

*Development of the
Water Resistojet Propulsion System
for Deep Space Exploration
by the CubeSat: EQUULEUS*



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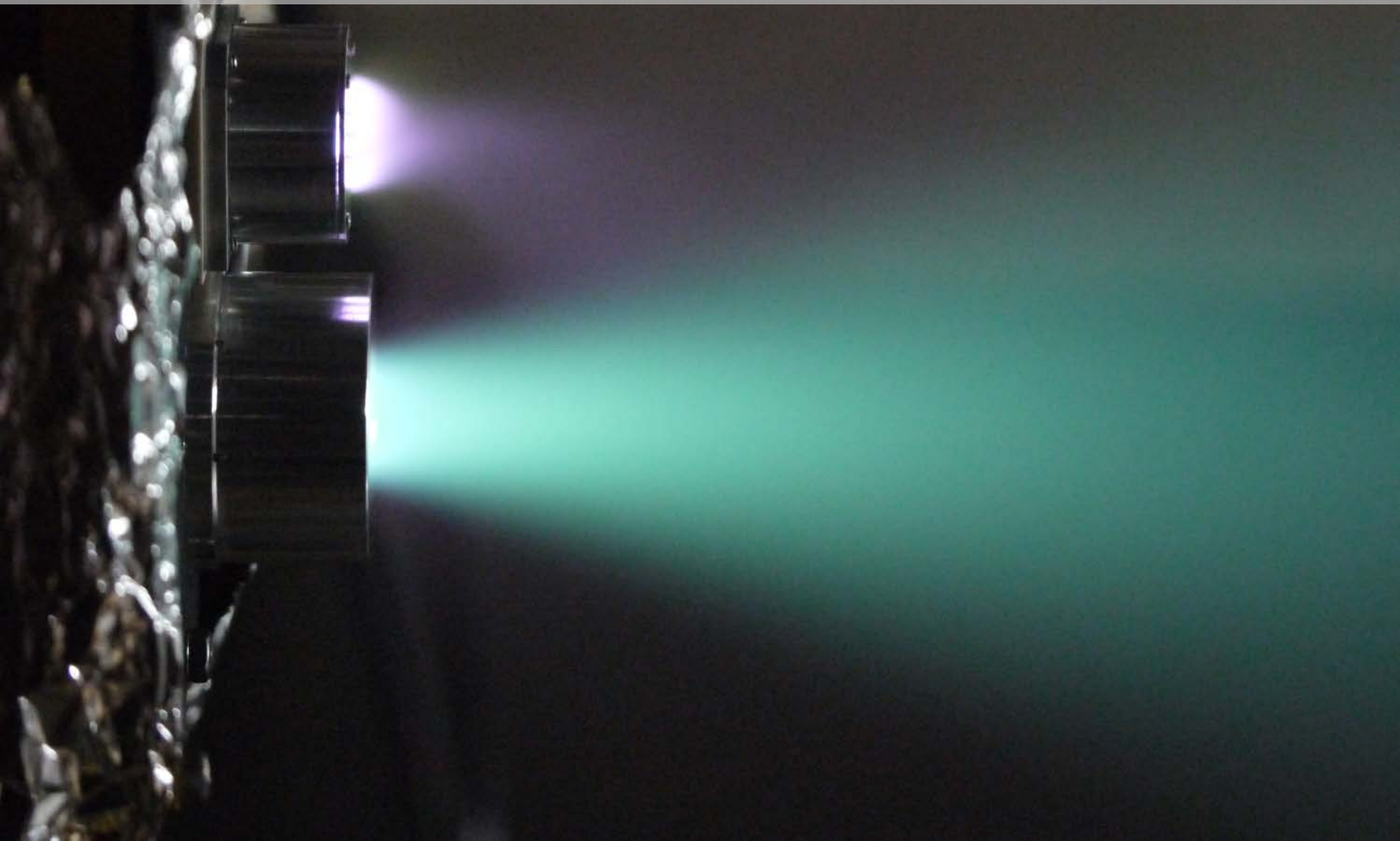
Kimiya KOMURASAKI



Micro-/Nano satellite missions are diversifying such as re-entry, constellation and deep space exploration.



Micro-propulsion systems
are indispensable for micro/nano-satellites.



Three things are required to the next-gen micro-propulsion system.

- Unpressurized
- Safe and easy-handling
- Multi-function



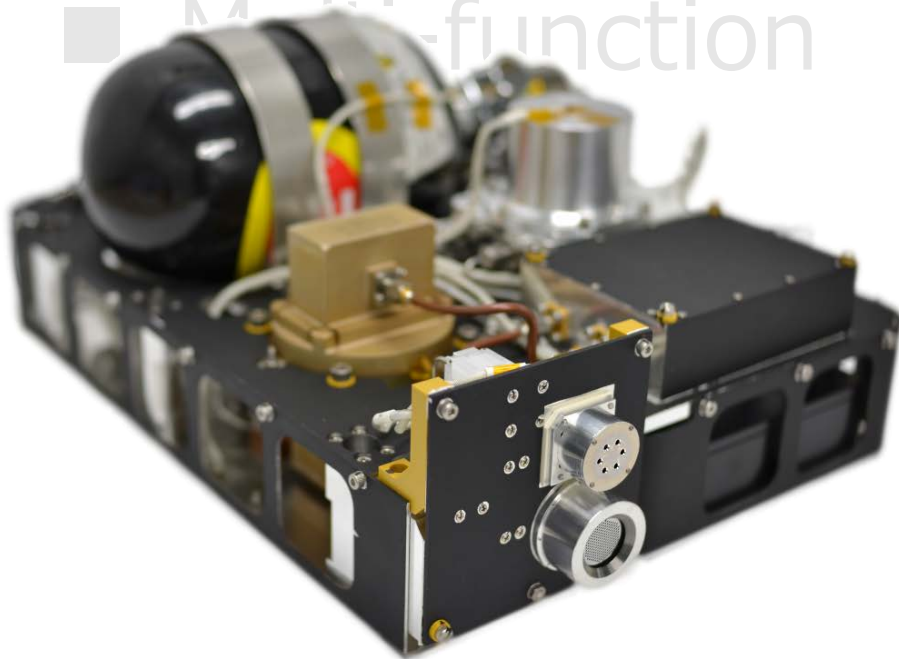
High pressure gas systems

increase dry mass fraction which does not contribute to thrust performance.

■ Unpressurized

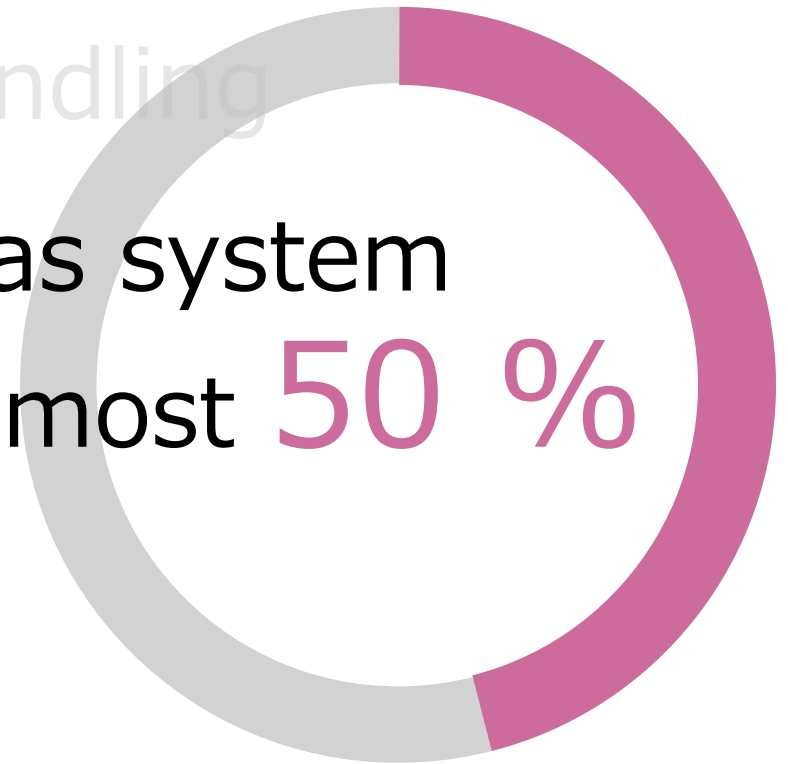
■ Safe and easy handling

■ Multi-function



Gas system

Almost **50 %**



Toxic propellant utilizing cost

is high which is critical for micro/nano-satellites.

- Unpressurized

- Safe and easy-handling



Multi-functions such as orbital transfer or reaction control system are necessary for deep space exploration.

■ Unpressurized

■ Safe and easy handling

■ Multi-function

RCS

Delta-V

EQUULEUS

by  THE UNIVERSITY OF TOKYO

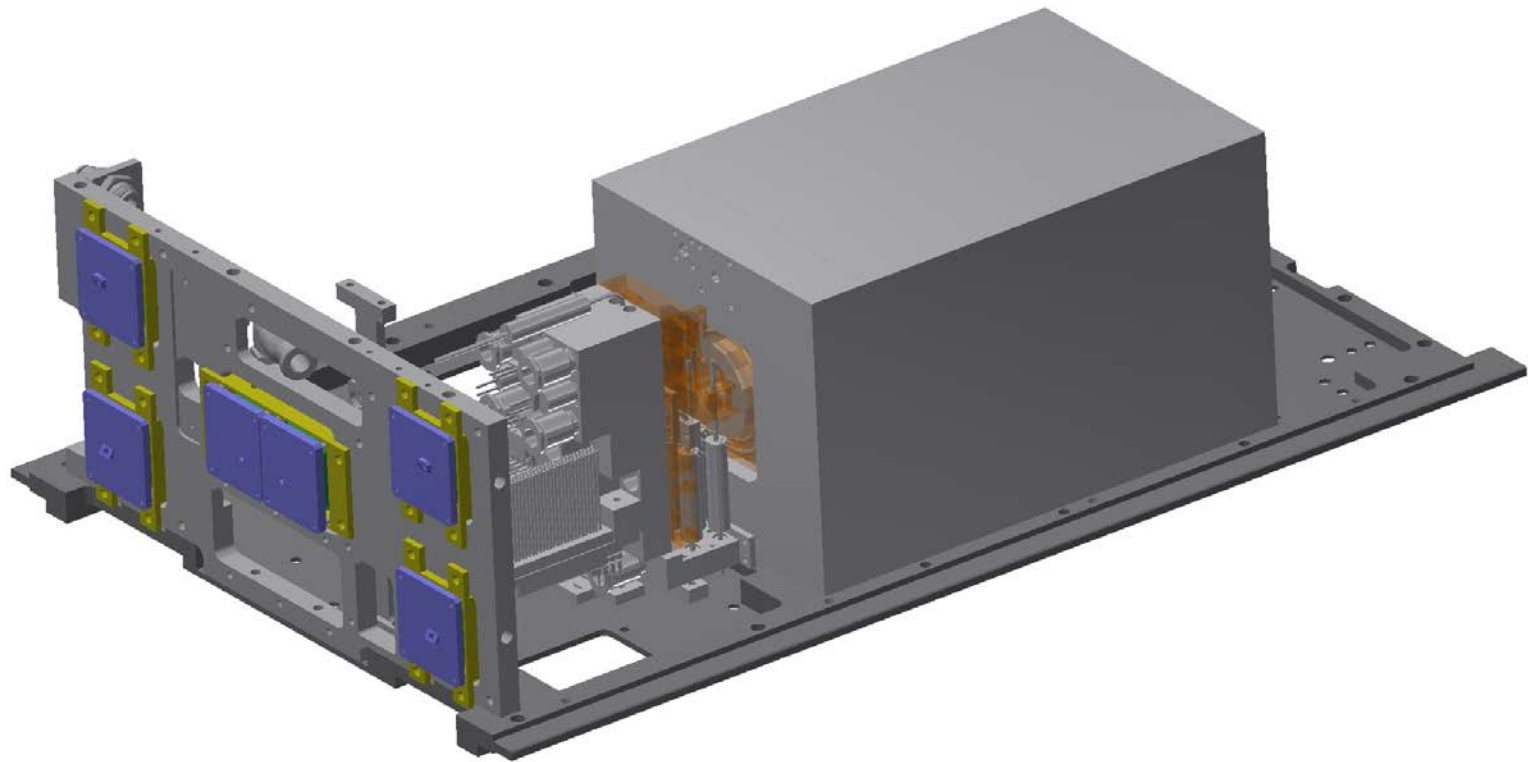
- Delta-V & RCS
- Smaller than 2.5U
- Short time maneuver



EQUULEUS,
EQUilibriUm Lunar-Earth point 6U Spacecraft
Will Be Launched on SLS EM-1

AQUARIUS

AQUA ResIstojet propUlsion System



AQUARIUS

AQUA ResIstojet propUlsion System



Propellant:

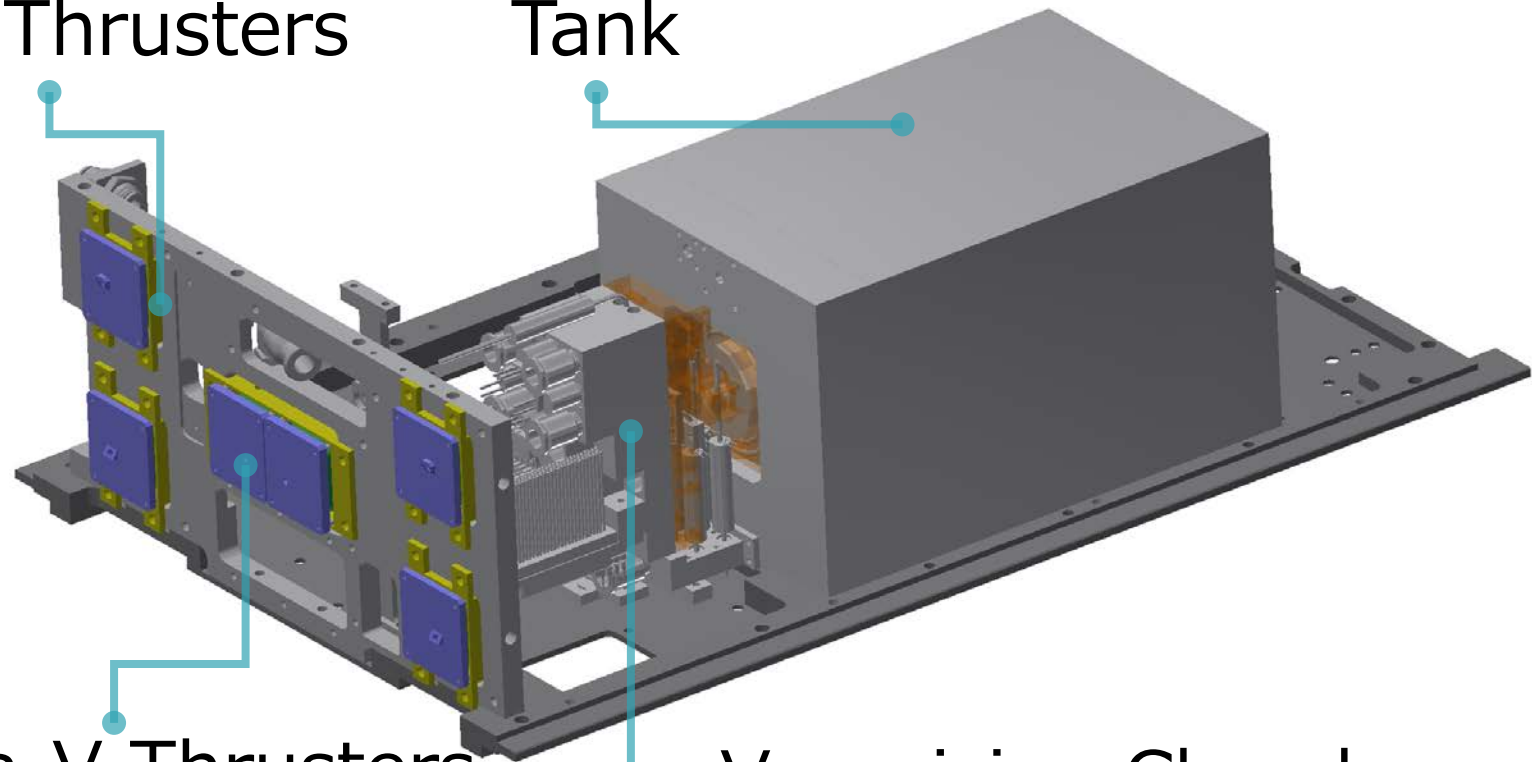
Water

AQUARIUS

AQUA ResIstojet propUlsion System

4x RCS Thrusters

Tank



2x Delta-V Thrusters

Vaporizing Chamber

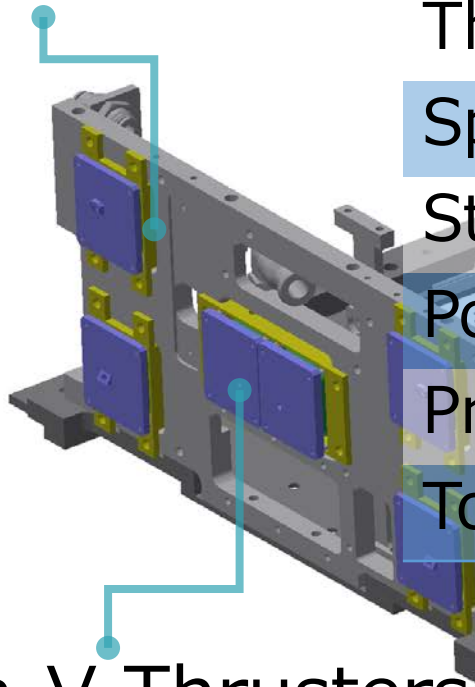
AQUARIUS

AQUA Resistojet propulsion System

Performance

Propellant	Water
Thrust	2 - 4 mN
Specific impulse	>70 s
Stored pressure	< 100 kpa
Power consumption	12 - 15 W
Propellant mass	1.2 kg
Total Delta-V	~ 70 m/s

