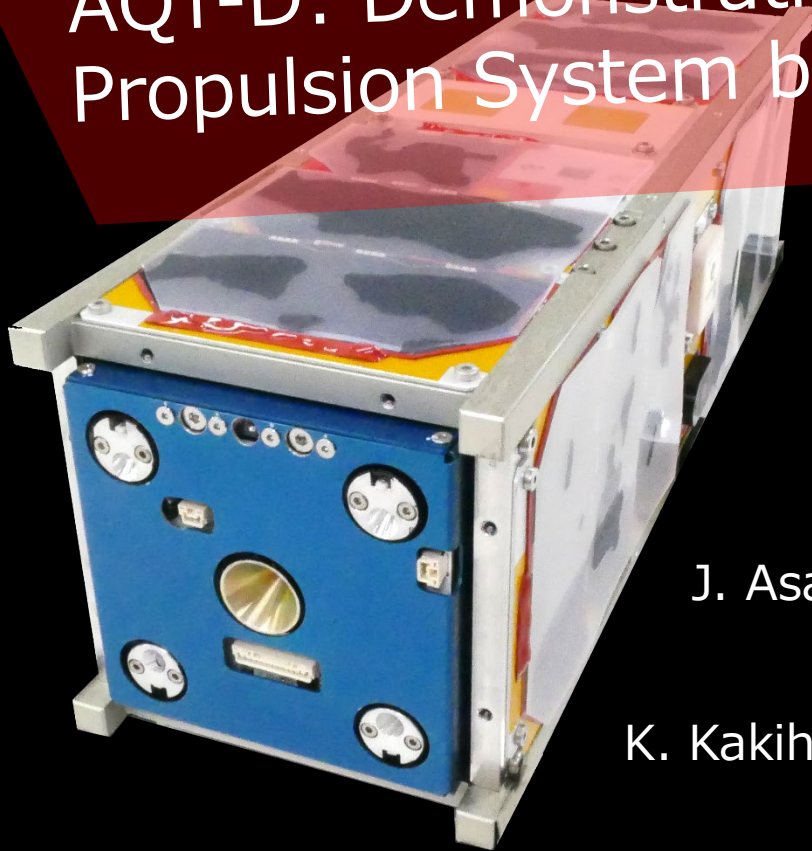


SSC19-WKV-07

# AQT-D: Demonstration of the Water Resistojet Propulsion System by the ISS-Deployed CubeSat



J. Asakawa, K. Yaginuma, Y. Nakagawa, Y. Tsuruda

**Hiro Koizumi**

K. Kakihara, K. Yanagida, Y. Aoyanagi, T. Matsumoto

M. Ikura, S. Matsushita, Y. Murata



THE UNIVERSITY OF TOKYO

# Space Propulsion Laboratory

for Small Satellite Conference 2019  
The University of Tokyo





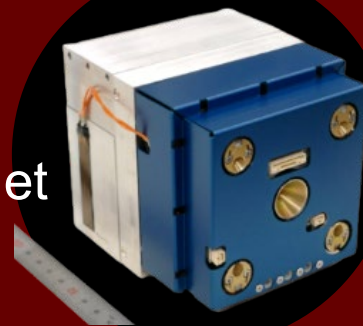
