59th session of the Scientific and Technical Subcommittee
of the Committee of Peaceful Uses of Outer Space

“Development of a rocket powered by a detonation engine”

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Outline

- **Introduction,**
- **Development of Rotating Detonation Engine,**
- **Laboratory tests,**
- **Experimental Flight,**
- **Conclusions.**

Why Detonation Propulsion?

- **Higher energy release rate, higher thermodynamic efficiency, and easier scaling compared with conventional engines using deflagration;**

- **Applicable to Jet and Rocket Engines, spaceplanes or high-speed airplanes.**

Detonation Engines:

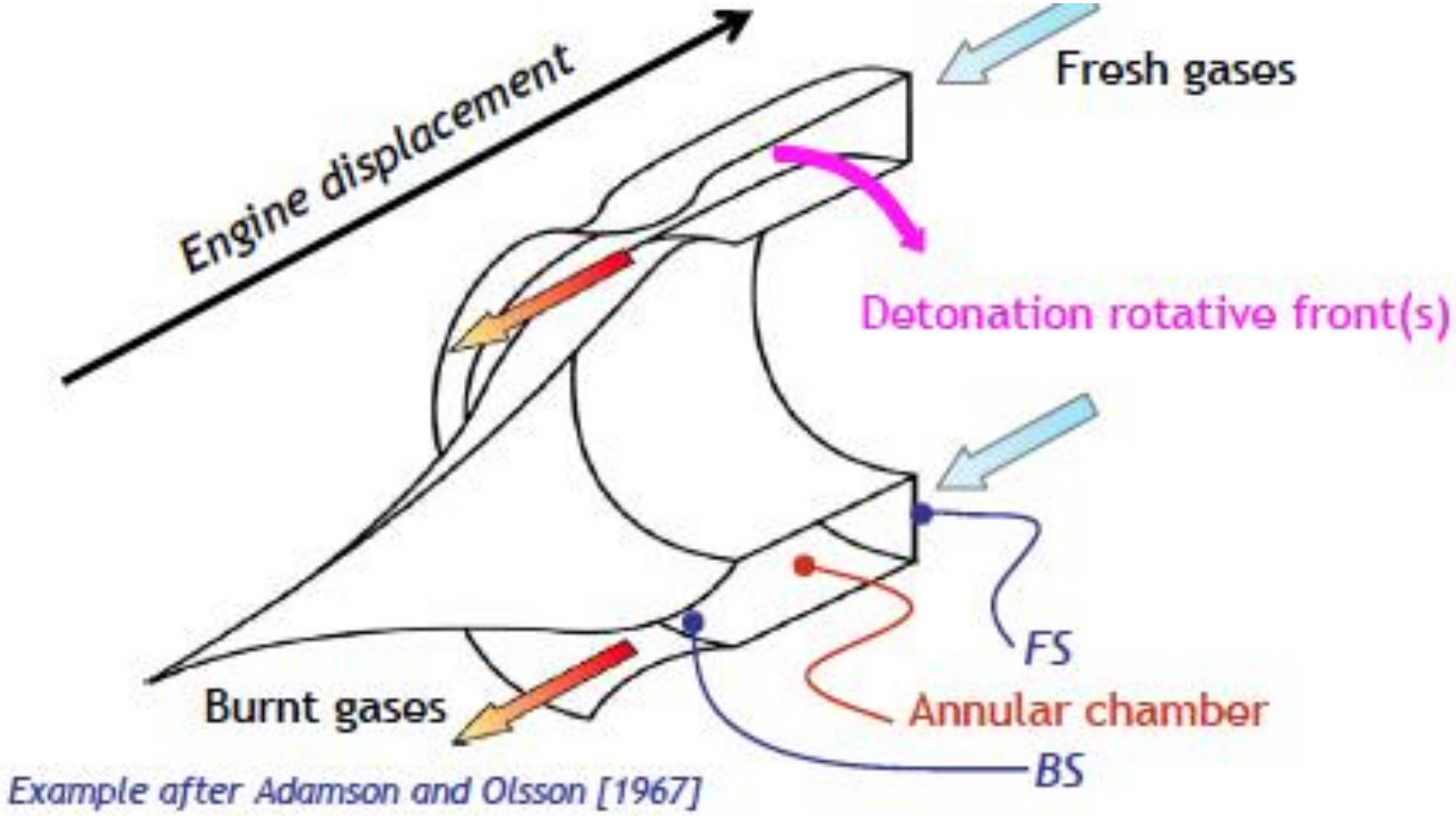
- **Standing Detonation Engine:**
  - **Continuous injection of combustible gas - simple system.**
  - **Injection velocity is strictly limited (faster than CJ value), but narrow operating conditions.**