4x RCS Thrusters

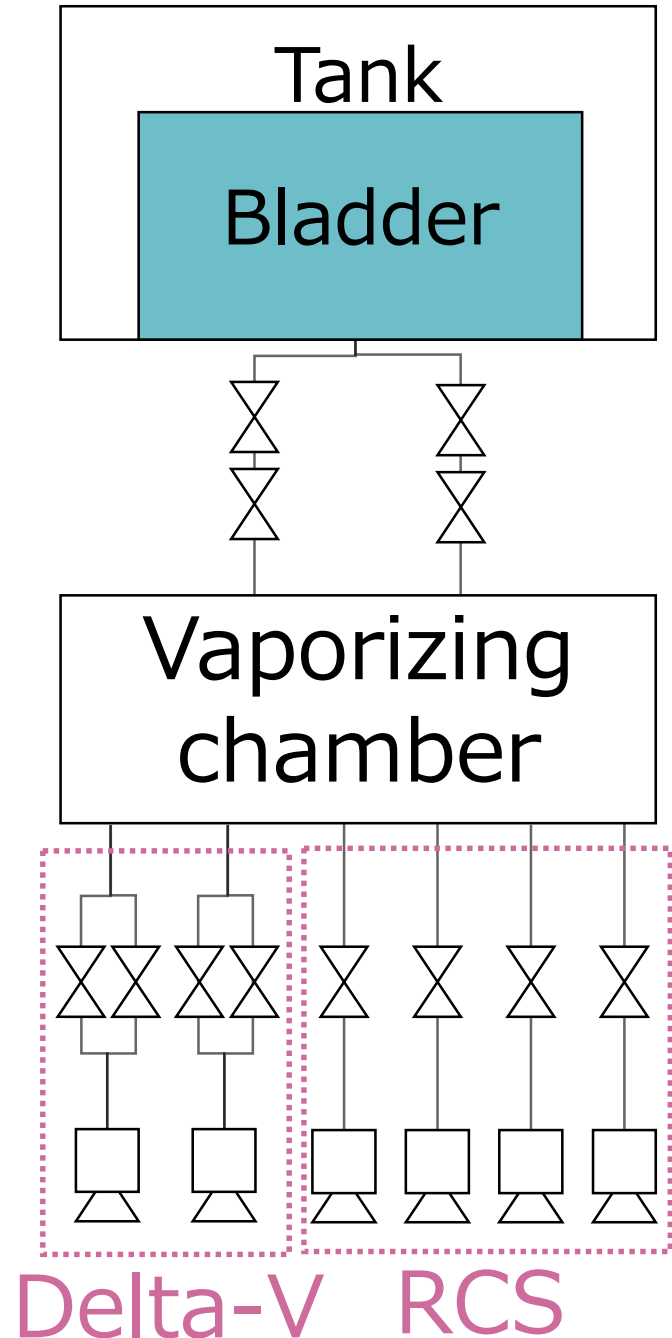


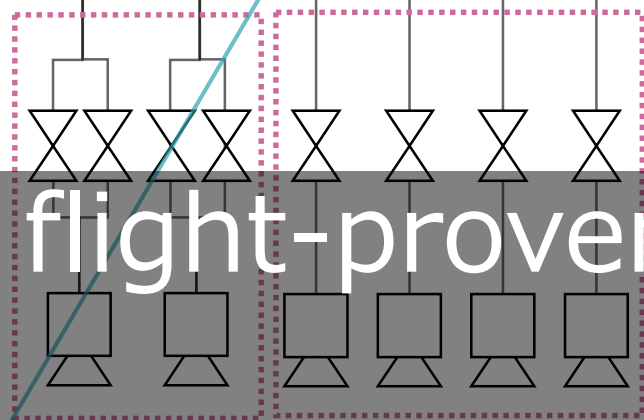
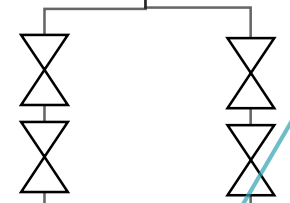
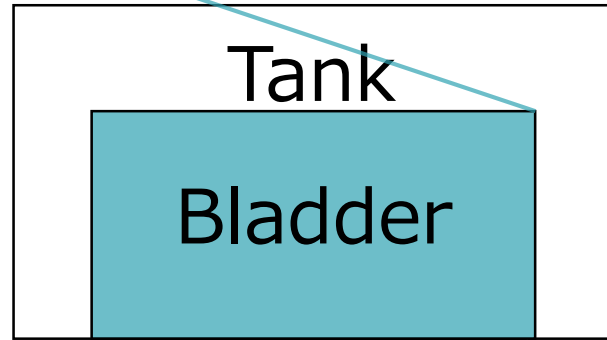
2x Delta-V Thrusters

Vaporizing Chamber

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AQUA ResIstojet
propUlsion System





Delta-V

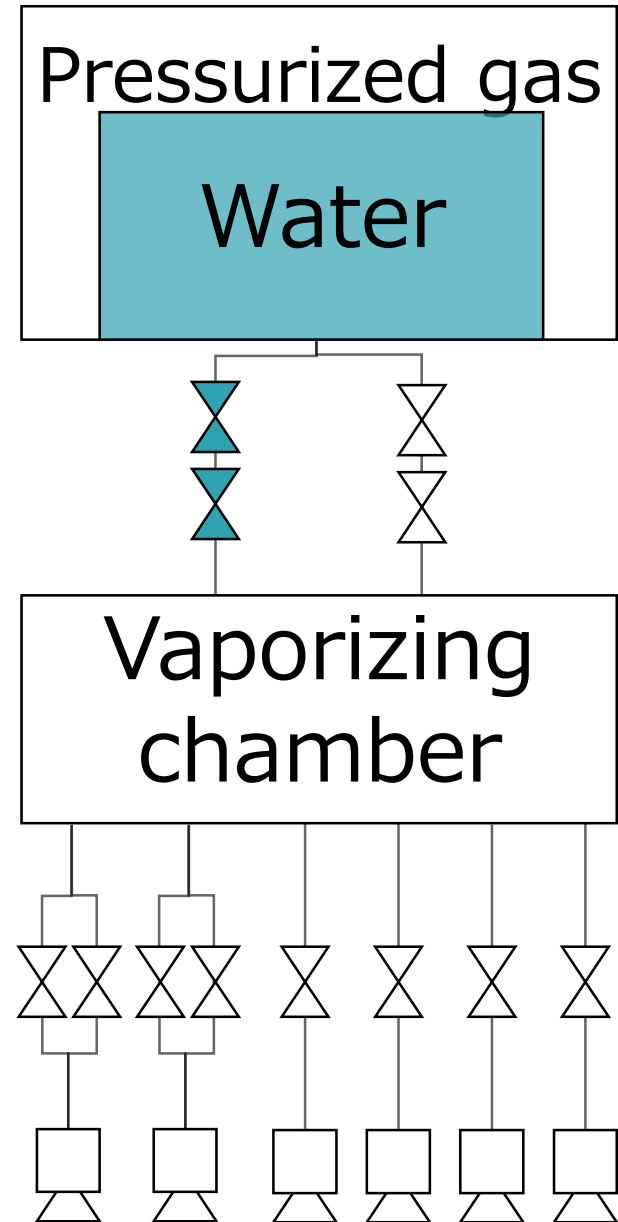
RCS

Bladder (COTS and flight-proven) are inserted in the tank.

1. Water is injected from tank to vaporization chamber by actuating regulation valves.

2. Water droplets attach to the inner wall and vaporize

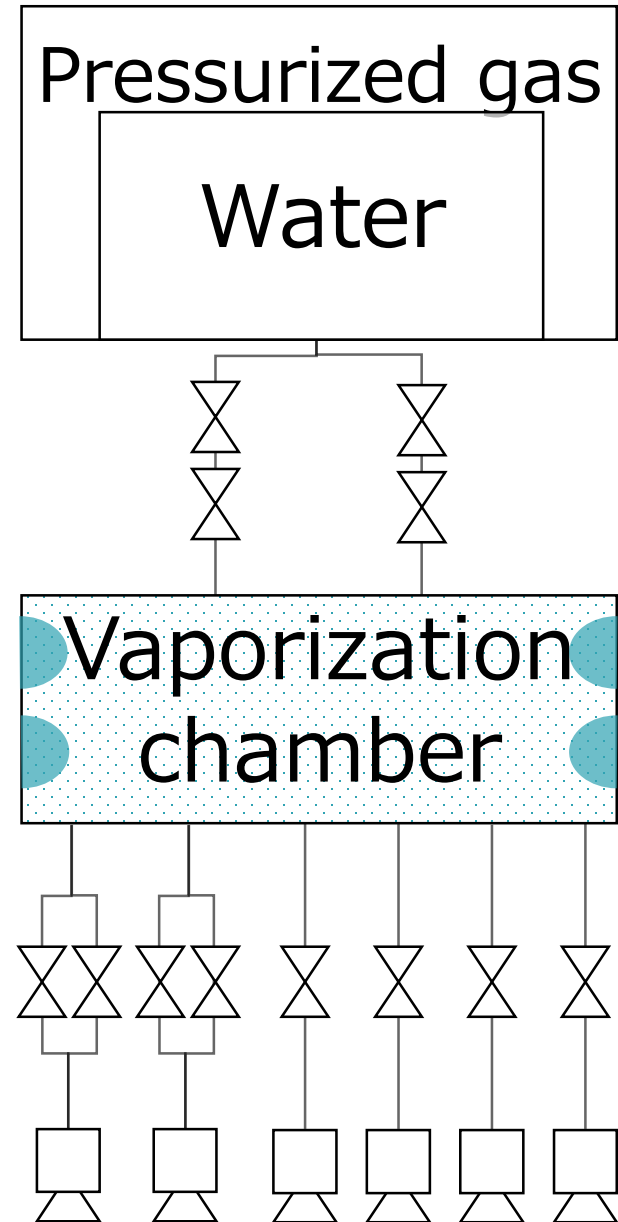
3. Saturated water vapor flows to nozzle by actuating thruster valves



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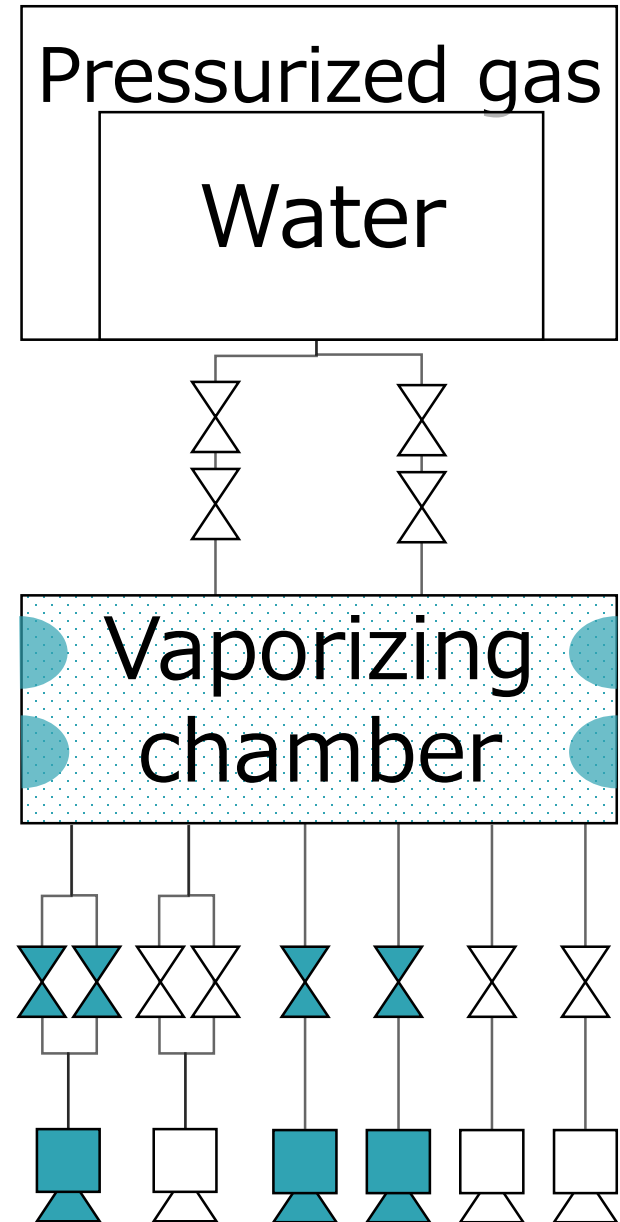
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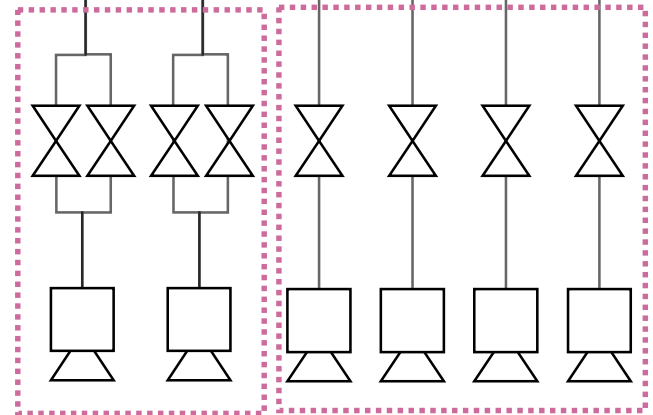
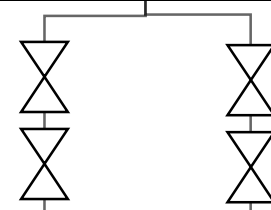
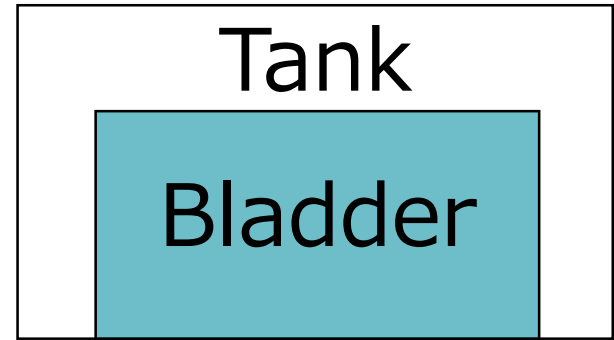
$< 100 \text{ kPa}$
 $\approx 20 \text{ }^\circ\text{C}$



