Development and Testing of HTP Monopropellant Thruster for Space Applications

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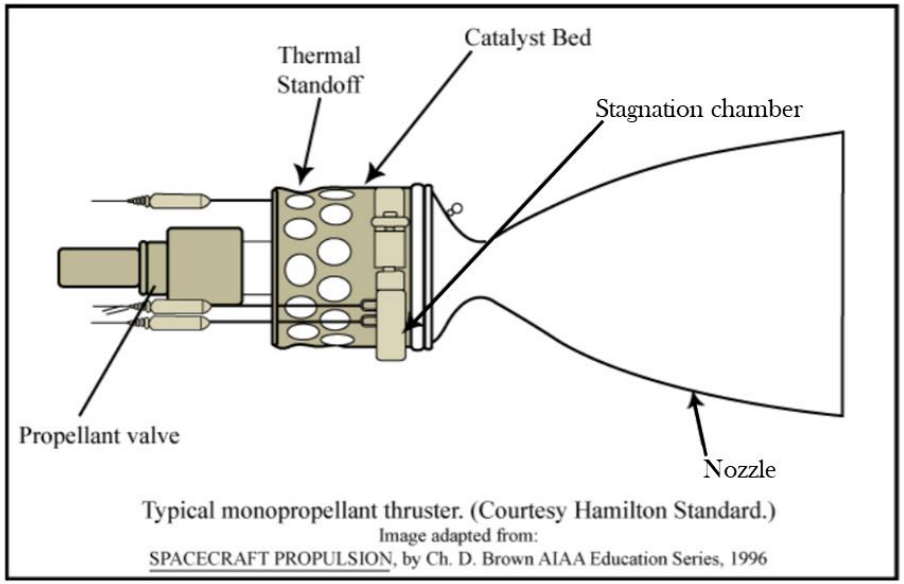
Introduction to Monopropellant Thrusters



Typical monopropellant thruster. (Courtesy Hamilton Standard.)
Image adapted from:
SPACECRAFT PROPULSION, by Ch. D. Brown AIAA Education Series, 1996

- Single propellant flows through a catalyst bed
- Exothermic decomposition of the propellant creates hot gas mixture
- The decomposition products are exhausted through the nozzle to obtain thrust
- Conventional propellant – Hydrazine (N_2H_4)

Why HTP?

HTP (High Test Peroxide), concentration > 80%

$$H_2O_2 \rightarrow H_2O + \frac{1}{2}O_2 + 98\ kJ/mol$$

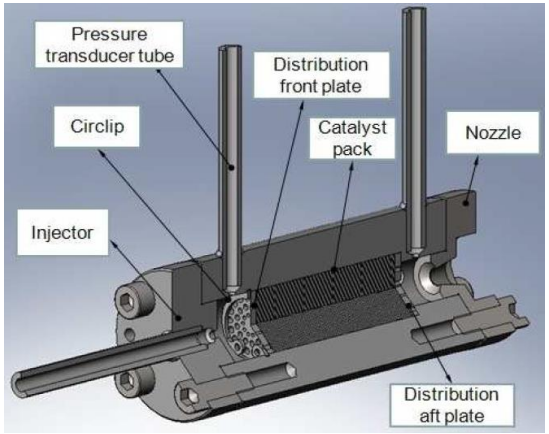
- "Green" propellant, reduced pollution and toxicity
- Safety during handling, manufacturing and testing
- Storable at room temperature

