Application of 3D-Printing and COTS Components in Micro-Propulsion Systems

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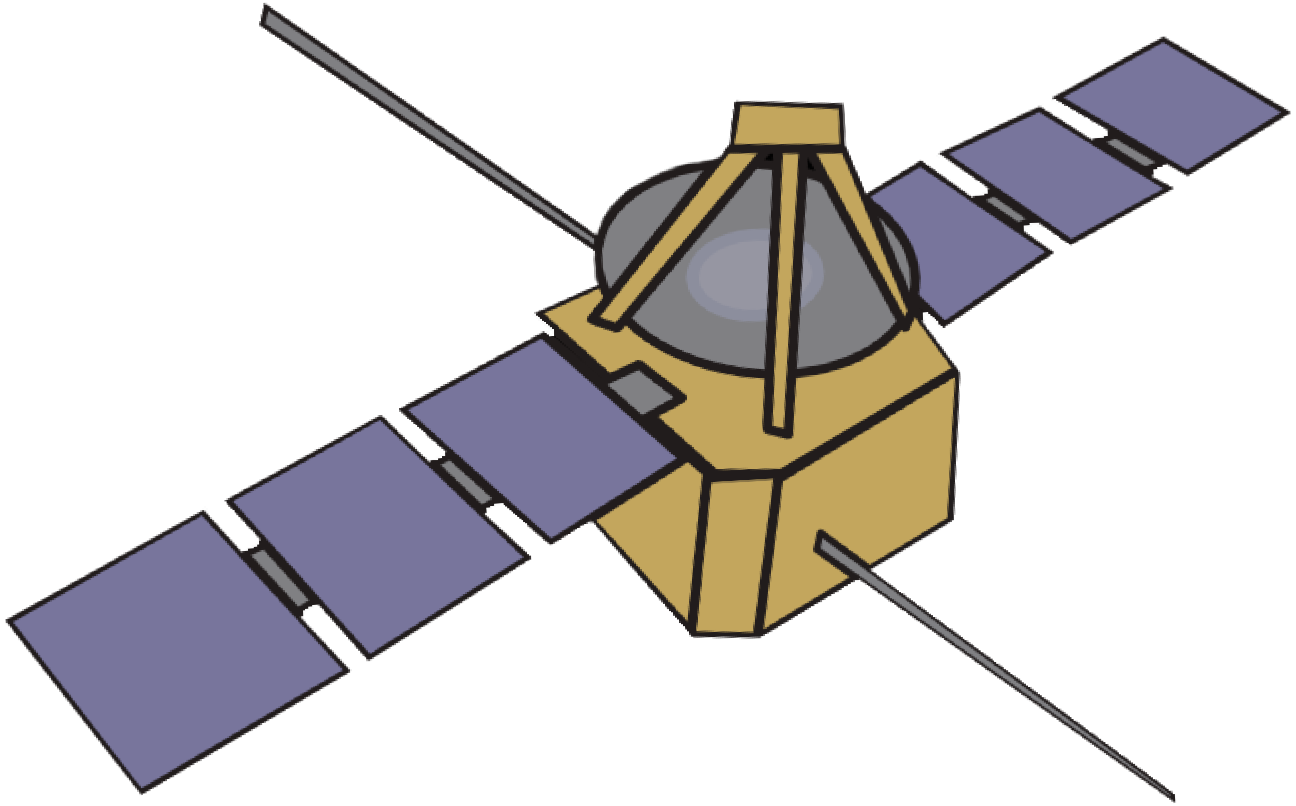


Micro Propulsion

Cold gas propulsion

Compressed gas/Liquefied gas, Traditional/MEMS/3D-Printed

Chemical propulsion

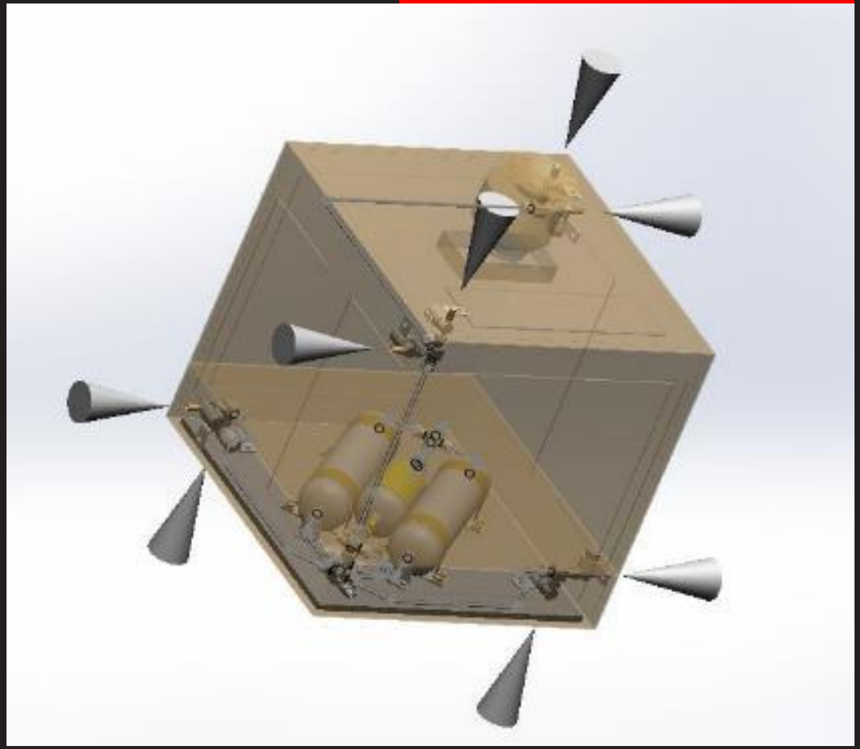
Monopropellant/Bipropellant

Electric propulsion

Arcjet/Hall Thruster/PPT/FEEP/Colloid thruster

Target Mission

Thrust Directions



25kg satellite

Power≤15W

System mass≤6kg

ΔV≥35m/s

50mN(altitude control)

150mN(orbit control)

Thrust accuracy≤5%

Target Mission

Cold gas system
(Liquefied gas)

- Power≤15W
- System mass≤6kg
- ΔV≥35m/s

Pressure/thrust control

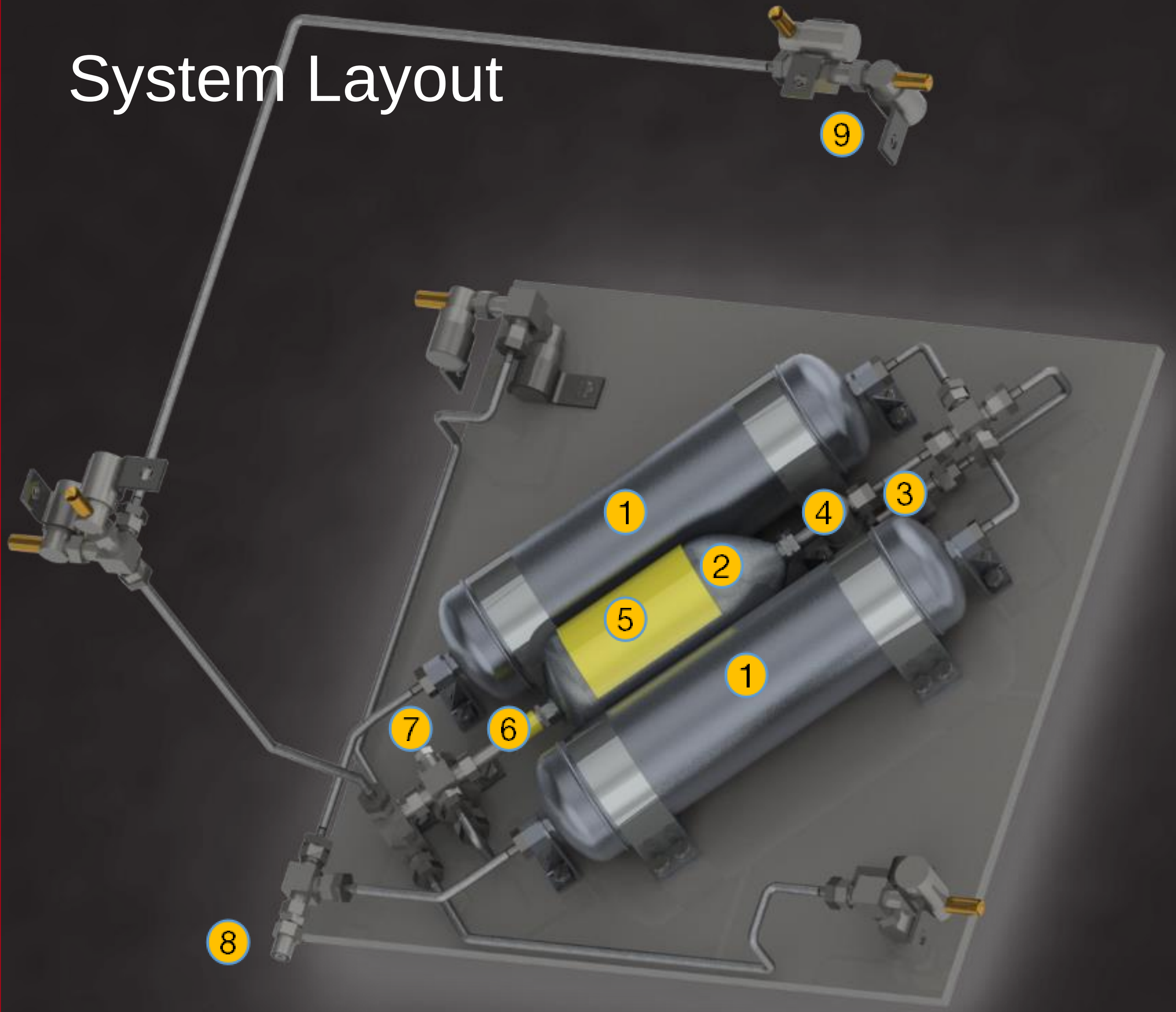
- 50mN(altitude control)
- 150mN(orbit control)
- Thrust accuracy≤5%