$< 4.0 \text{ kPa}$
 $\approx 20 \text{ }^\circ\text{C}$



$< 4.0 \text{ kPa}$
 $\approx 100 \text{ }^\circ\text{C}$



Delta-V

RCS

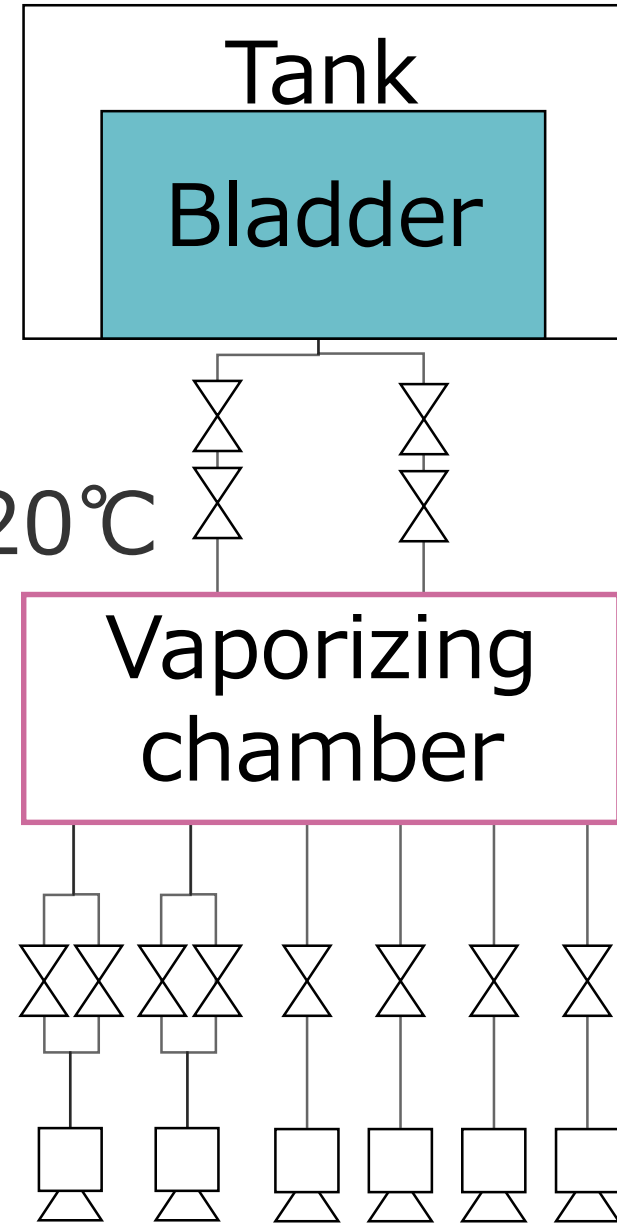
Energy Harvesting

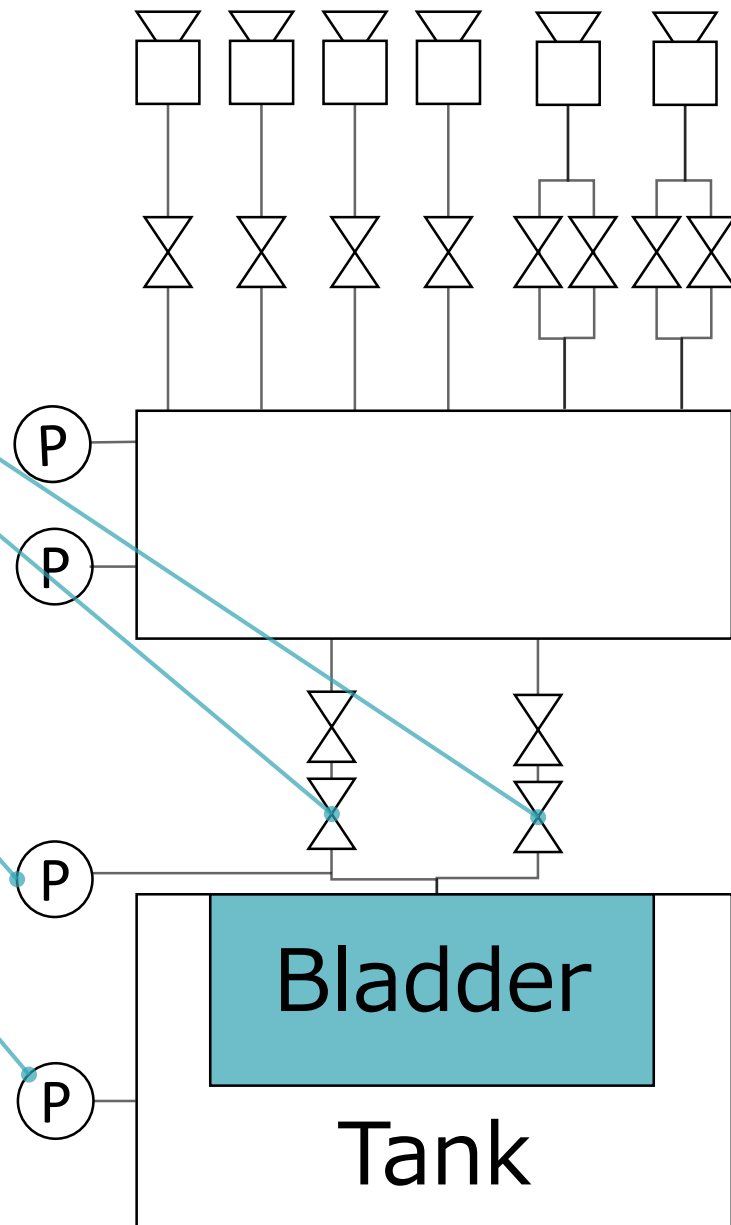
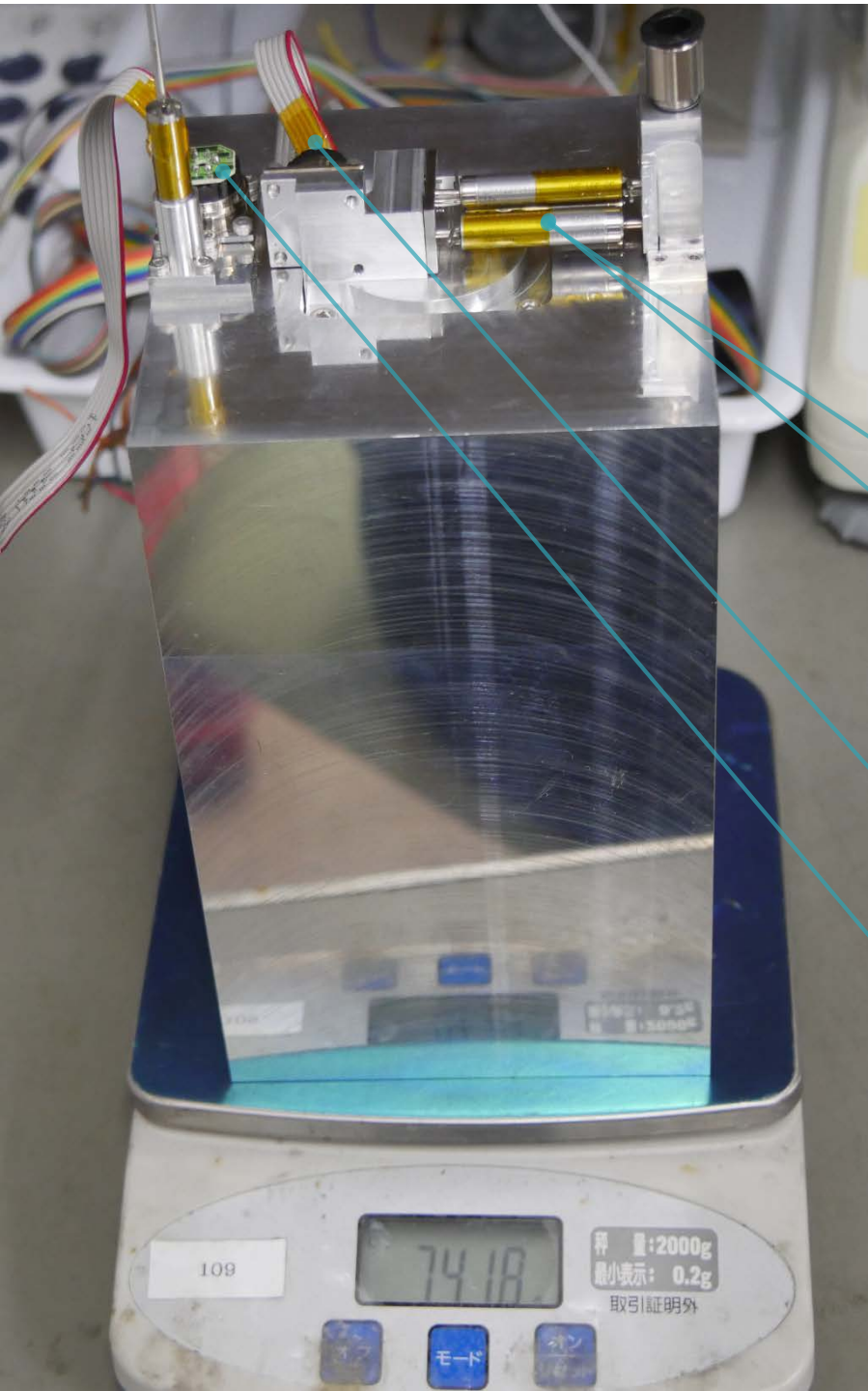
Communication

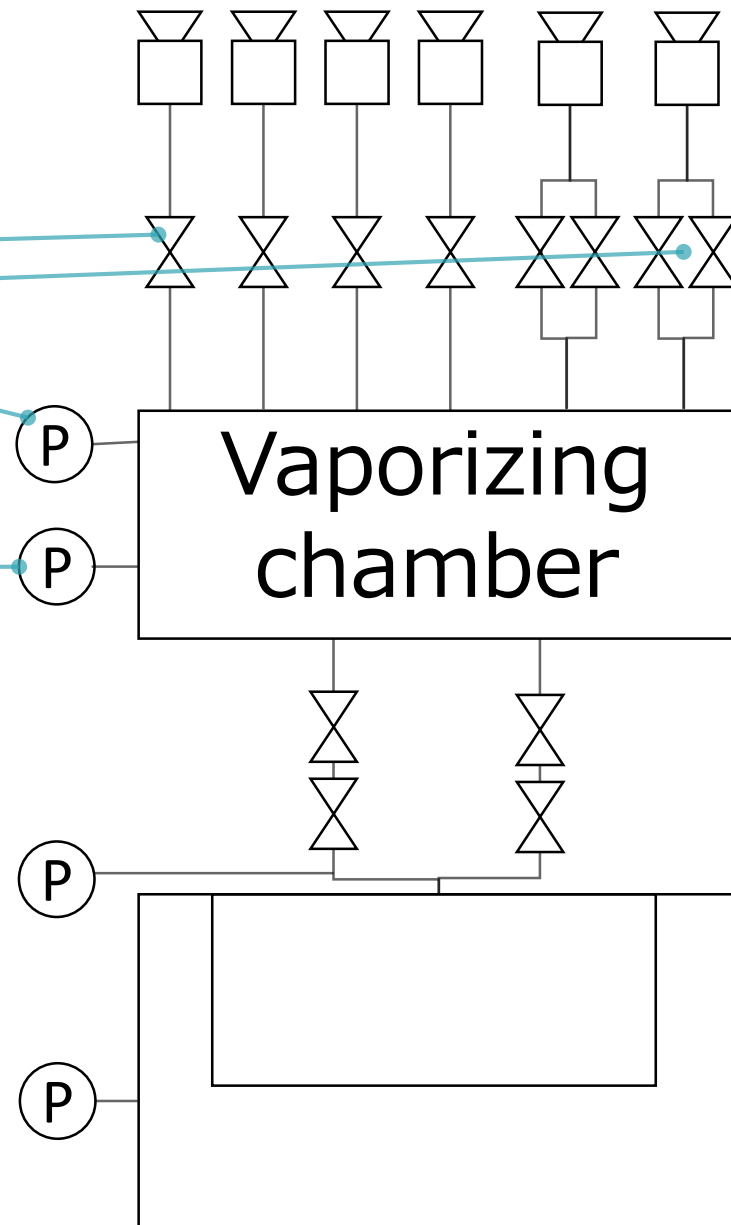
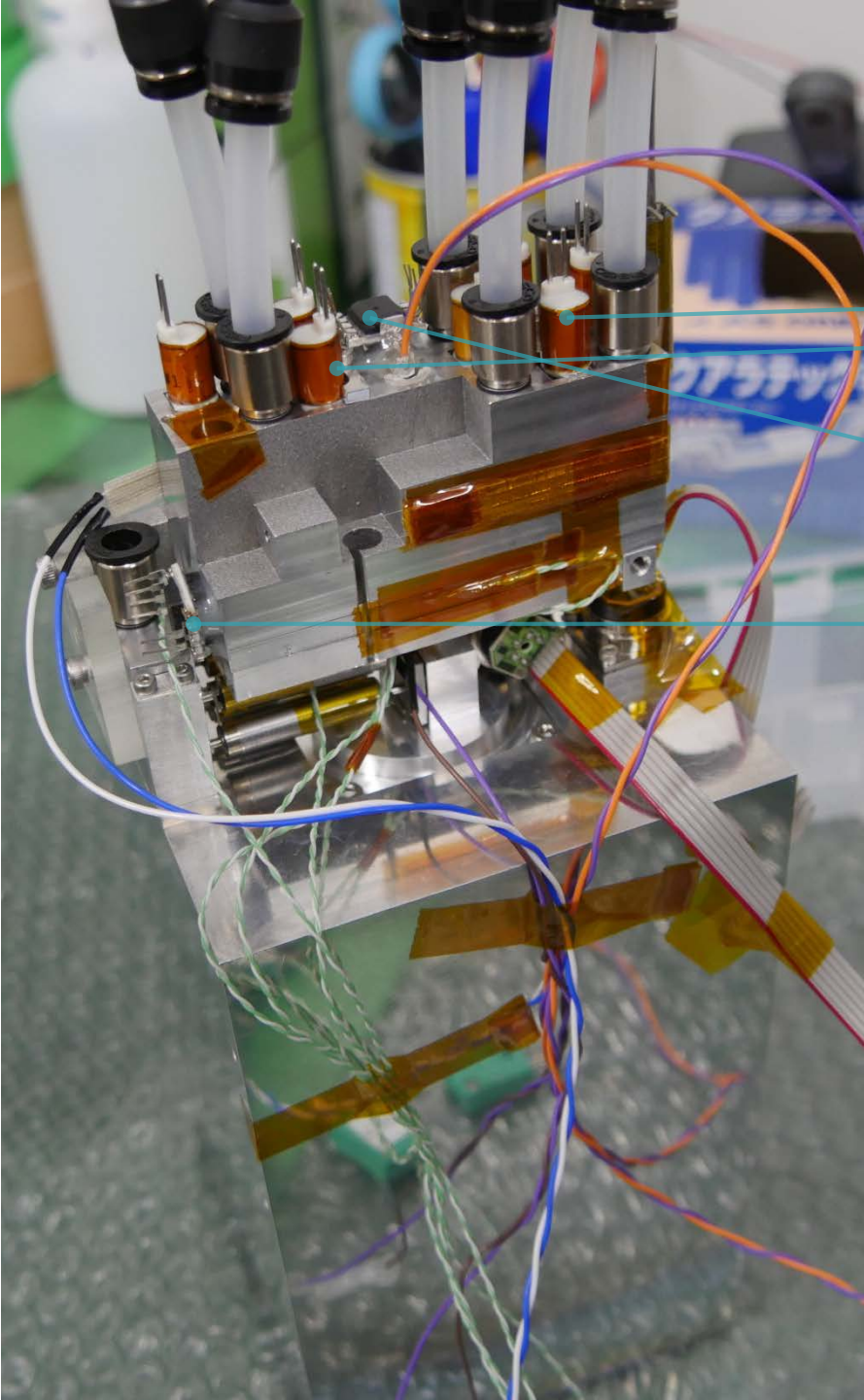
~ 30°C

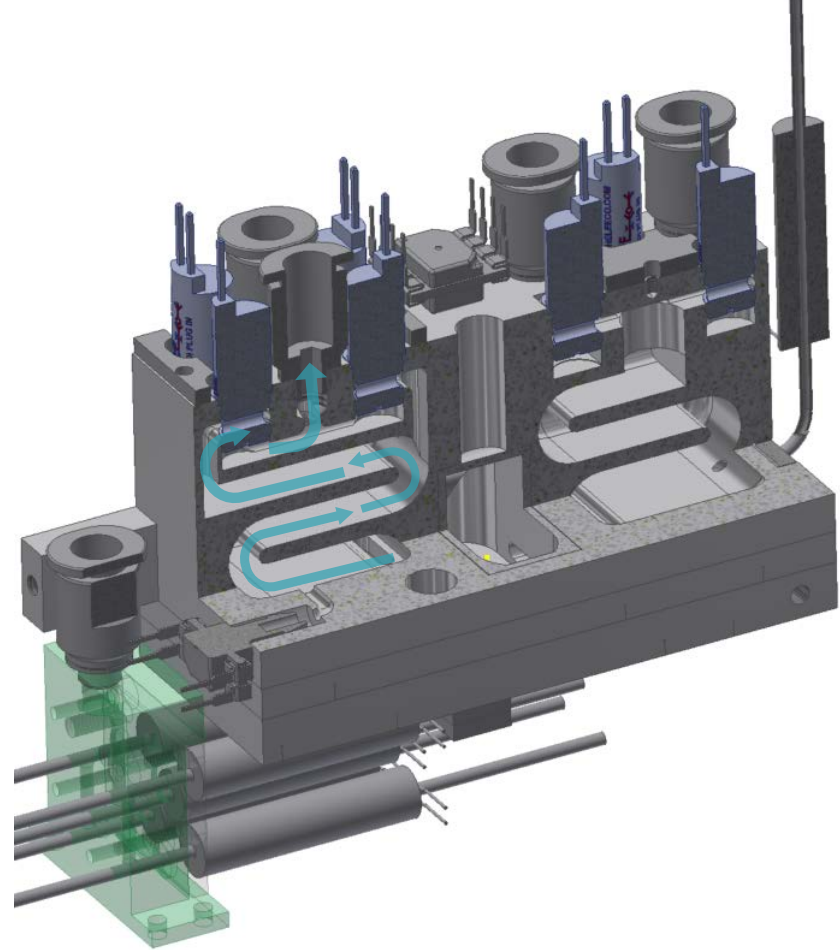
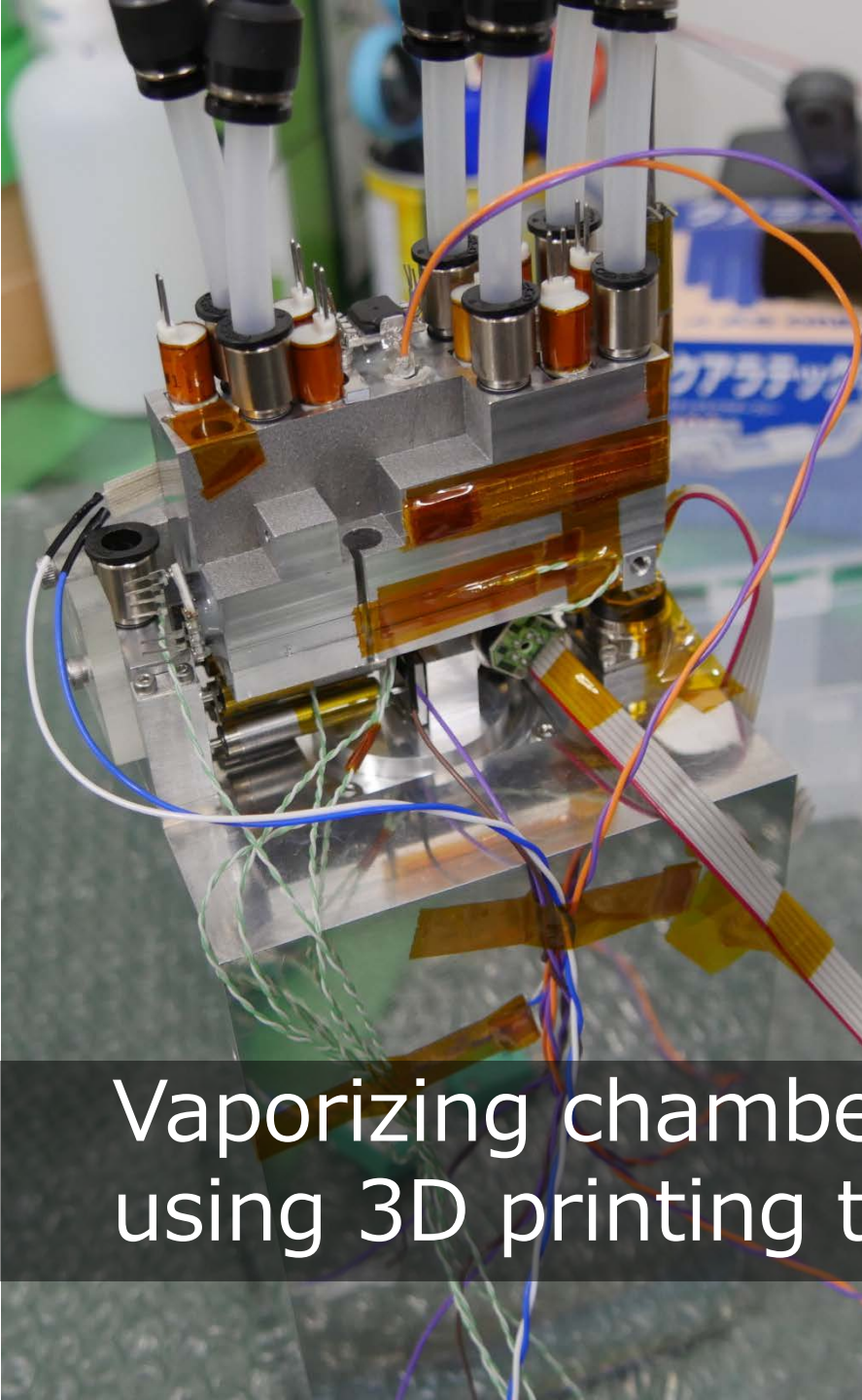


