CENTRAL EUROPEAN FP7 SPACE INFORMATION DAY in KRAKÓW

Space-related activities at the Warsaw University of Technology and Institute of Aviation

Prof. Piotr Wolański, WUT & IofA

Friday, 17 October 2008

Warsaw University of Technology

- Education – Space Technology
- Students parabolic flight campaign (since 1994)
- Students participation in ESA projects
- Building student’s cube satellite „PW-Sat”
- Research – Development of rocket engine based on continuous rotating detonation and small resistor thrusters

Space Activities of Students of the Warsaw University of Technology

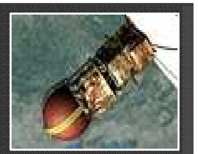
Warsaw University of Technology

Student Space Association

Student Space Engineering Scientific Group

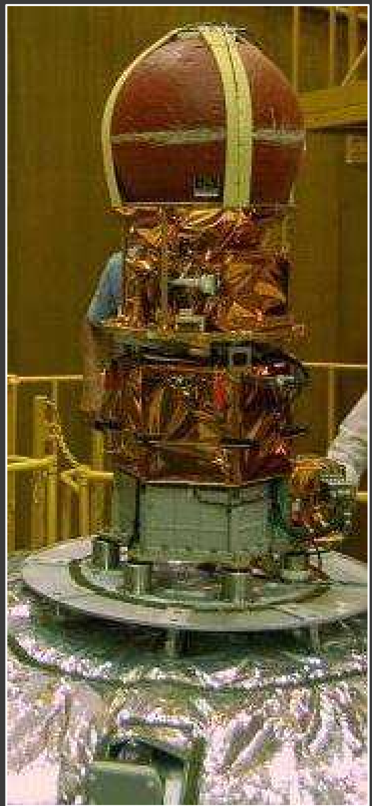
50 years of The Space Age

Students with invited guests



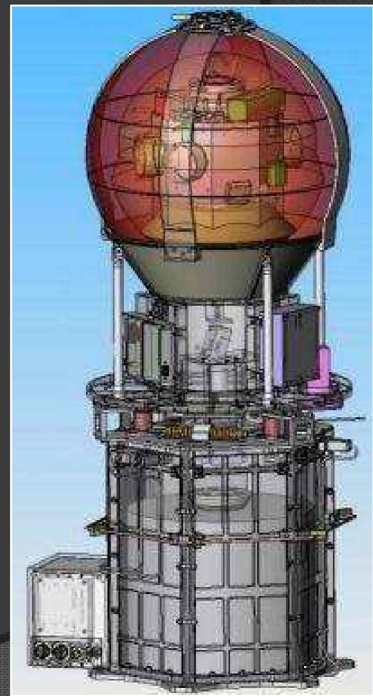
Young Engineers' Satellite 2

Demonstration of inexpensive method of bringing light cargo back from LEO

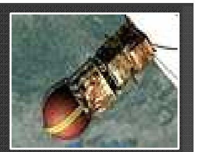


- Project was conducted as a professional ESA's mission

- Hundreds of European students took part



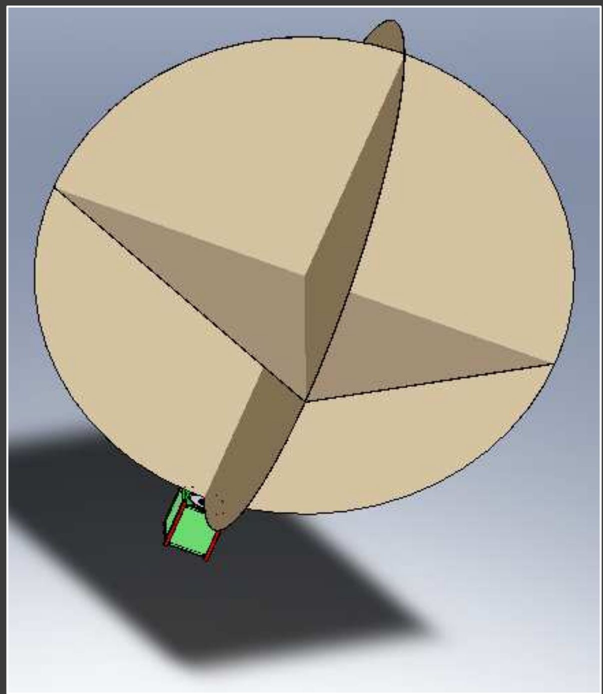
Young Engineers' Satellite 2

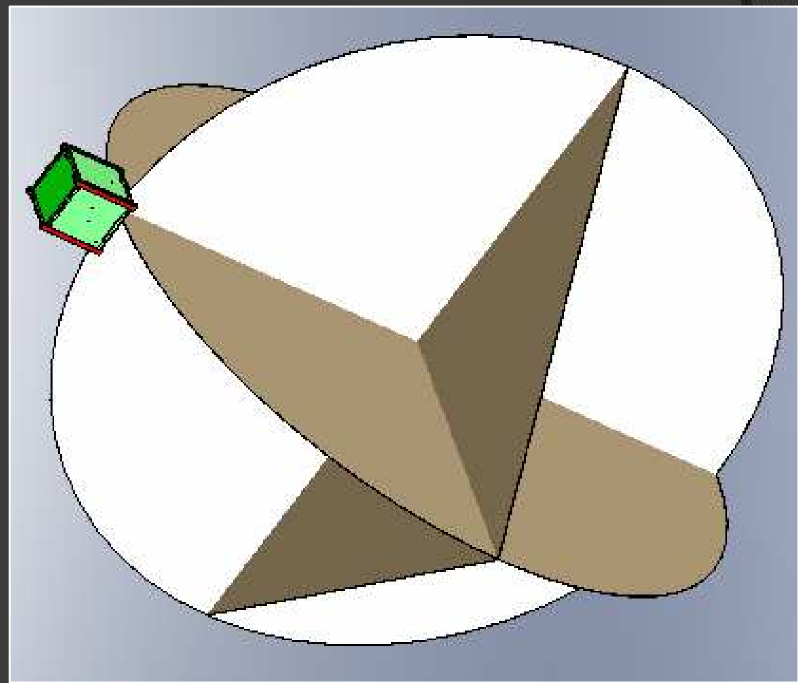


Fotino recovery attempt in Kazakhstan

PW-Sat

- First polish picosatellite (CubeSat)
- Mission goal: test of completely new method of intentional deorbitation



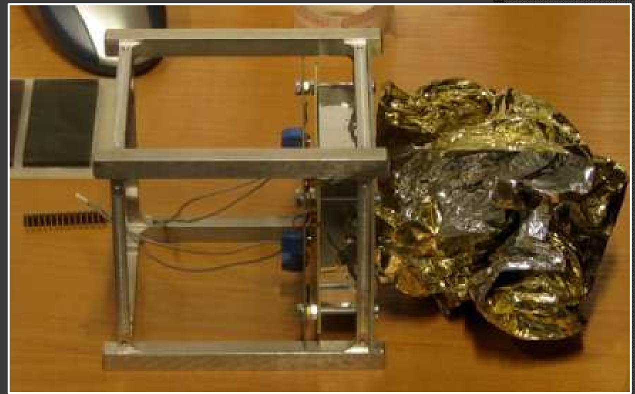


PW-Sat

- Destined to deploy thin foil structure to increase satellite’s face area

PW-Sat

Student team's work



Warsaw University of Technology & Institute of Aviation

- Preliminary design of small satellite launcher
- Research of small gaseous rocket engines
- Research of hybrid propulsion systems
- Participation in the 7FP „GRASP” – development of green propulsion systems

INSTITUTE OF AVIATION

Space Technology Department

Starting today...

Institute of Aviation
Space Technology Department

Our activities:

- Liquid rocket engines design
- Hybrid rocket motors design
- Rocket launchers mass optimization
- Numerical simulations of the rocket flight to the target orbit
- Combustion analysis
- Cooling systems analysis
- Rocket launcher design

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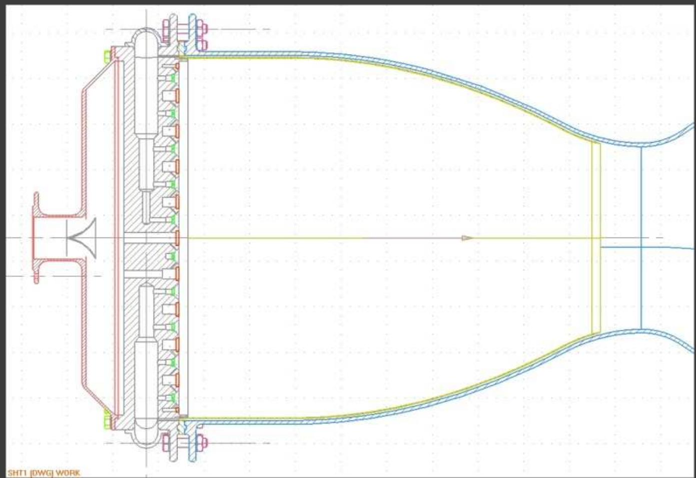
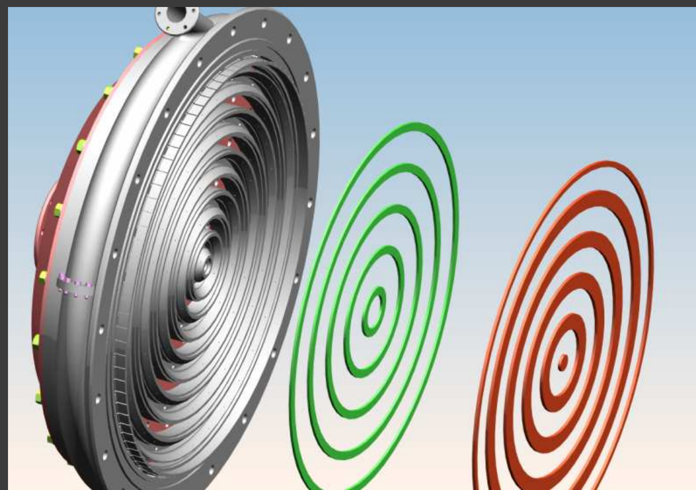
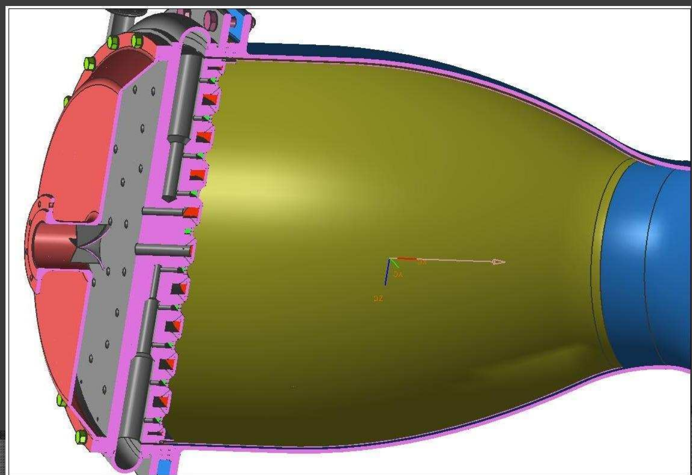
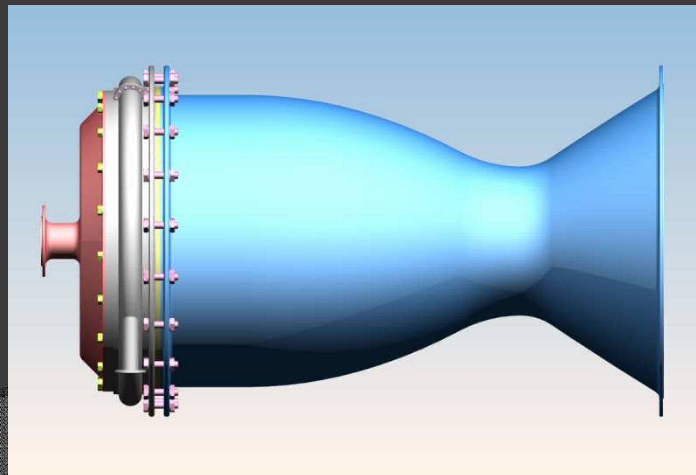
Liquid rocket engines design









