours

$$\dot{m}_{cool} = \dot{m}_{OX}$$
$$T_L max = 120°C$$





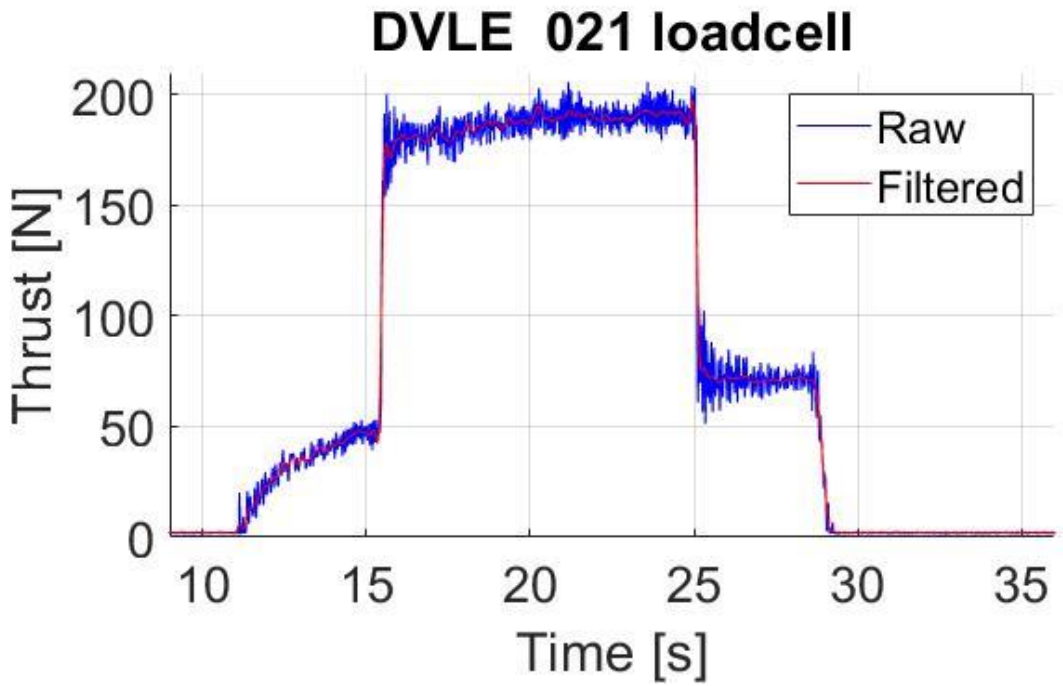
- Fuel injector
- Cooling system

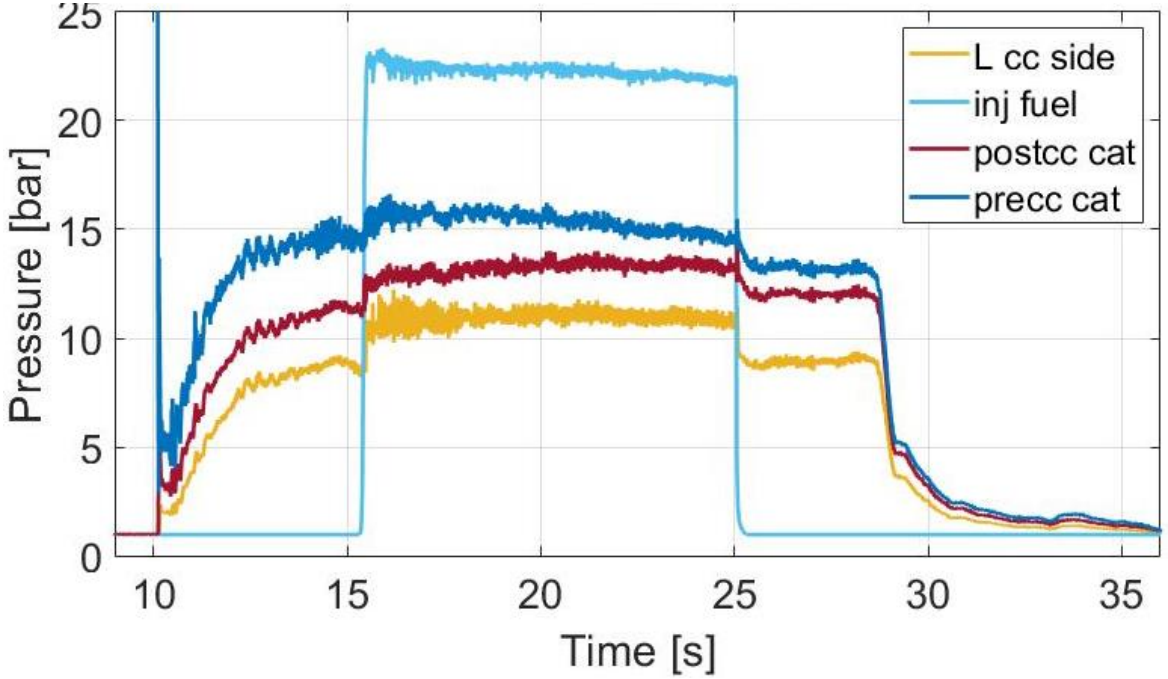
- Cooling system

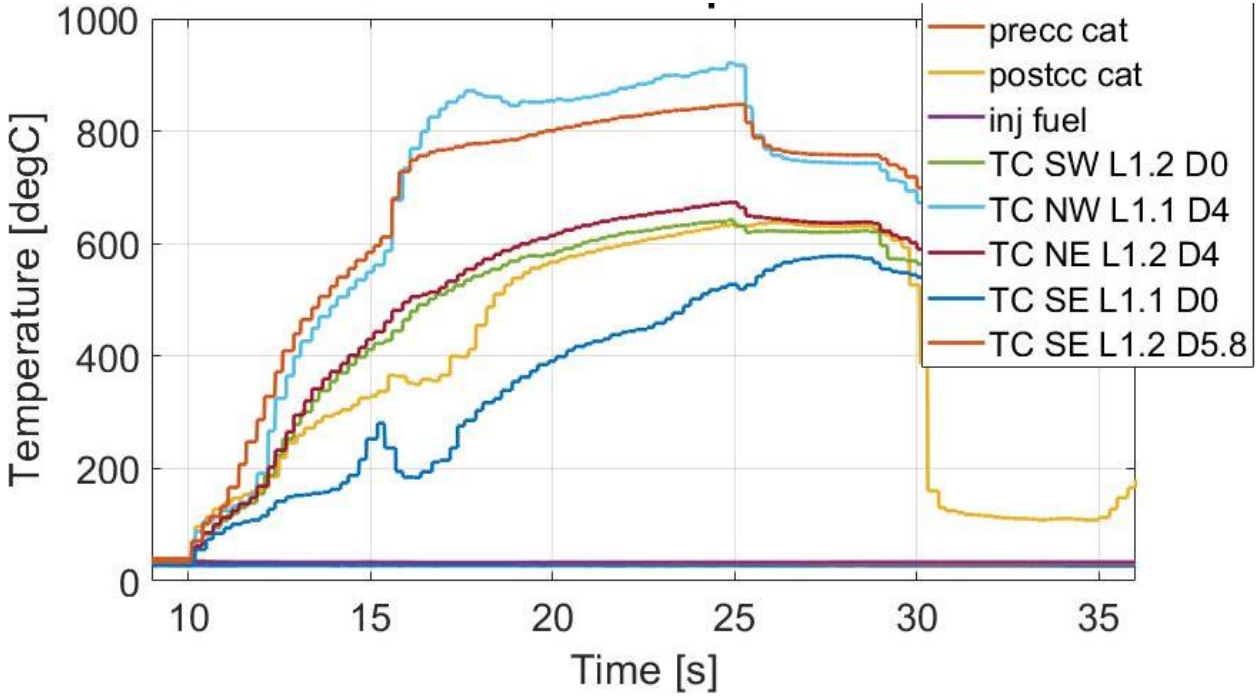
- Volume

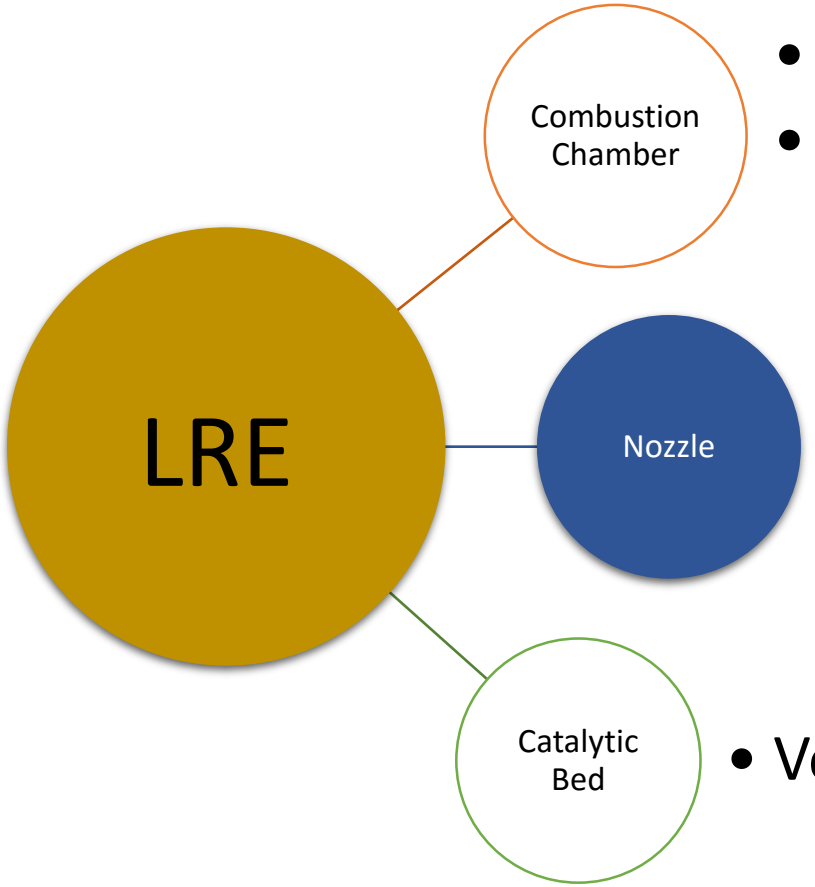