~ 20°C

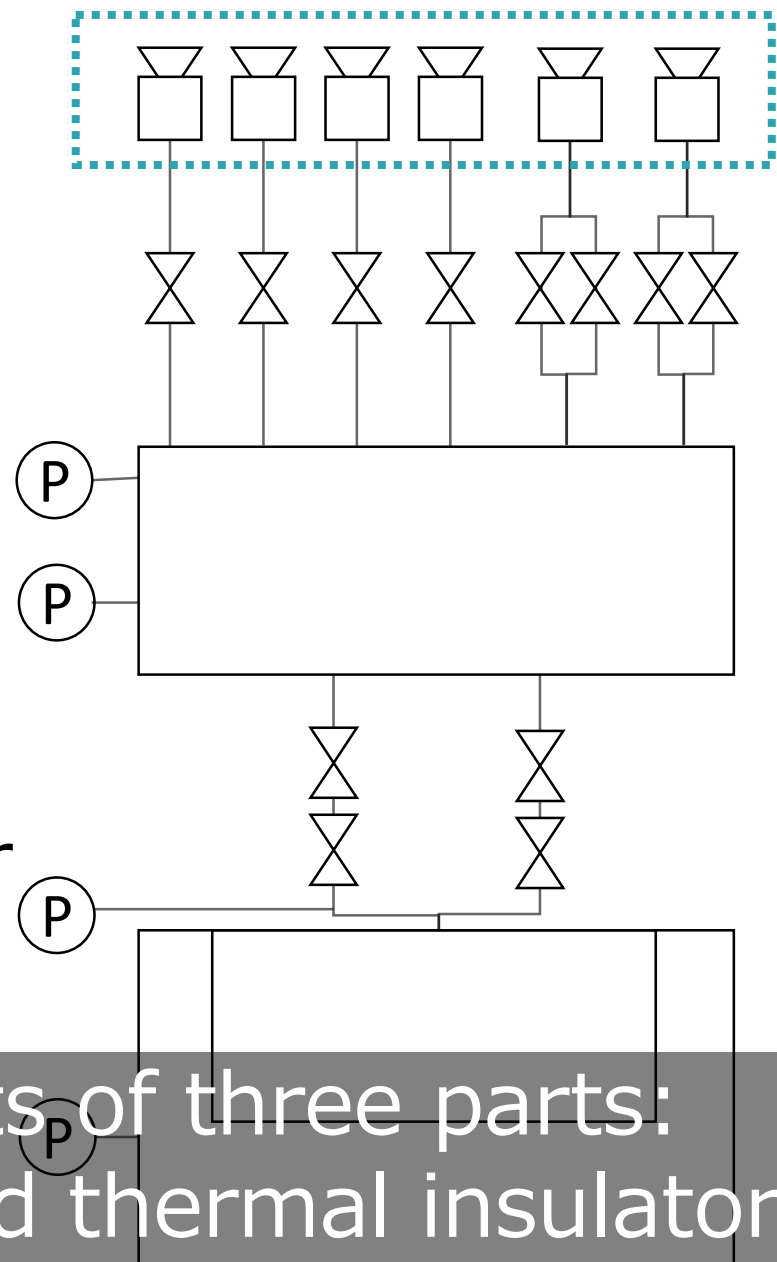
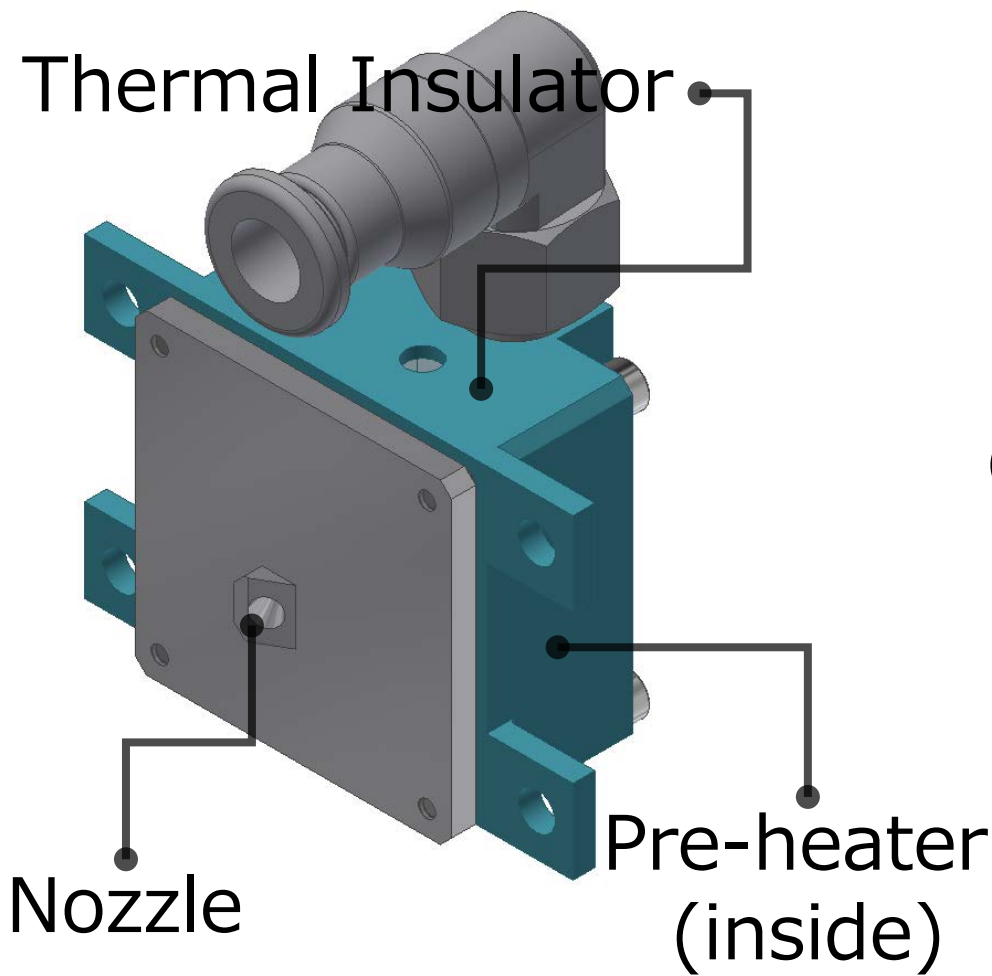




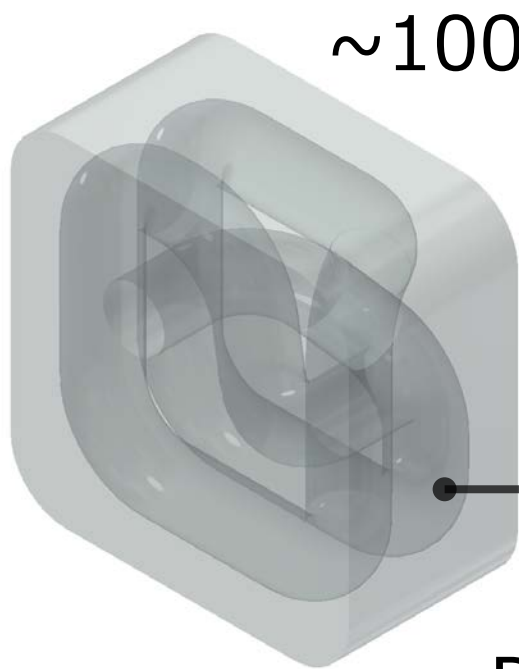




Vaporizing chamber was manufactured by using 3D printing technology.

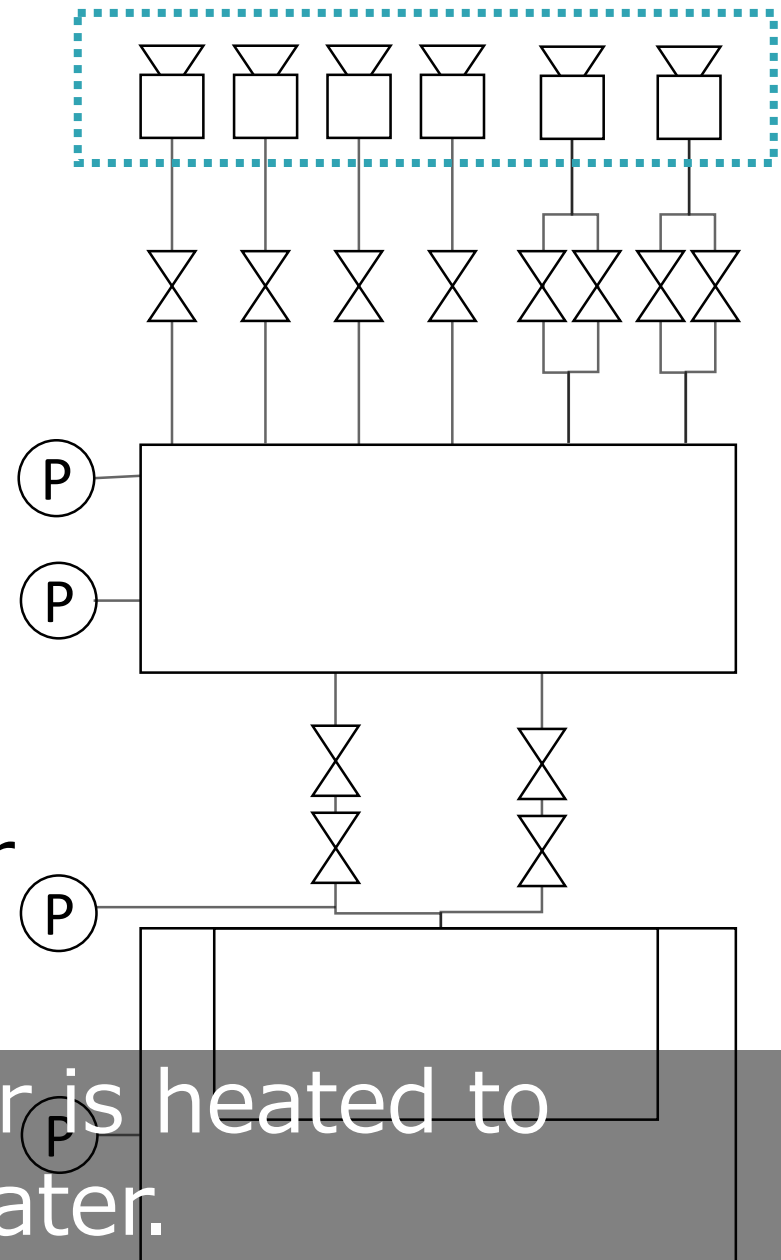


Thruster-head consists of three parts: nozzle, pre-heater and thermal insulator.

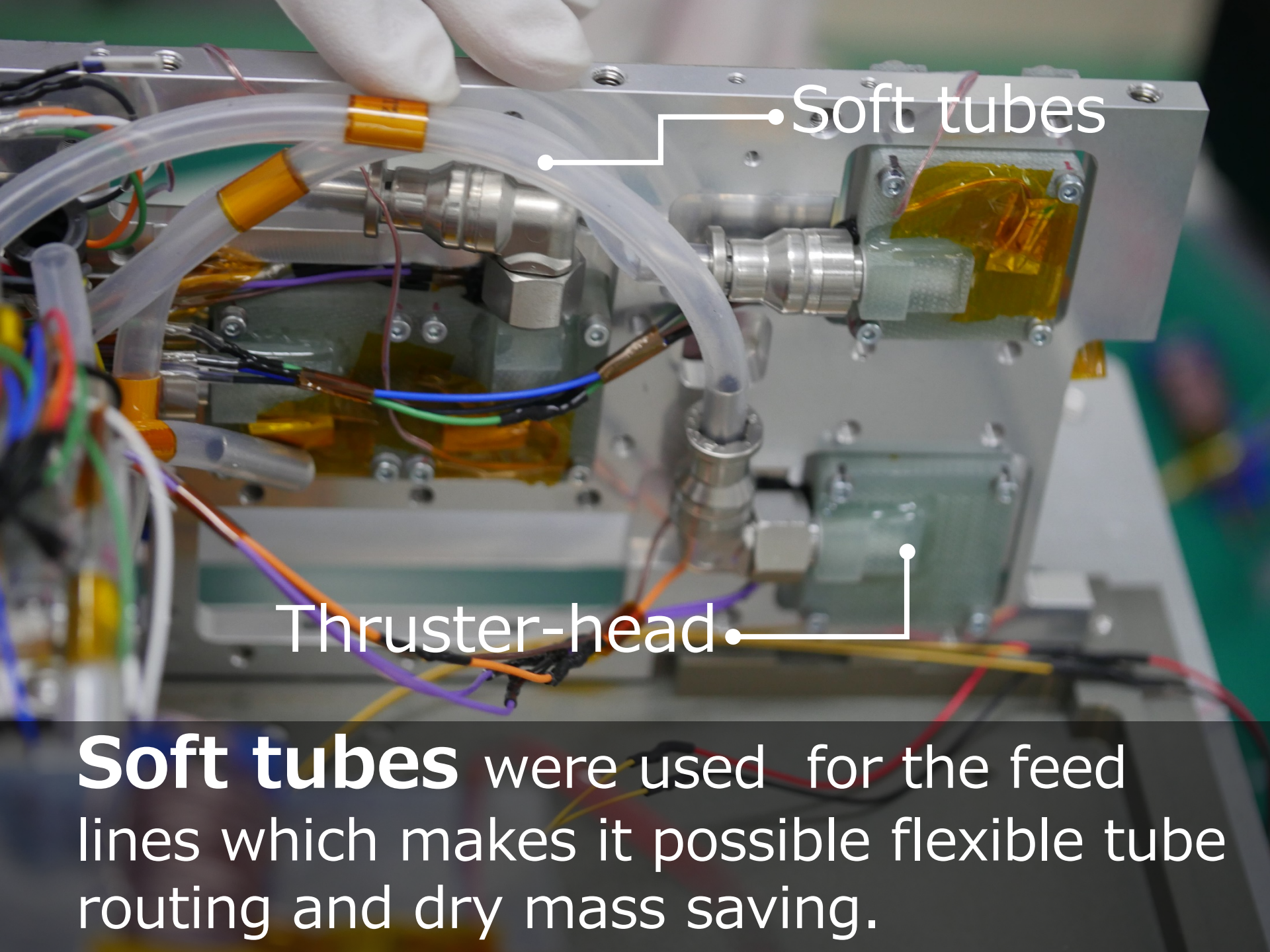


$\sim 100^{\circ}\text{C}$

Pre-heater
(inside)



Saturated water vapor is heated to $\sim 100^{\circ}\text{C}$ at the pre-heater.