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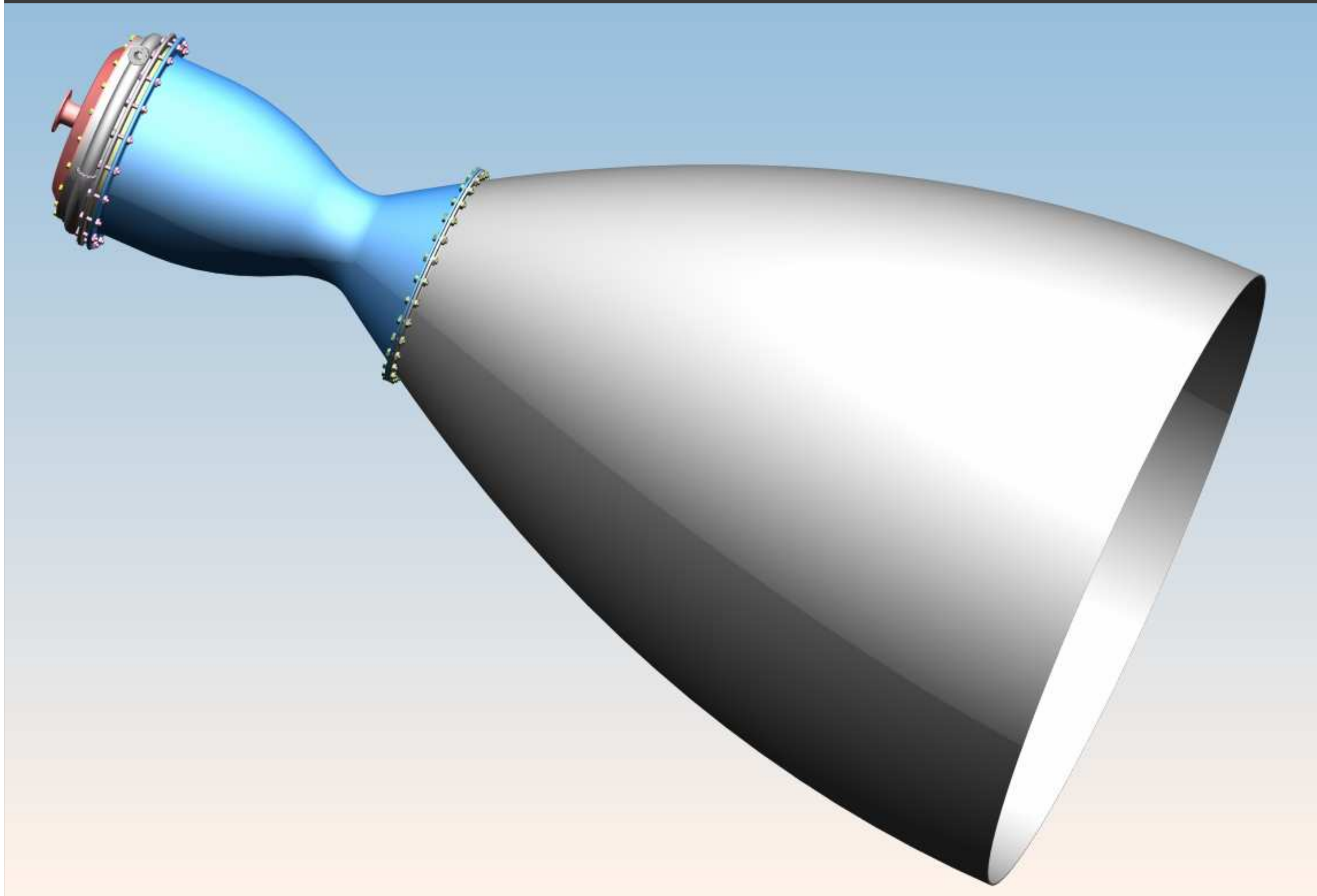
Rocket engine feeding liquid propane and liquid oxygen



Engine parameters

Fuel: Liquid propane(LC_3H_8)

Oxidiser: Liquid oxygen(O_2)

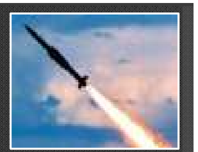
Maximum thrust: 62 kN

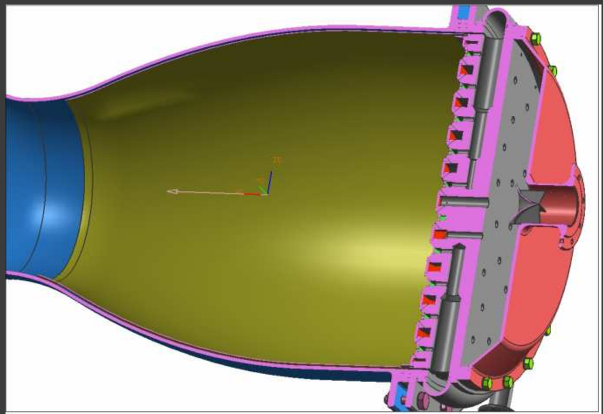
Mass: 107 kg

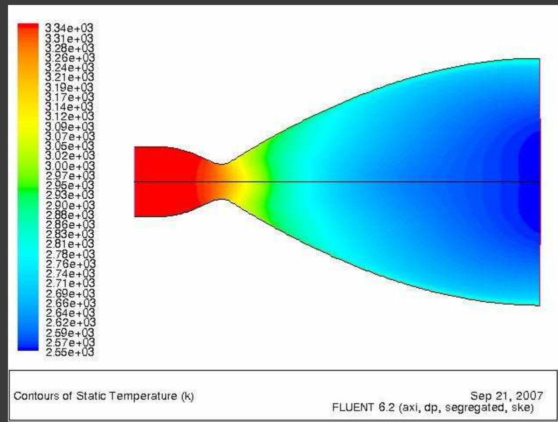
Nozzle area ratio: 49

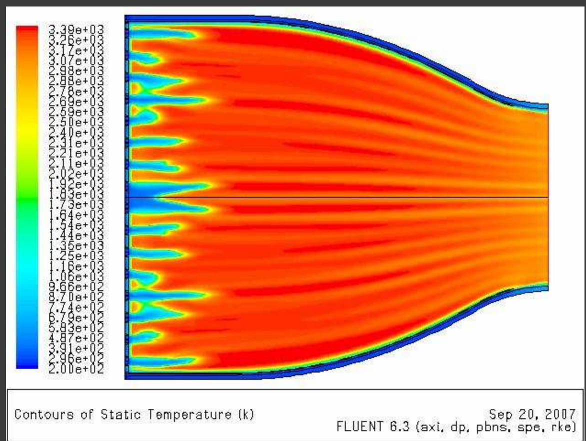
Thrust to weight ratio: 61

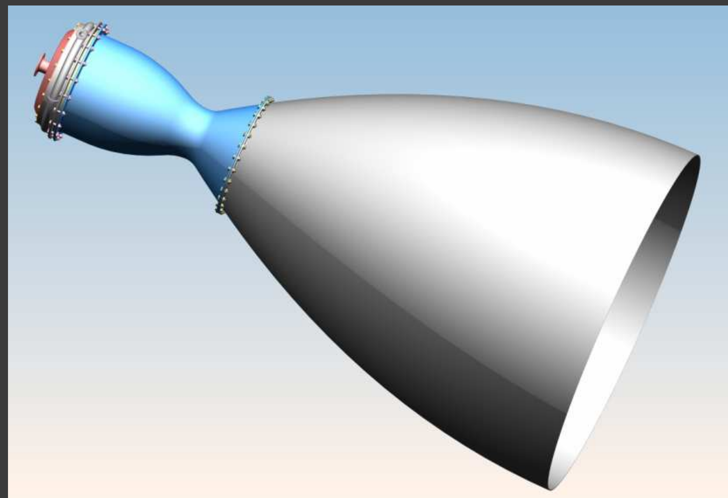
Design and calculations of LOx-LCH_4 rocket's engine











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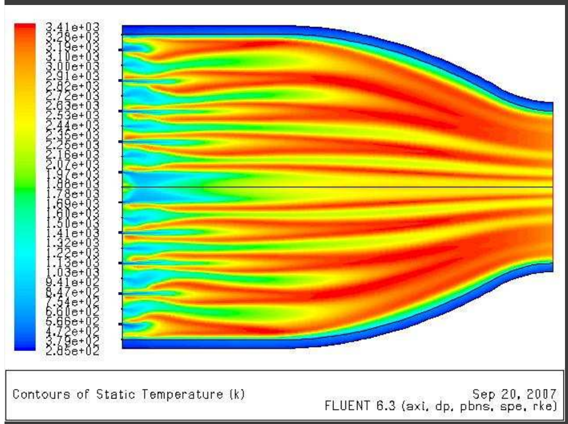
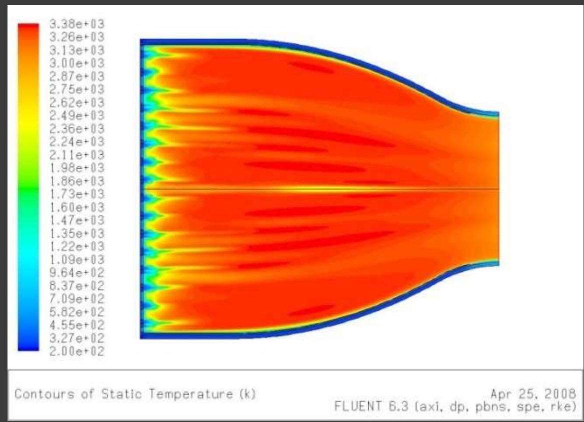
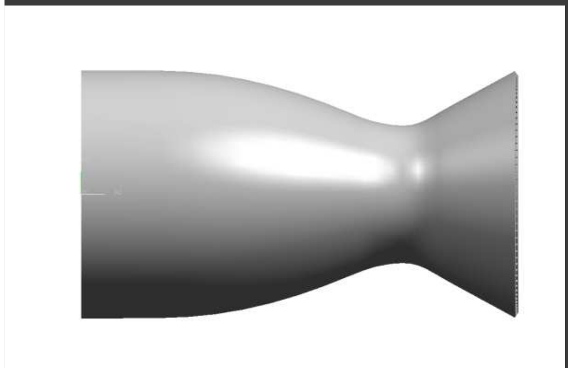
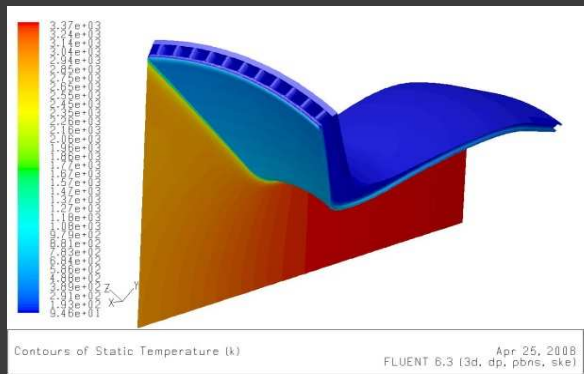