Experimental activity

N°test	ISP eff	Tmax wall
21	0,85	630 °C





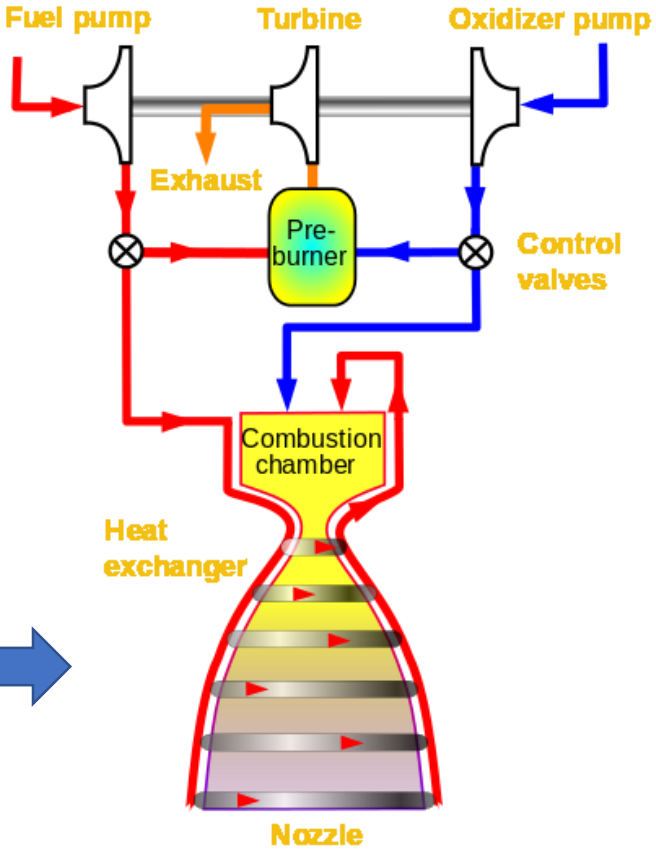




- Fuel injector
- Cooling system

- Cooling system

- Volume



OF=6.5

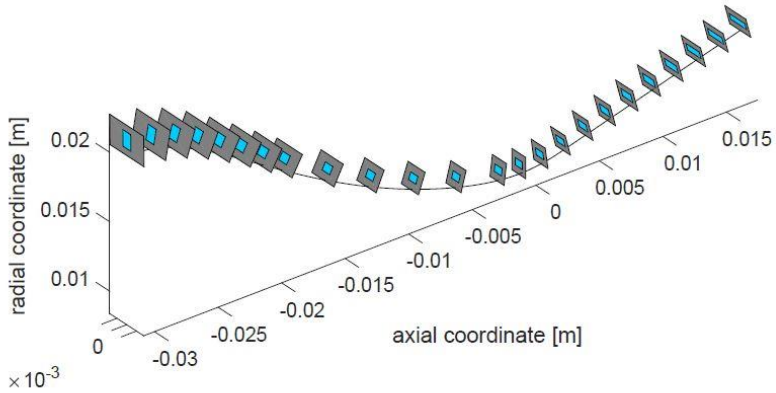
T ↘↘

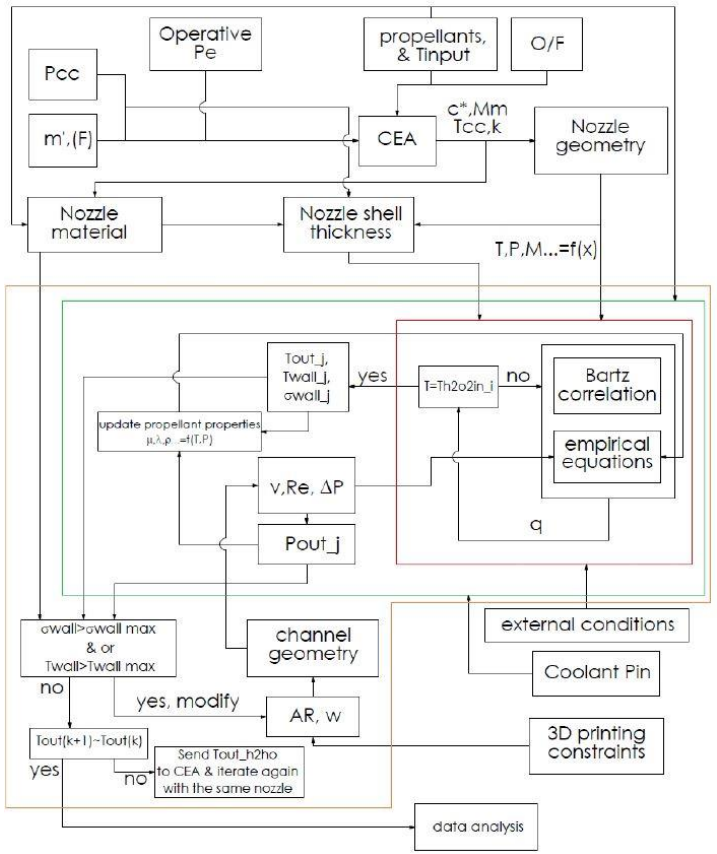