Soft tubes

Thruster-head

Soft tubes were used for the feed lines which makes it possible flexible tube routing and dry mass saving.

100 cables

Pressure sensors x4

Drain valves x3

Tank

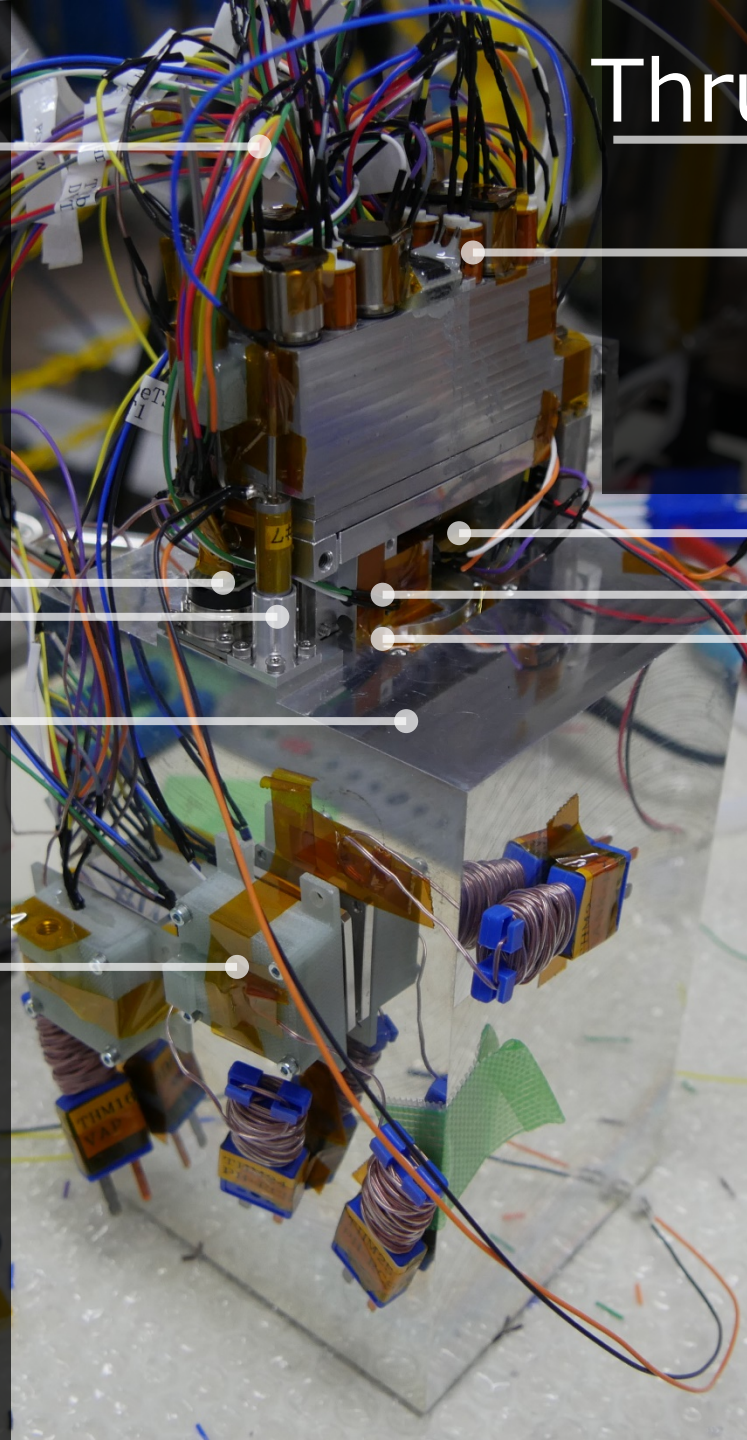
Nozzles x6

Thruster-valves x8

Regulation valves x4

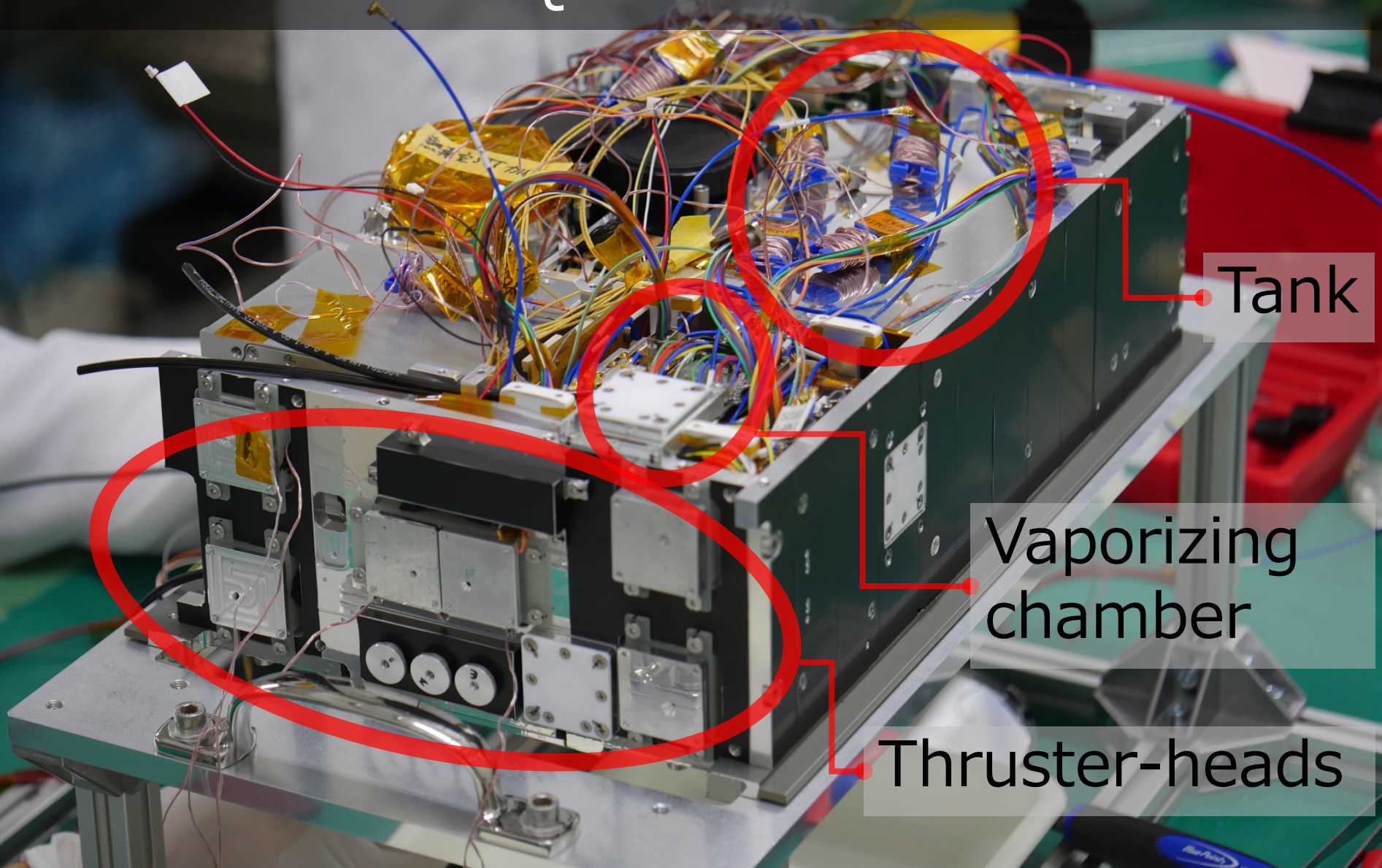
Thermal Sensors x16

Heaters x 11



AQUARIUS-EM

was onboard EQUULEUS-EM



Tank

Vaporizing chamber

Thruster-heads

A close-up photograph of a person wearing white gloves working on a complex electronic device. The device is mounted on a metal frame and features various components, including a central vaporizing chamber and two communication devices. The vaporizing chamber is highlighted with a white dashed box. Two purple arrows point downwards from the top communication device to the vaporizing chamber, and two purple arrows point upwards from the bottom communication device to the vaporizing chamber, indicating a sandwiched configuration. The background is blurred, showing more of the device and its wiring.

Communication

Vaporizing chamber

Communication

Vaporizing chamber was sandwiched by the two communication devices for energy harvesting