Home

Missions

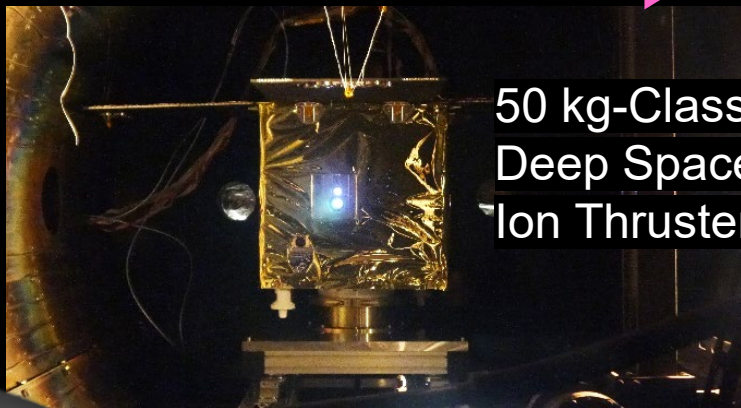
50 kg-Class  
LEO  
Solid Rocket Motor



3U CubeSat  
ISS-Deployed  
Water Resistojet

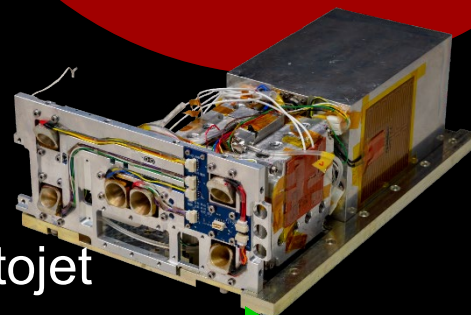


50 kg-Class  
LEO  
Ion Thruster



50 kg-Class  
Deep Space  
Ion Thruster

6U CubeSat  
Cis-Lunar  
Water Resistojet



2012

2013

2014

2015

2016

2017

2018

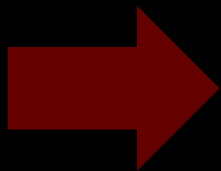
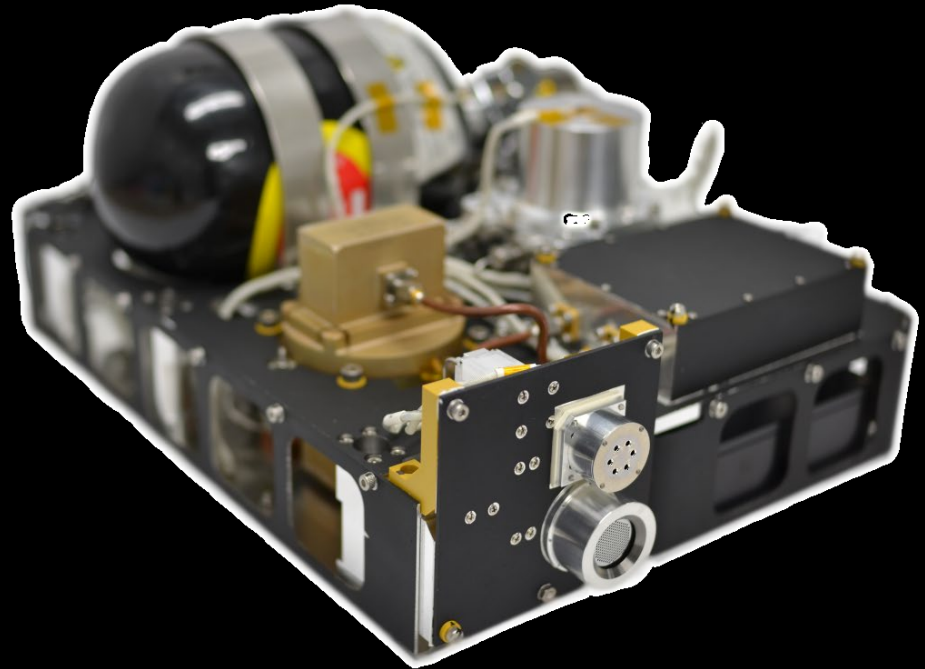
2019