Cooling liquid

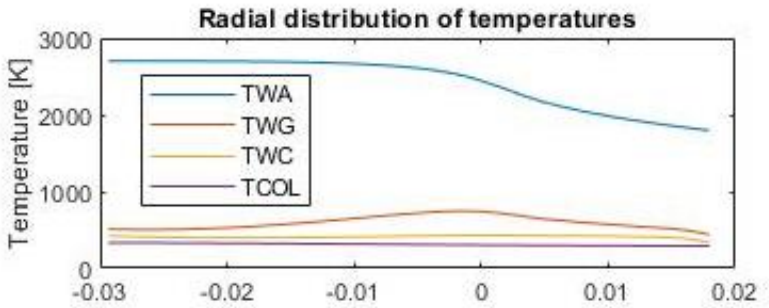
~~Fuel~~

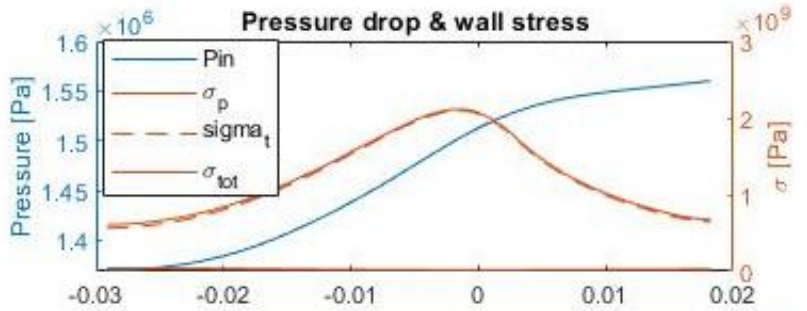
Oxidizer

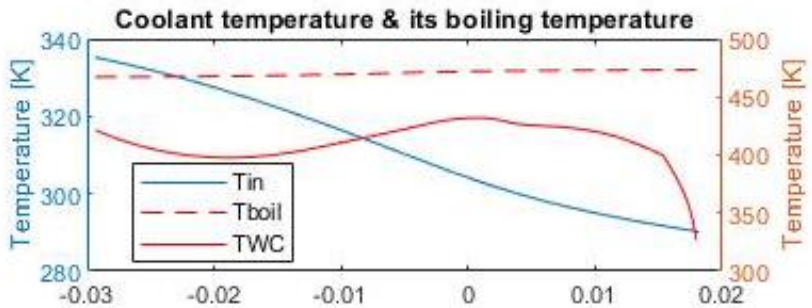
Nozzle

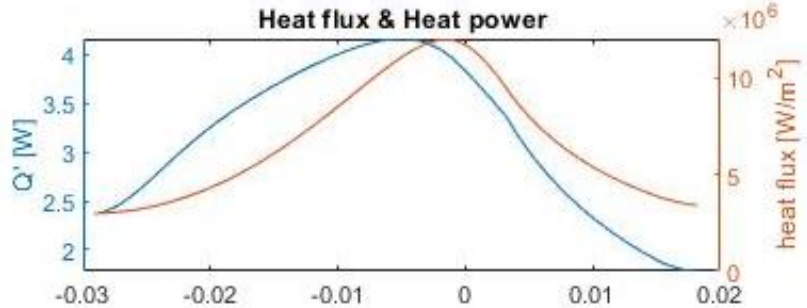

radial coordinate [m]
axial coordinate [m]
×10^-3

