

Design of a Hybrid Rocket Engine with Swirling Oxidizer Injection

Olivier Jobin, Mathieu Chartray-Pronovost and Guillaume
Villeneuve

June 19, 2018

TEAM 59



Introduction



Outline

- Engine Overview
 - Hybrid Rocket Engines
 - Engine Layout and Function
- Combustion Mechanics
 - Swirling Injection
 - Fuel Mechanical Characteristics
- Test Bench
 - Structure
 - Data Acquisition

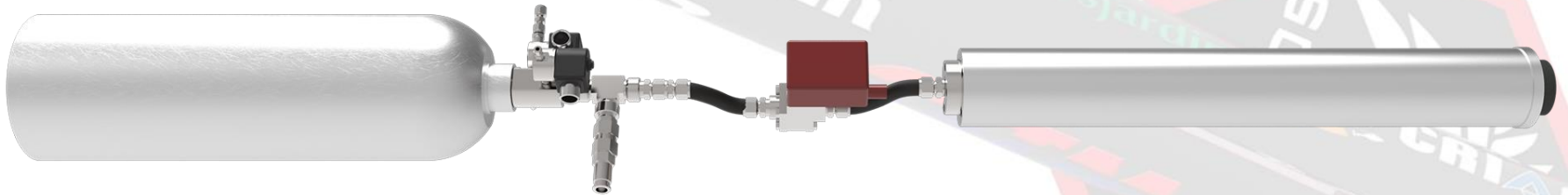


POLYTECHNIQUE
MONTREAL

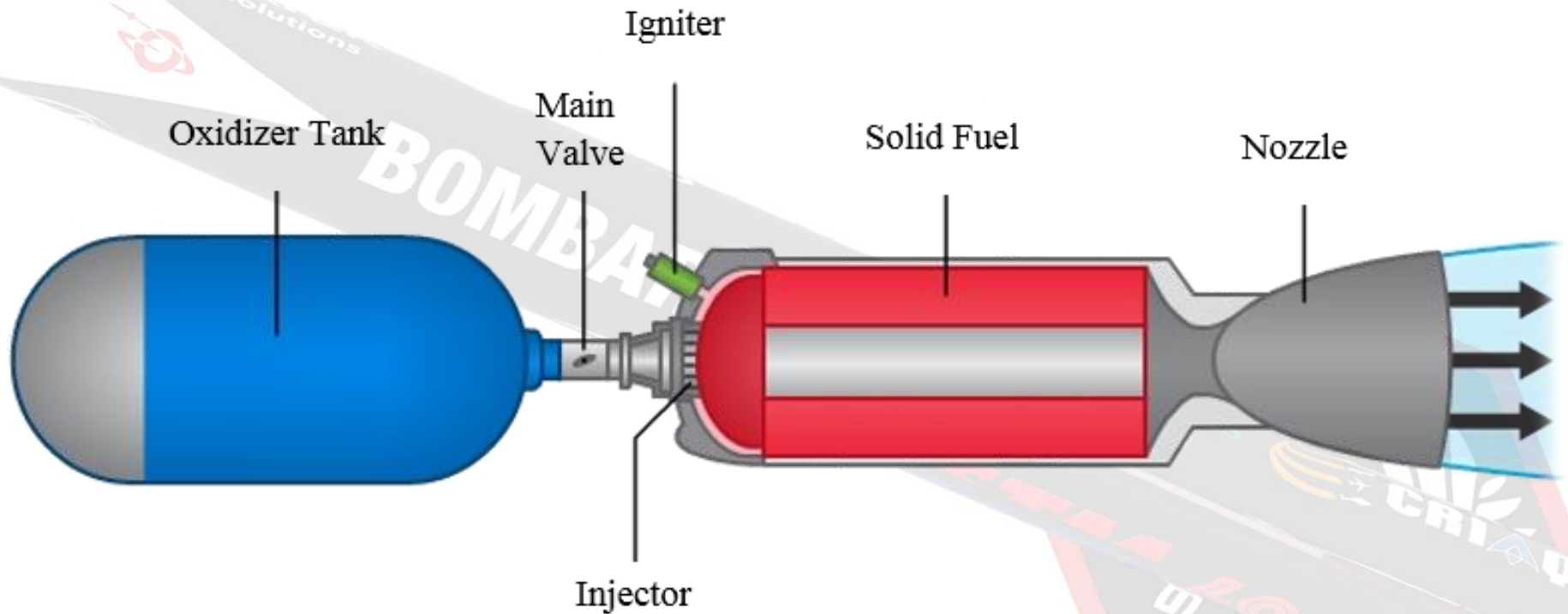
LE GÉNIE
EN PREMIÈRE CLASSE



Engine Overview



Hybrid Rocket Engines

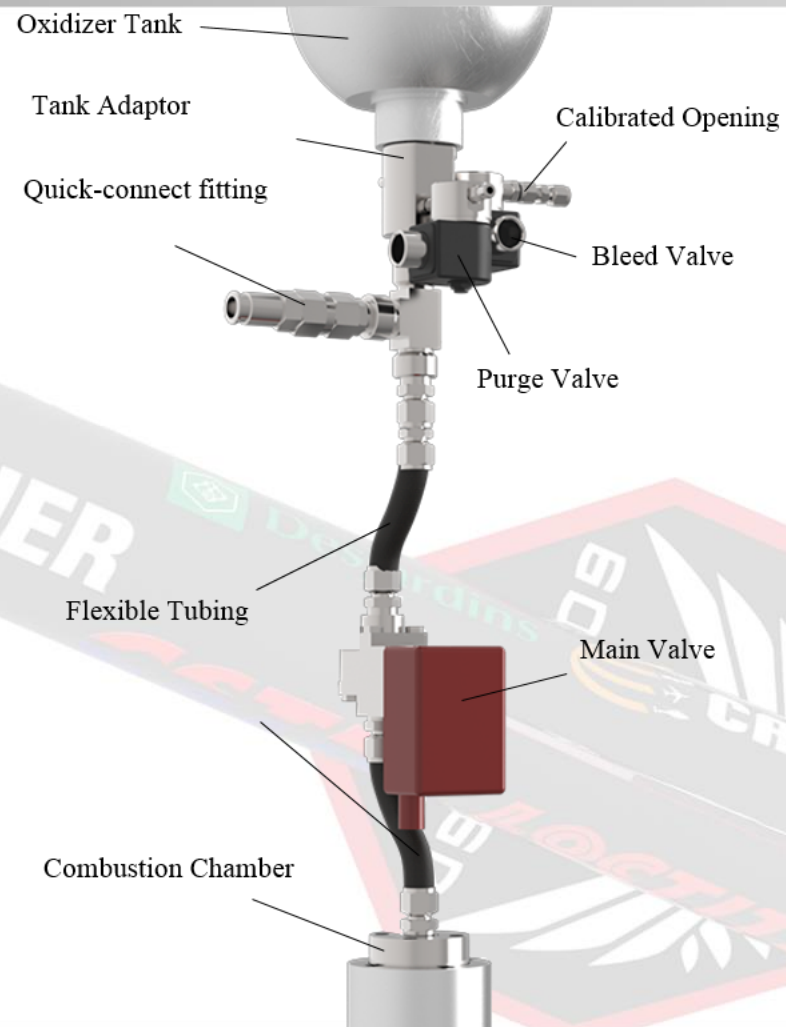


Why a Hybrid?