Target Mission

Quick and Cheap {

- Additive Manufacturing
- Commercial Off-The-Shelf Components

System Layout



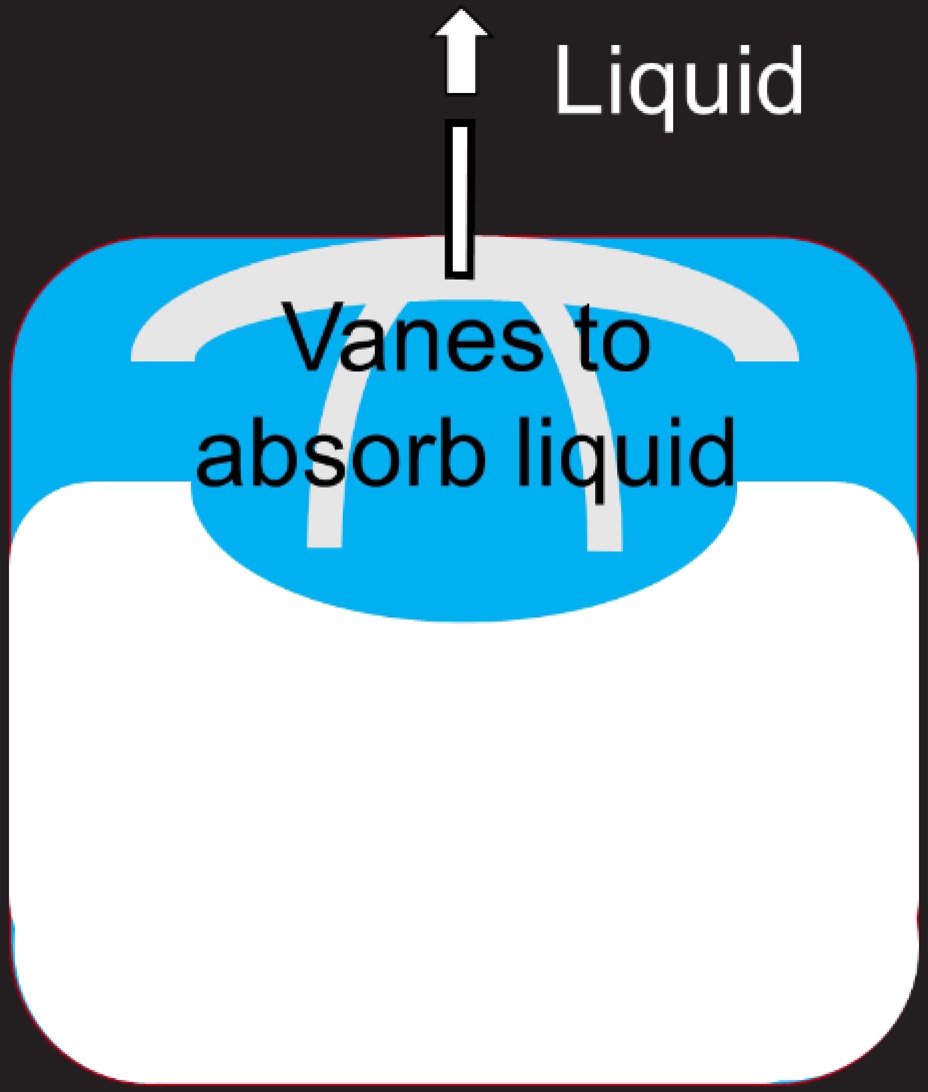
1. Tank×2
2. 3D-Printed Plenum
3. Pressure Sensor ×2
4. Isolation Valve
5. Heater
6. Filter
7. Temperature Sensor
8. Fill/Drain Valve
9. Solenoid Valve&Nozzle ×8

OUTLINE

- Simplified Tank Design
- Thrust Control
- Additive Manufactured Components
- Thrust Measurement

Simplified Tank Design

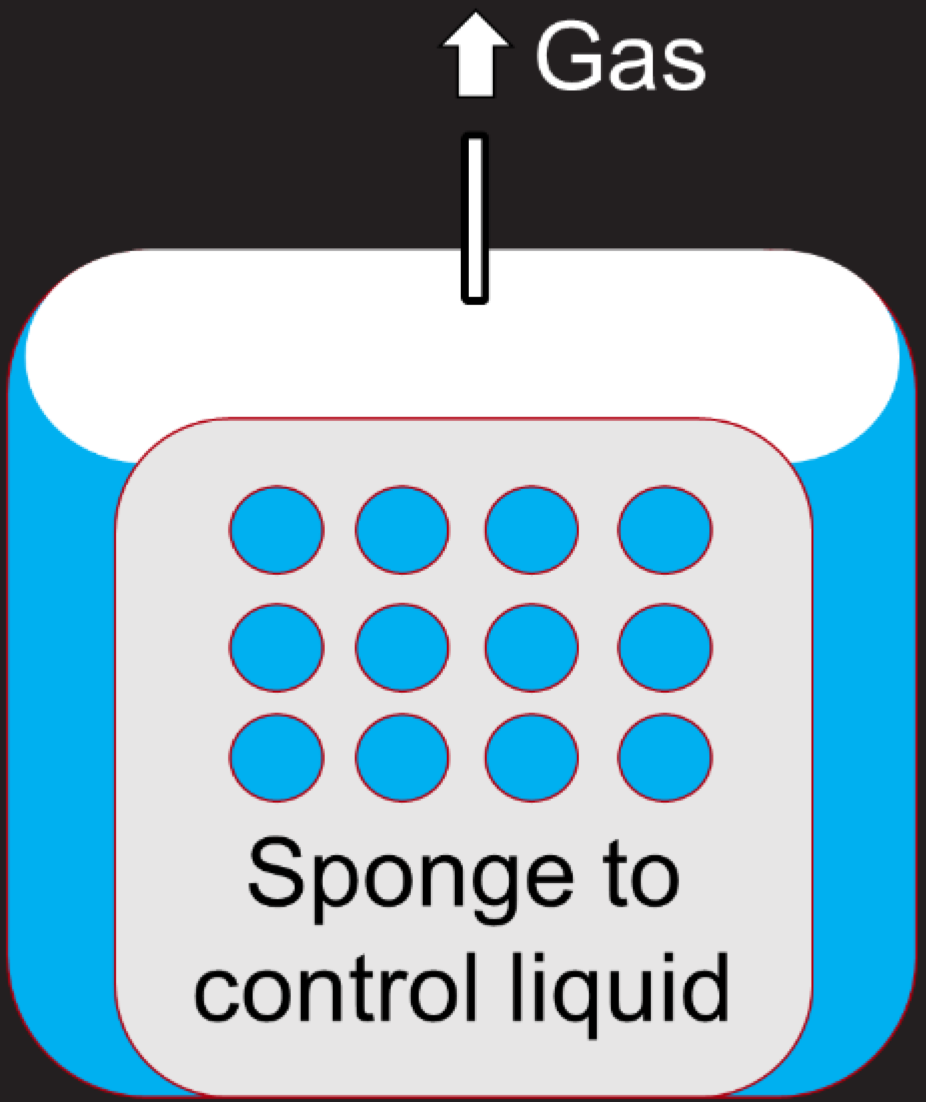
Traditional Tank Design with PMD



For chemical propulsion:

Light weight
Cheap
Reliable

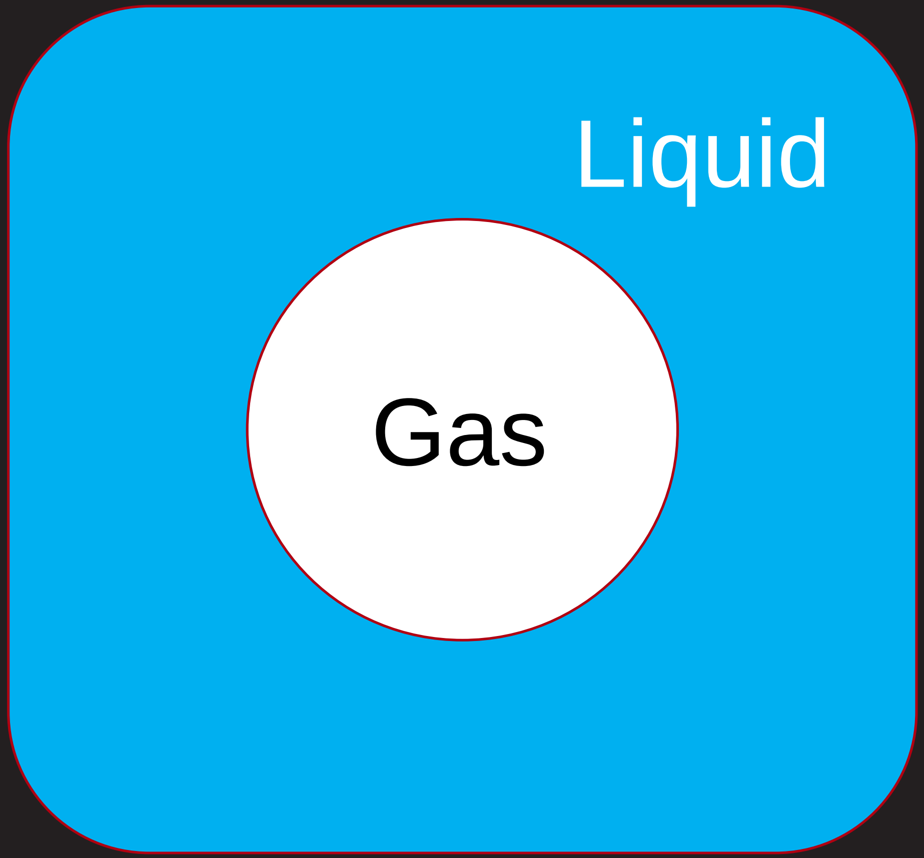
Traditional Tank Design with PMD



For liquefied gas propulsion:

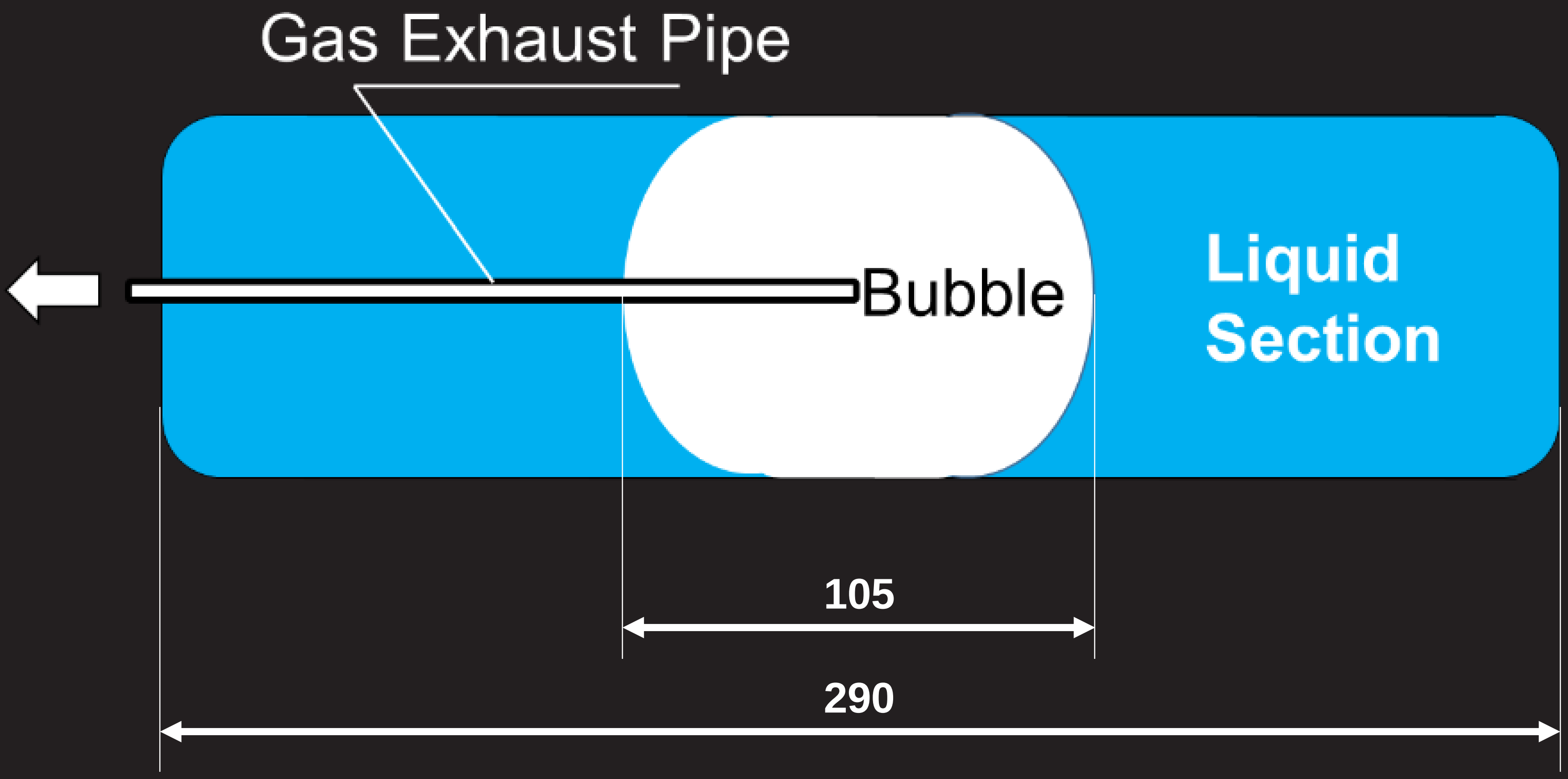
Heavy
&
Size of existing tanks
don't match the satellite

Simplified Tank Design



Two-phase interface in microgravity
(when infiltrating)

Simplified Tank Design



Simplified Tank Design

Lightweight

Cheap

Only add a pipe to the tank

No sloshing control

Thrust Control

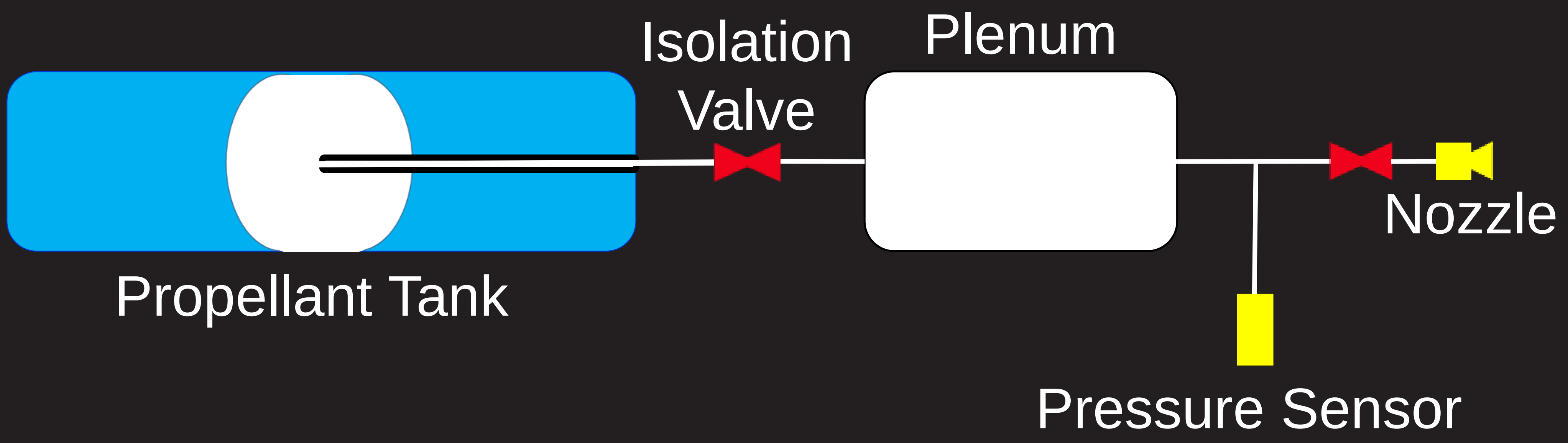
How to regulate pressure/thrust?