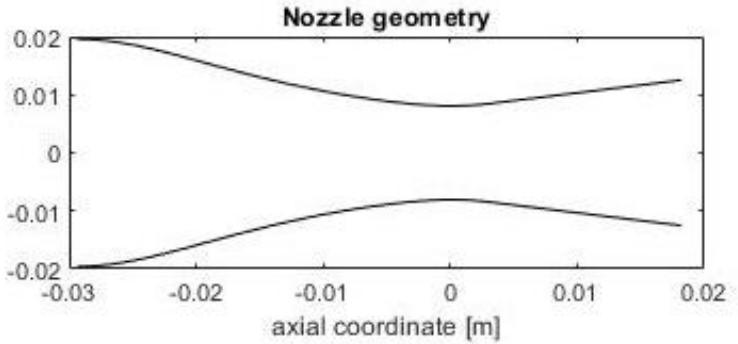

Operative Pe
propellants, & Tinput
O/F
Pcc
m',(F)
CEA
c*,Mm Tcc,k
Nozzle geometry
Nozzle material
Nozzle shell thickness
T,P,M...=f(x)
Tout_j, Twall_j, σwall_j
yes
T=Th2o2in_j
no
Bartz correlation
update propellant properties μ,λ,ρ ...=f(T,P)
empirical equations