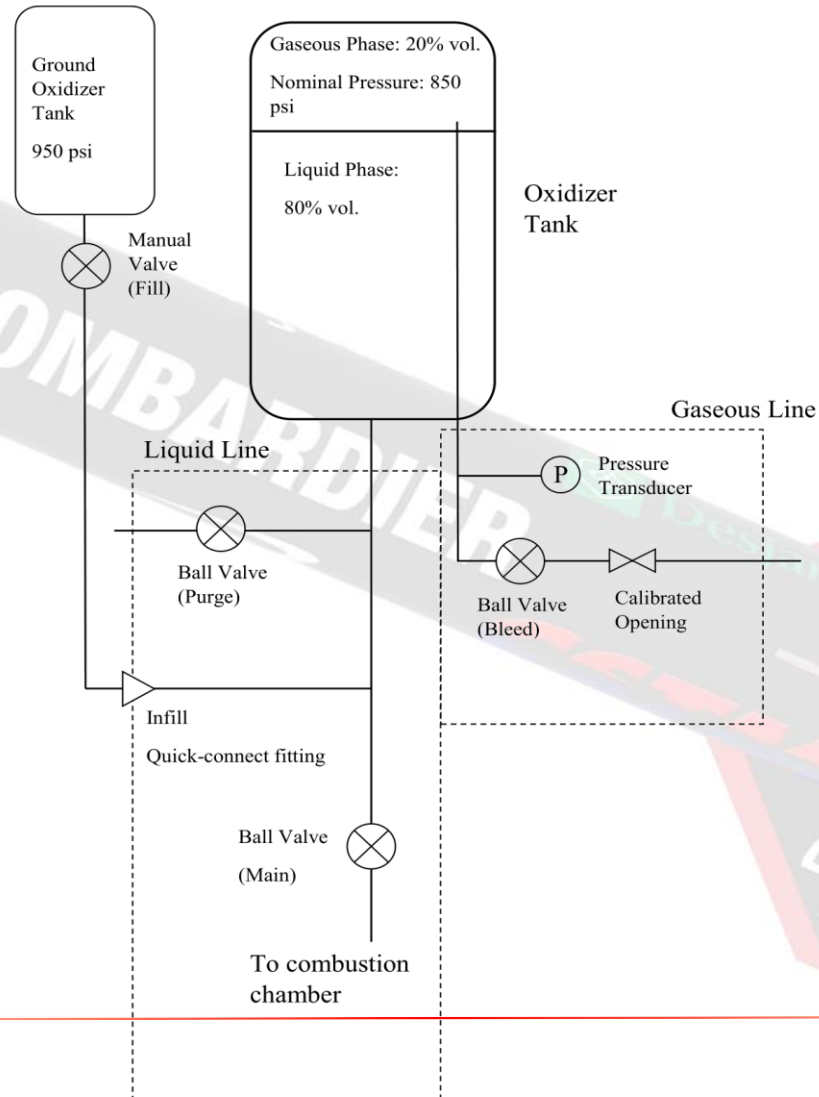
- Less complex than liquid engines
- Safer than both solid and liquid engines
- Propellants are subject to less regulations and easier to come by for hybrids

Engine Overview

- Fuel : Paraffin
 - Additive : Alpha-Olefin
- Oxidizer : Nitrous Oxide
- Average Thrust : 2400 N
(540 lbf)
- Burn Time : 7 s



Engine Overview



Combustion Mechanics

Injection

- Important part of engine design
- Takes in liquid oxidizer
- Outputs biphasic oxidizer
- Parameters: Pressure loss, injection area, mass flow



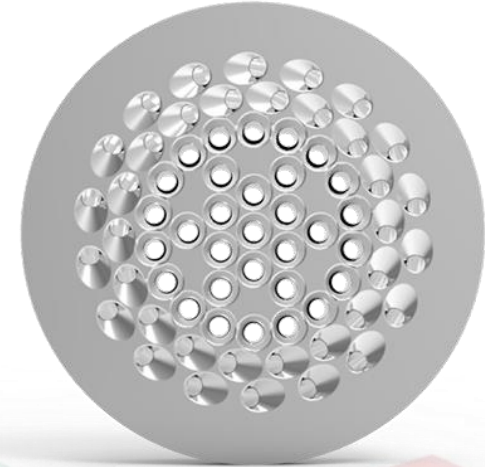
POLYTECHNIQUE
MONTREAL

LE GÉNIE
EN PREMIÈRE CLASSE



Our Injector

- Swirling injector
- Induces helicoidal flow
- Fuel-Oxidizer mix stays in chamber longer
- Higher combustion efficiency