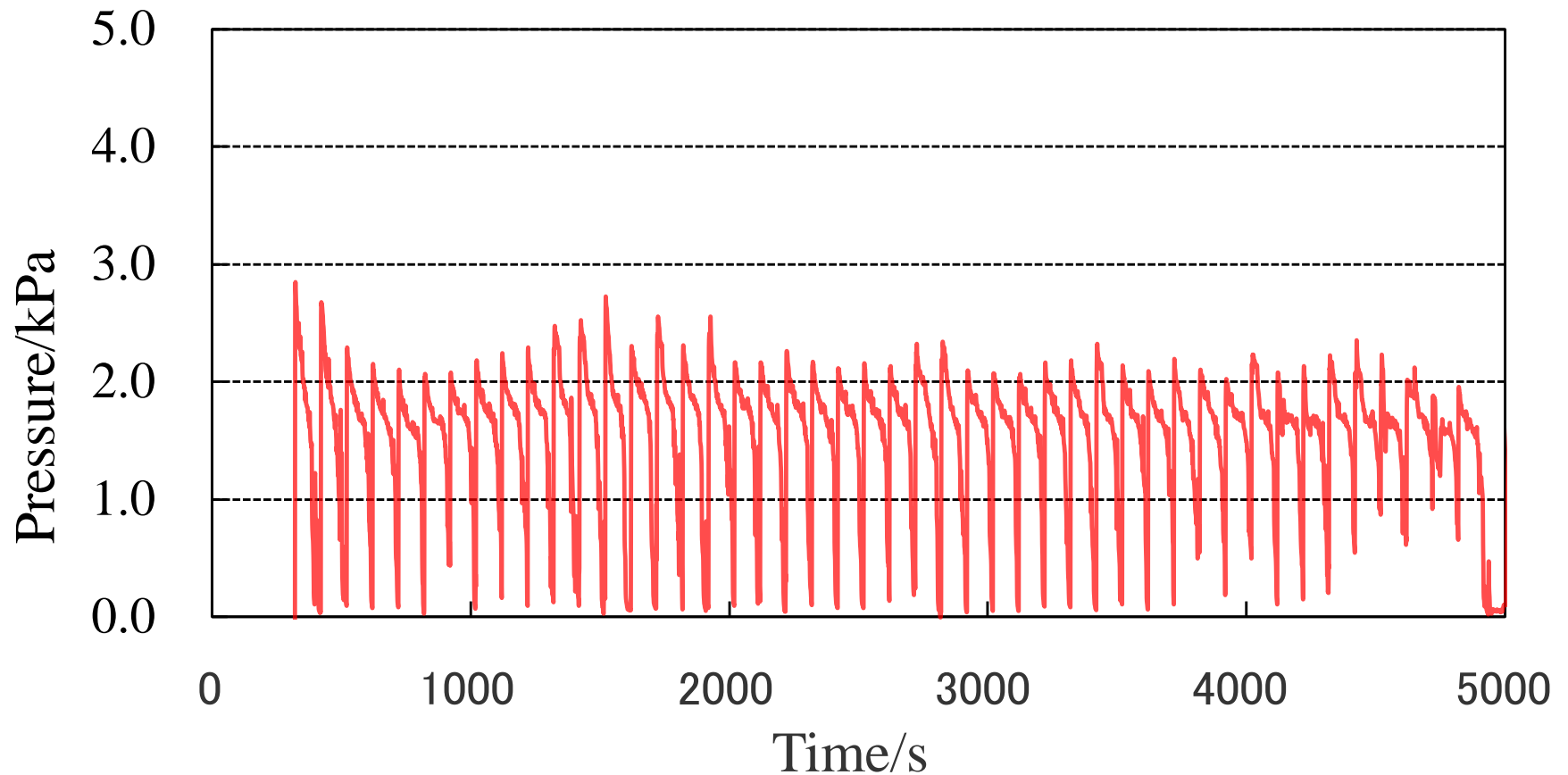
1st Firing test

before the environmental test



1st Firing test

before the environmental test

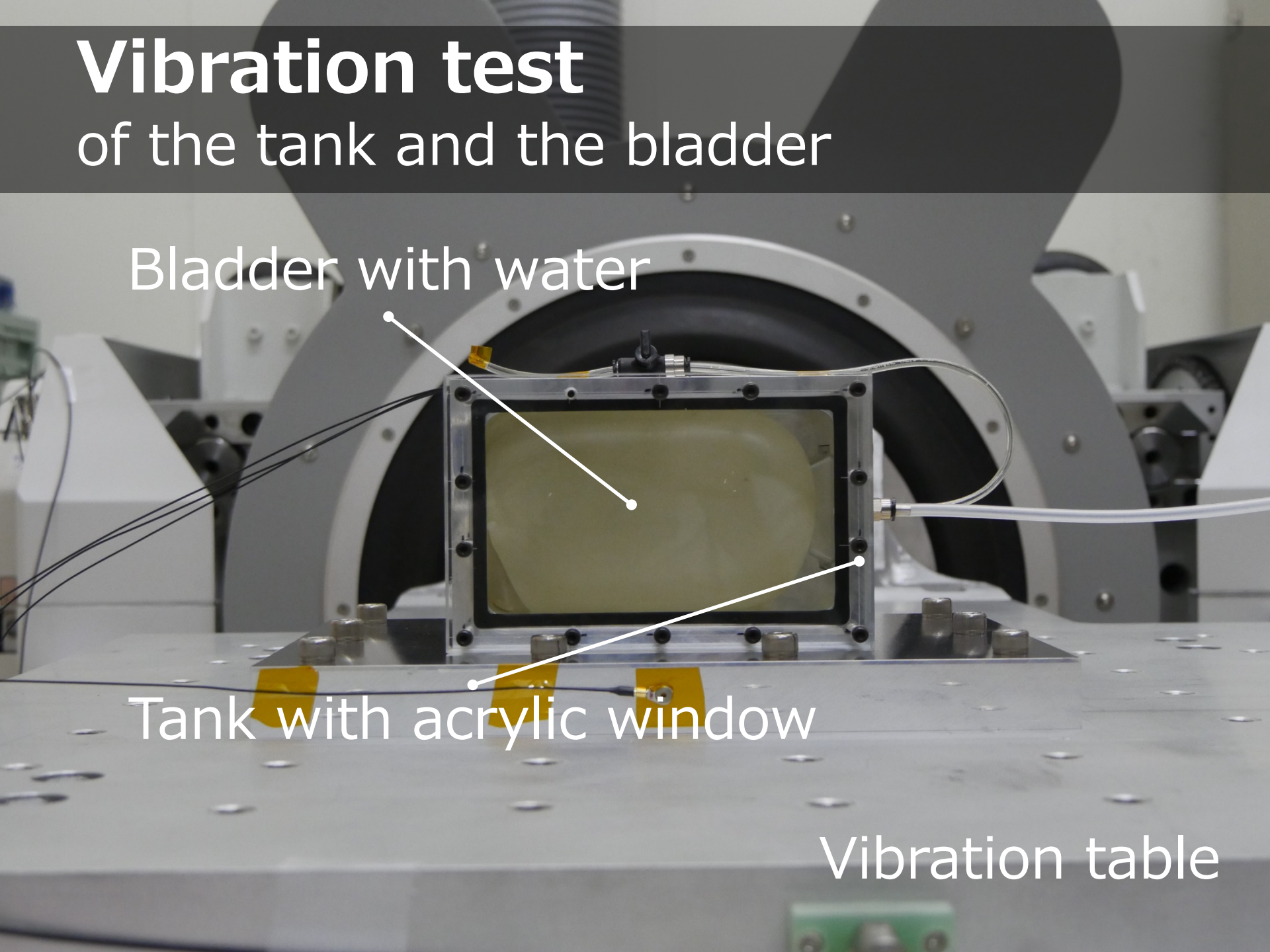


Vibration test of the tank and the bladder

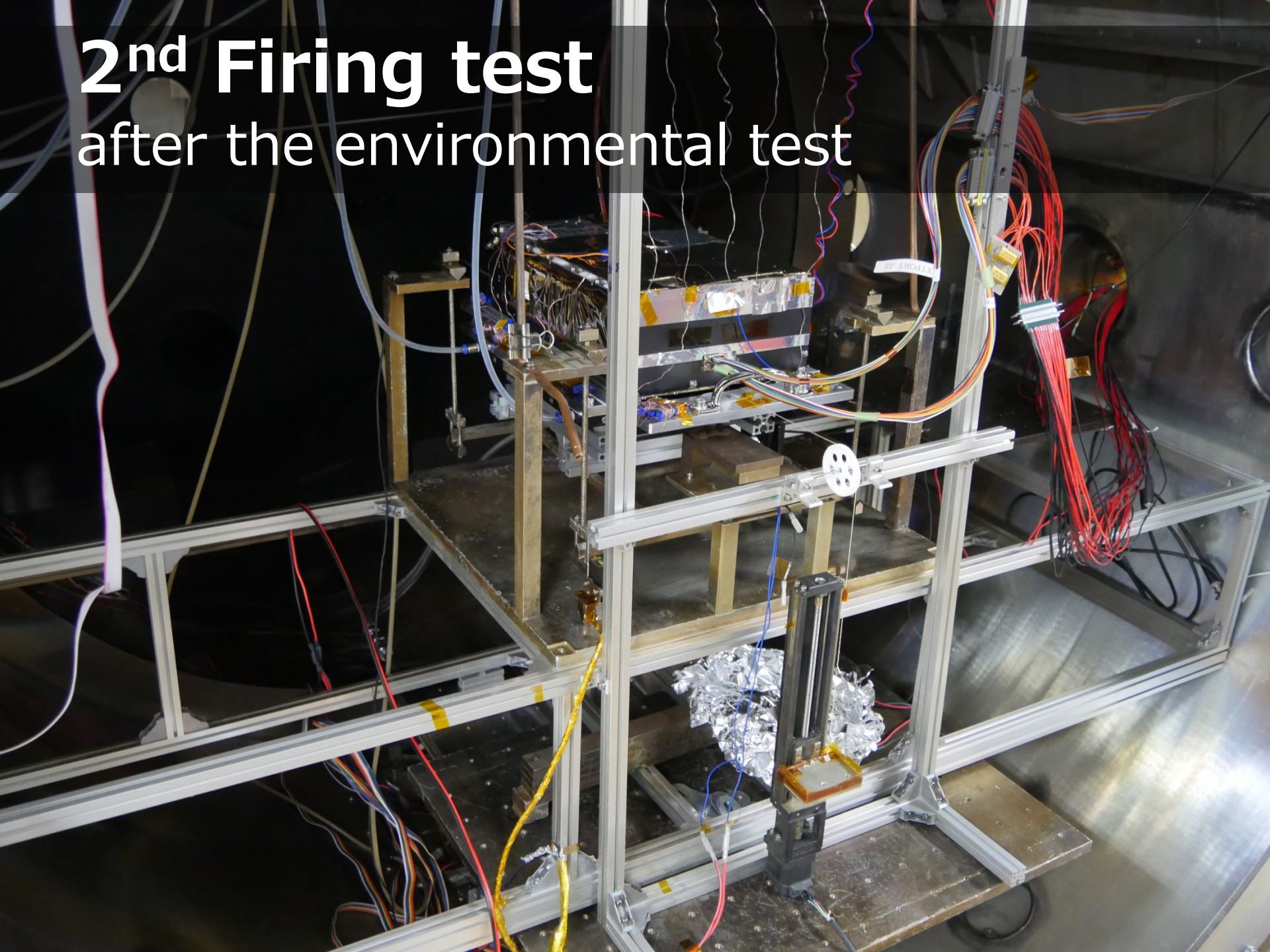
Bladder with water

Tank with acrylic window

Vibration table

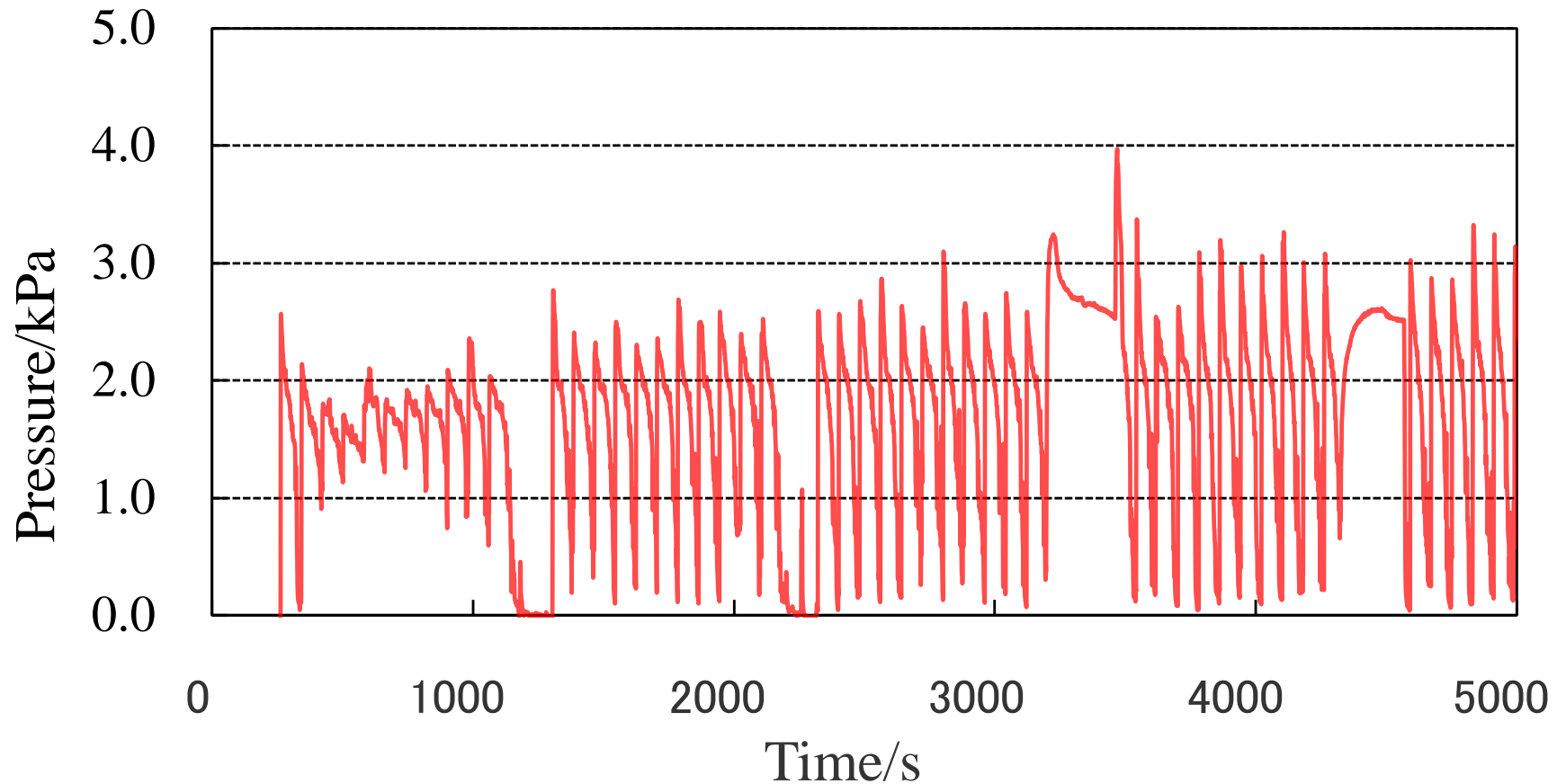


2nd Firing test after the environmental test



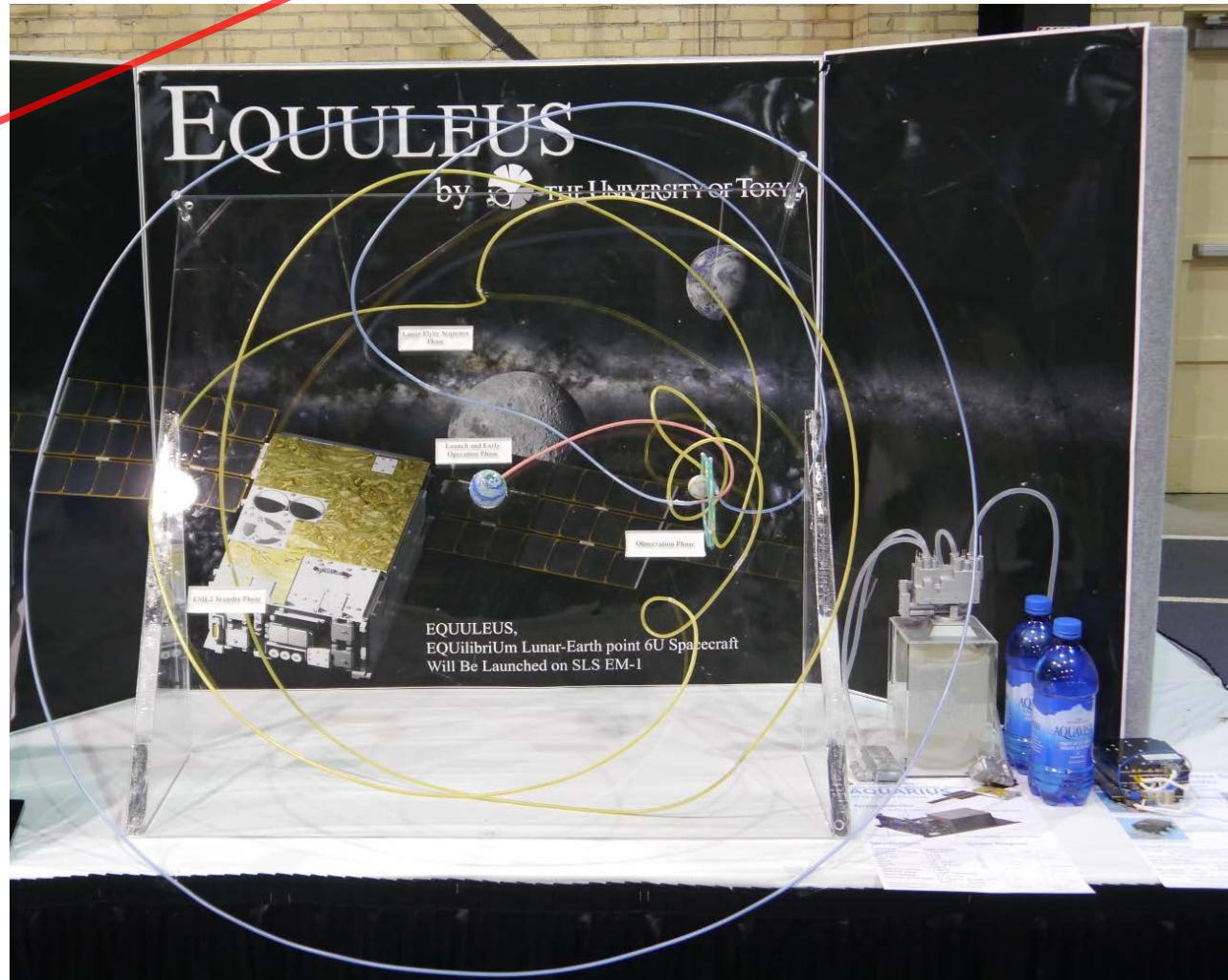
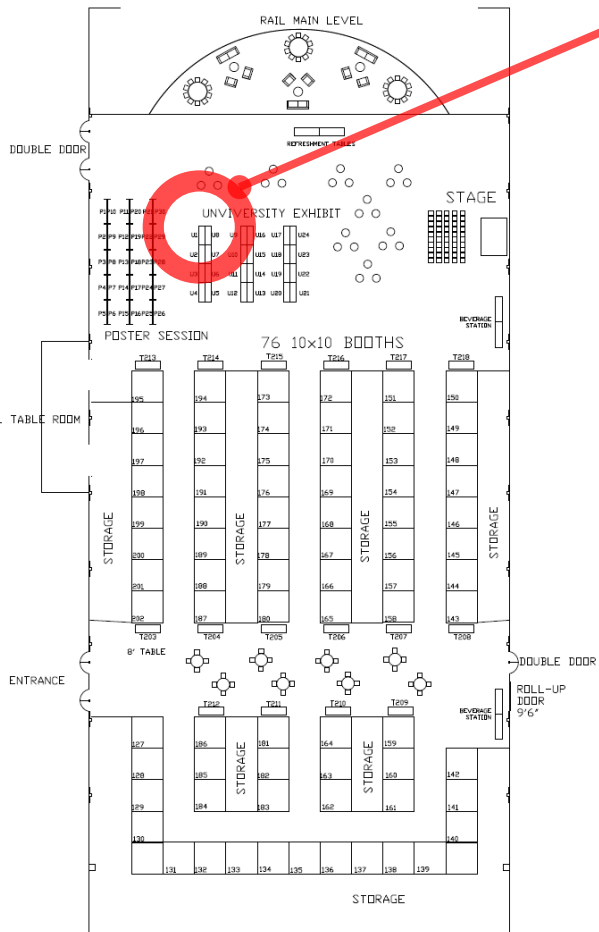
2nd Firing test

after the environmental test

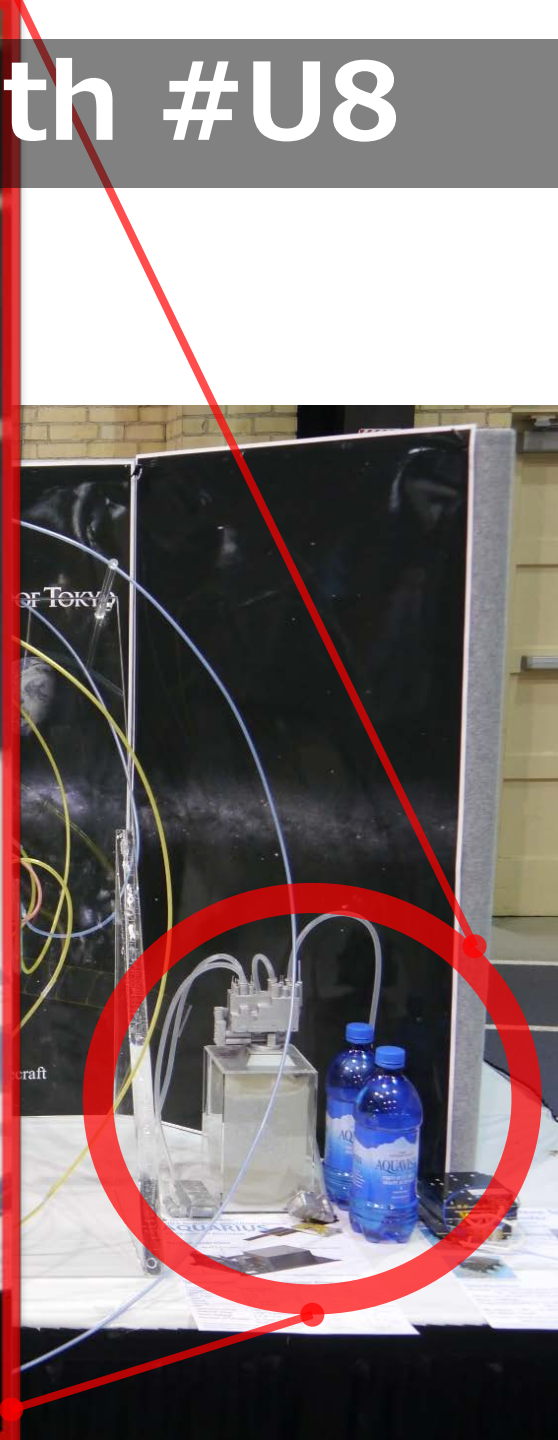
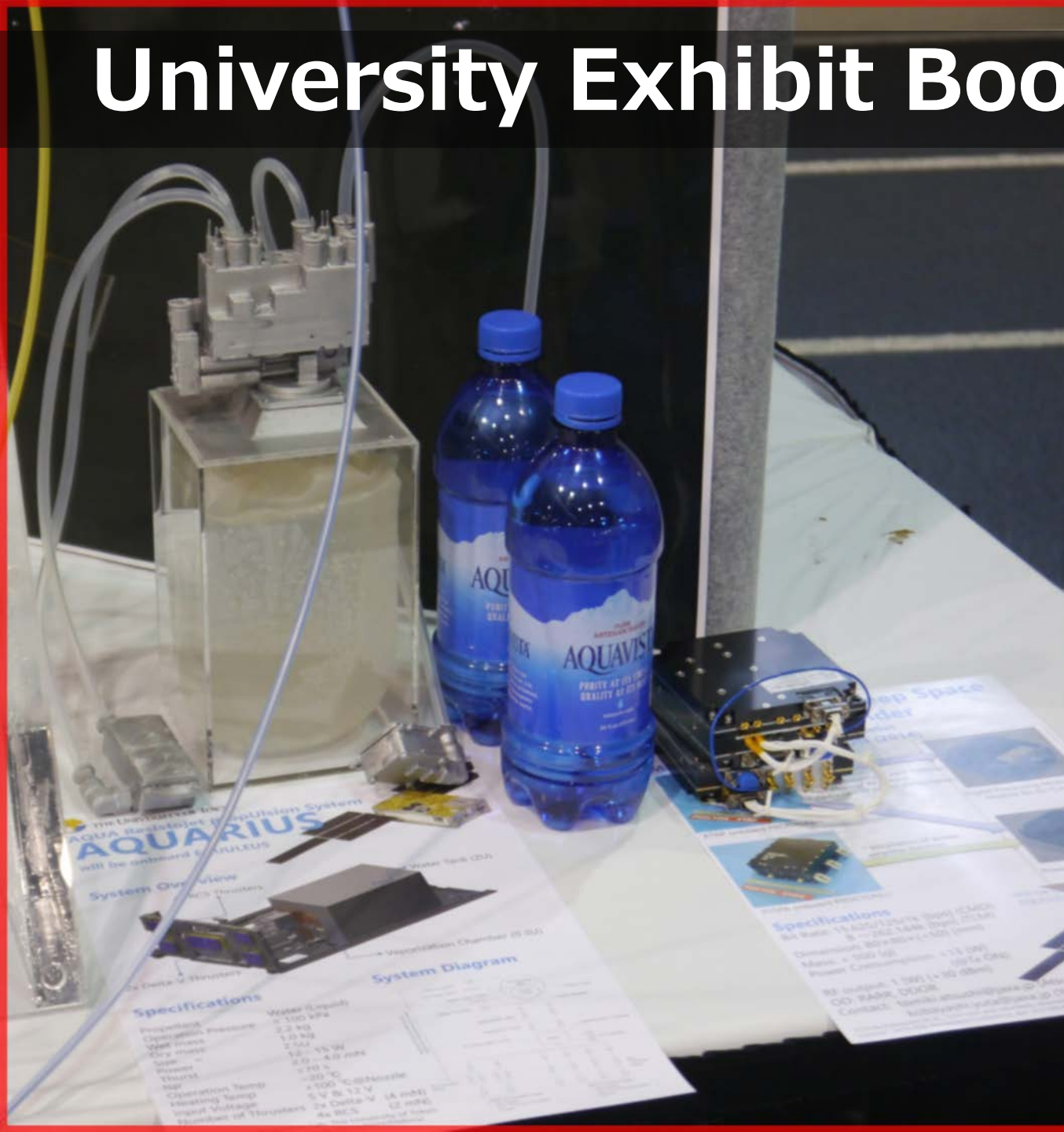