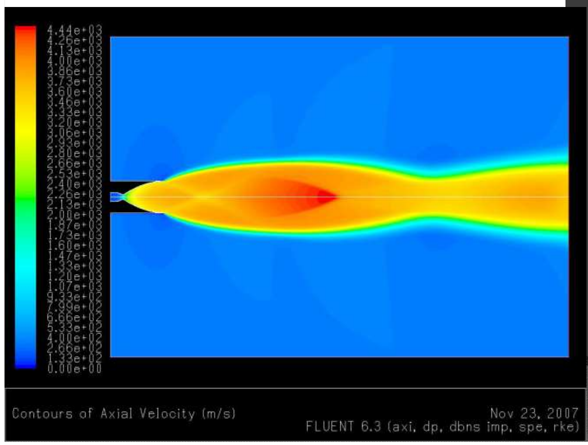


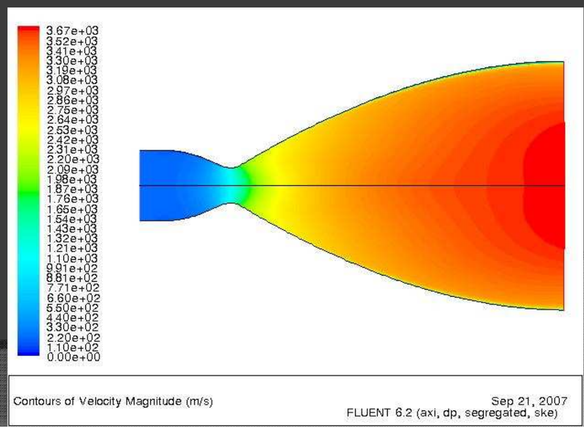
Combustion analysis of ecologically-safe propellants





Cooling systems analysis





Nozzle flow analysis

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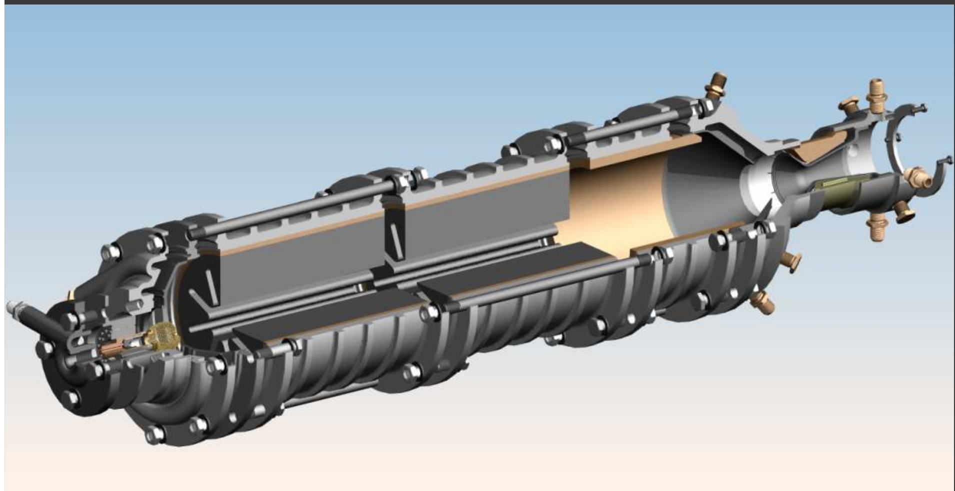
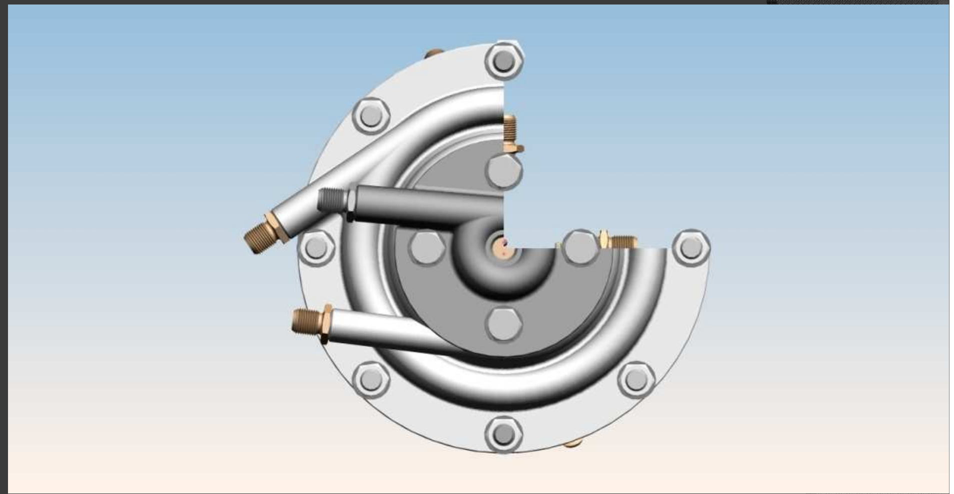
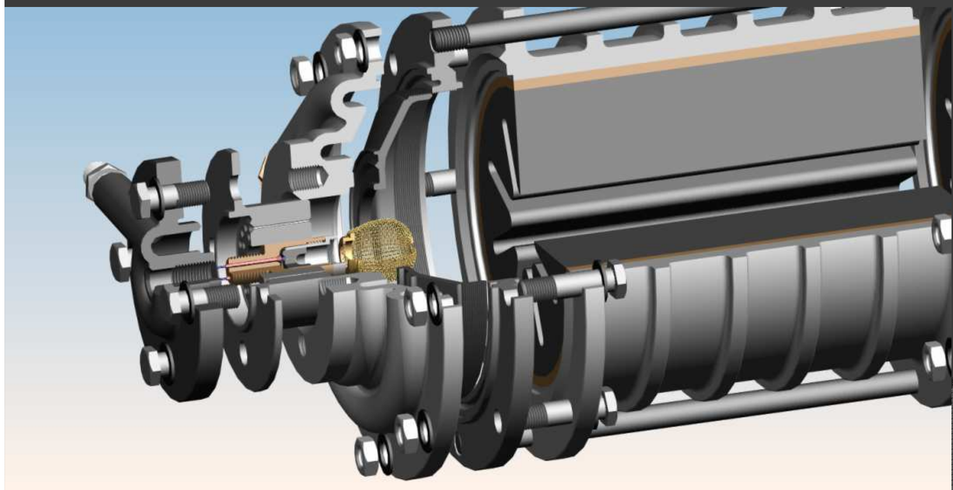
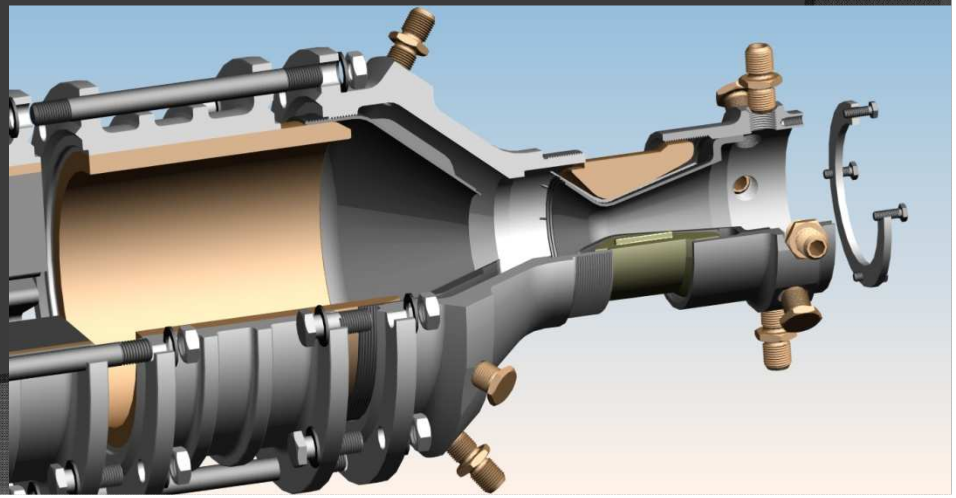
Hybrid rocket motors design









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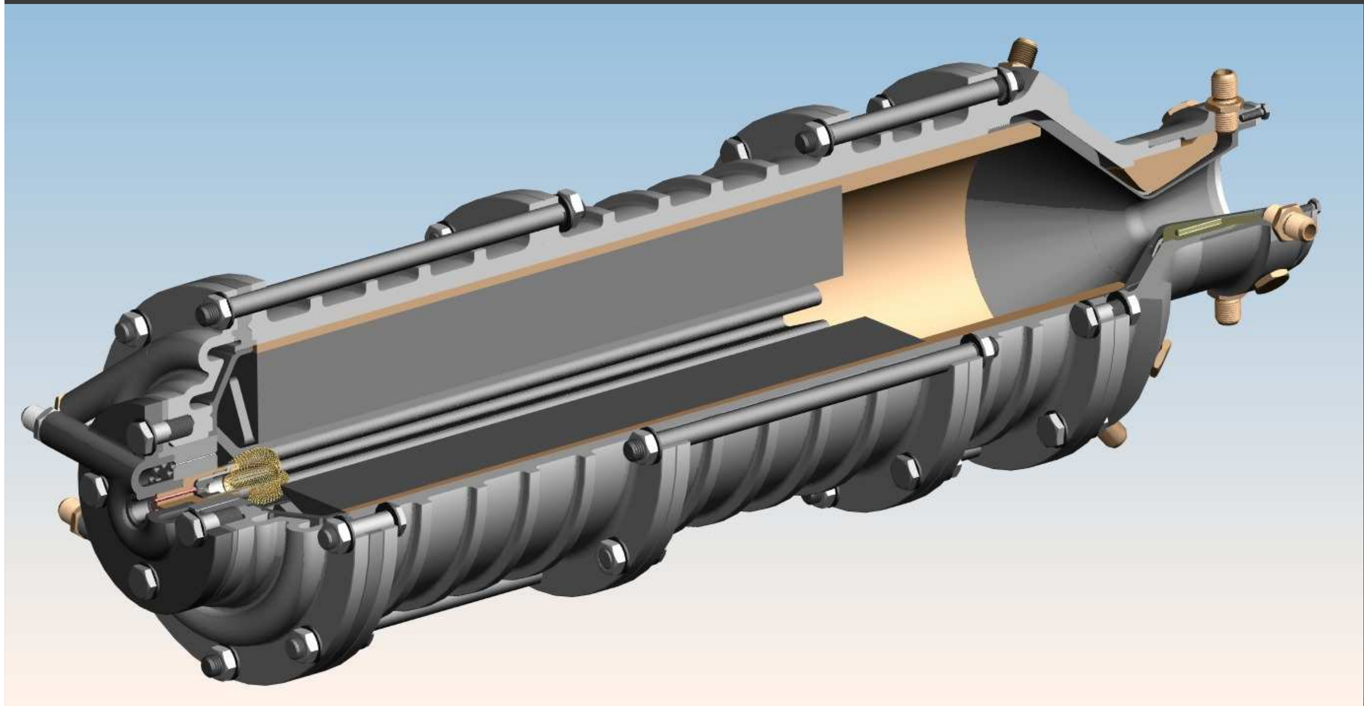
Hybrid rocket motor structure