- **Pulse Detonation Engine (PDE):**
  - **Wide operating conditions (flight Mach number = 0~5).**
  - **Repetitive and intermittent thrust - complicated system for fast purging, refilling and reinitiating.**

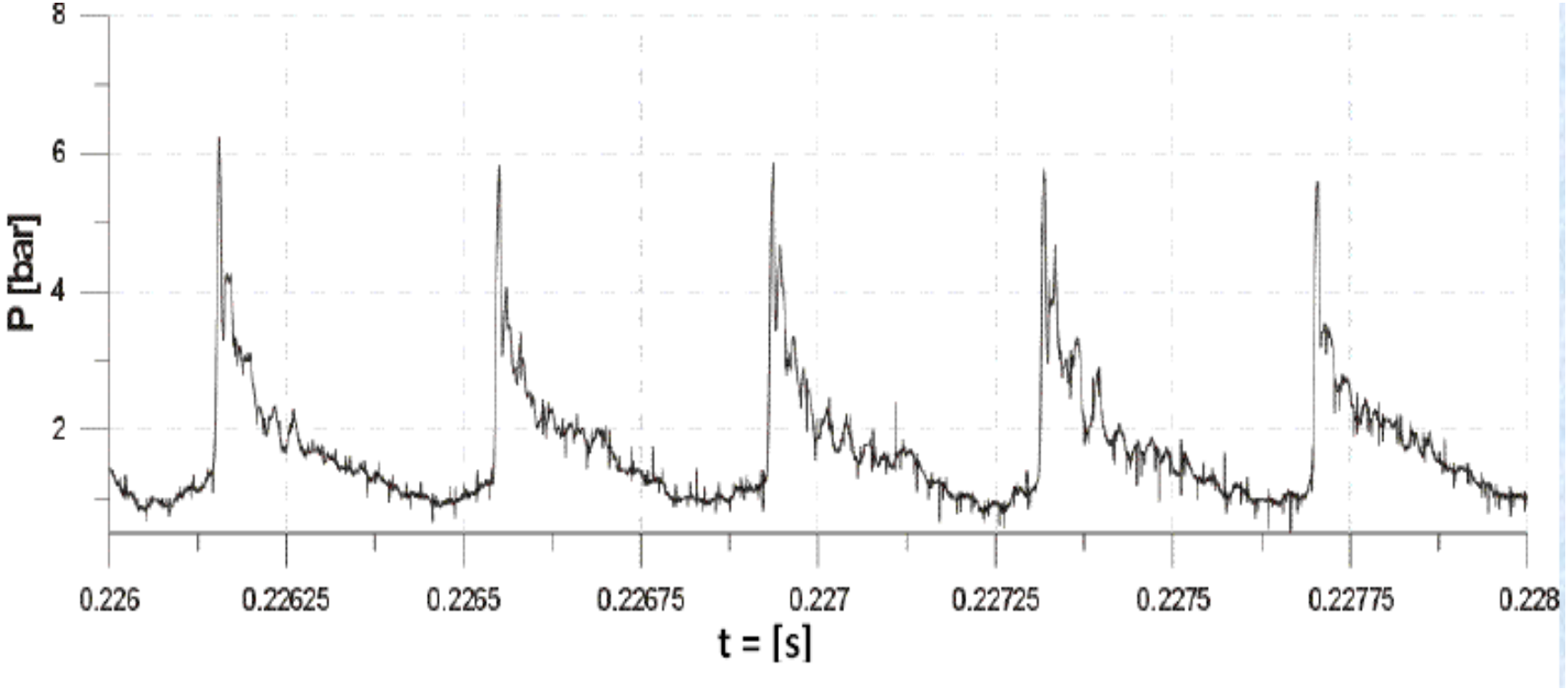
- **Rotating Detonation Engine (RDE):**
  - **Simple configuration and higher thrust due to continuous injection.**
  - **Wide operating conditions without limitation of injection velocity.**