Mechanical regulating valve

Electronic closed-loop valve

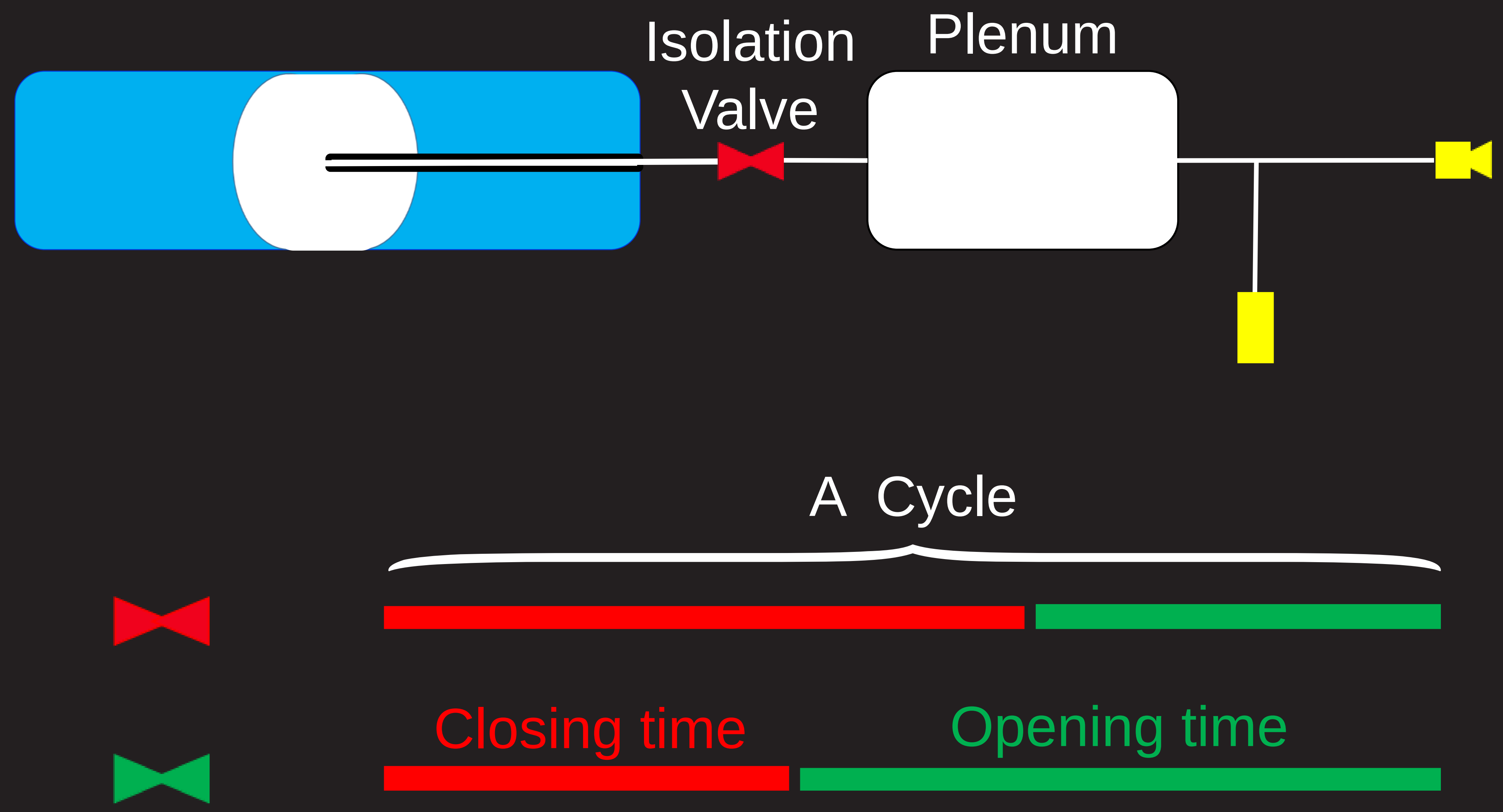
Bang-Bang control in a plenum

Bang-Bang Control in Plenum



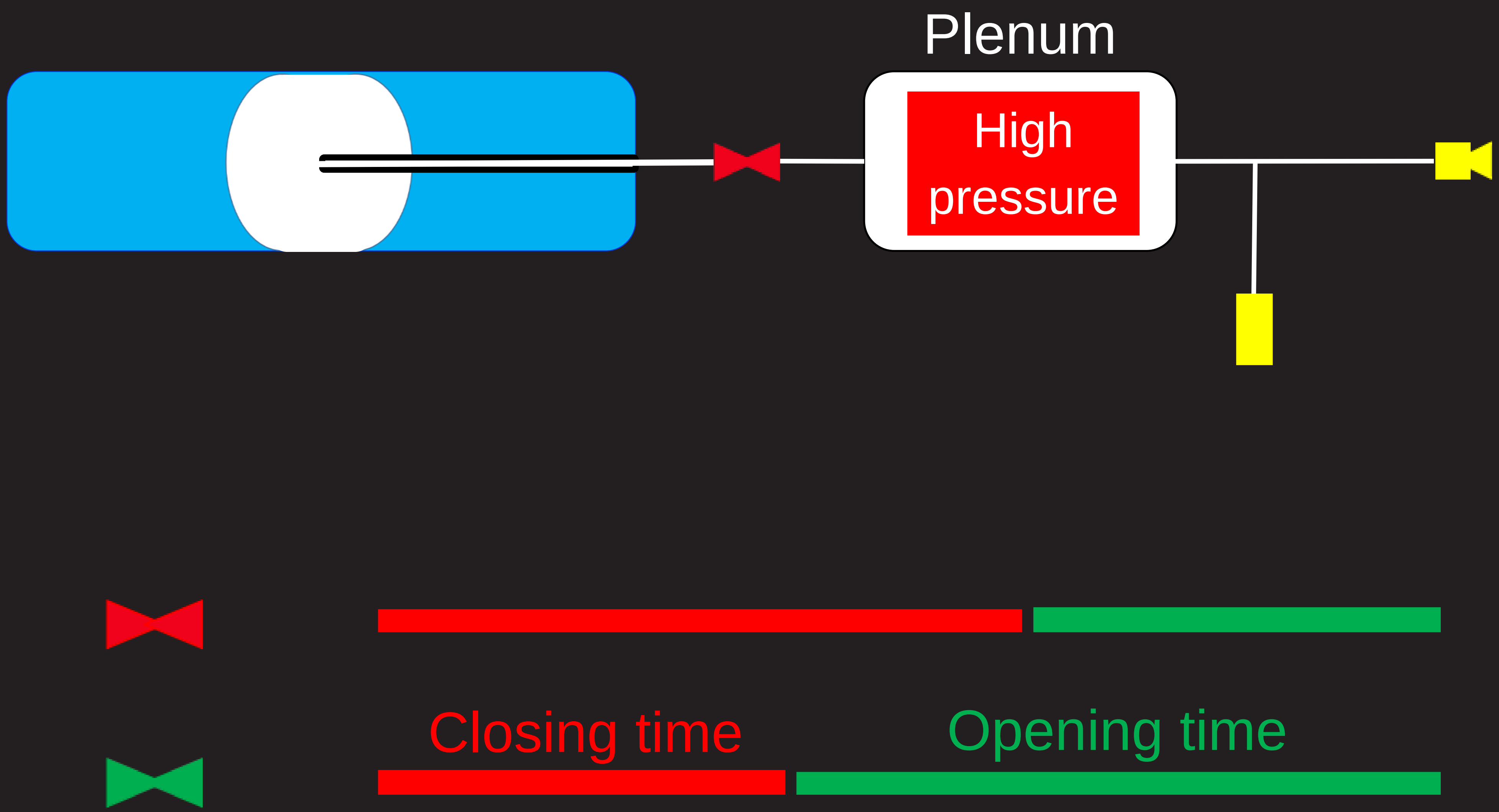
Pressure in Plenum → Thrust

Bang-Bang Control in Plenum



Nozzle valves are omitted here

Bang-Bang Control in Plenum



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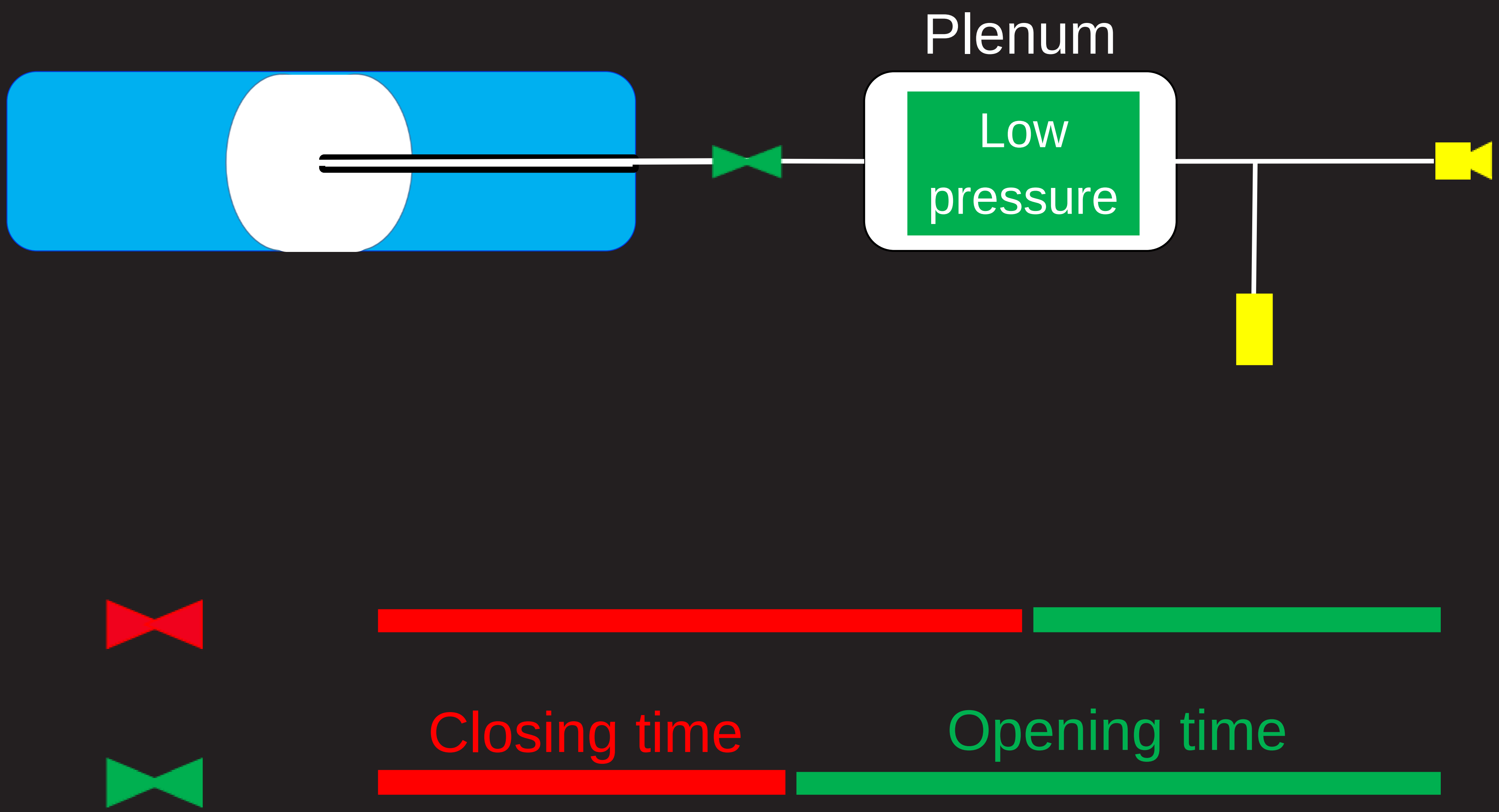
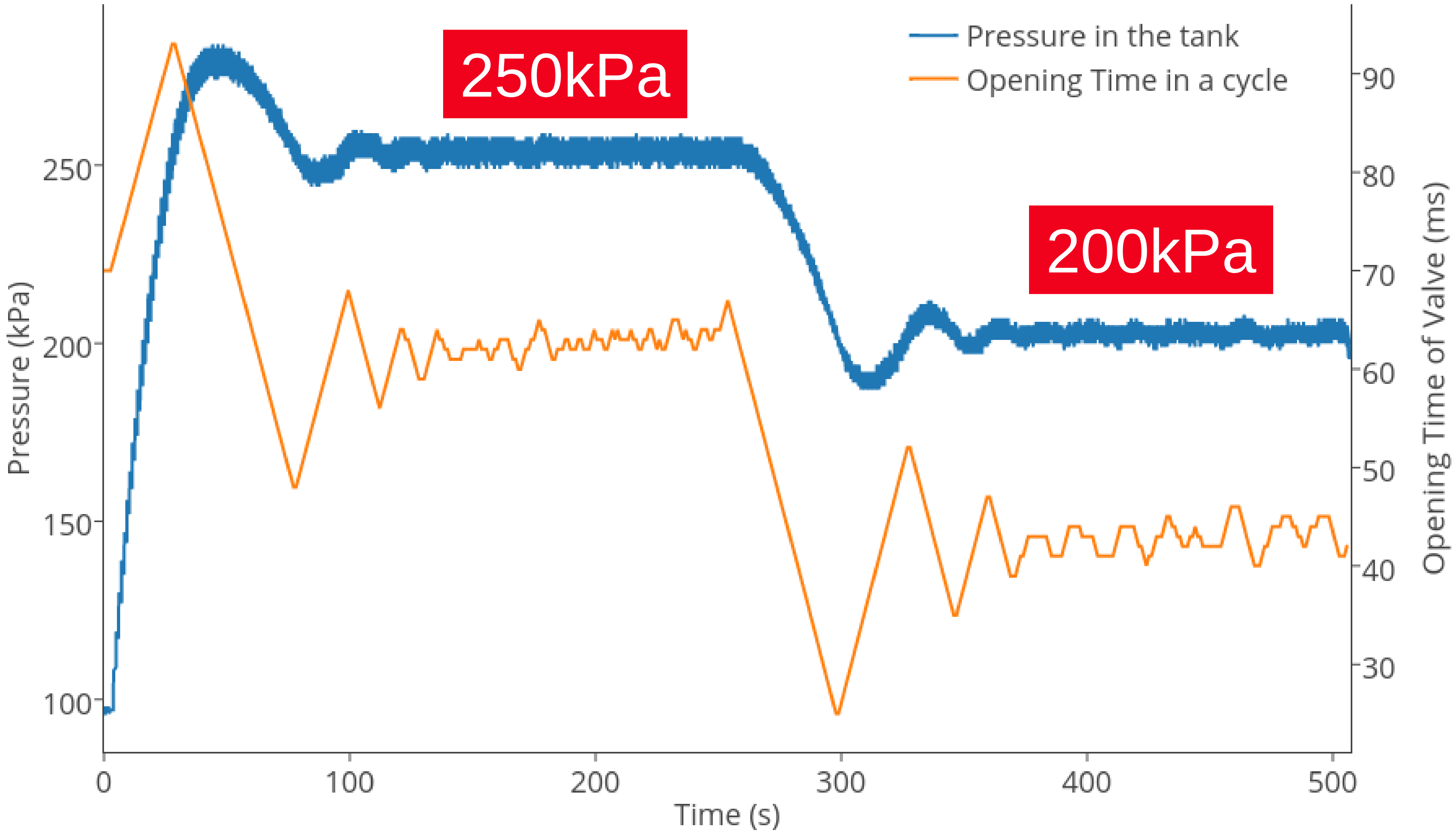