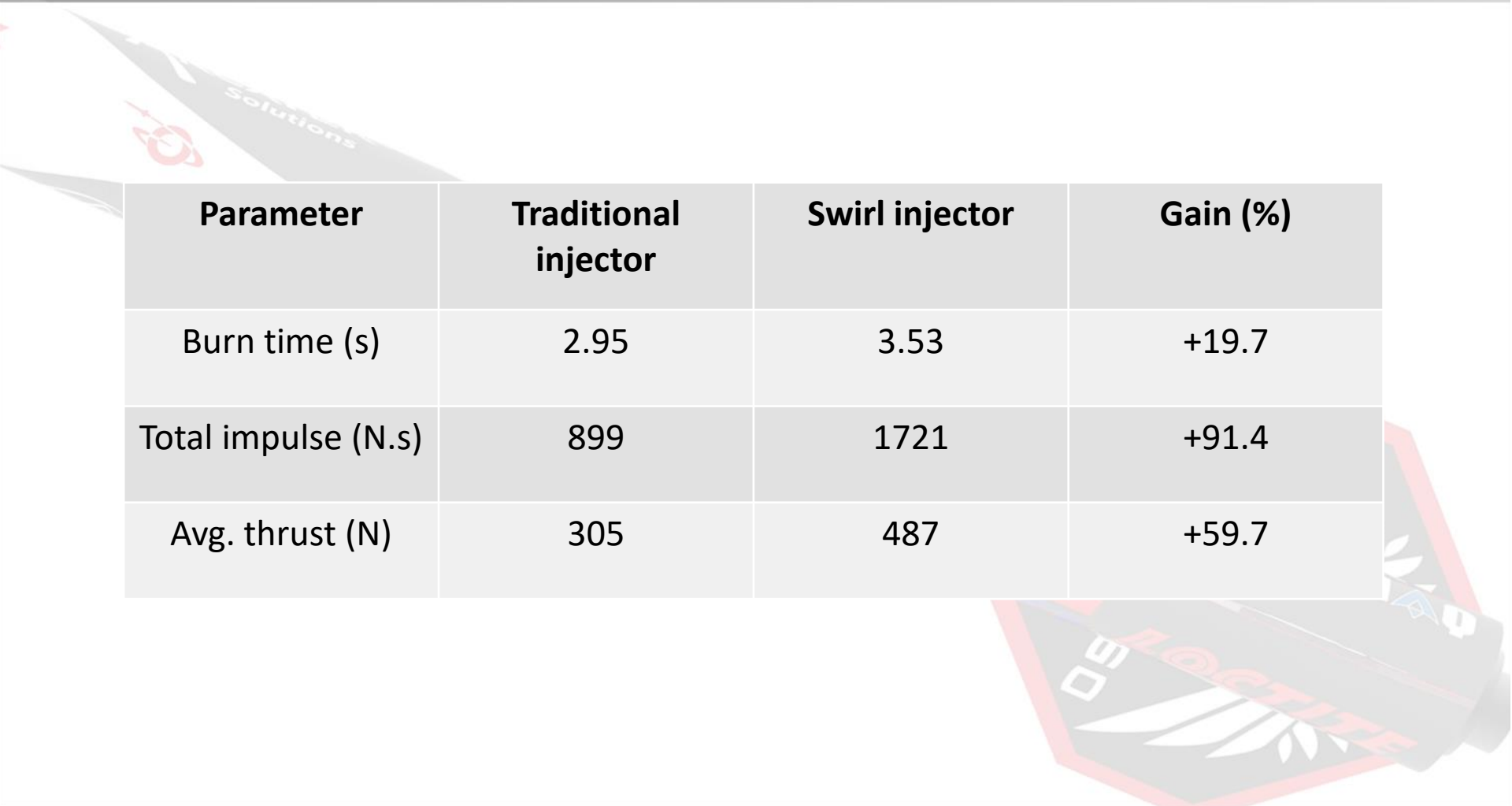
POLYTECHNIQUE
MONTREAL

LE GÉNIE
EN PREMIÈRE CLASSE

Image : Oronos Polytechnique



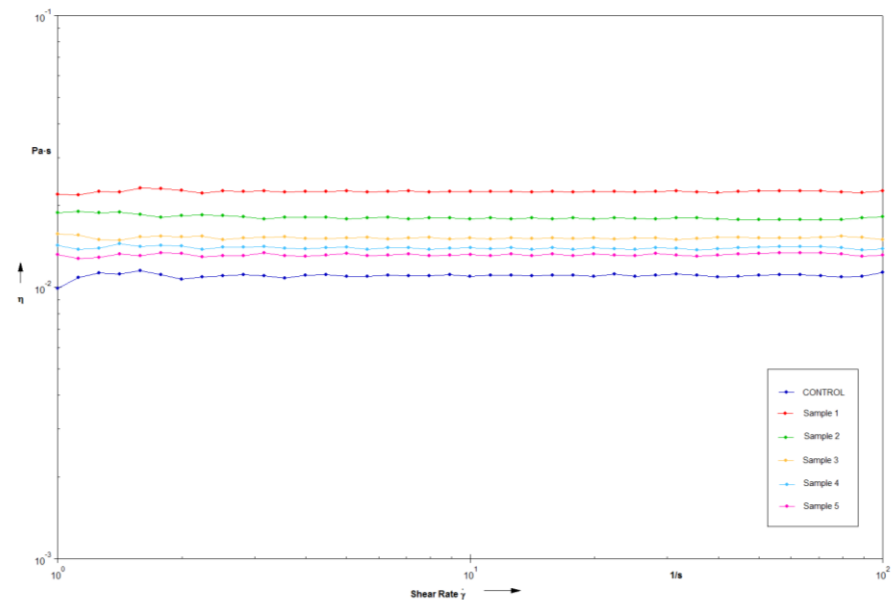
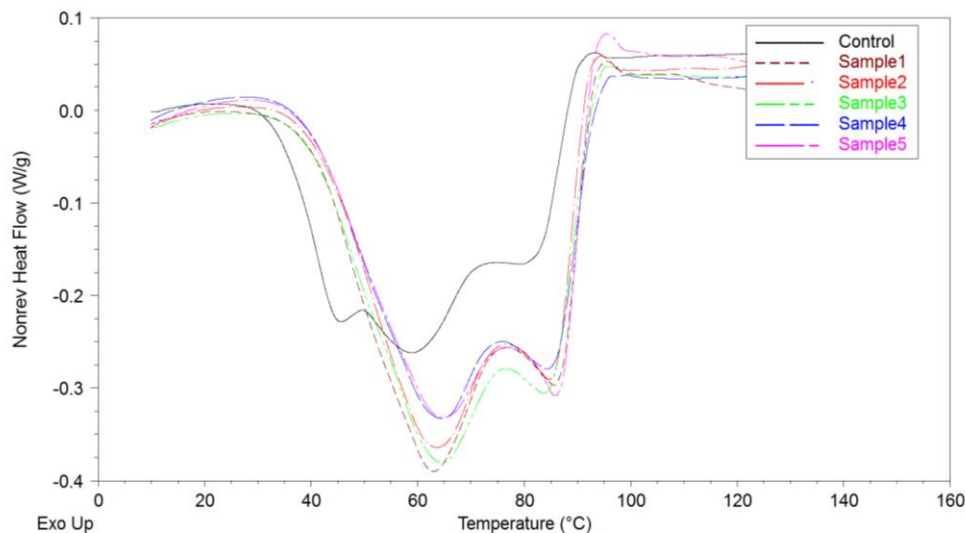
Injector comparison



Parameter	Traditional injector	Swirl injector	Gain (%)