Motor parameters

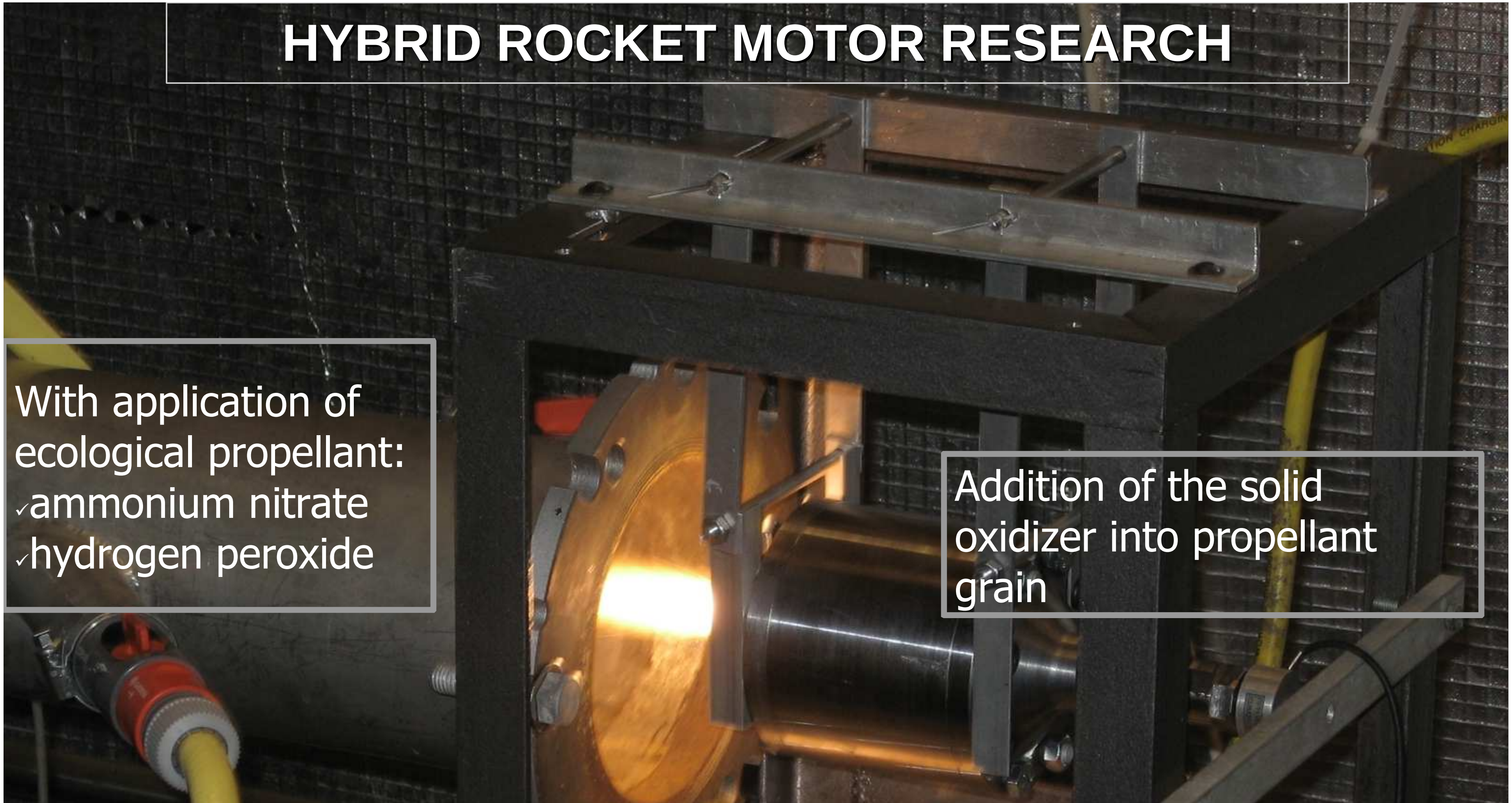
Fuel: HTPB+Al+AN

Oxidiser: H_2O_2

Maximum thrust: 1kN

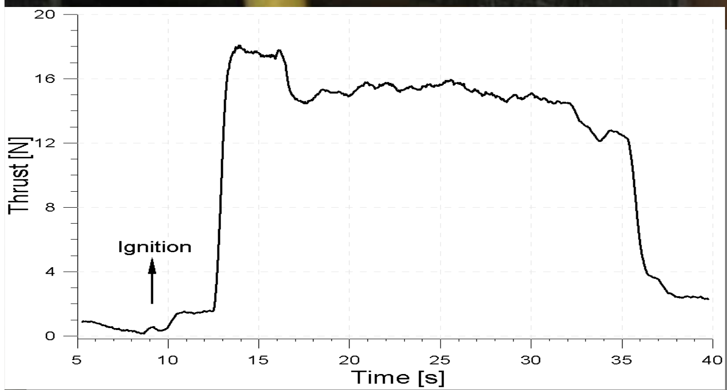
Nozzle area ratio: 6

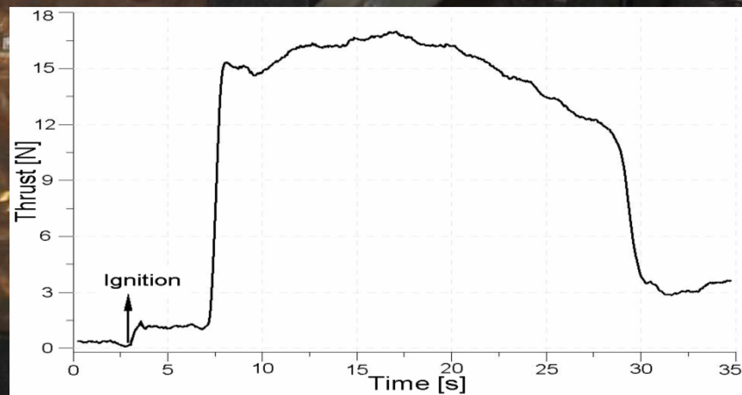
HYBRID ROCKET MOTOR RESEARCH



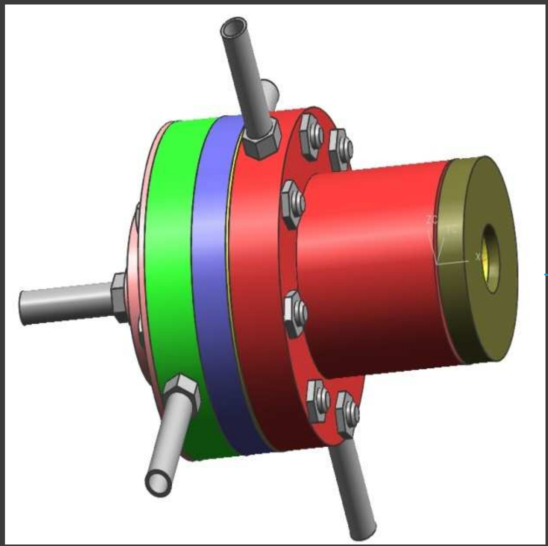
With application of ecological propellant:
- ✓ammonium nitrate
- ✓hydrogen peroxide

Addition of the solid oxidizer into propellant grain



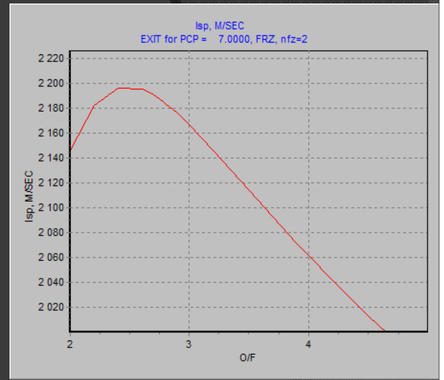


Gas-fueled rocket engines(IoA,WUoT MEiL ITC)

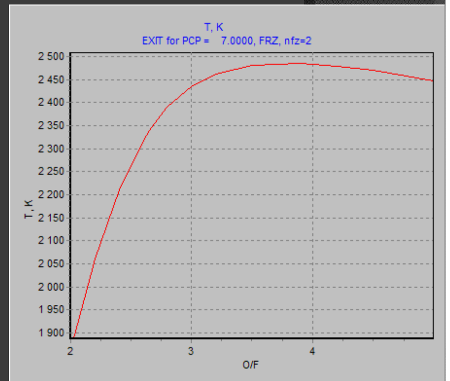


Designing

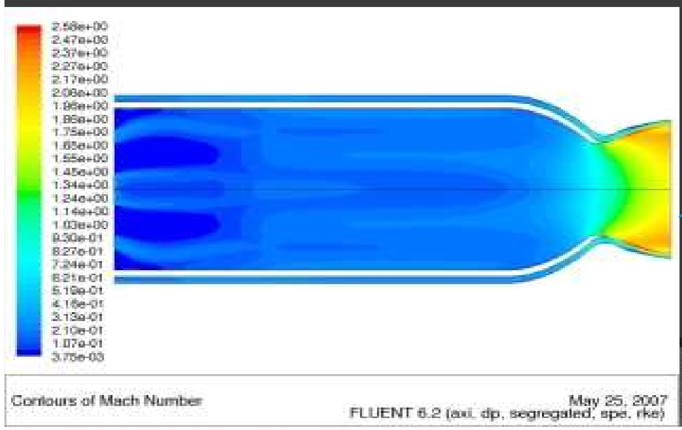
Testing

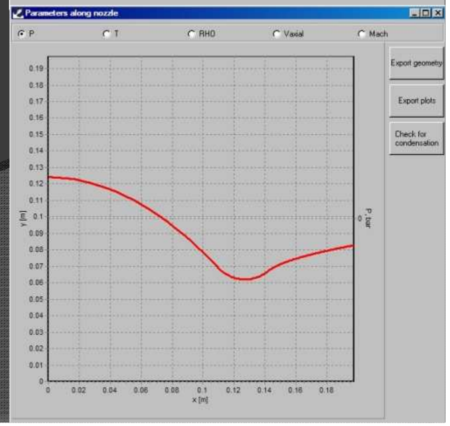


Optimization



Parameter	Chamber	Throat	Exit
p, atm	7	4,1	1
T, K	3304	3170	2861
Mach number	-	1	1,97
A/A_T	4	1	1,935
(ISP), m/s	-	-	2097,0





Computations

“Development of rocket launcher for 100 kg satellites” Low cost access to SPACE

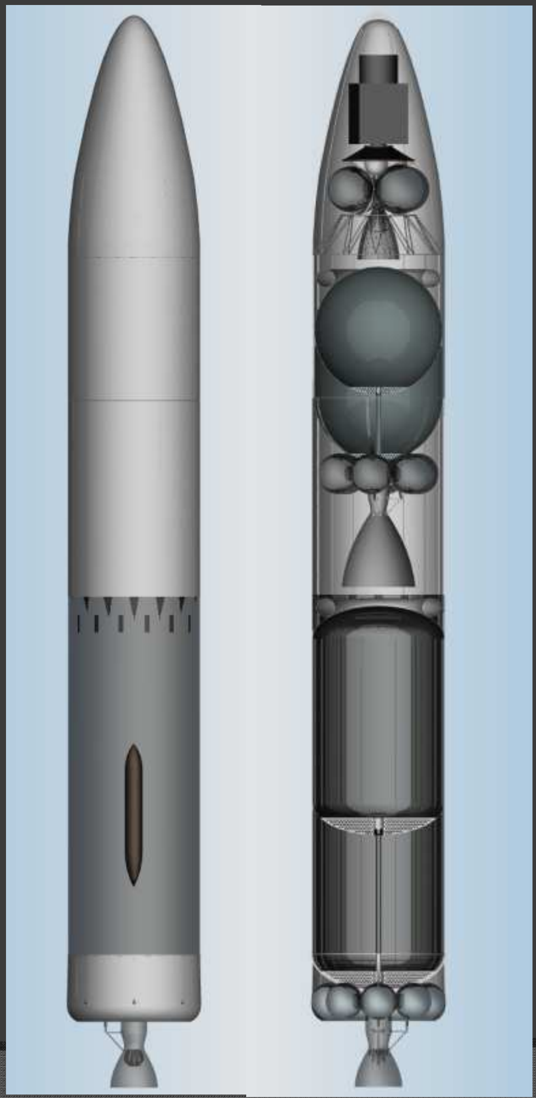
Piotr Wolanski and Jan Kindracki,
Warsaw University of Technology, Warsaw, POLAND