Bang-Bang Control in Plenum



Nozzle valves are omitted here

Why choose plenum?

If residual liquid enter the pipeline,
the plenum will help it vaporize



5% accuracy achieved by a 0.5L plenum

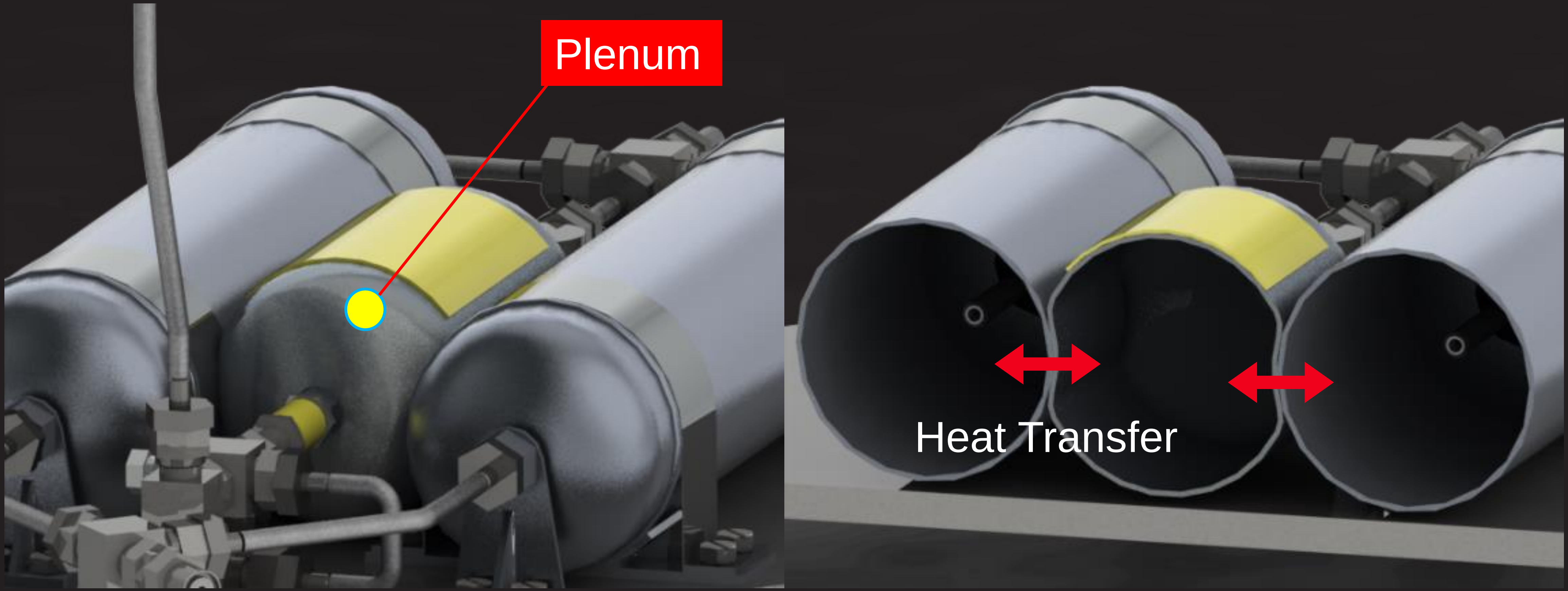
Additive Manufactured Micro Propulsion

Why use additive manufacturing?

The same electronics and valves can be integrated in different missions quickly

But tank production needs more time for welding and examination

Why use additive manufacturing?

