Hybrid rocket systems for advanced low-cost hypersonic flight test platforms

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TECHNOLOGY FOR PROPULSION AND INNOVATION

A University of Padua Spin-off

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T4i is a spin-off of Padua University born in 2014 to transfer into the market technologies developed within university of Padua since 2006

Main research areas:

ELECTRIC PROPULSION

Development of space thrusters based on helicon source technology

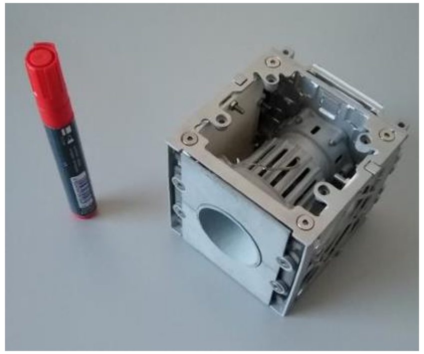
HYBRID PROPULSION

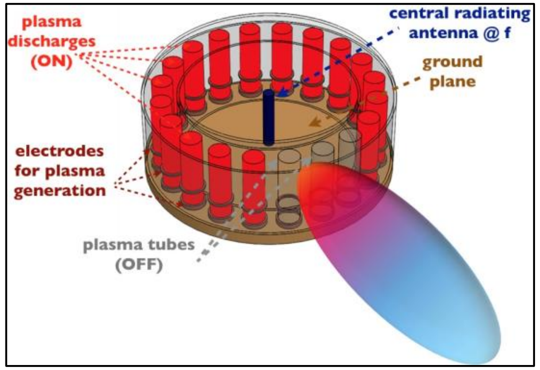
Development of hybrid rockets for aeronautic and space applications