  ⇒ **Low operative cost**

- High volumetric specific impulse

  ⇒ **Compatible for space applications**

In this research, the goal is to improve TRL of HTP monopropellant thruster



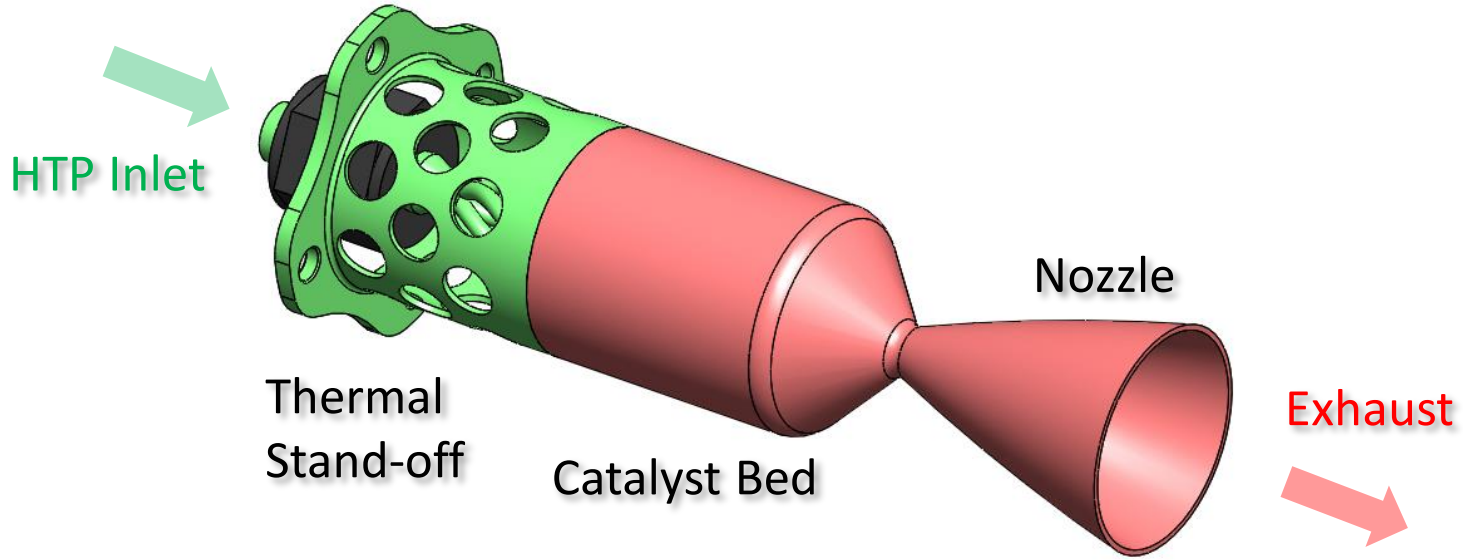
Present Work

- Motor Design
- CFD investigation of channeling phenomena
- Thermal analysis of the nozzle
- Structural analysis
- Implementation of the fuel feeding line for the experimental set-up

Motor Design

Main Characteristics:

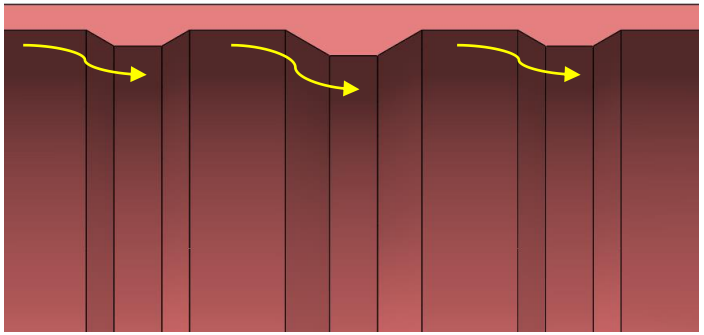
- Additive Manufacturing (3D print)
- Minimum Components
- Multiple Configurations
- Weight Optimization ≈ 90gr



Anti-Channeling Feature

Channeling:

- By-pass of liquid HTP near the wall
- Decomposition efficiency is decreased

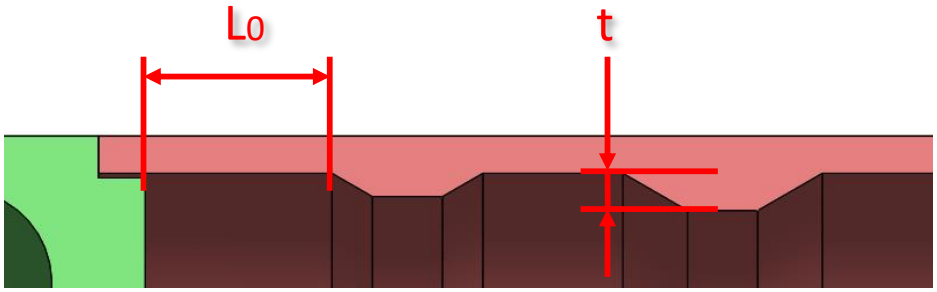


Suggested Solution:

- Disturbance to the near-wall flow
- Preventing a by-pass flow
- Directing the fluid through the bulk catalyst
- CFD investigation leads to selected design

Anti-Channeling Feature

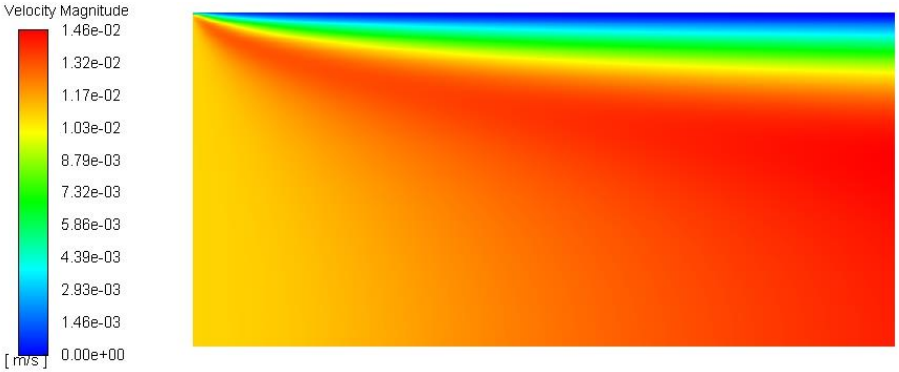
- 2D RANS Simulation
- Axisymmetric Model
- Steady-State
- Fluid: Liquid HTP
- Laminar Flow

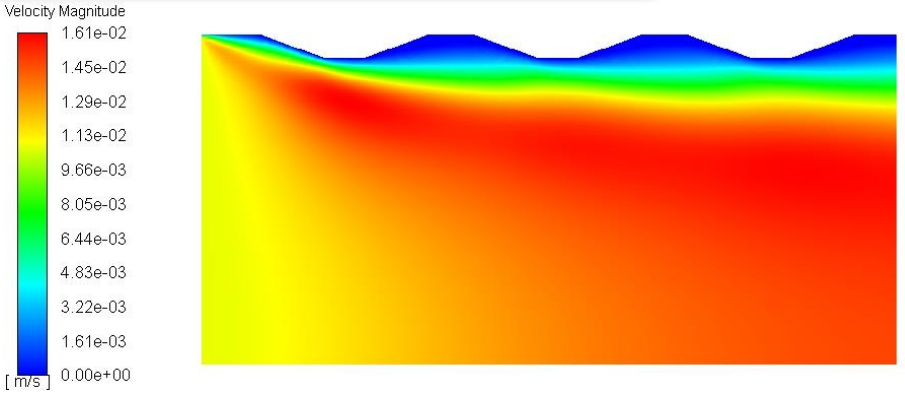


n = number of disturbances

Preliminary results:

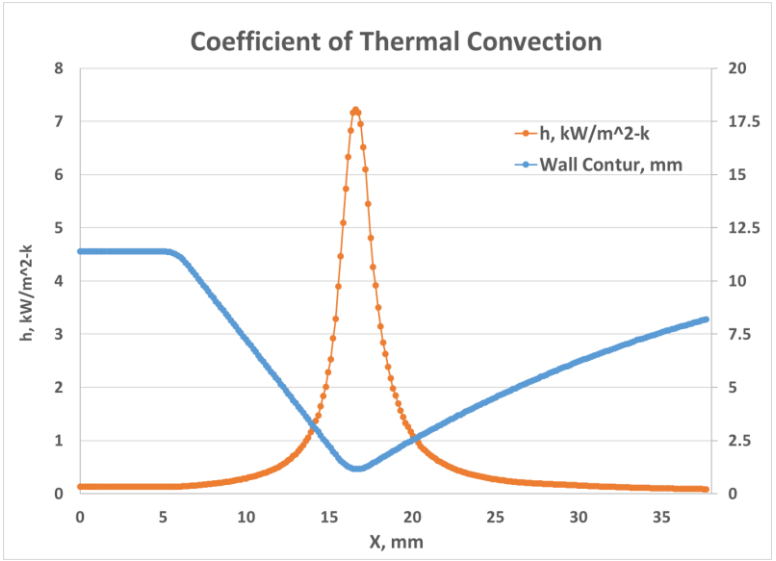
- Boundary layer thickness increase
- Outlet mass flow at 1mm distance from the wall decrease ≈ 40%





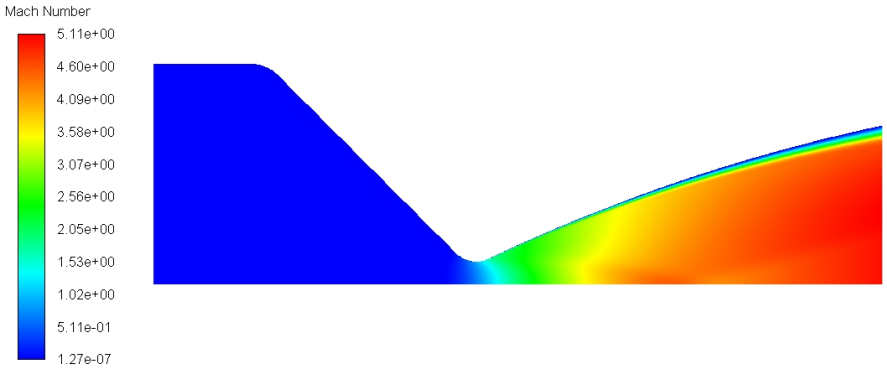
Thermal Analysis of The Nozzle

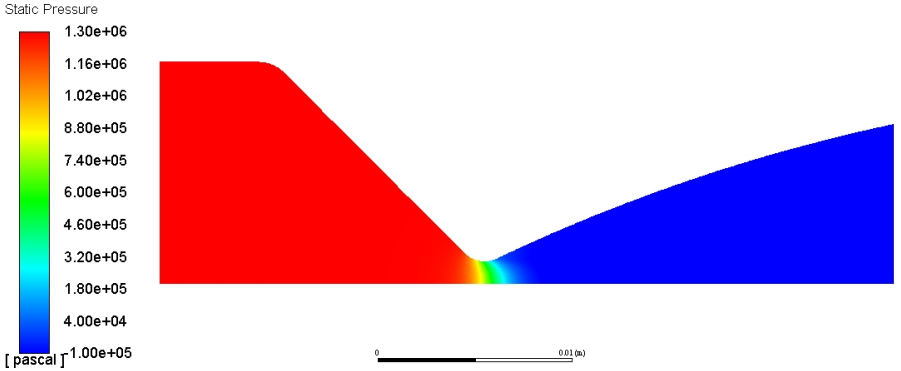
- 2D RANS Simulation
- Steady-State
- Fluid: HTP decomposition products