Wojciech Florczuk, Paweł Surmacz, Michał Folusiak, Karol Świderski,
Dominik Kublik, Kamil Sobczak; Institute of Aviation, Warsaw, POLAND

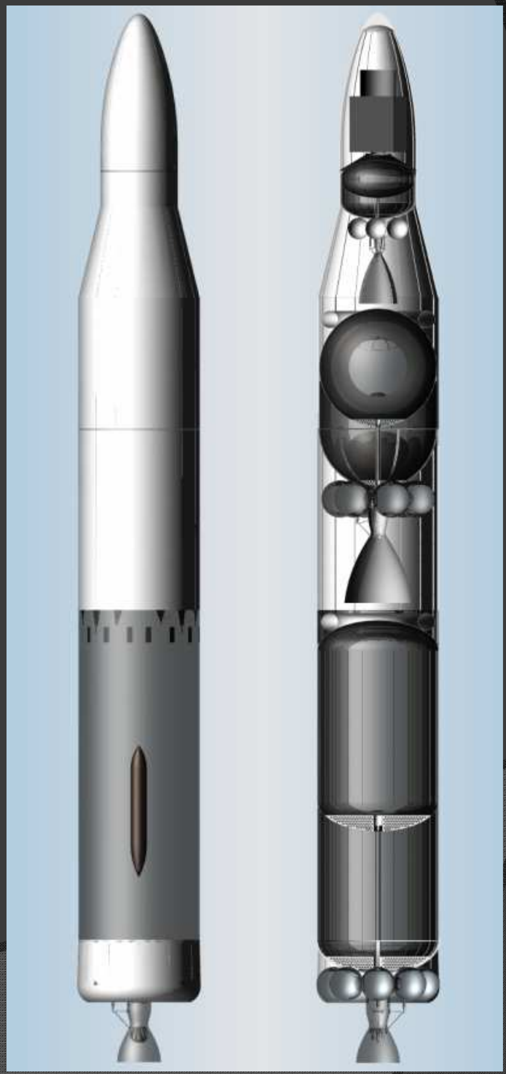
3-STAGE ROCKET GEOMETRY

Two different configurations are considered

First version



Second version



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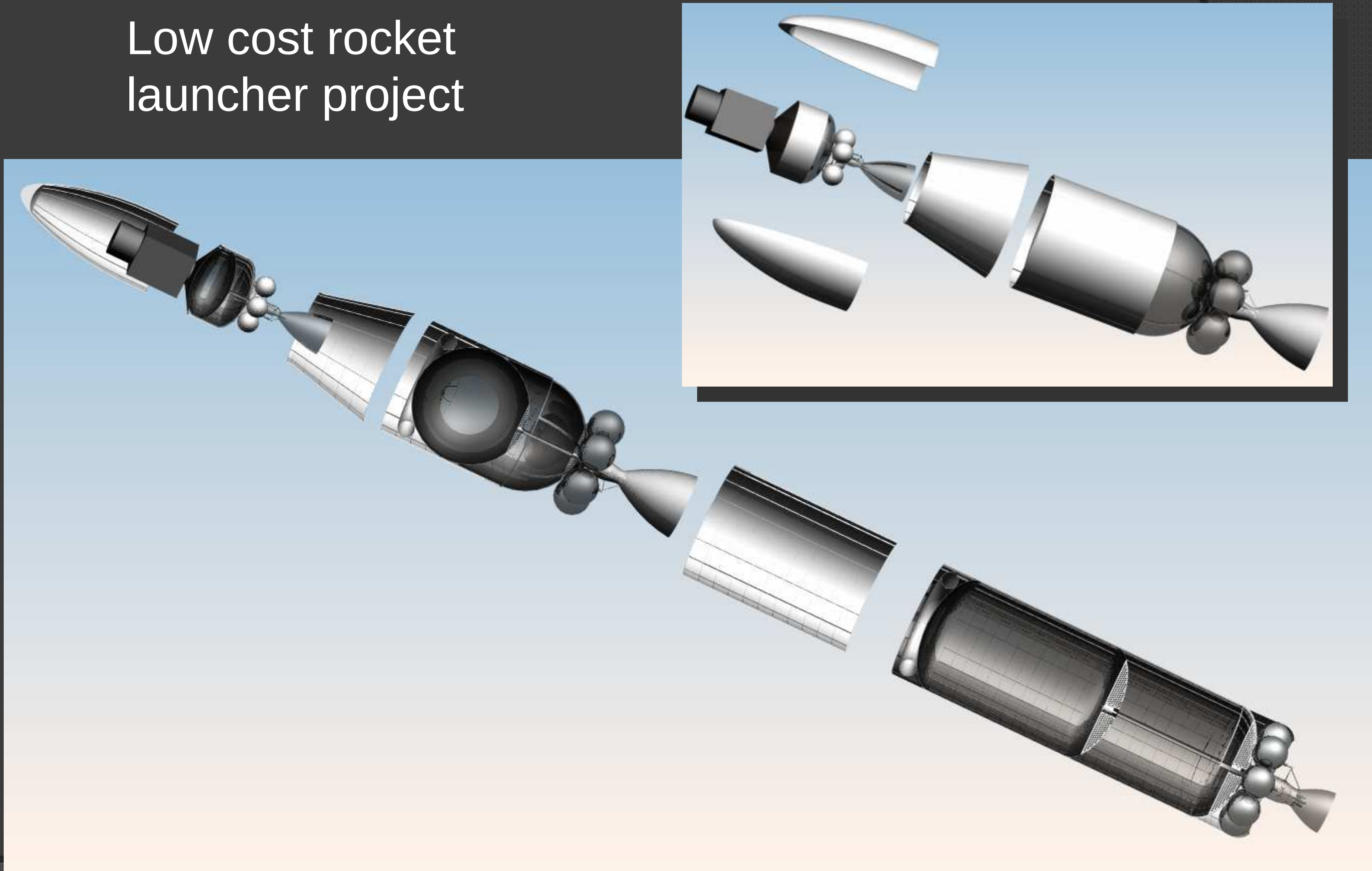
Low cost rocket launcher project



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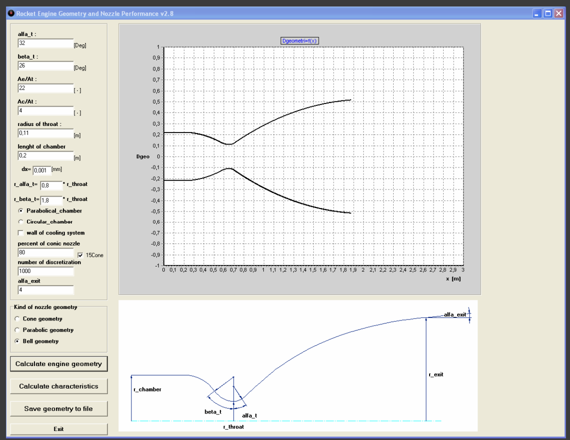
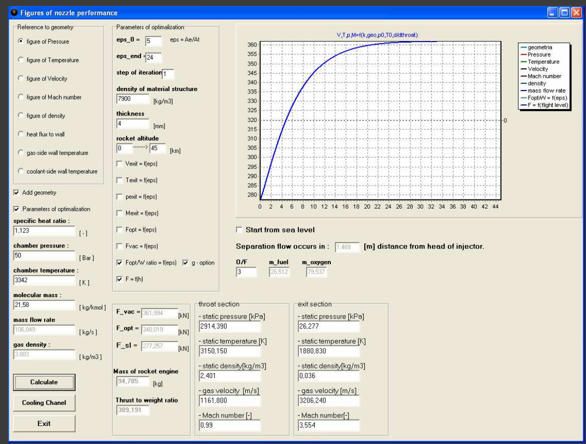
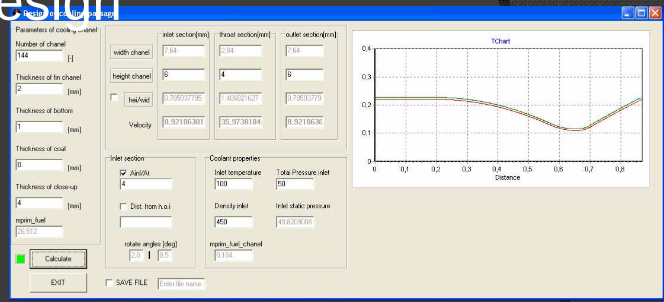
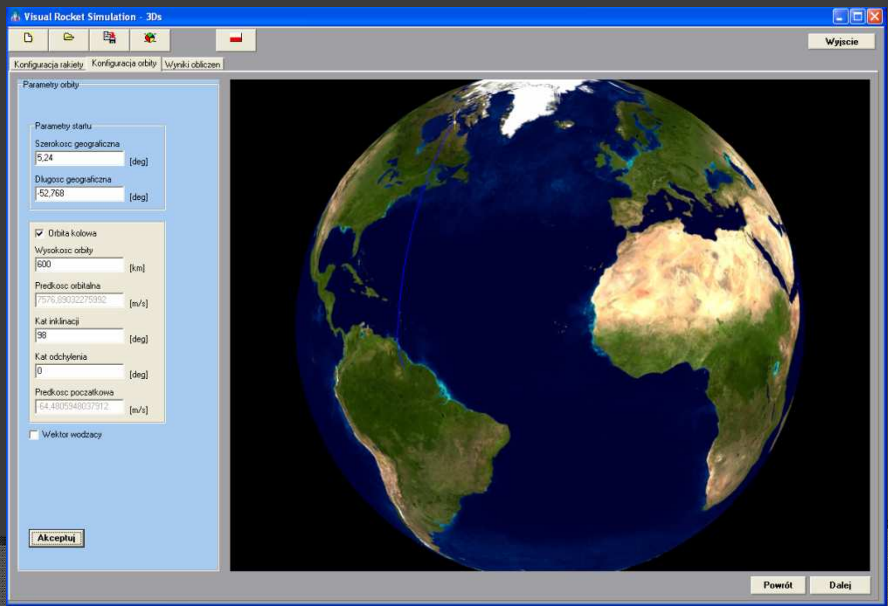