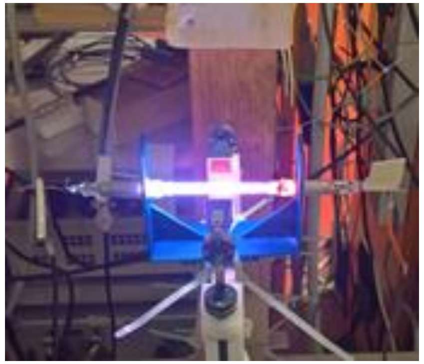
TELECOMMUNICATION

Design development and testing of plasma based antennas

SUPPORT TO AEROSPACE INDUSTRIES

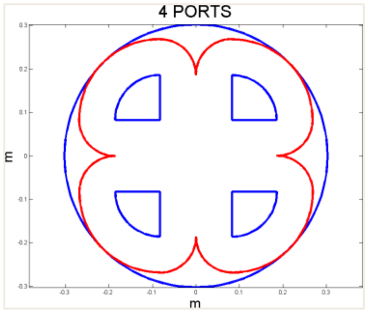




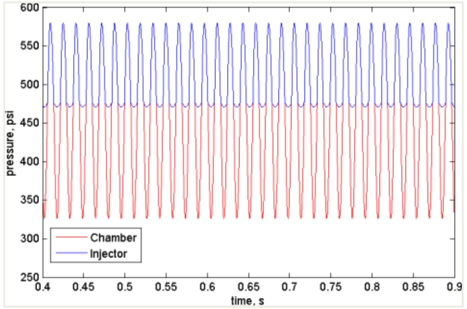


0D / 1D Analysis

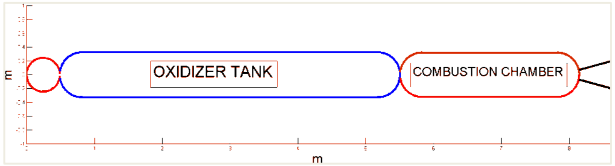
Design



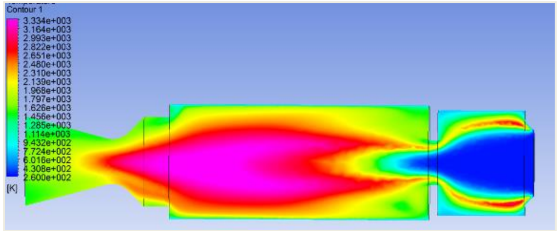
Transient behaviour



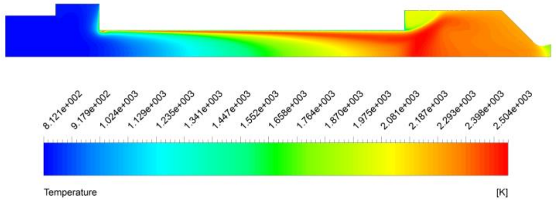
Optimization



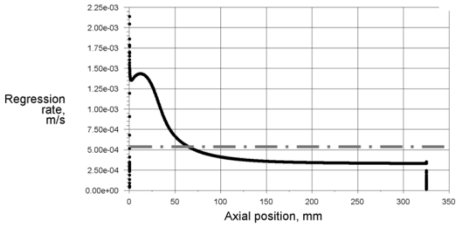
Mixing Devices



Internal ballistic analysis



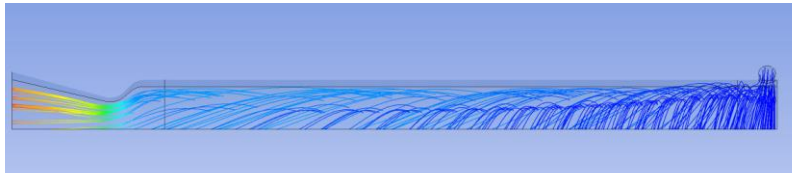
Self calculation of regression rate



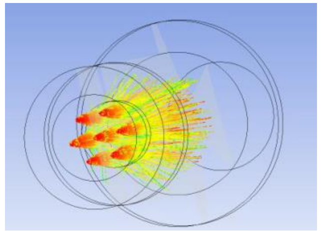
Commercial CFD and Customization

2D / 3D steady state simulations

Vortex Injection



Liquid Injection



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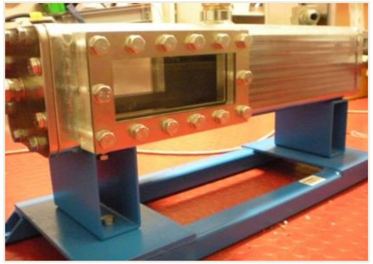
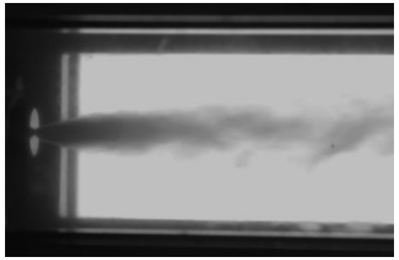
Experimental Skills

Cold testing

Injection characterization test bed

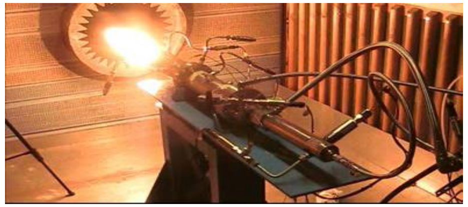




Lab-scale testing

Characterization and optimization of several configurations:

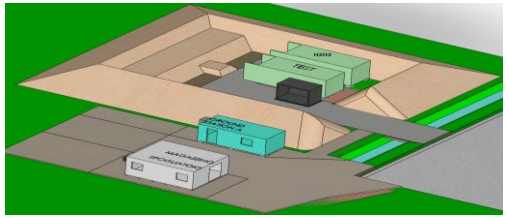
- 0.1-1 kN class, GOX-plastic
- 1-3 kN class, N2O-plastic
- 0.1-1 kN class HTP-plastic



Increased-scale testing

30 kN N2O-paraffin

10 kN HTP-paraffin



Open air testing

Minimum footprint equipment

Existing Hypersonic Flight Test Bed

- Flight test beds are an important complementary asset to ground test bed
- Flight test bed are able to provide a unique set of tests
- Capability of testing system and subsystems
- New player into the market