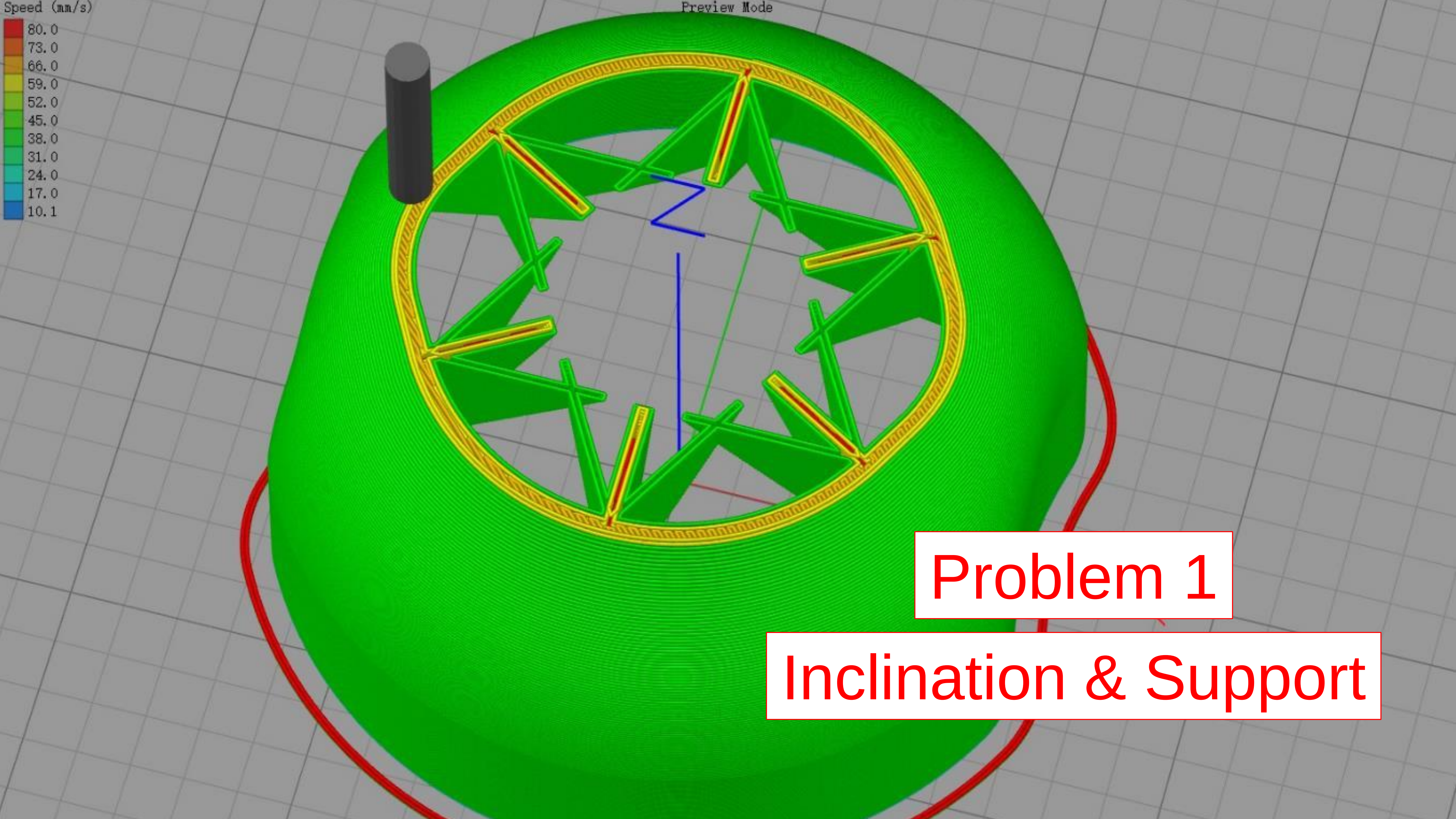


The plenum is a special-shape pressure vessel

Which process?

Metal AM

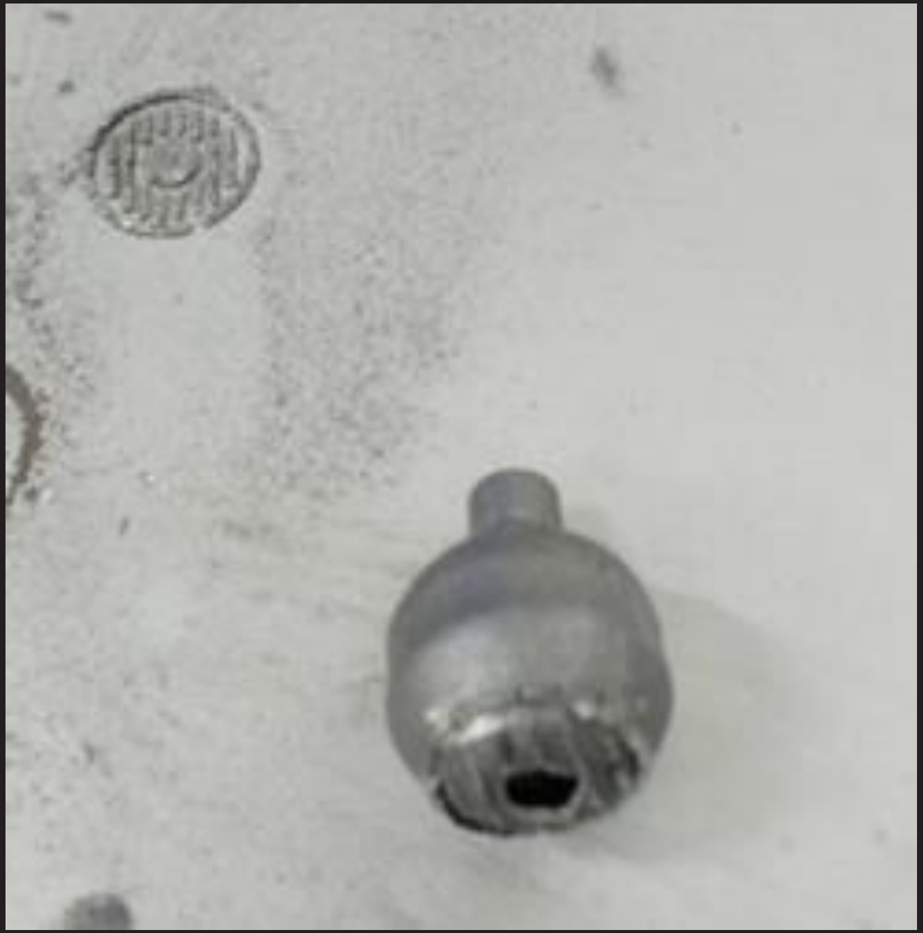
- Powder bed fusion — SLS/SLM/EBM
  - Small size, mature
- Powder-based deposition — LENS
  - Large size
- Wire-based deposition — EBF3
  - Larger size, quicker