Burn time (s)	2.95	3.53	+19.7
Total impulse (N.s)	899	1721	+91.4
Avg. thrust (N)	305	487	+59.7

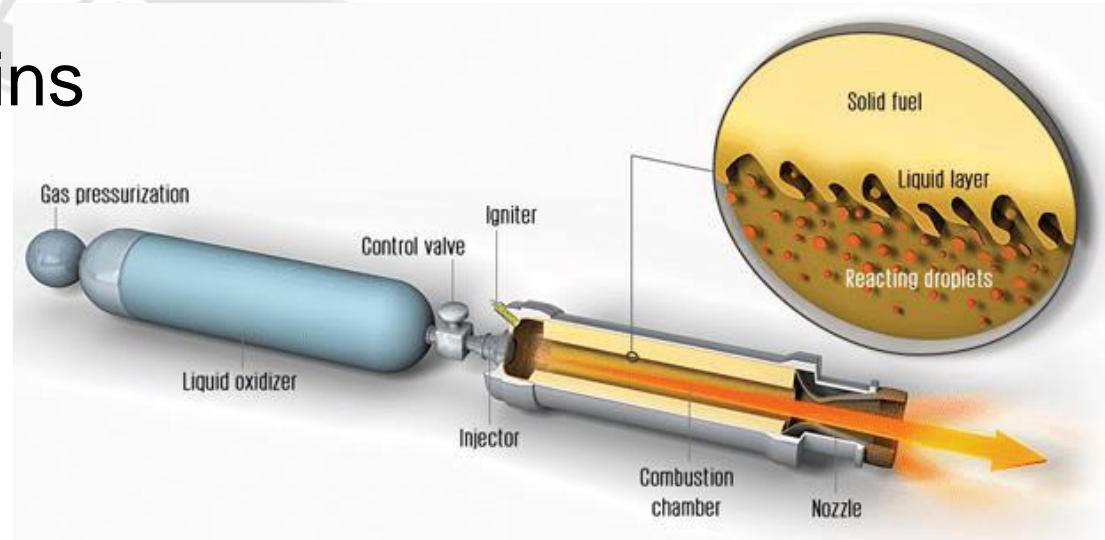
Solid fuel properties

- 80% Paraffin wax and 20% alpha-olefin
- Multiple static tests to determine composition
- Rheology and DSC analysis