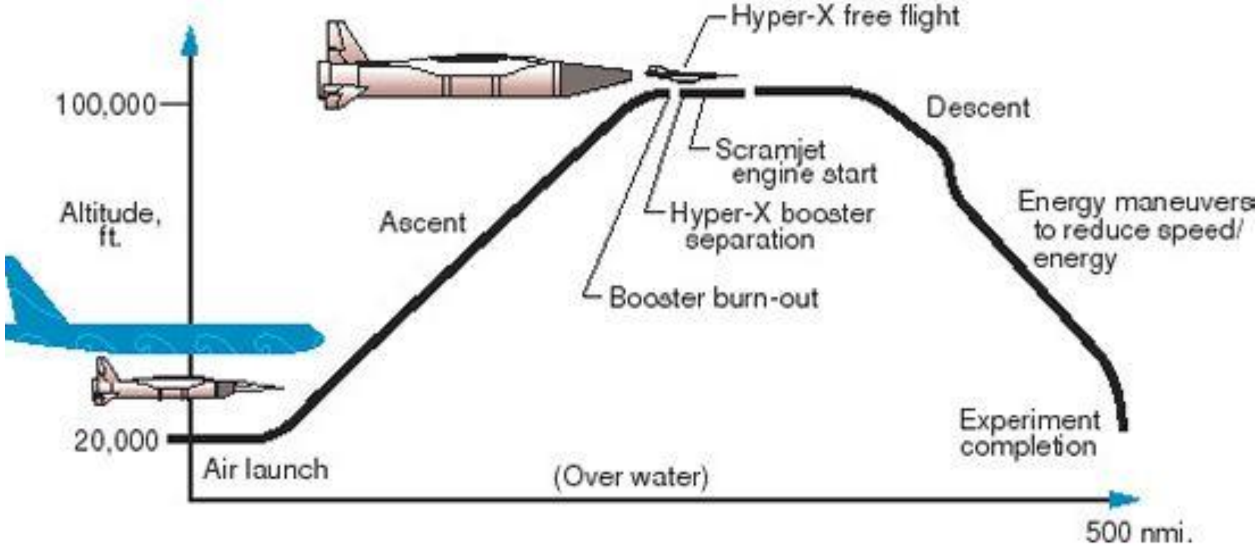
Go Launcher

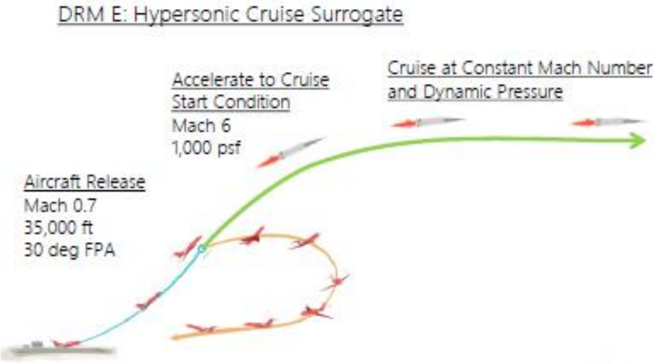
NASA - Phoenix Missile Hypersonic Testbed