University Exhibit Booth #U8 @ Field House

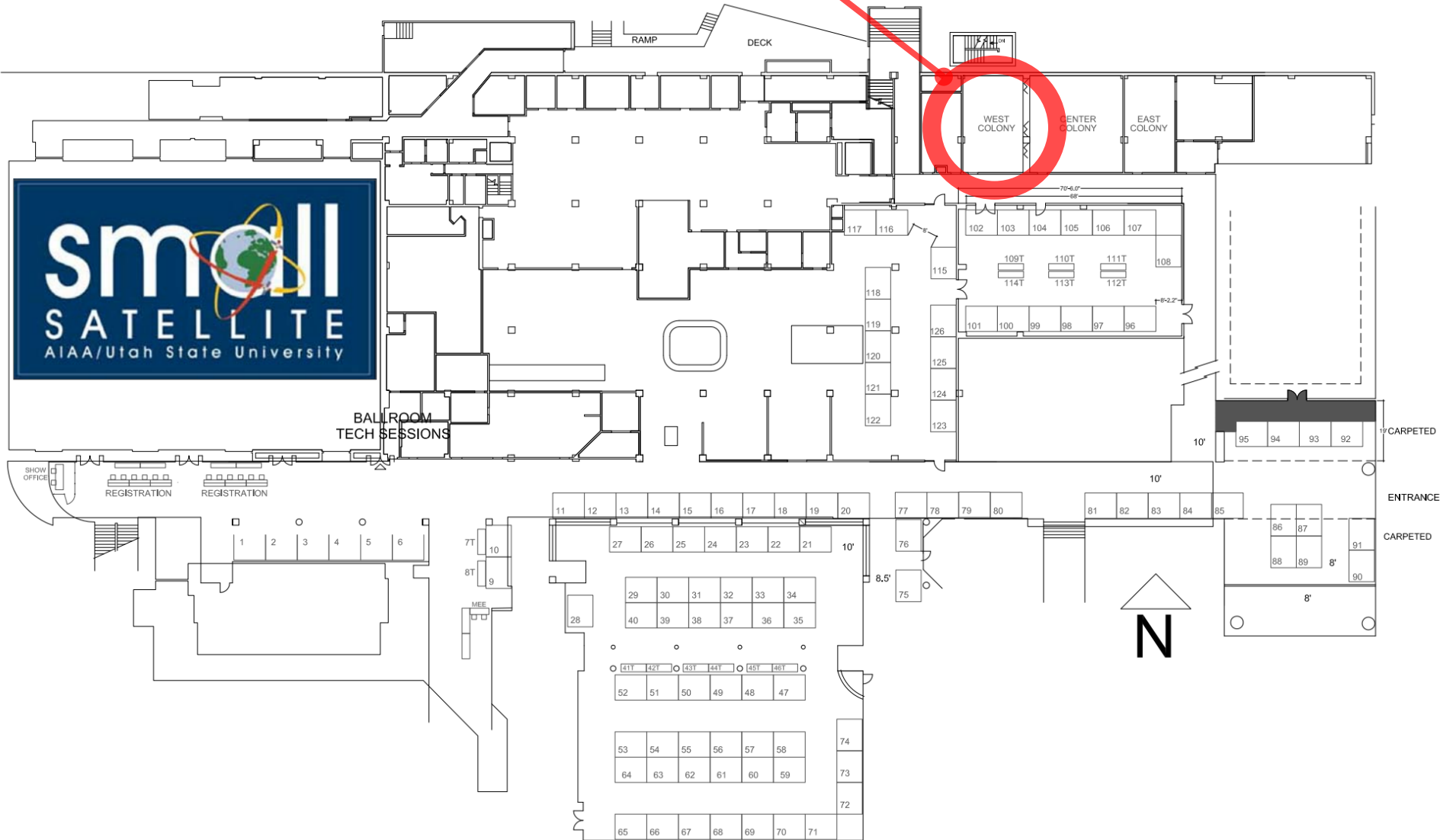
NORTH



University Exhibit Booth #U8



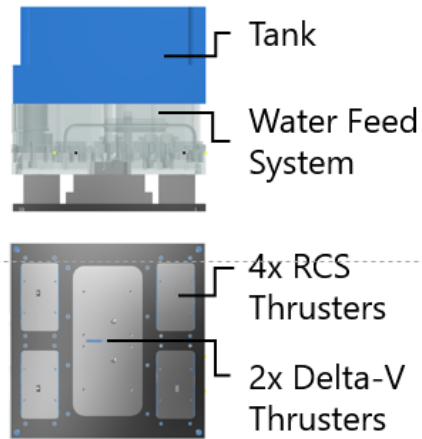
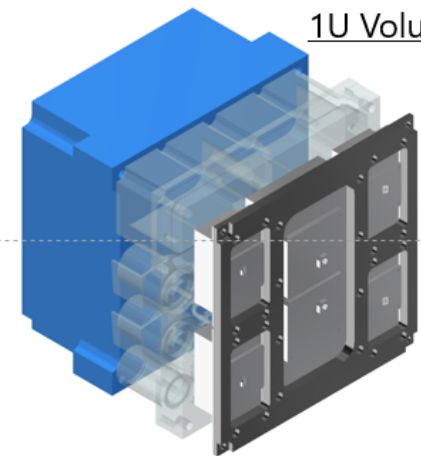
Ministry of Economy, Trade, and Industry of Japan @ West Colony



Ministry of Economy, Trade, and Industry of Japan @ West Colony

Water Resistojet

1U Volume

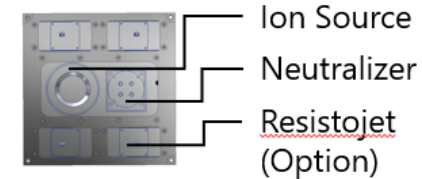
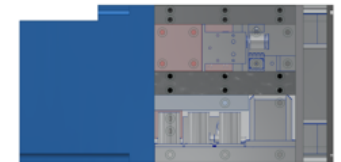
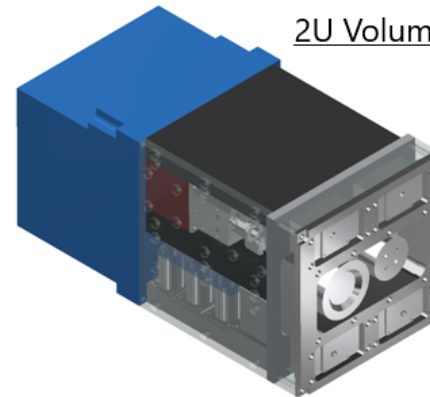


Wet Mass < 1.0 kg
 Dry Mass 0.50 kg
 System Power 10 – 15 W

Thrust 2.0 – 4.0 mN
 I_{sp} 70 s
 Delta-V 25 m/s (14kg S/C)

Water Ion Thruster

2U Volume



Wet Mass < 3.0 kg
 Dry Mass 2.0 kg
 System Power 35 – 40 W*
 *Target Value

Thrust > 150 μ N
 I_{sp} 1000 s*
 Delta-V 700 m/s (14kg S/C)



Plume of water ion thruster

If you want to know the details,
 please come to our booth!!

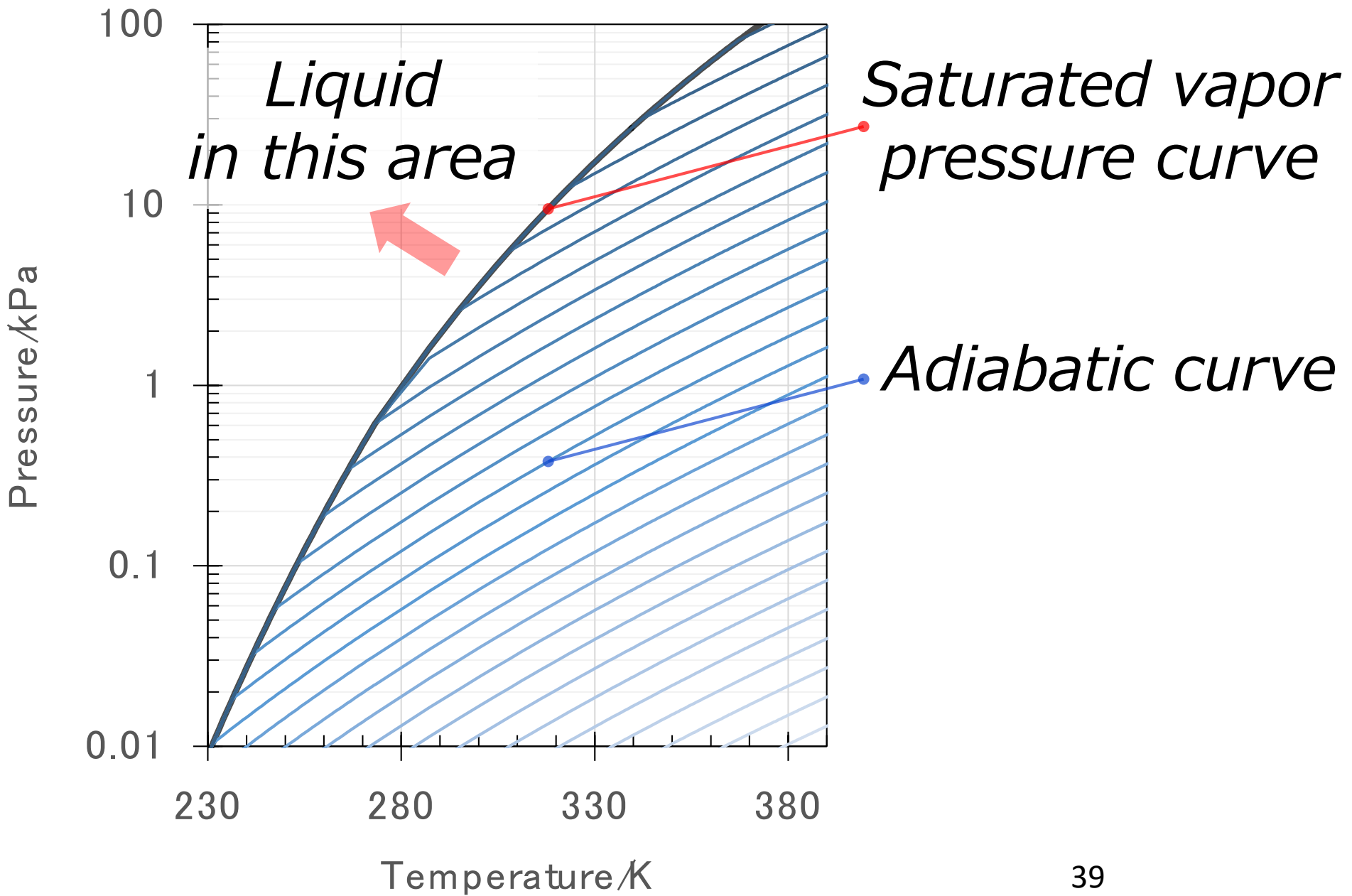
Questions?

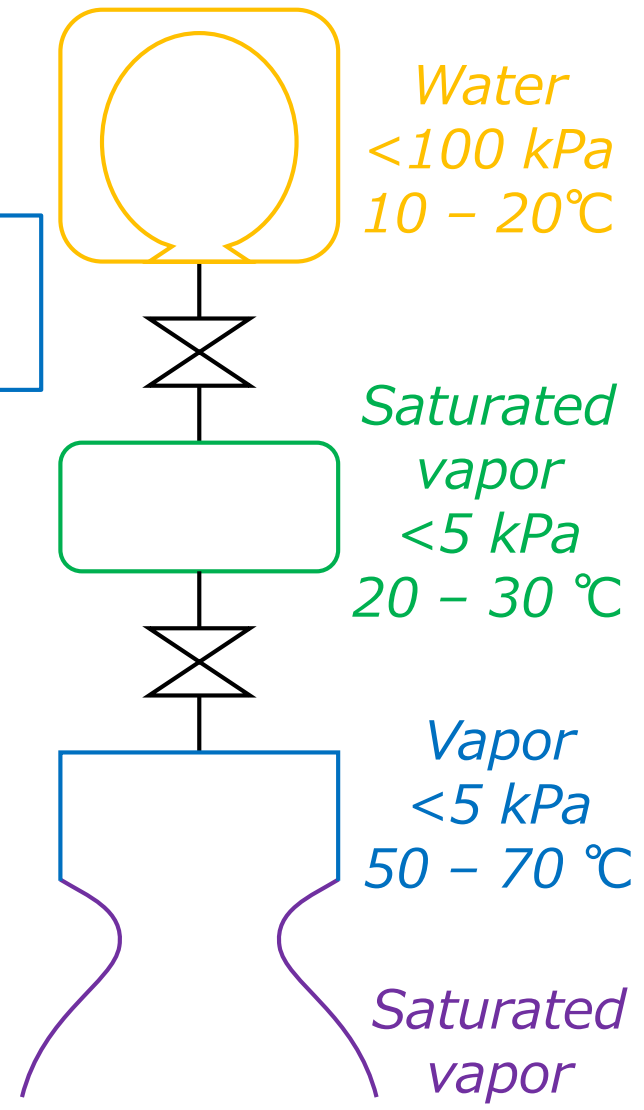
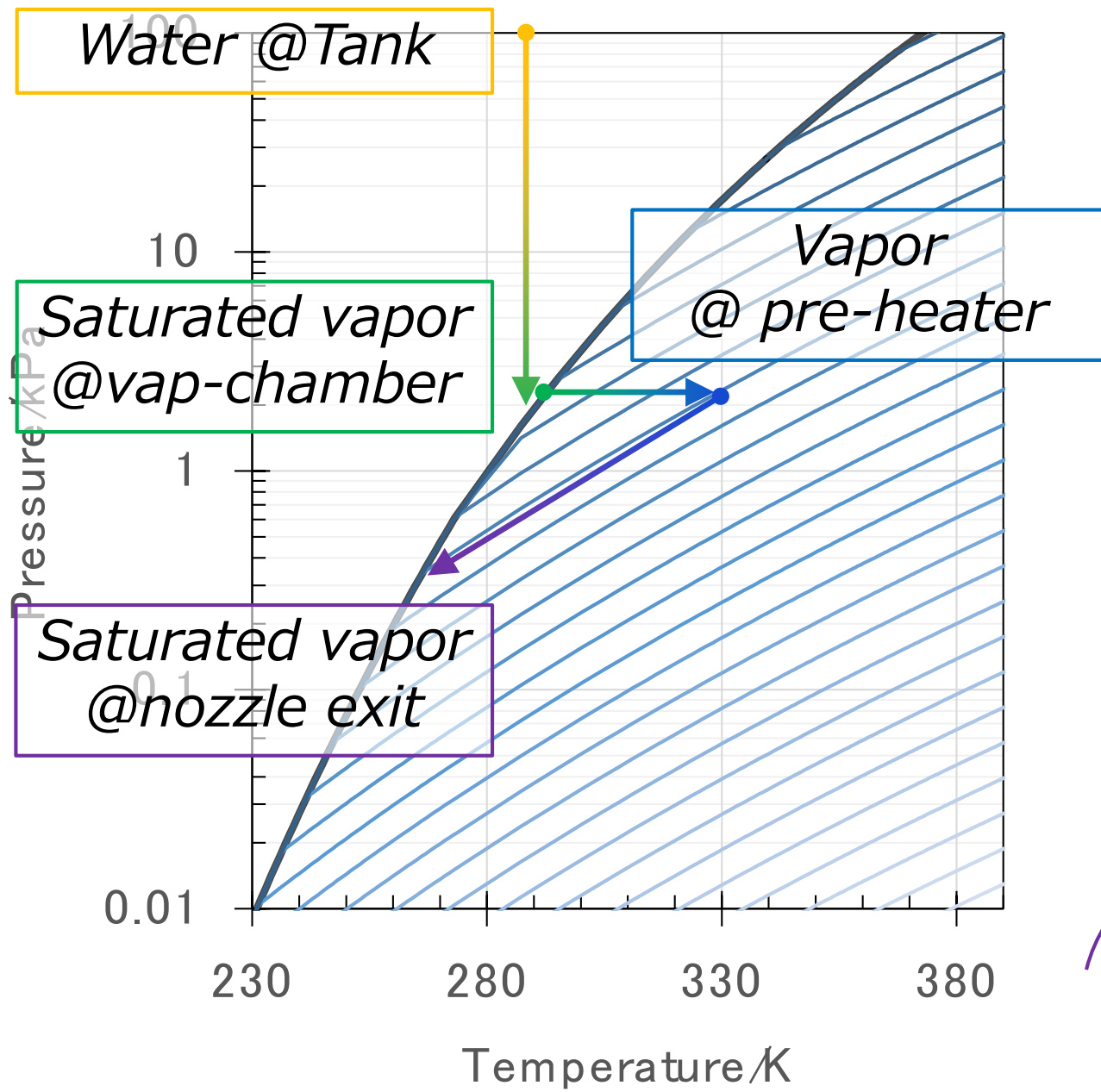
Update information will be presented at
International Electric Propulsion Conference