Alpha-olefin effects

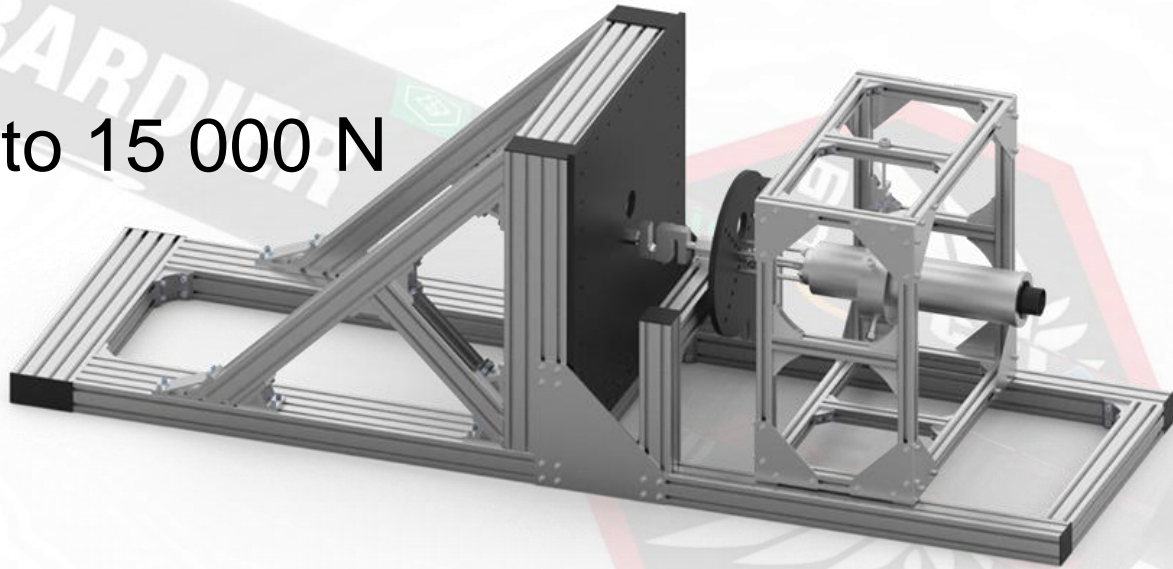
- Increased viscosity
- Increased regression rate
- More brittle fuel grains



Test Bench

Test Bench

- Modular
- Adaptable to a large range of engine dimensions
- Supports thrust up to 15 000 N
- Security factor: 2



Data acquisition

Sensor	Data retrieved	Linked parameter
Longitudinal load cell	Thrust over time	Thrust curve
Lateral load cell	Thrust over time	Lateral thrust (unwanted)
Oxidizer tank load cells	Mass over time	Oxidizer mass flow
Pressure transducer (pre-injection)	Pre-injection pressure	Oxidizer pressure Injector pressure loss
Pressure transducer (post-injection)	Combustion pressure	Combustion pressure
Oxidizer tank pressure transducer	Oxidizer tank pressure	Oxidizer tank pressure and temperature
Combustion chamber thermocouples	Temperature	Ignition status