X51 wave rider

X43 test bed

Existing Hypersonic Flight Test Bed





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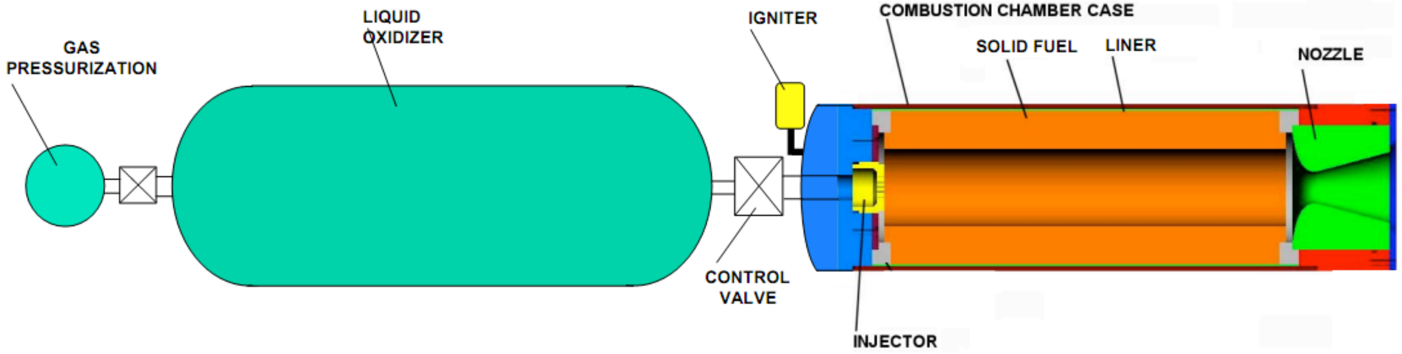
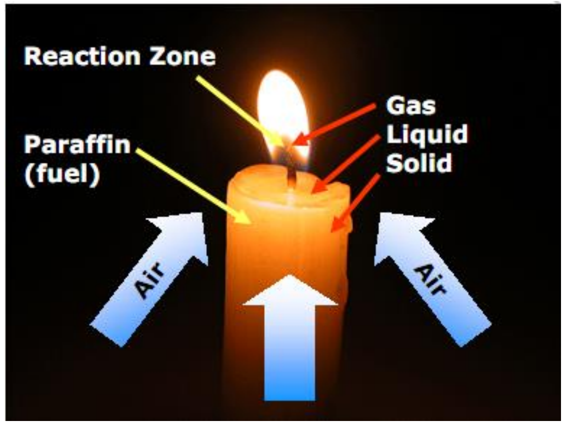
Fuel and oxidizer are physically separated

One of the two is in solid phase

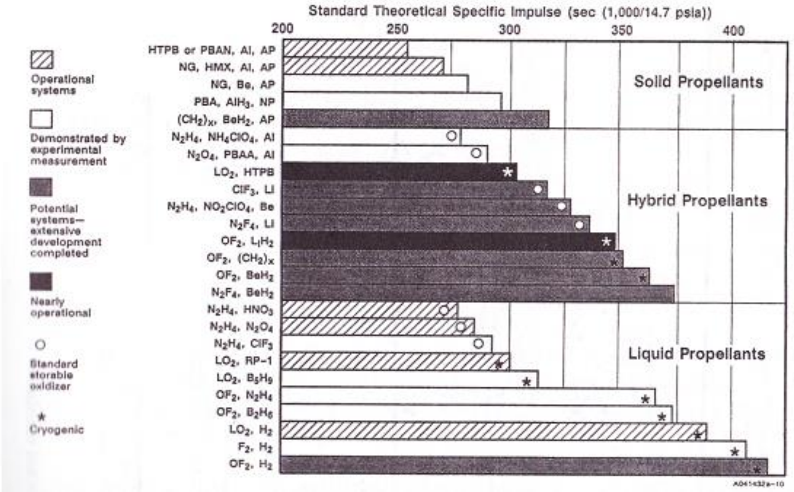
(generally the fuel) -> inert grain



Diffusive flame



Theoretical specific impulse



Hybrid Advantages

Compared to	Solids	Liquids
Simplicity	*- Chemically simpler - Tolerant to processing errors*	*- Mechanically simpler - Tolerant to fabrication errors*
Safety	*- Reduced chemical explosion hazard - Thrust termination and abort possibility*	*- Reduced fire hazard - Less prone to hard starts*
Performance Related	*- Better Isp performance - Throttling/restart capability*	*- Higher fuel density - Easy inclusion of solid performance additives (Al, Be)*
Other	*- Reduced environmental impact*	*- Reduced number and mass of liquids*
Cost	*- Reduced development costs are expected - Reduced recurring costs are expected*	