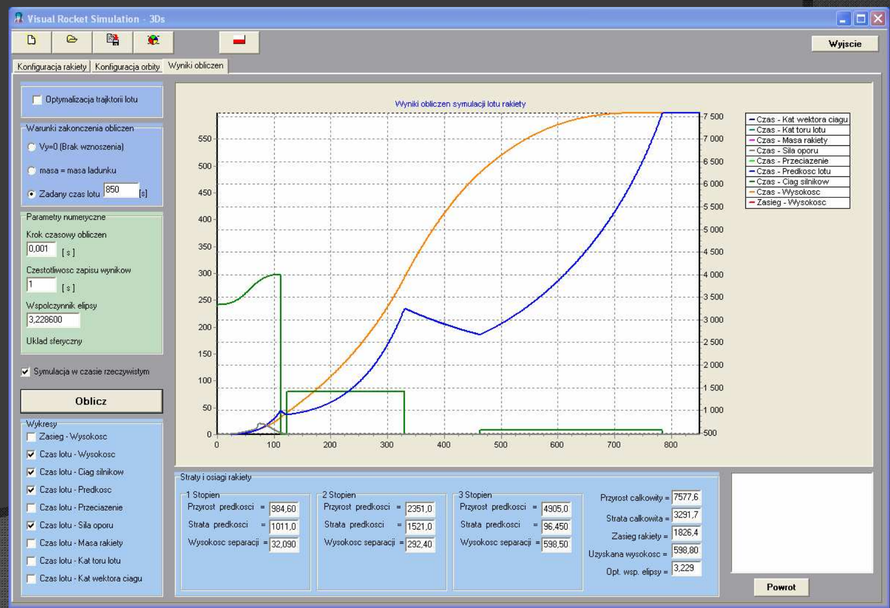


Program to rocket engine design



Flight simulation of rocket launcher



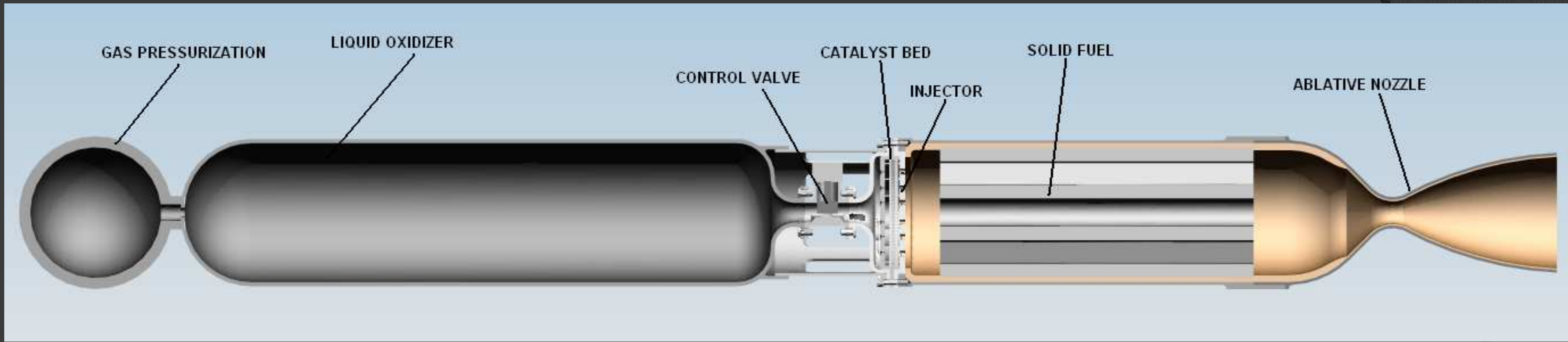


HYBRID ROCKET MOTOR CONCEPT

HYBRID MOTOR TECHNOLOGY RESEARCH AND DEVELOPMENT

Warsaw University of Technology
Institut of Aviation

WHY HYBRID ROCKET MOTOR?



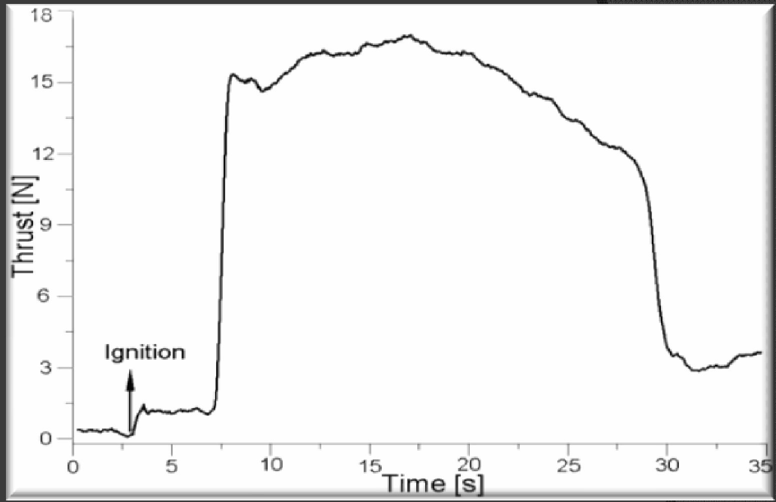
Significant advantages over liquid engines and solid motors

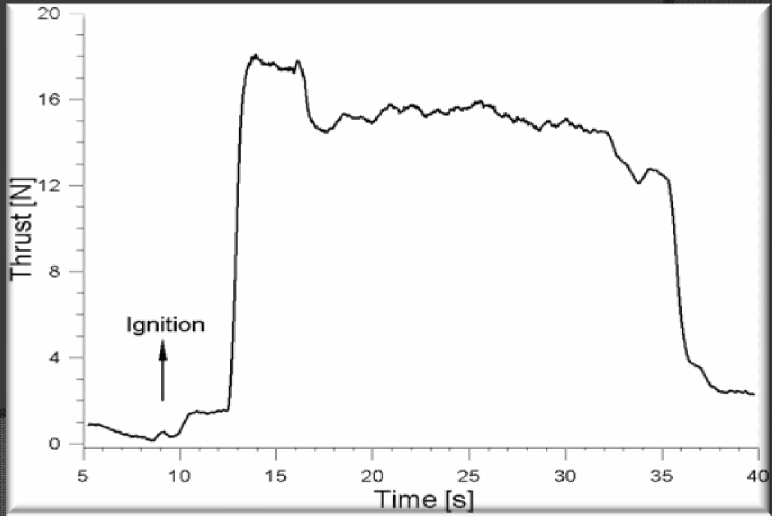
Feature	Compared to	
	Solid	**Liquid**
Safety	Zero TNT equivalent, fuel separated from oxidizer	Reduced fire and explosion hazard
System	Throttling capable, restartable	Simplicity, reduced mass of liquids
Performance	Better specific impulse performance	May be easily improved by additives (aluminum)
Environment	Does not require toxic or environmentaly hazardous materials (ammonium perchlorate, etc.)	Comparable to $RP1/O_2$

EXPERIENCE

Warsaw University of Technology

- Small hybrid rocket motor designed for thrust 18 N
- Utilization of $HTPB/Al/NH_4NO_3$ and GOx
- Measurement of thrust and chamber pressure





HYBRIDS UTILIZATION

AND POTENTIAL CAPABILITIES OF APPLICATION

In general: HTPB + N_2O

- Space tourism

- Maneuver and orbital transfer vehicles

- Reusable spacecrafts

- Lunar and planet landers

PROPELLANT

HTPB (Hydroxyl-Terminated Polybutadiene)

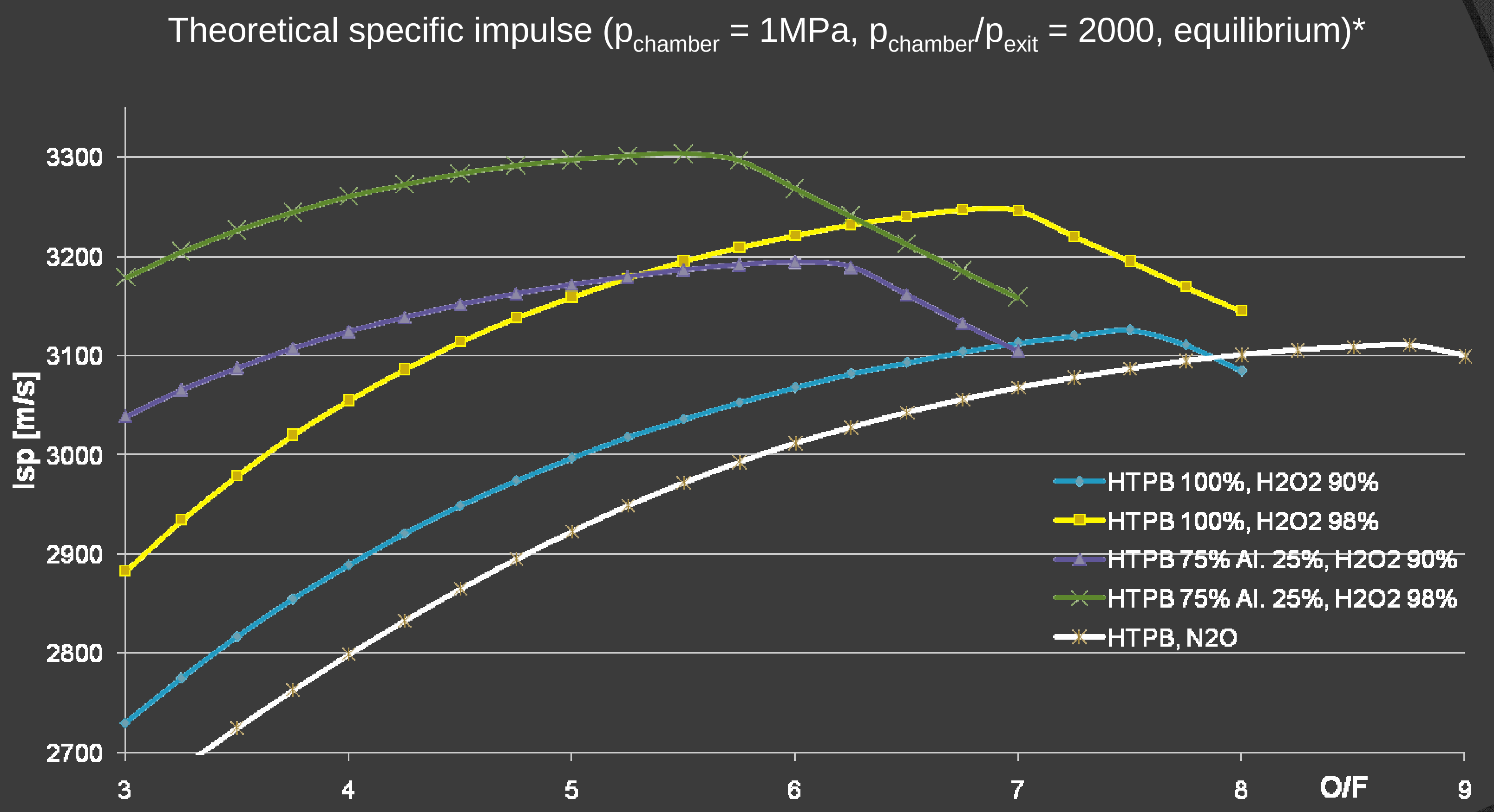
- Non-toxic, storable, non-explosive
- Low-cost,
- Excellent mechanical properties

H_2O_2

- Non-toxic, storable
- Might be low-cost
- High density
- Monopropellant characteristics

- BETTER PERFORMANCE THAN HTPB + N_2O
- SELF-IGNITION (CATALYST BED APPLIED)

PERFORMANCE



* CEA code

OUR GOAL

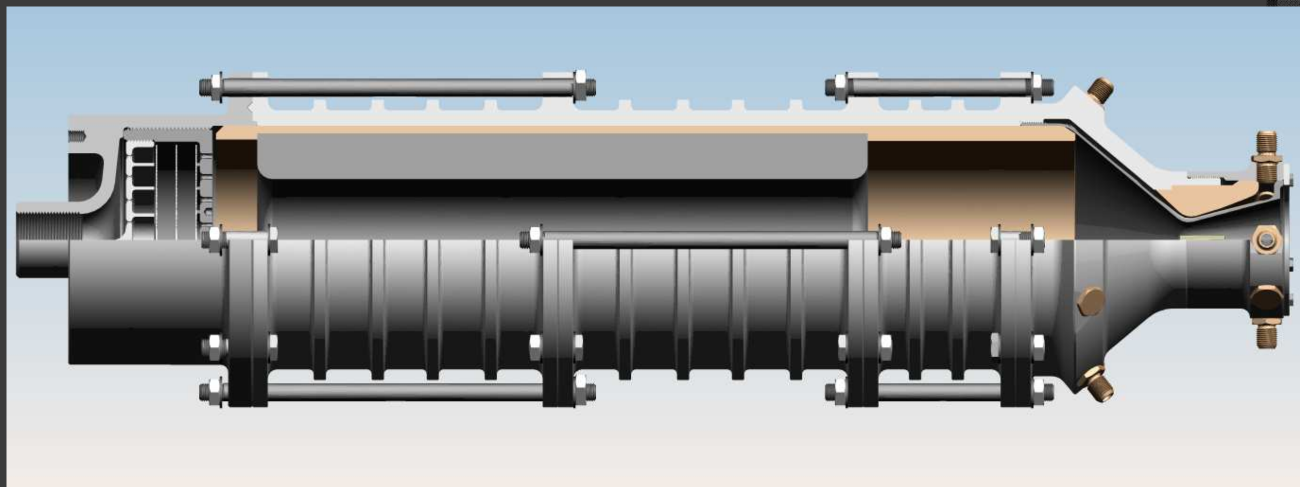
- Hybrid motor research and technology development
  - ✓ Simple
  - ✓ Safe
  - ✓ Environmentally-friendly