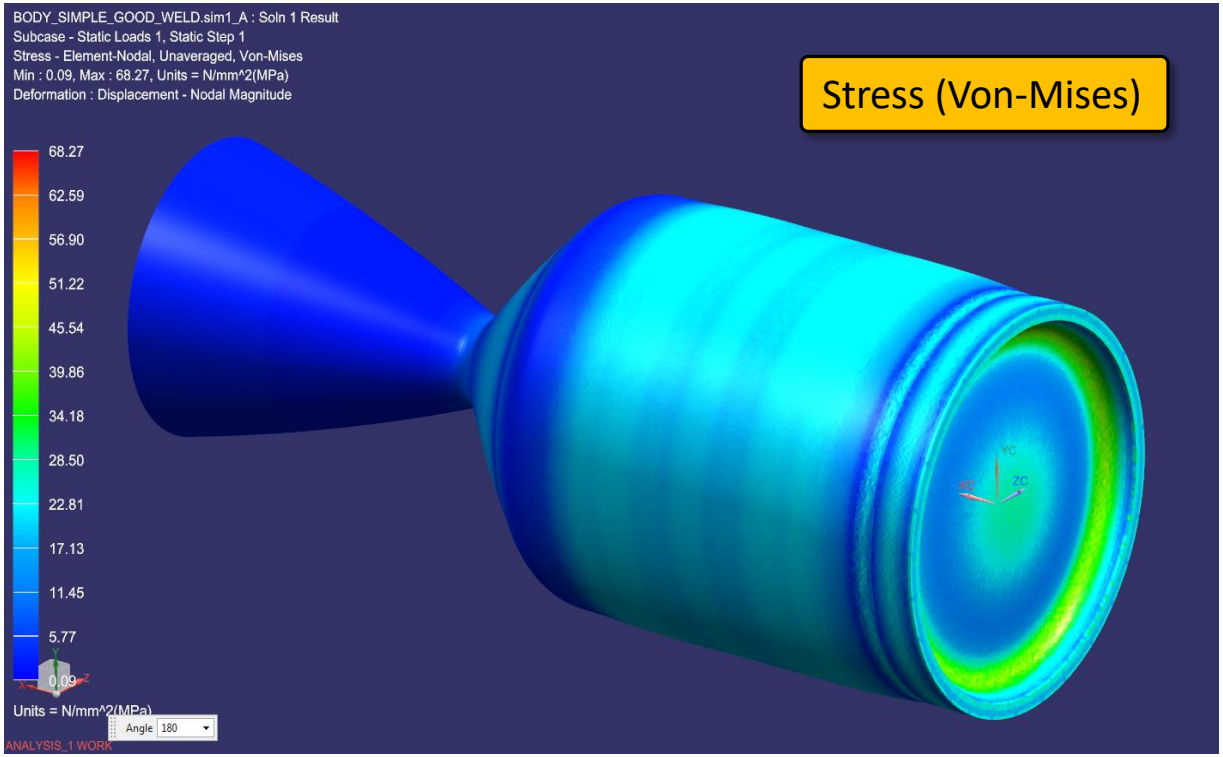
Preliminary Results:

- Evaluation of Convection Rate ≈ 2.4 W/cm^2
- Coefficient Of Thermal Convection
- Low Temperature Gradient at the wall < 5°C
- Low Thermal Stress