- Tipping point technology:
  - -> small investment
  - -> substantial consequences
- Liquids and solids:
  - -> mature propulsion technologies
  - -> only small incremental improvements
  - -> Need of heavy infrastructures

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Advantage of Hybrid Propulsion

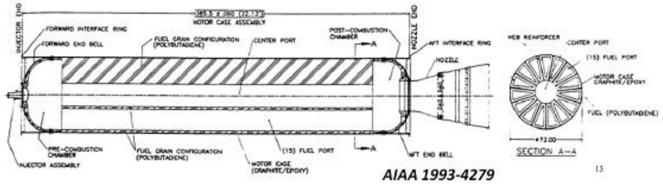
Hybrid Propulsion offers several advantage respect to solid propulsion

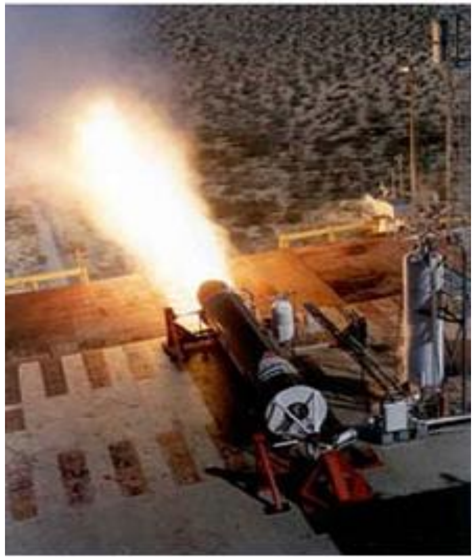
- **Higher safety due to separation between oxidizer and fuel**
- Capability of turning on and off the motor and to perform real time variation of the thrust profile.
- **Reduced manufacturing and management costs**
- **Green propellant**
- **Reusability**
- **Easy integration** into aircraft

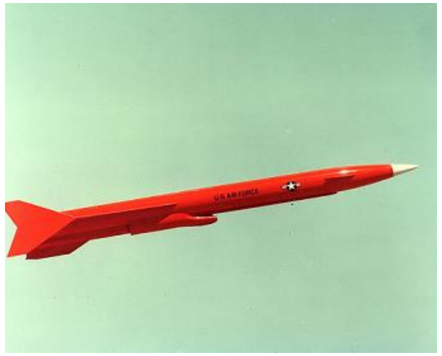
SpaceShipOne

- Ansari X-Prize winner (2004)
- First private suborbital manned spacecraft

In the early 1990's AMROC was founded to develop commercial hybrids. They tested large 250klbs thrust motors. Venture failed in the late 90's.