- Design and testing of small hybrid rocket motors

  Application:
  - ✓ small and medium-size satellites – maneuver and orbital transfer
  - ✓ landers

ESSENTIAL RESEARCH
AND DEVELOPMENT

- Catalytic decomposition of hydrogen peroxide
- Fuel regression rate
- Combustion stability – flame stabilisation devices
- Combustion efficiency
- Ignition delay



Gas Resistojet Thruster for Medium Size Satellite Attitude Control System

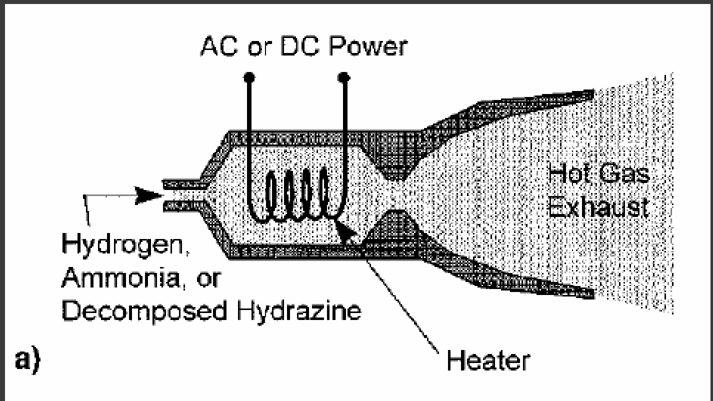
Project supported by PECS

Arkadiusz Kobiera, Piotr Wolański

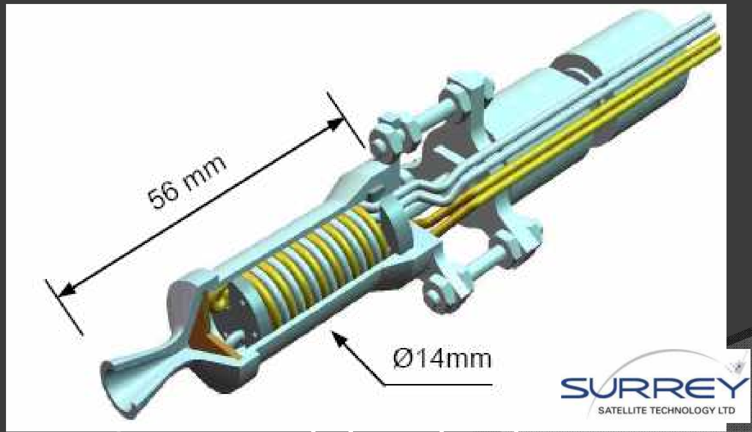
Warsaw University of Technology

Goal of the project

The main goal of the project is investigation of possibilities of use supercapasitors as a power source for resistojet thruster applied on a medium size satellite.



General work principle



Commercial resistojet

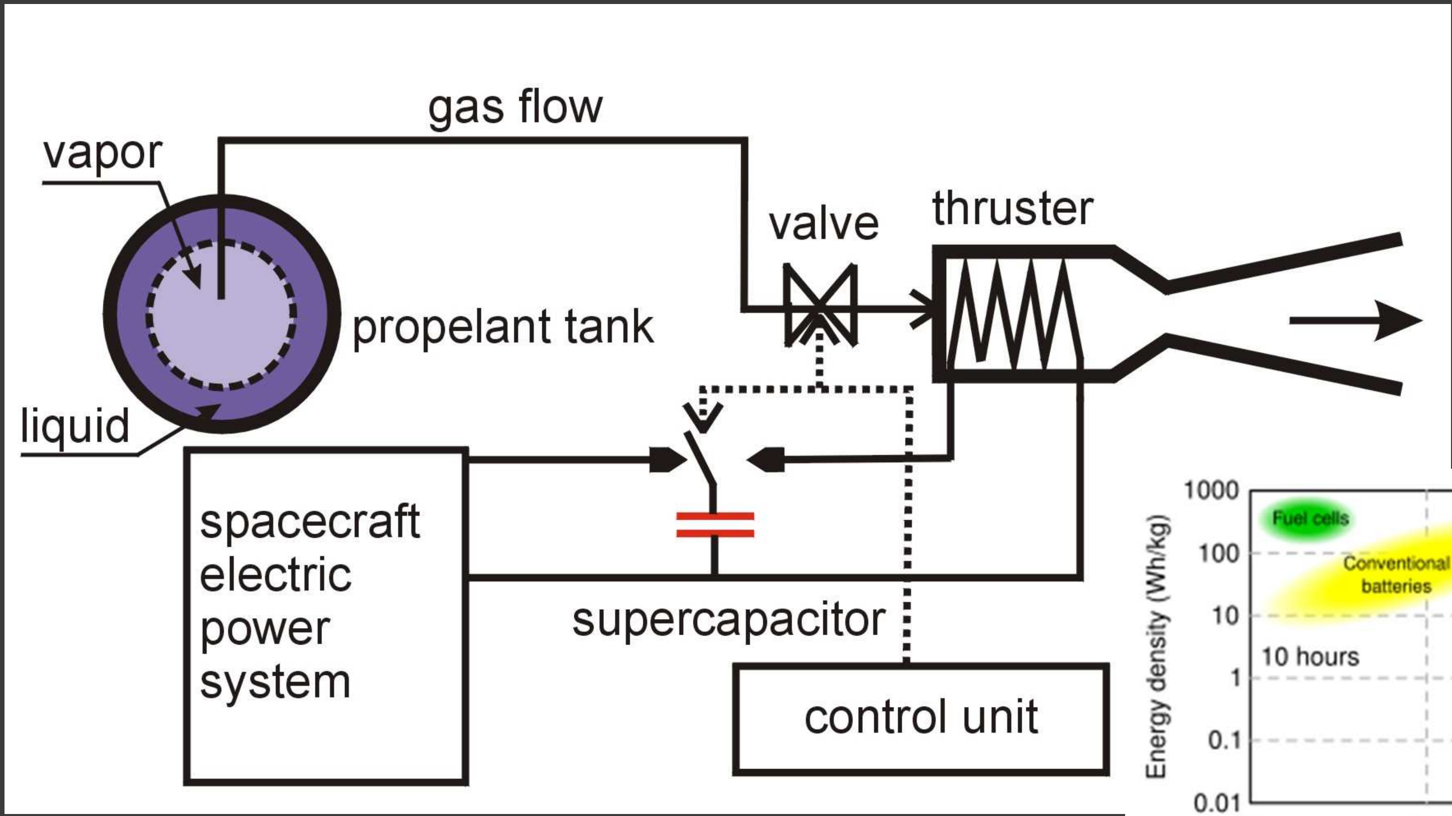
Main problems

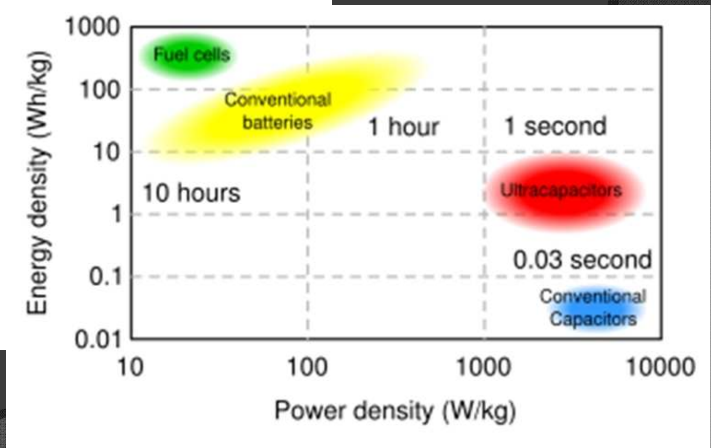
The main problems which have to be solved for succesful use of the resistojet are:

- **material issues – the propellant degrades the material of the heater at high temperatures,**
- **decreased specific impulse due to large heat losses and viscous friction (small size of the heater and the nozzle, low Reynolds number flow),**
- **thermal inertia of the heater, necessity of use of high power sources.**