Rotating Detonation Engine (RDE)

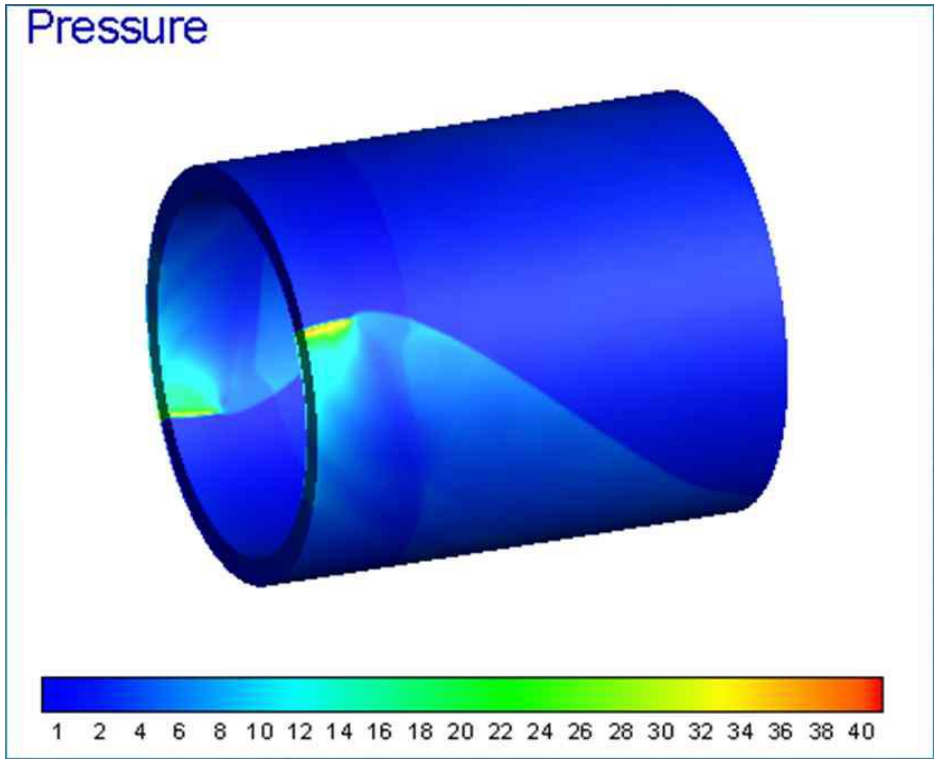
- **In early sixties of the last century Voitsekhovskii, Mitrofanov and Topchiyan performed experiments on continuously rotating detonation and research were also conducted at the University of Michigan - Ann Arbor, USA;**
- **In early 21th Century research on RDE were initiated in Russia, Poland and France and followed by USA and China;**
- **Experimental research are followed by numerical simulations of the RDE in all mentioned countries and in Japan, Singapore and Korea.**