Teledyne Ryan **AQM-81 Firebolt** target Drone

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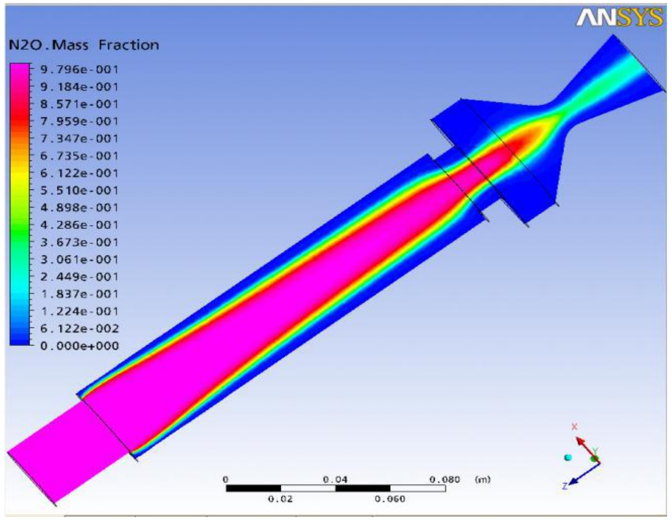
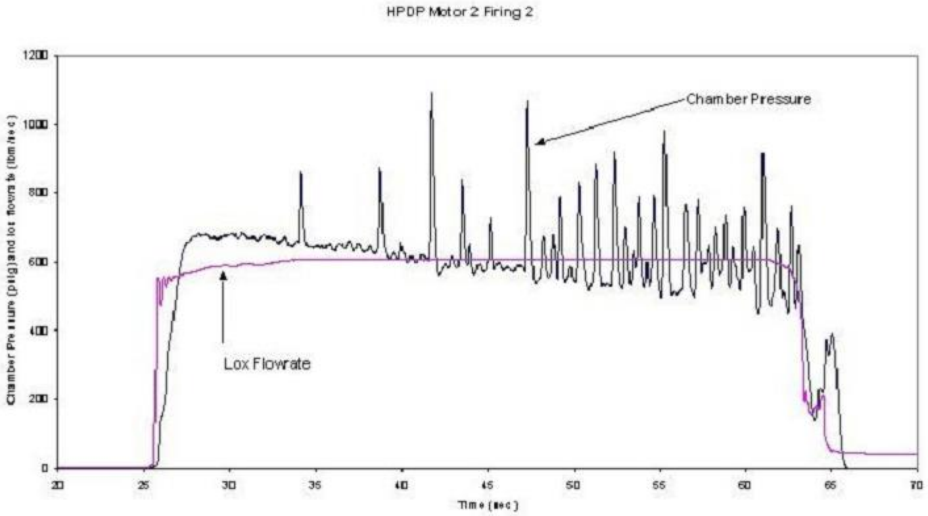
Classical Hybrid Issues

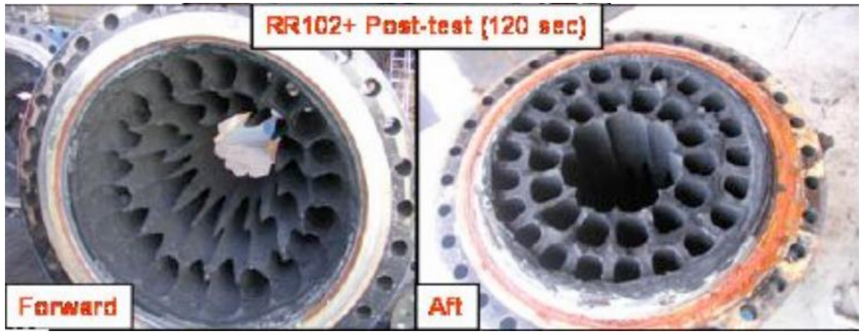
Low efficiency



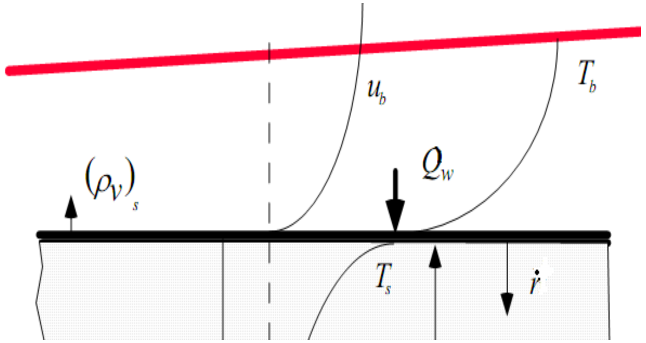
Instabilities



Residuals



Low regression rate



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Hybrid rocket @University of Padua: RATO Booster

Hybrid motor development activities:

Hybrid booster for Rocket Assisted Take-Off (RATO) 20kN peak thrust, 3.5 sec burning time hybrid rocket motor