Proposed Solution

USE OF THE SUPERCAPACITORS TO OVERCOME THE POWER SUPPLY PROBLEMS AND THE THERMAL INERTIA OF THE SYSTEM



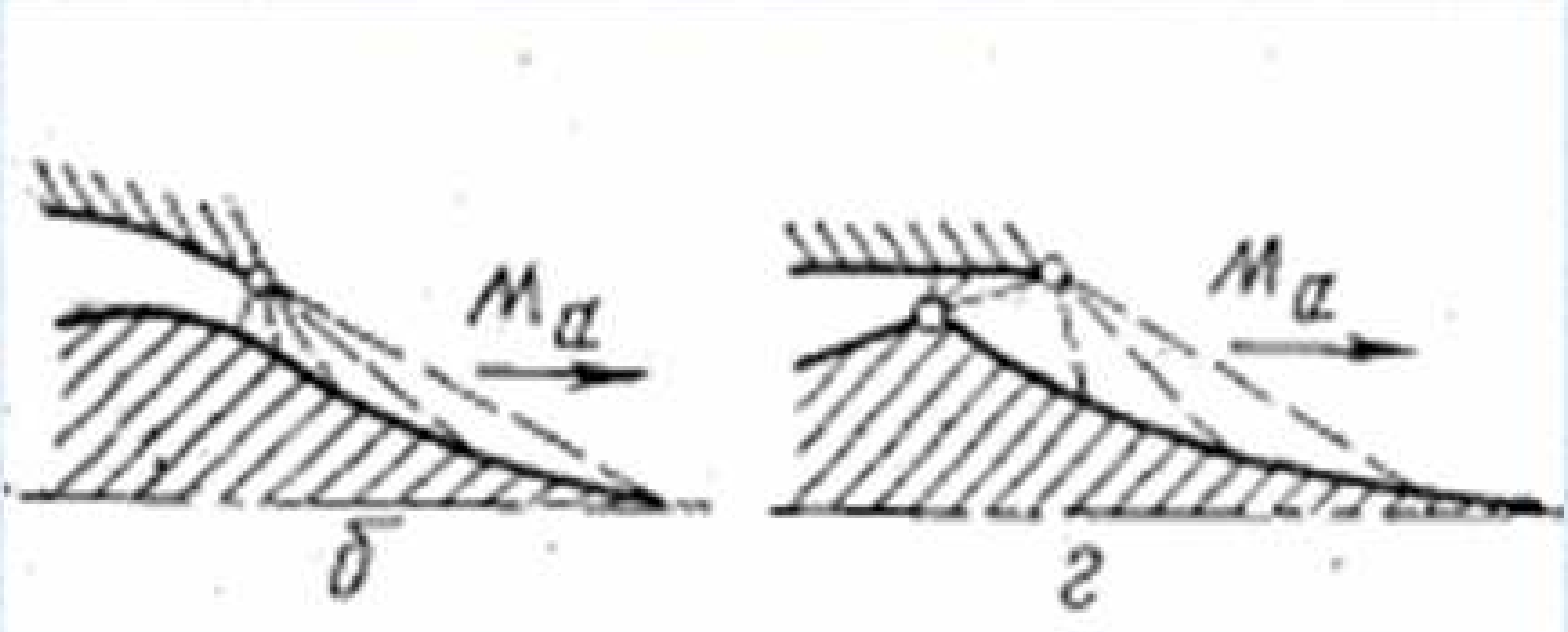


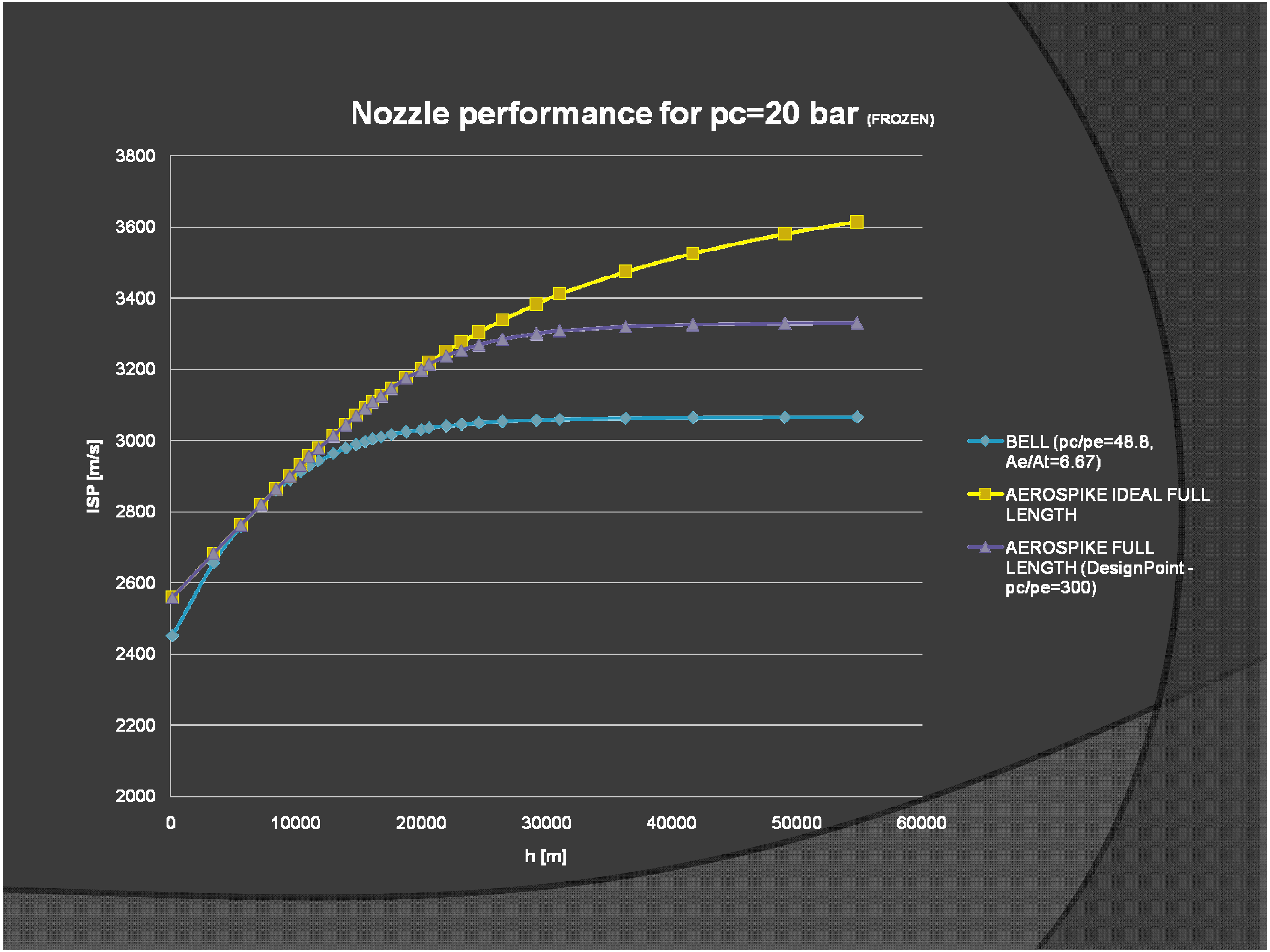
Project details

Vacuum tank prepared for test of the resisitojet

- Timing: 2009--2011
- Bugdet: ~ 300 k€

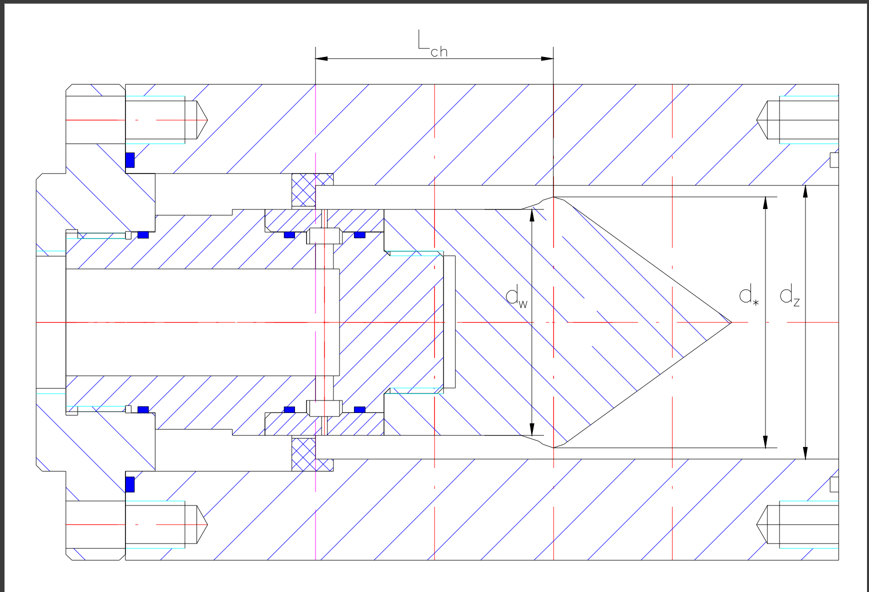
Aerospike Nozzle





Nozzle performance for pc=20 bar (FROZEN)
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
ISP [m/s]
0
10000
20000
30000
40000
50000
60000
h [m]
BELL (pc/pe=48.8, Ae/At=6.67)
AEROSPIKE IDEAL FULL LENGTH
AEROSPIKE FULL LENGTH (DesignPoint - pc/pe=300)

ROTATING DETONATION – ROCKET ENGINE



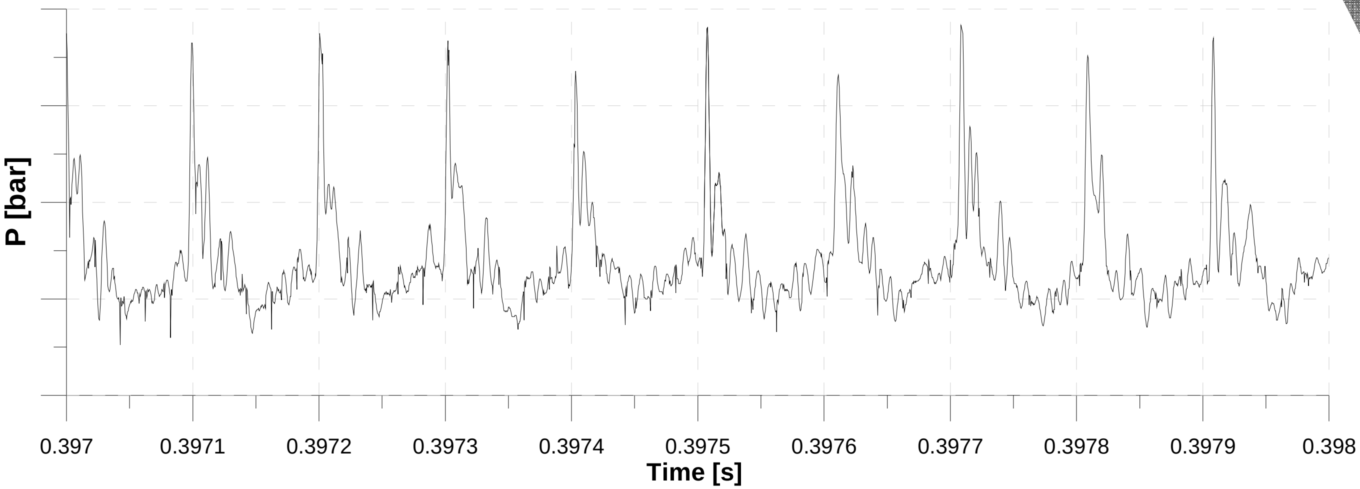
d_w – inner diameter of the channel,

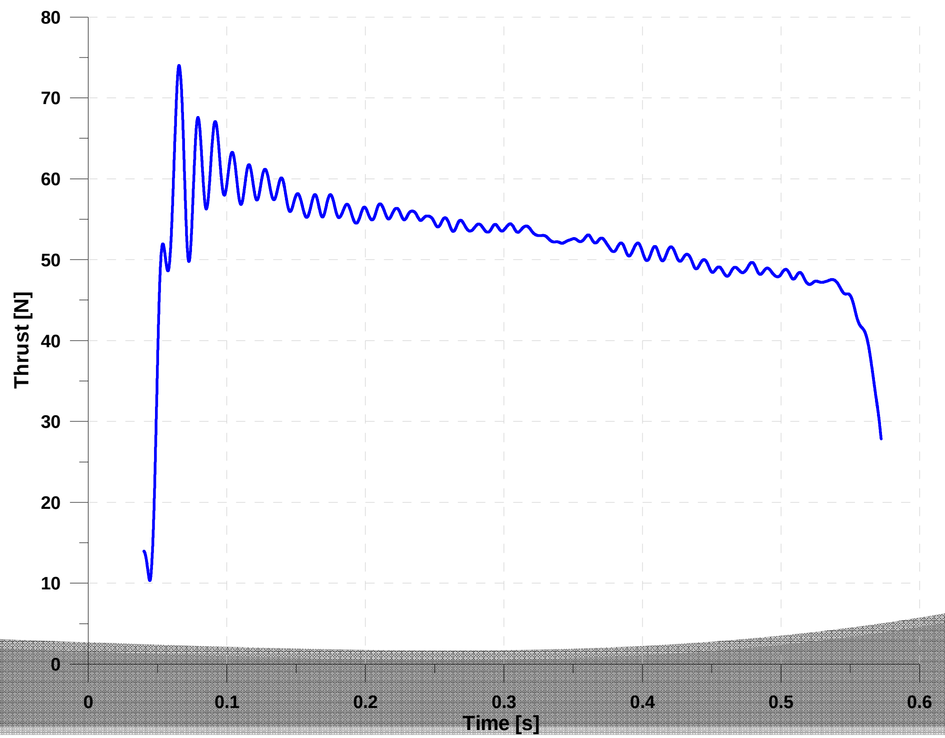
d_z – outer diameter of the channel

d_* - throat diameter

L_{ch} – channel length

THRUST and PRESSURE vs TIME





Pressure vs time

Methane-Oxygene mixture, initial conditions p=0,05bar; nozzle 77deg

Thank You for your attention !