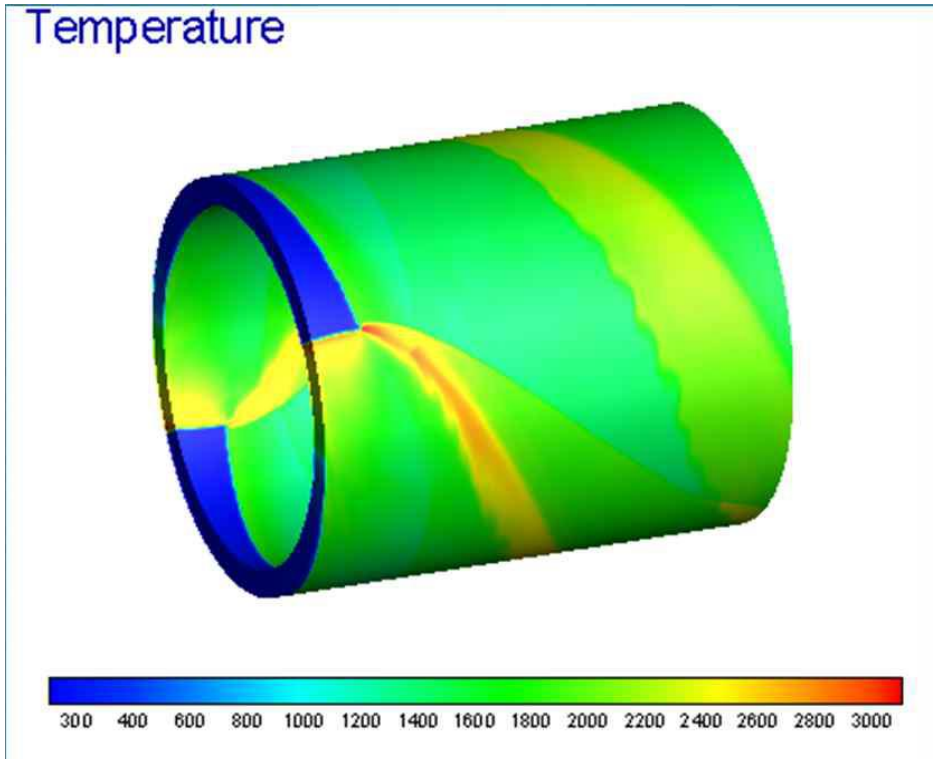


Rocket Engine based on continuously Rotating Detonation



Typical pressure variation for stable CRD in an annular chamber tested at the Warsaw University of Technology