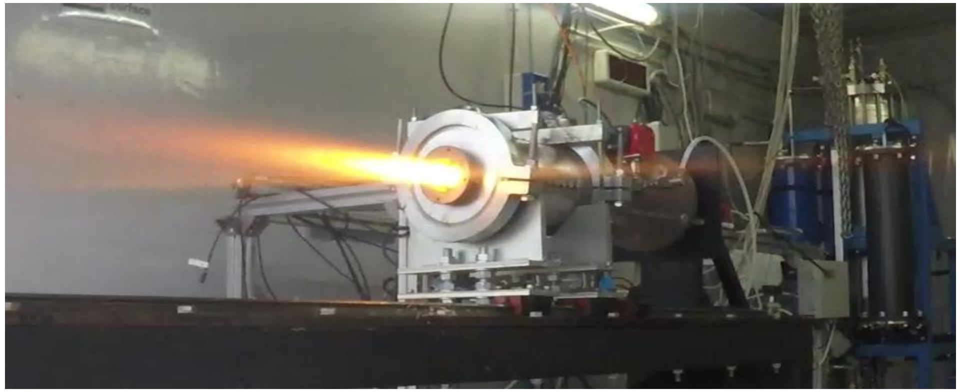


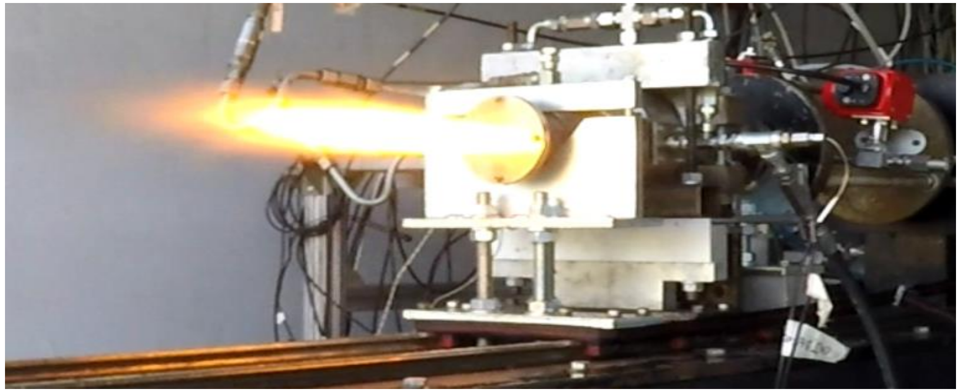

- **Sep. 2006**: Start Feasibility phase
- **July 2007**: Cold test
- **July-Sept. 2008**: sub-scale and modeling
- **Dec. 2008-March 2009**: full-scale testing on test stand and modeling
- **April 2009-July 2009**: 1̂ flight prototype (steel-aluminum) test stand and flight test
- **End of 2010**: 2̂ flight prototype (carbon fiber-aluminum) test stand and flight test

Hybrid rocket @University of Padua/T4i: Hydrogen peroxide small scale motors

- Dozens of fire tests performed
- 80s tests successfully performed
- Re-ignition and throttling (1:5) with catalyst bed demonstrated
- Thin film theory demonstration