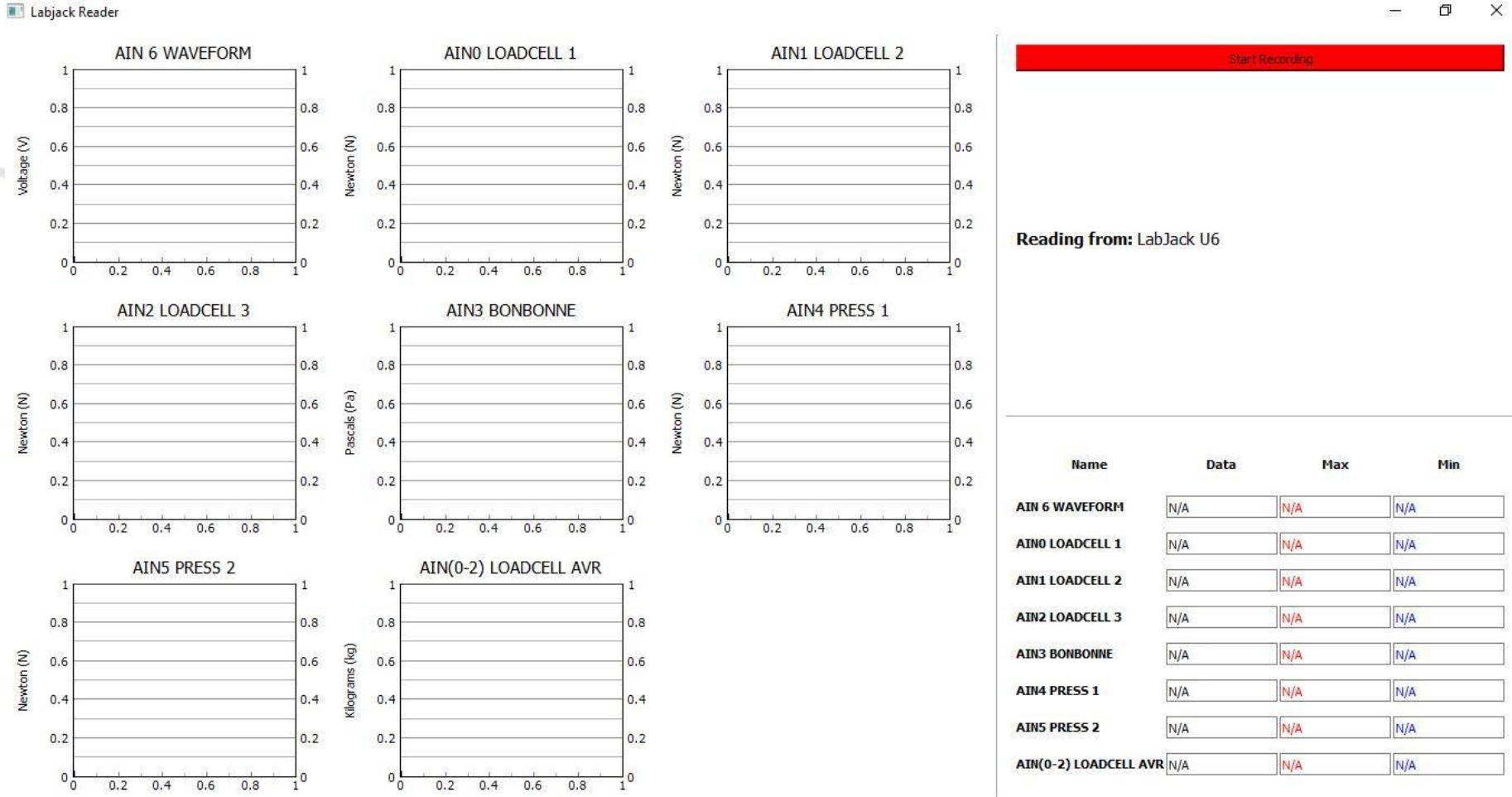


POLYTECHNIQUE
MONTREAL

LE GÉNIE
EN PREMIÈRE CLASSE



Data acquisition interface



Conclusion

Static Fire - Pictures



References

Paul Castellucci. « **Scale-Up Tests of High Regression Rate Paraffin-Based Hybrid Rocket Fuels** ». In : Journal of Propulsion and Power (2004).

Enrico Paccagnella, Arif Karabeyoglu, Francesco Barato and Daniele Pavarin « **Scaling of Hybrid Rocket Motors with Swirling Oxidizer Injection** ». In : 51st AIAA/SAE/ASEE Joint Propulsion Conference (2015).

T.S. Lee, A. Potapkin and NATIONAL CHENG KUNG UNIV TAINAN (Taiwan). « **The Performance of a Hybrid Rocket With Swirling GOx Injection** ». Defense Technical Information Center, 2002

G.P. Sutton et O. Biblarz. **Rocket Propulsion Elements**. John Wiley & Sons, 2010. isbn : 9780470080245.

Questions ?