v,Re, ΔP
Pout_j
q
σwall>σwall max & or Twall>Twall max
channel geometry
external conditions
Coolant Pin
no
yes, modify
AR, w
Tout(k+1)~Tout(k)
3D printing constraints
yes
no
Send Tout_h2ho to CEA & iterate again with the same nozzle
data analysis

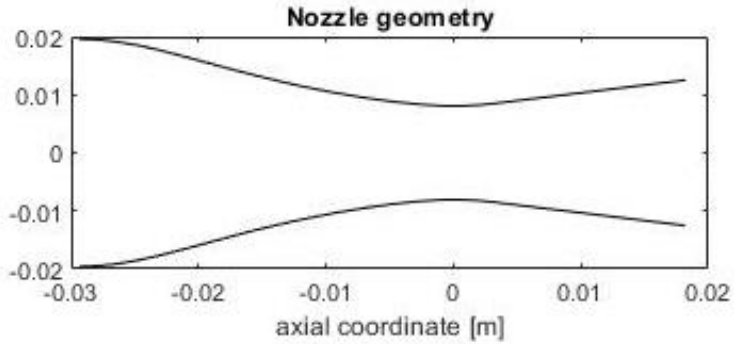

Radial distribution of temperatures
Temperature [K]
TWA
TWG
TWC
TCOL


Pressure drop & wall stress
Pressure [Pa]
σ [Pa]
Pin
σp
sigma_t
σtot


Coolant temperature & its boiling temperature
Temperature [K]
Tin
Tboil
TWC


Heat flux & Heat power
Q' [W]
heat flux [W/m^2]