<u>**Motor operation at subscale level has been proven**</u>

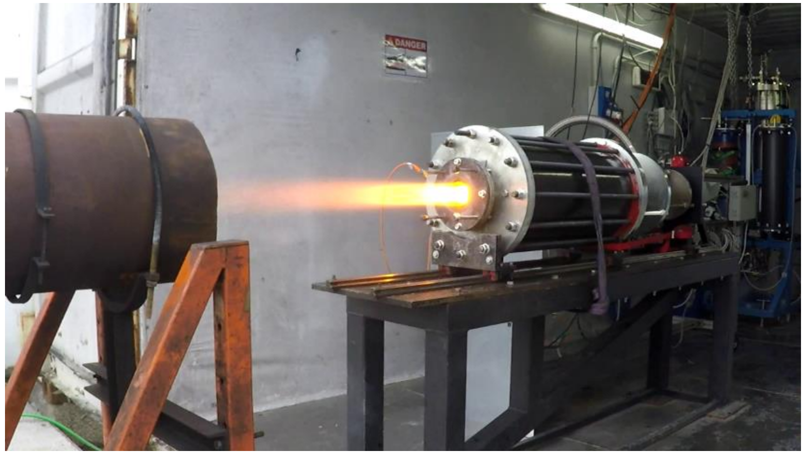


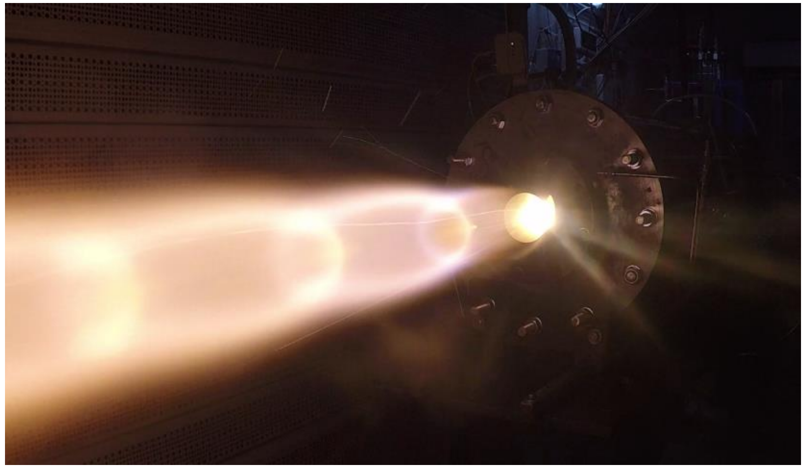


Hybrid rocket @University of Padua/T4i: Hydrogen Peroxide major scale motor

- Tens of tests performed
- Easy operation of the system achieved
- Efficiency up to 95% achieved

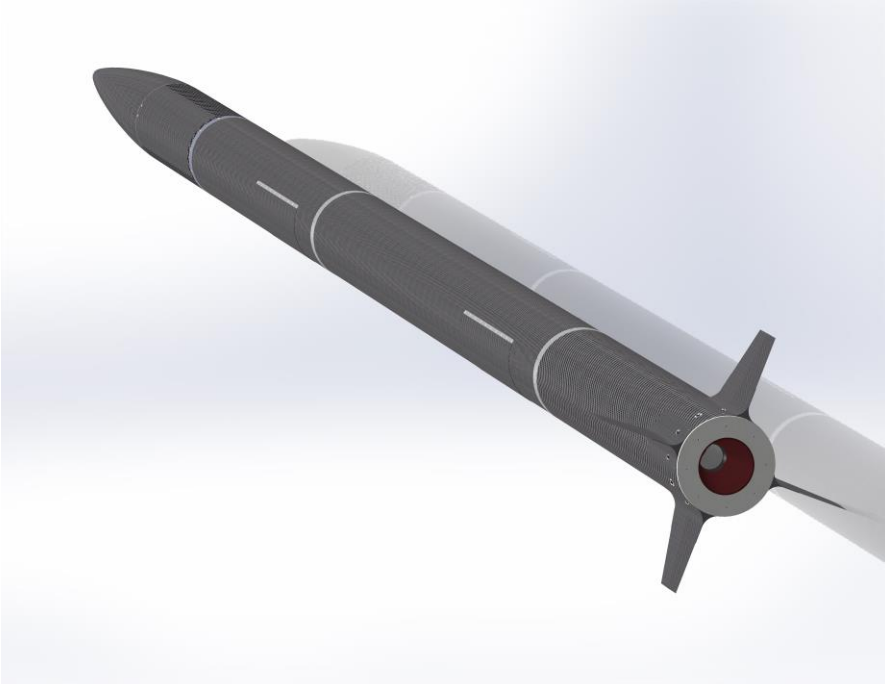
10 kN motor successfully tested up to 50 s





Flight test

- >20 km – HTP /Paraffin hybrid rocket
- Test bed to demonstrate motor performances
- Internal design in cooperation with University of Padua
- First flight Q1 2020



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Conclusions

- Airborne hypersonic test bed are a fundamental development asset
- Hybrid rocket system are a valuable asset to drastically reduce costs and increase versatility
- Hybrid rocket technology provide also reusability options
- Hybrid rocket technology is very suitable also to airborne platforms
- Important technology milestone have been achieved in Italy in developing high-performance hybrid rocket systems