(Oct. @Atlanta)

Contact: j.asakawa@al.t.u-tokyo.ac.jp

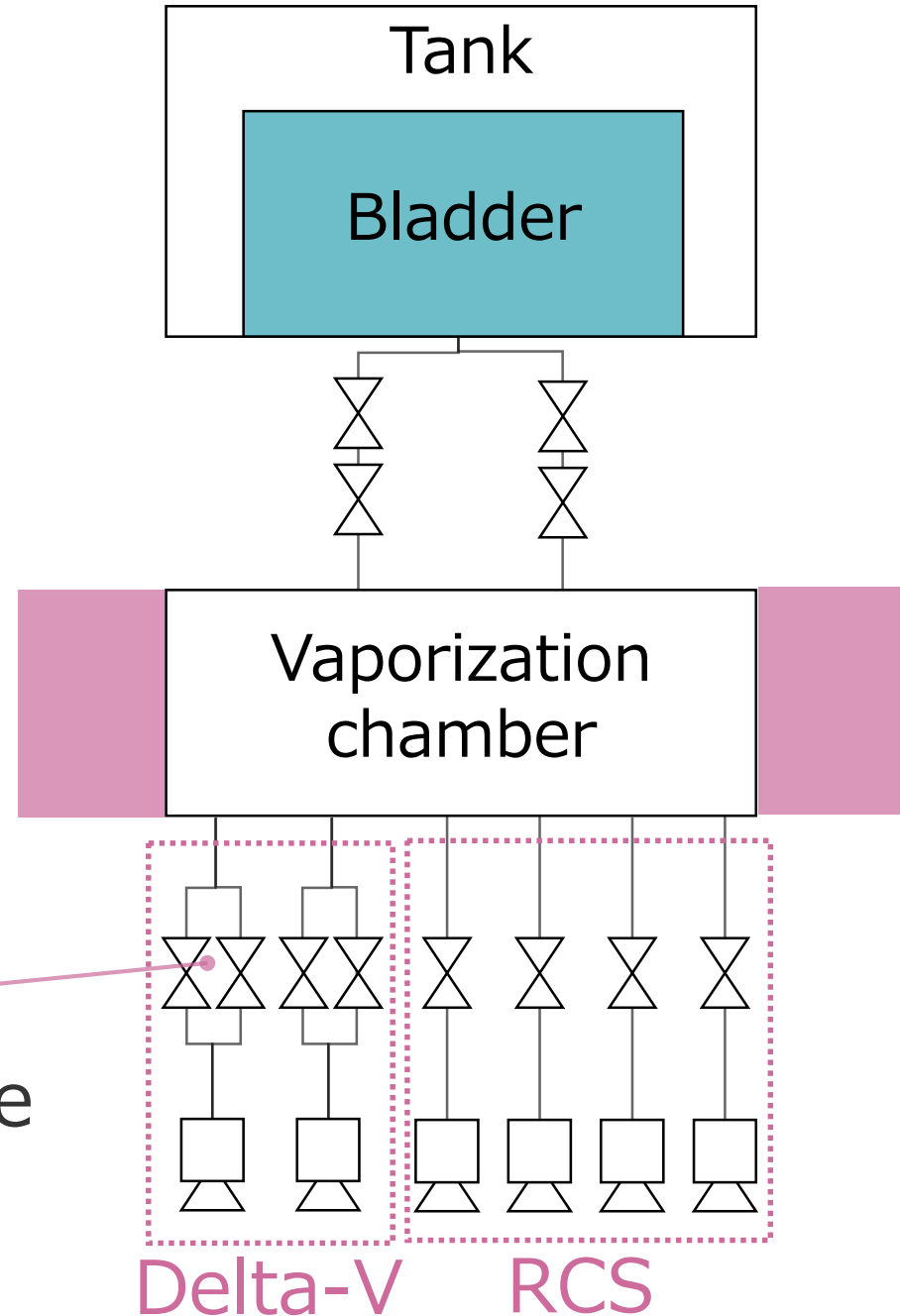






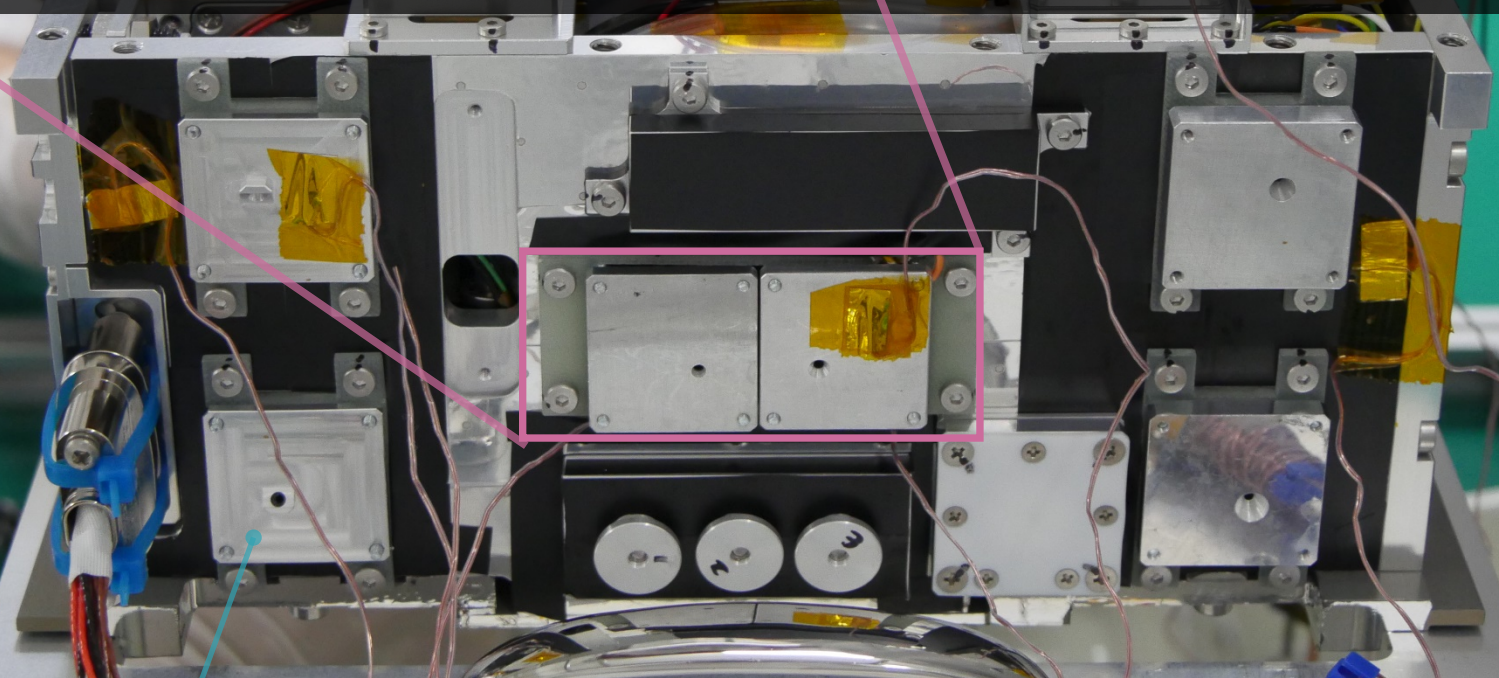
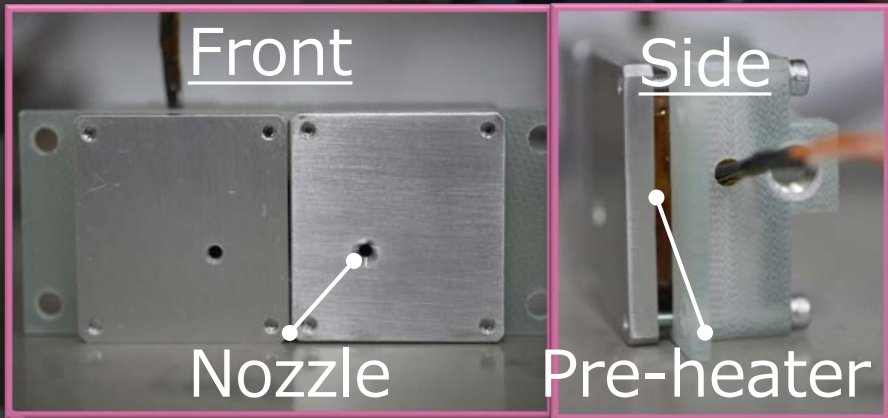
AQUARIUS

AQUA Resistojet
propulsion System

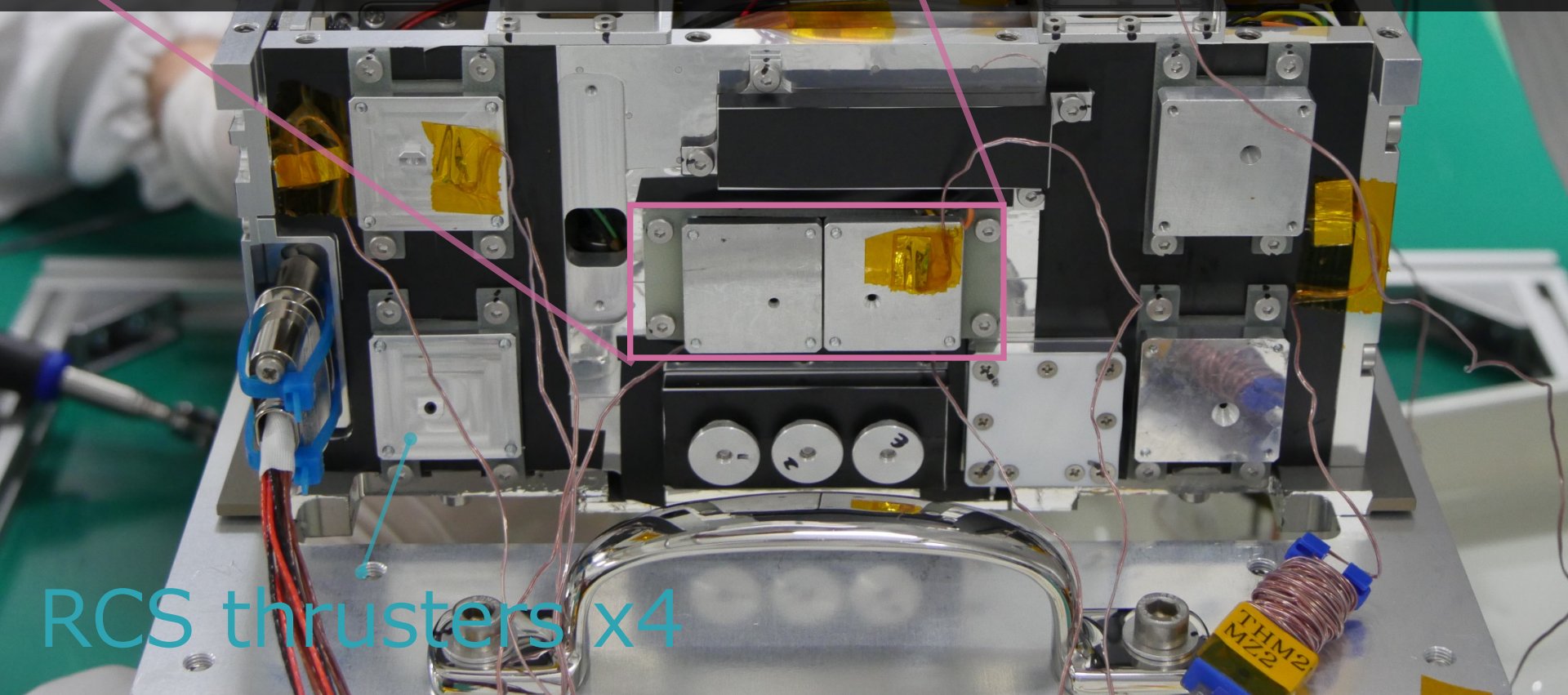


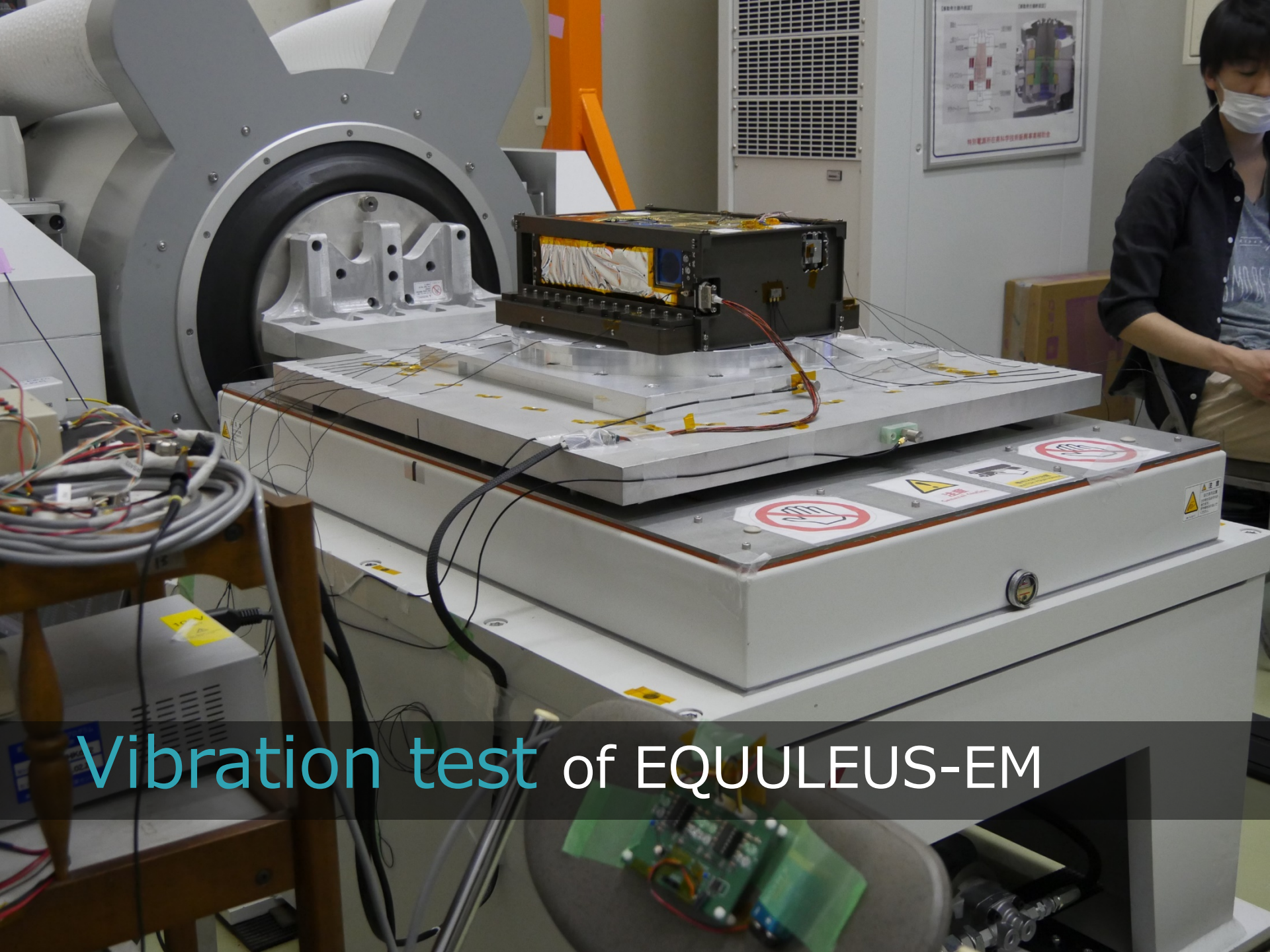
Parallel valves
to increase mass flow rate
For delta-V thrusters

Delta-V thrusters x2



RCS thrusters x4





Vibration test of EQUULEUS-EM

- Why we use water
- Operating principles
- Design, integration and test