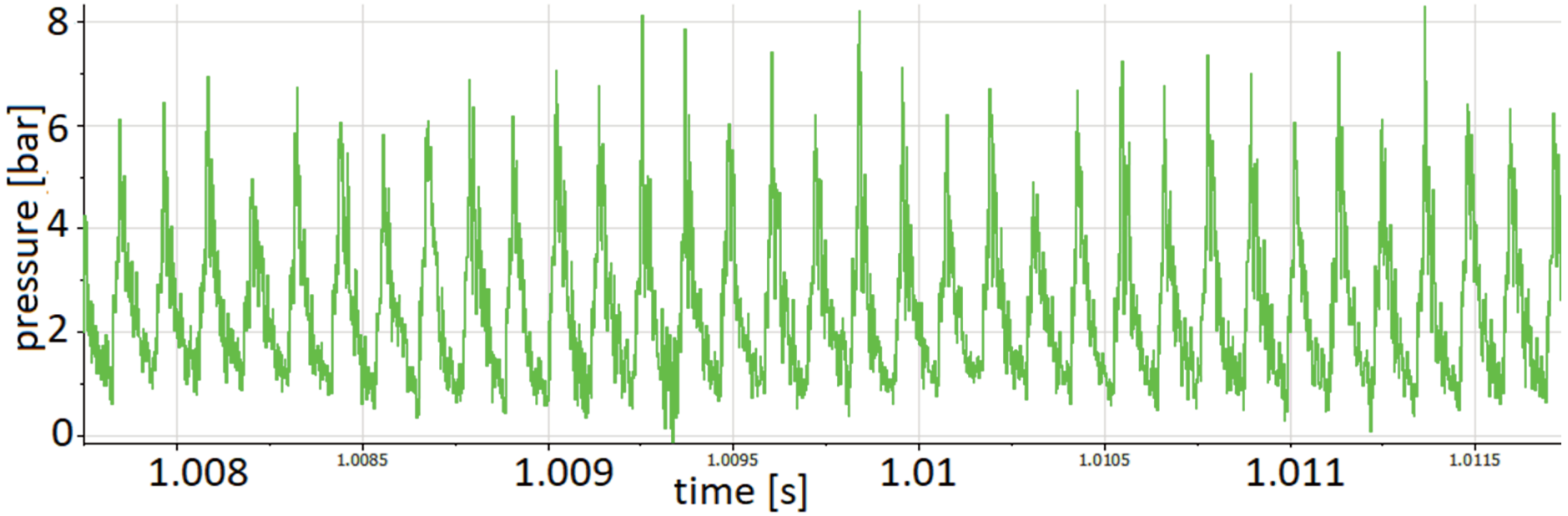




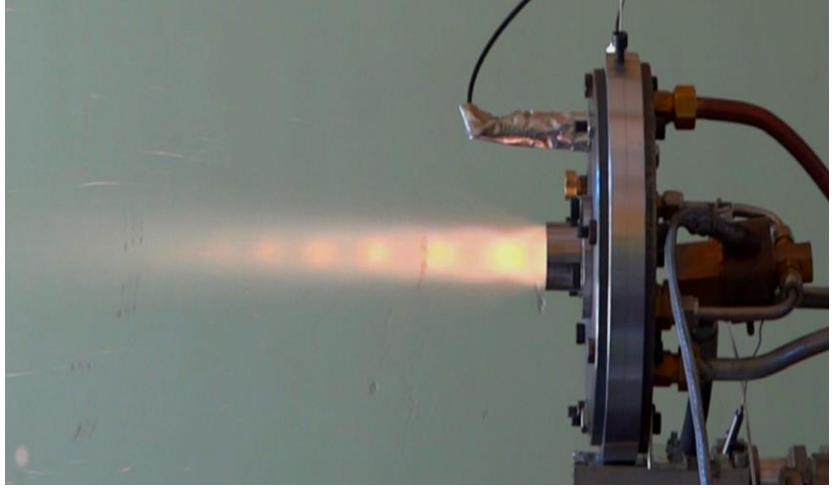
Graphical presentation of two detonation heads propagating in annular chamber

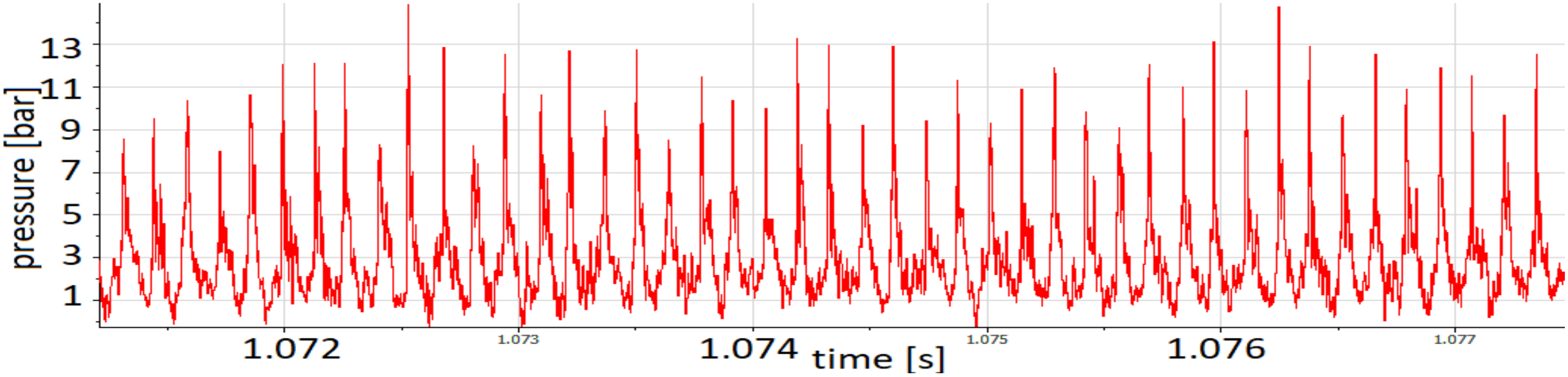
(from:Yi, T.H., Lou, J., Wolanski, P., Turangan, C., Khoo, B.C., “Effect of nozzle shapes on the performance of continuously rotating detonation engine”, AIAA paper 2010-0152, 2010, DOI: 10.2514/6.2010-152)