Nozzle geometry
axial coordinate [m]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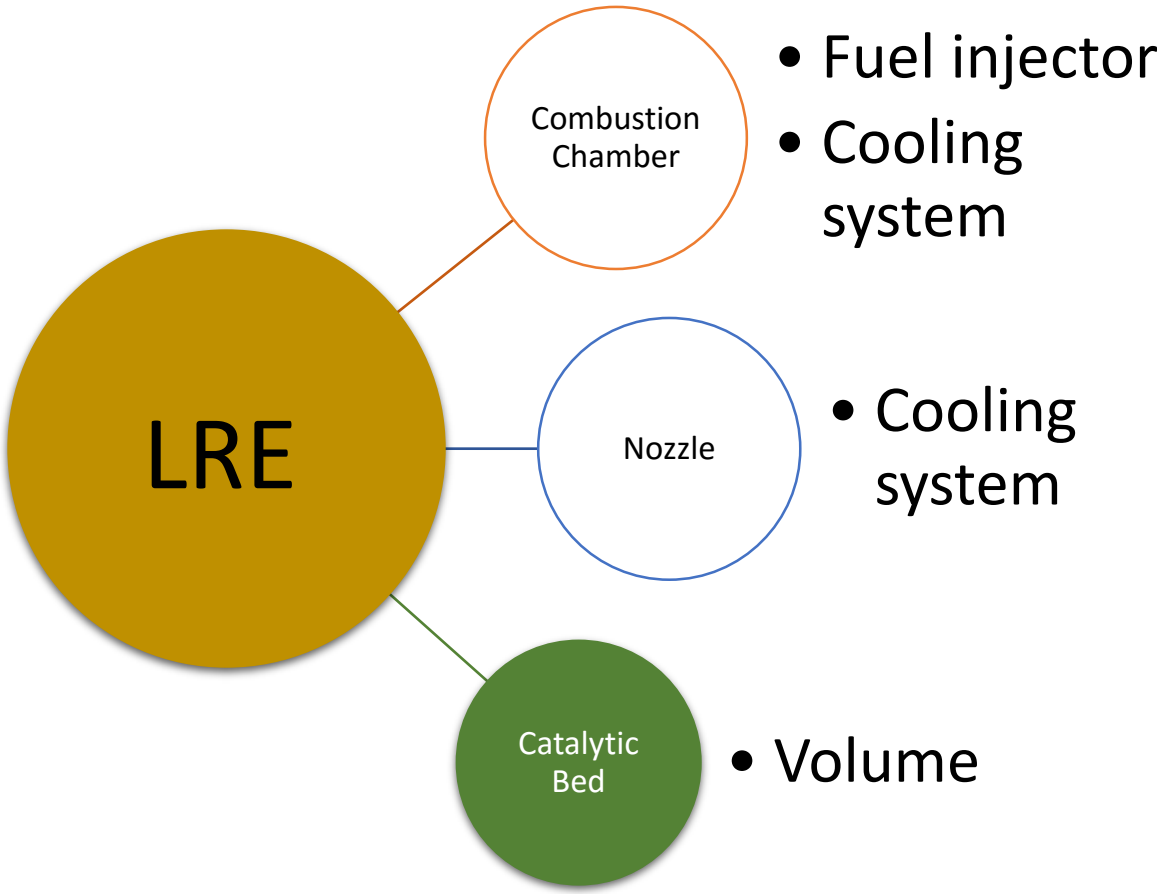
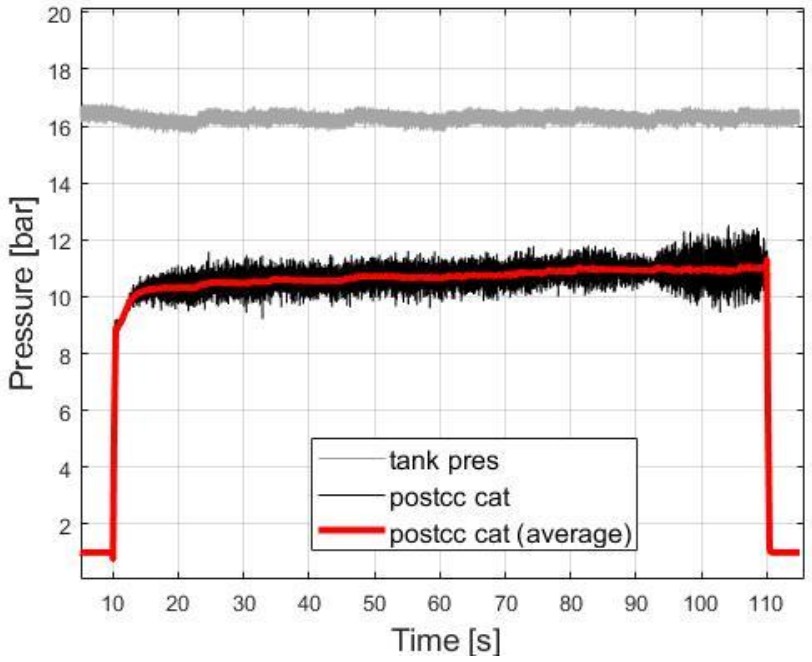