Problem 1

Inclination & Support

3D-Printed Components



Scaling Model

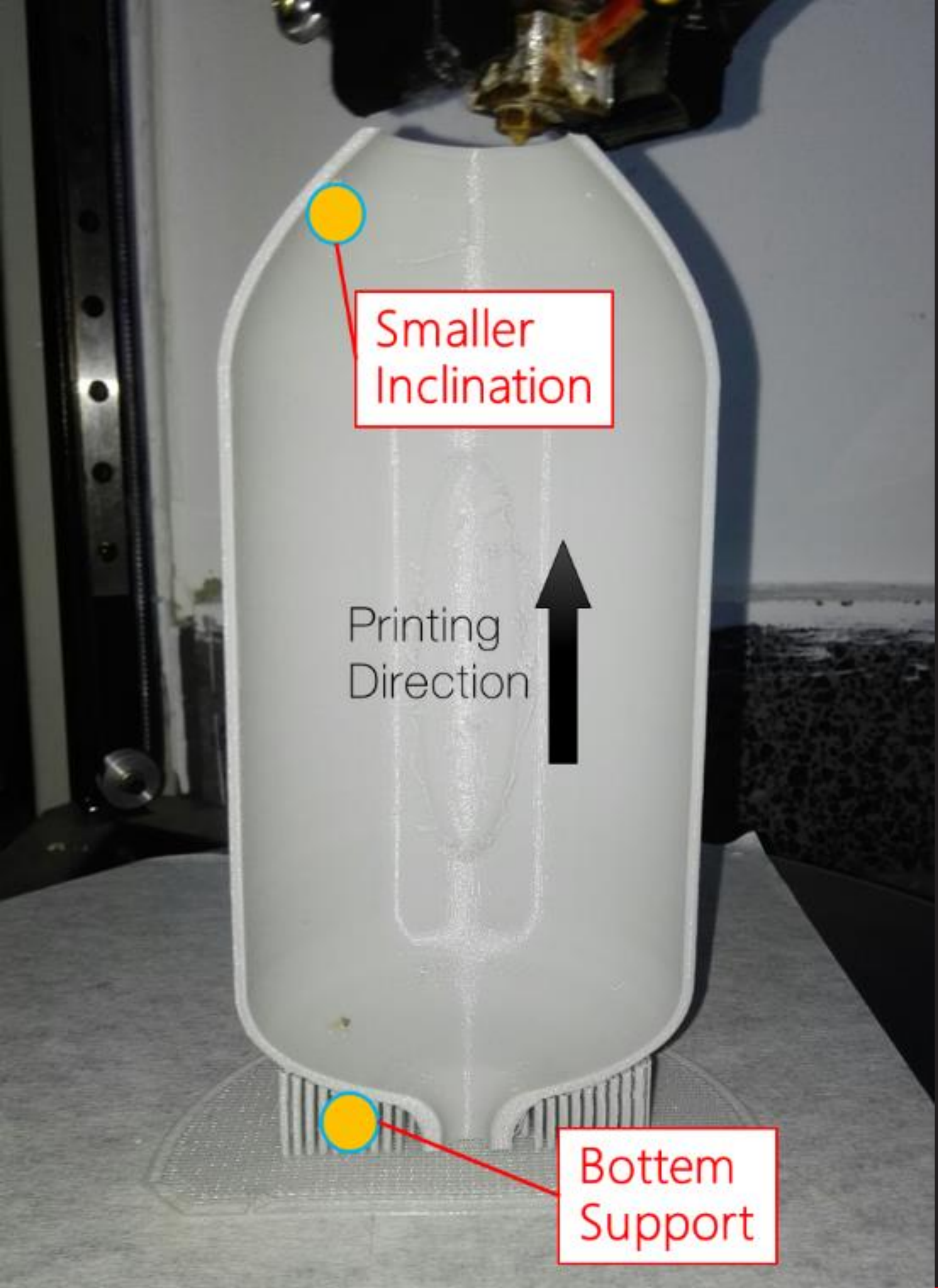
Problem 2

Thin wall

↓

Damage during removing

1:1 Model of the Plenum

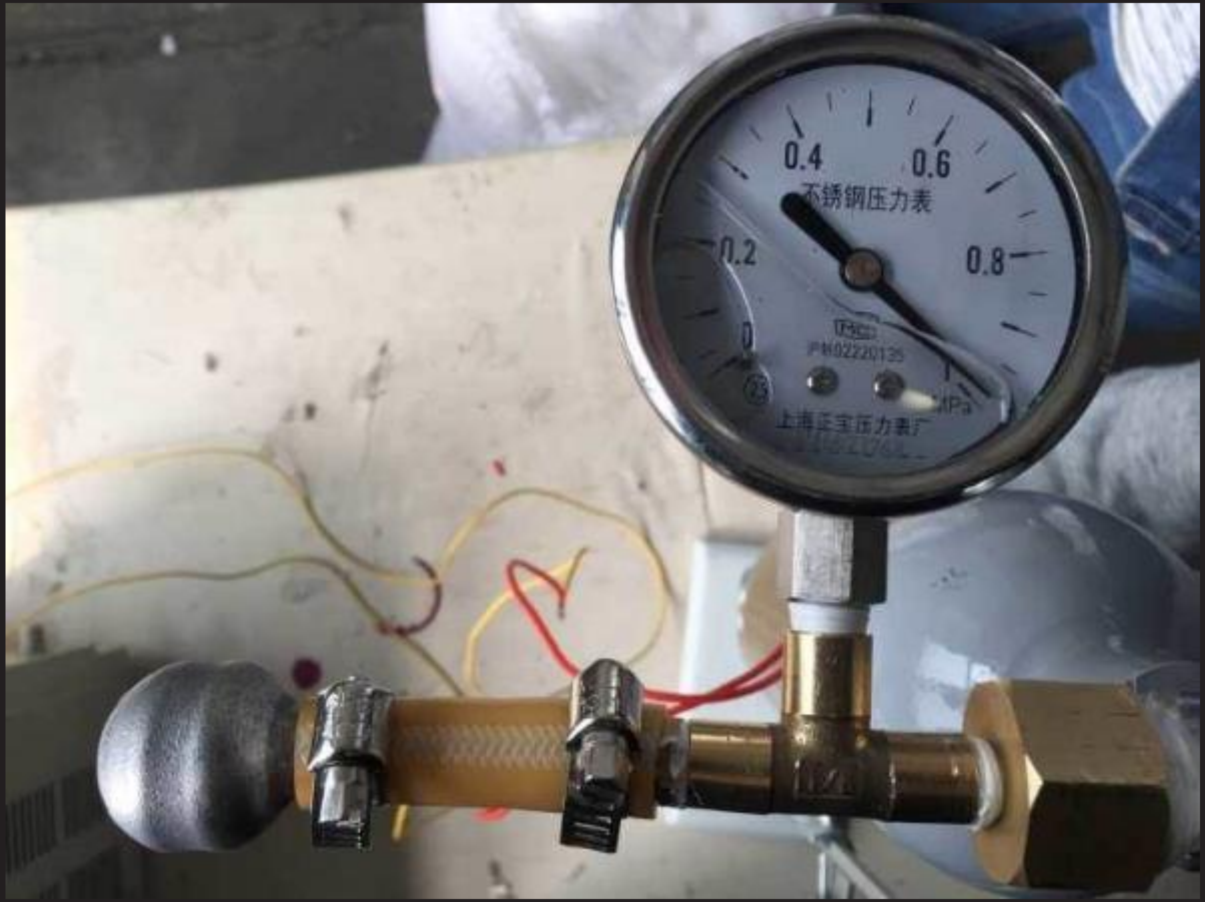


Solutions:

Different Inclinations

Minimum wall thickness
≥ 1.5mm

3D-Printed Components

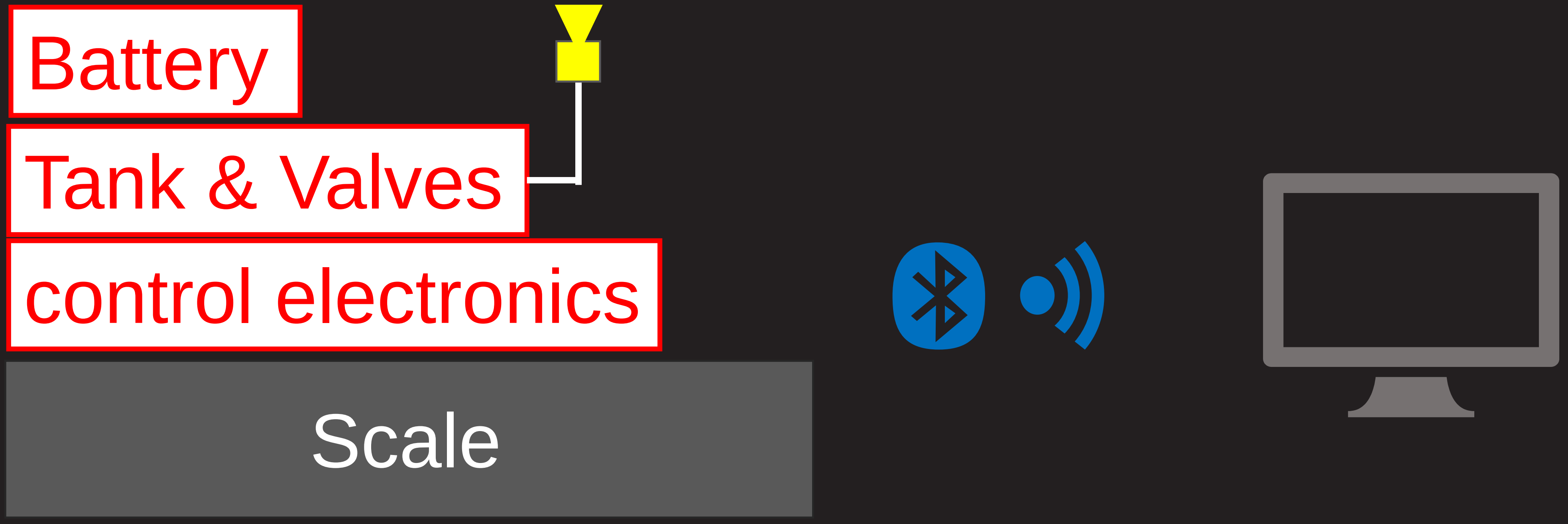


Scaling model withstood a 1MPa(145Psi) test.

Processing cost of the complete plenum is $1860.