Development of the Liquid Propelled Detonative Engine for the Experimental Rocket

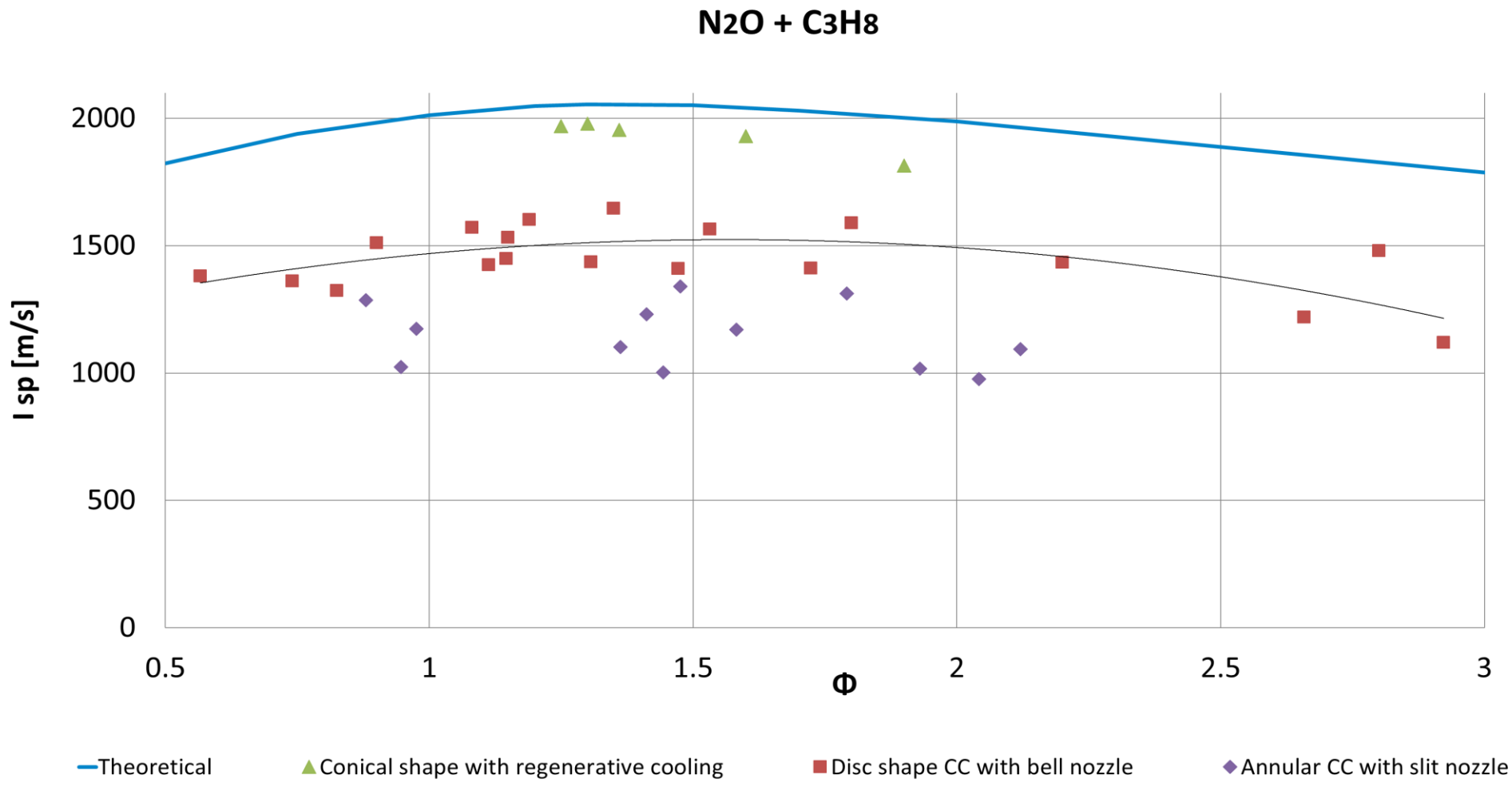


Test of the Rocket Engine with annular detonation combustion chamber supplied by a liquid N_2O and C_3H_8