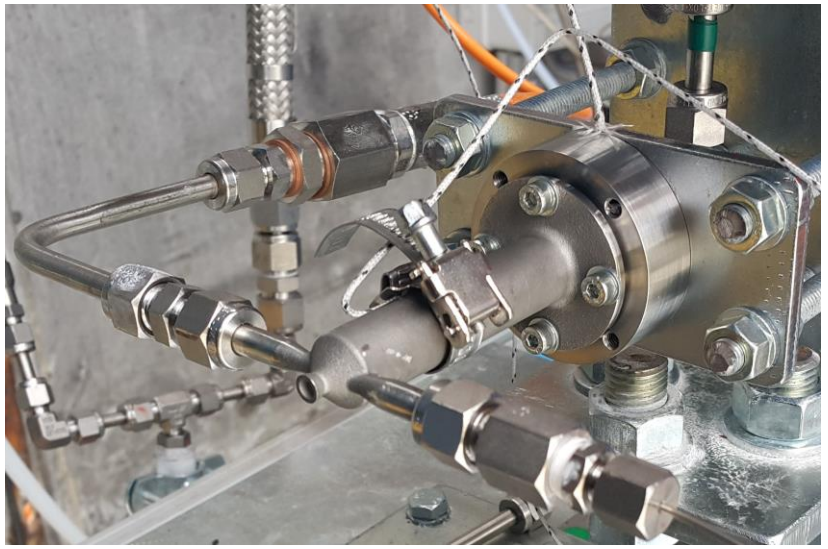
- Fuel injector
- Cooling system

- Cooling system

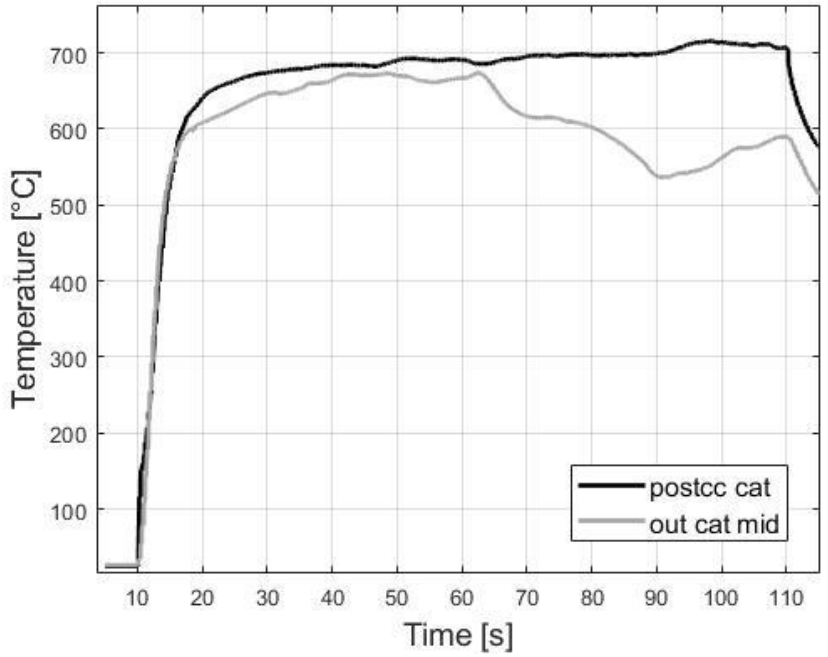
- Volume

10N Monopropellant





tb [s]	c* eff	Twall_max [°C]
100	0,93	680



Outcome

1. 3D printing Knowledge
2. Material capabilities
3. Catalytic Saturation Volume

M. Santi, I. Dorgnach, F. Barato, D. Pavarin,''Design and Testing of a 3D Printed 10 N Hydrogen Peroxide Monopropellant Thruster'', AIAA Propulsion and Energy Forum and Exposition, 19-22 August 2019