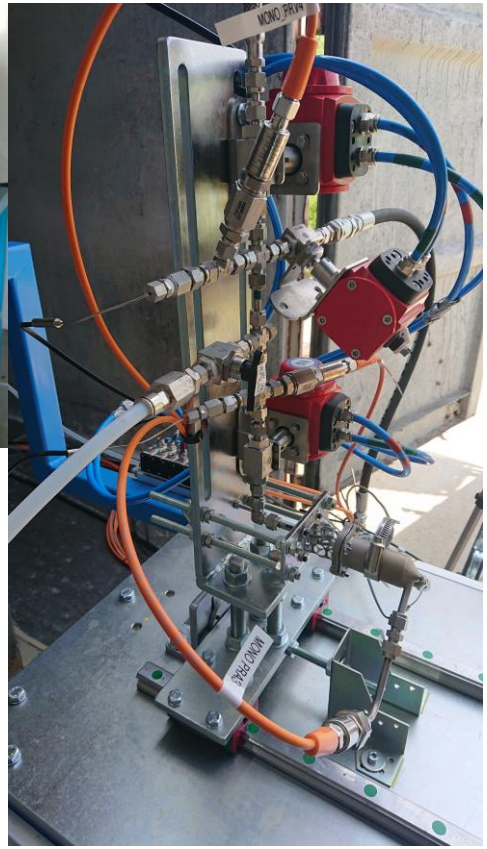
Structural Analysis



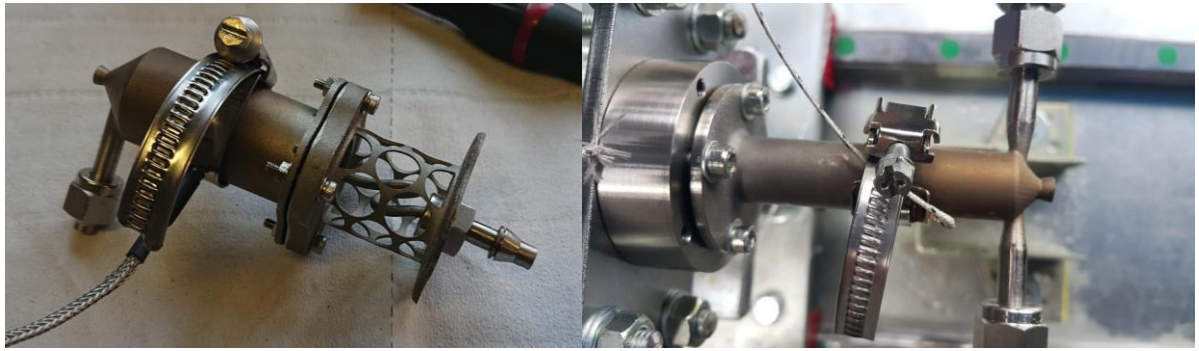
- Load Case: Max. Internal Pressure
- High Safety Factor

Experimental Activity

Equipped Test Facility



Test Bed



Various Monopropellant Motors (other programs)

Future Work

- Motor Production
- Experimental Set-Up Modification - Fast Response Valve for Pulse Mode Operation
- First Fire Test Campaign
- Motor Scaling – Design, Production and Test

PhD Activity

Level	Work Package	Hours	1st Year				2nd Year				3rd Year			
1.0	**Bibliographic Research**	**210**	**150**	**60**										
1.1	State of the Art Research	70	70											
1.2	Methods of Numerical Analysis	70	40	30										
1.3	Methods of Experimental Analysis	70	40	30										
2.0	**Numerical Investigation**	**1200**	**150**	**250**	**330**	**270**	**200**							
2.1	Motor design	150	100	50										
2.2	Injector Design	150	50	100										
2.3	Thermal Analysis	150		100	50									
2.4	Test Matrix	350			200	150								
2.5	Data Analysis	300			80	120	100							
2.6	Numerical Correleation	100					100							
3.0	**Experimental Activity**	**700**					**100**	**350**	**250**					
3.1	Experimental Set-up	250					100	150						
3.2	Test Matrix	300						150	150					
3.3	Data Analysis and Validation	150						50	100					
4.0	**Motor Scaling Test**	**950**							**100**	**270**	**330**	**250**		
4.1	Up-Scaled Motor Design and Analysis	300							100	200				
4.2	Experimental Set-up	100								70	30			
4.3	Test Matrix	350									250	100		
4.4	Data Analysis and Validation	150									50	100		
4.5	Experimental Correleation	50										50		
5.0	**Exploitation**	**100**											**100**	
5.1	Spacecraft / Satellite Attitude Control and Main Propulsion System	50											50	
5.2	Engine Comparison / Market Analysis	50											50	
6.0	**Thsis and Documentation**	**600**				**50**				**50**		**100**	**200**	**200**
	Total Hours	**3760**	**1260**				**1320**				**1180**			

Thank you for your attention

Any questions?