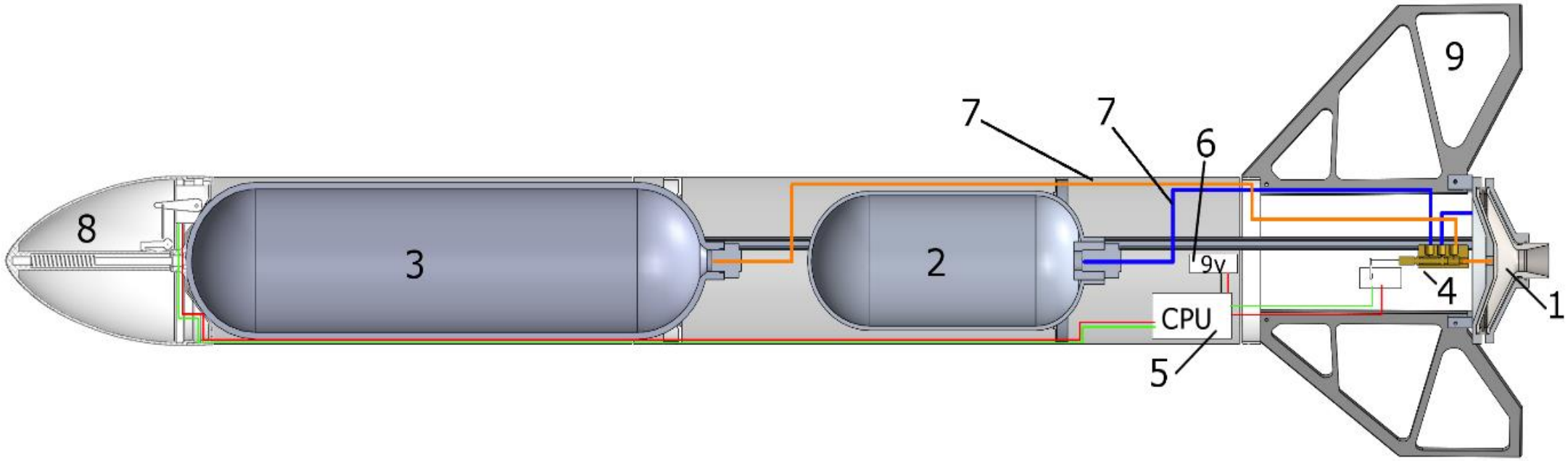


Test of the Rocket Engine with disk detonation combustion chamber supplied by a liquid N_2O and C_3H_8