Thrusts Measurement

Thrusts Measurement



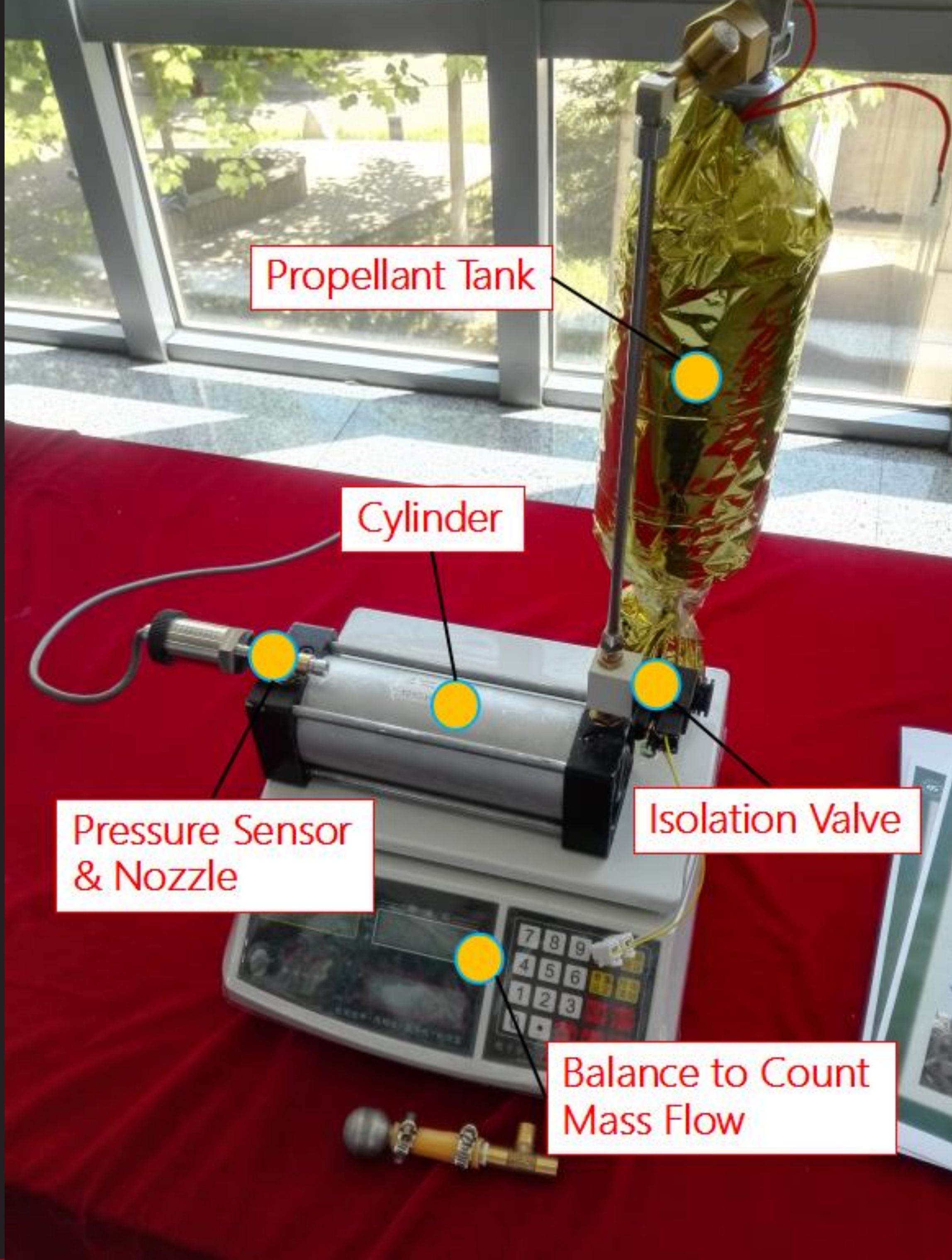
Scale capability: 30kg/0.1g

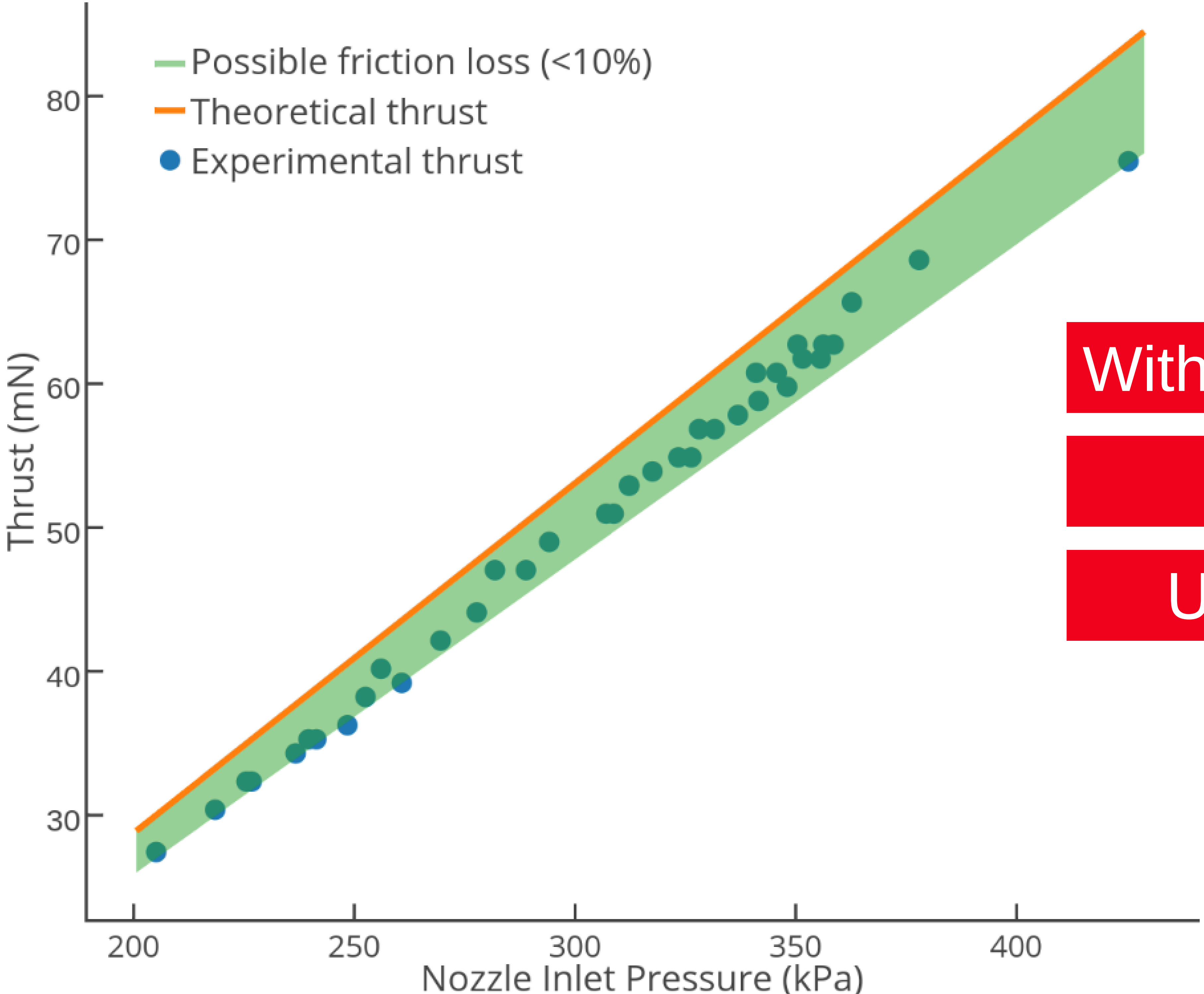
Whole propulsion system is placed on the scale

No wiring/pipeline interference

Thrusts Measurement

Thrust measurement of prototype

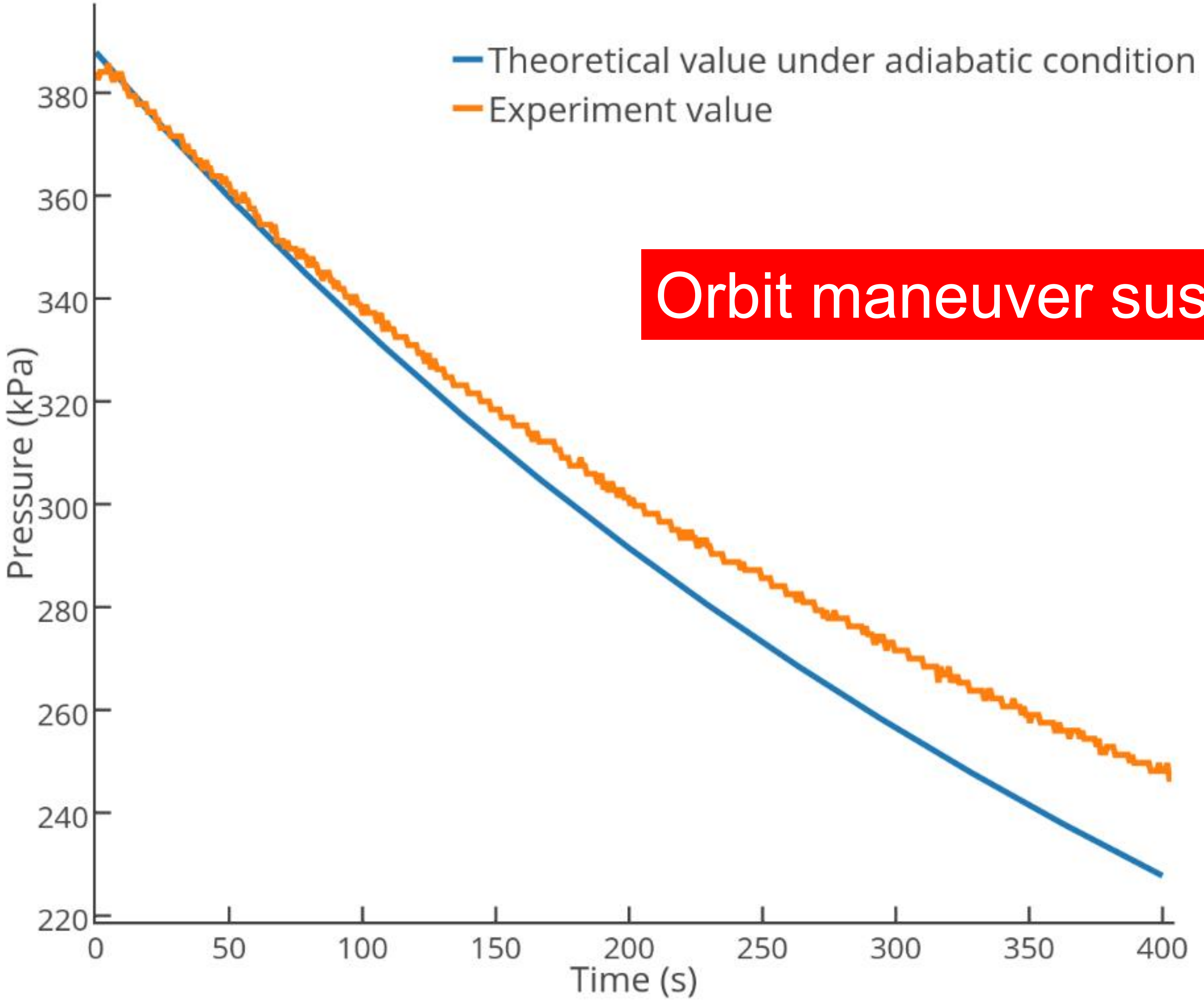




Within friction loss range

Calibrated

Uncertainty ≤ 1mN



Orbit maneuver sustainable time≥200s

Conclusion

Conclusion

1. Prototype test have been completed, and the design meets the requirement of the target mission.

2. Commercial SLM method can meet the requirement of small-satellite-size components now.

3. Novel gas extract method has been proposed.

A sophomore research program in BUAA

Thank you for listening!
And questions?

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