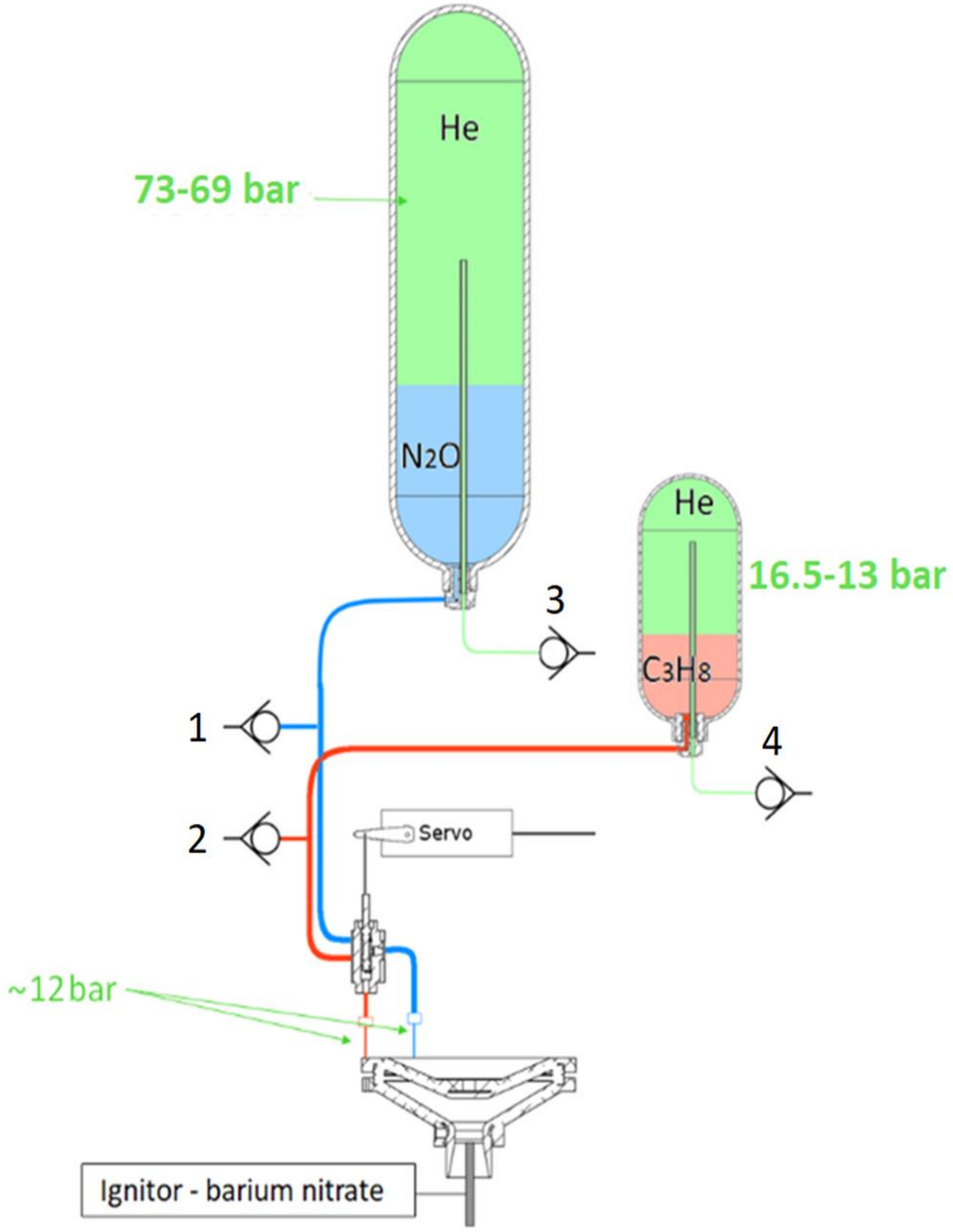


Specific impulse in different shape detonation chambers for different mixture composition. Red points – disk-shaped combustion chamber, purple points – annular combustion chamber, green points – experiments with cone shape chamber with regenerative cooling system. Blue line shows theoretical specific impulse calculated by NASA CEA Code

Detonative rocket engine, supplied by liquid propane and nitrous oxide (C_3H_8-N_2O) tested at the Łuksiewicz-Institute of Aviation in Warsaw



Configuration of the experimental rocket powered by RDE



Scheme of the propellant supply system for a rocket engine:
1- check valve for loading the nitrous oxide,
2-check valve for loading of the propane,
3,4 – check valves for pressurizing oxidizer and fuel tanks with helium

Initial sequence of the rocket flight

The world’s first launch of the rocket powered by a detonation engine

more on: https://ilot.lukasiewicz.gov.pl/en/the-worlds-first-launch-of-a-rocket-powered-by-a-detonation-engine/

Summary

- **At the Łukasiewicz-Institute of Aviation in Warsaw many pioneering works were conducted on application of continuously rotating detonation to propulsion systems including turbine engine and rocket engines;**
- **Experimental rocket powered by detonation engine was developed and tested;**
- **This rocket test was the world's first demonstration of successful use of detonation engine that allow flight of the rocket under its own power;**
- **Such propulsion system will improve performance of the future space propulsion systems.**

Thank you for your attention!