2020

# MIPS [míps]

Miniature Ion thruster Propulsion System

Total mass: 8.1 kg  
Thrust: 200  $\mu\text{N}$   
Isp: 740 s



Hodoyoshi-4

Size: 66 kg

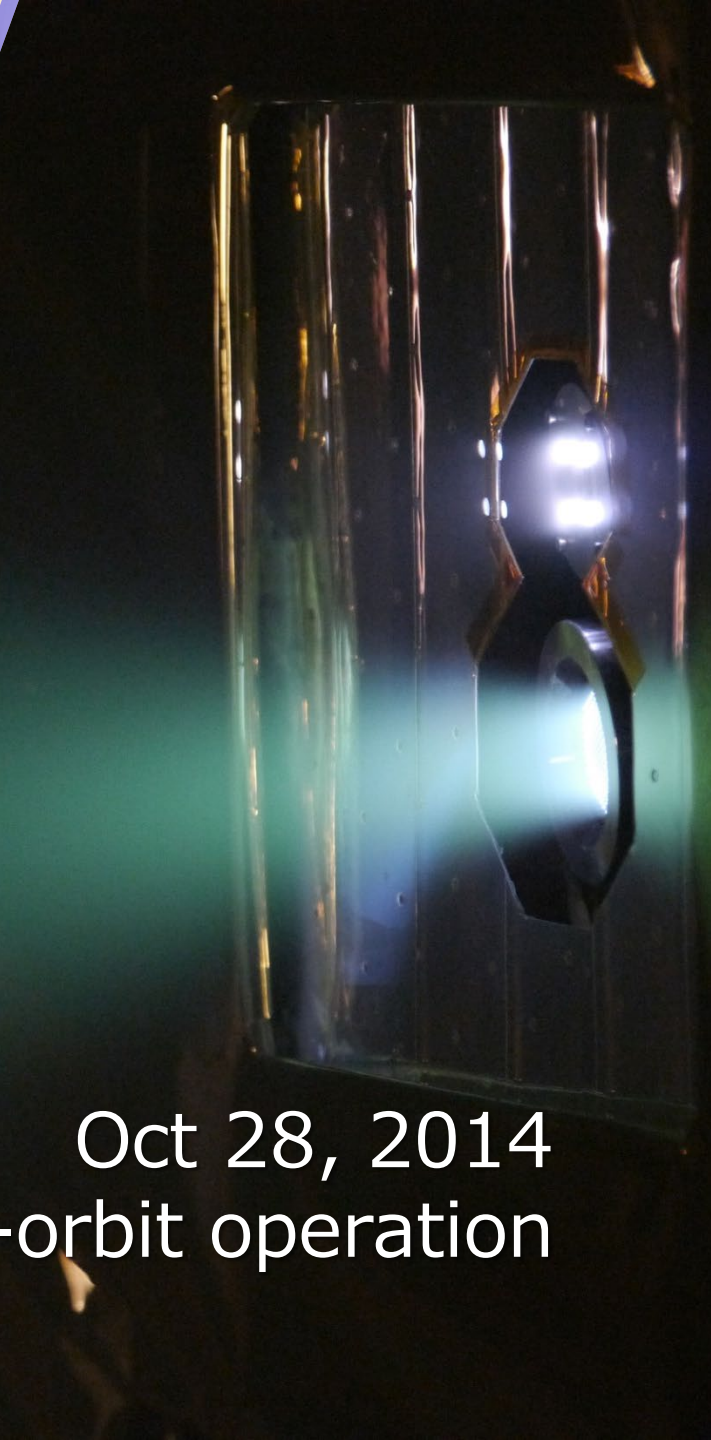
Launch: June 19<sup>th</sup>, 2014







Oct 28, 2014  
In-orbit operation





# I-COUPS [áikú:z]

Ion thruster and **C**old-gas thruster  
**U**nified **P**ropulsion **S**ystem



**PROCYON**

Size: 66 kg

Heliocentric orbit

# I-COUPS [áikú:z]

Ion thruster and **C**old-gas thruster  
**U**nified **P**ropulsion **S**ystem

Xenon  
cold-gas thruster



$I_{sp}$ : 24 s  
 $F$ : 20 mN

+

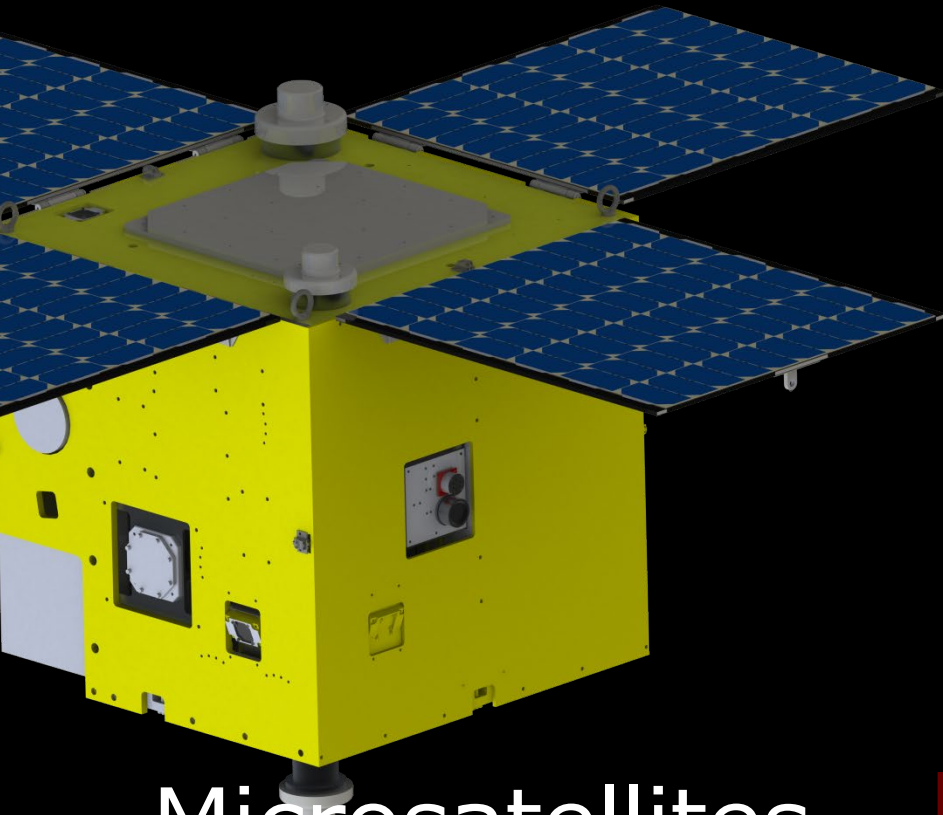
Xenon  
ion thruster

$I_{sp}$ : 1000 s  
 $F$ : 0.35 mN

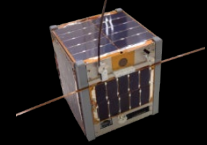
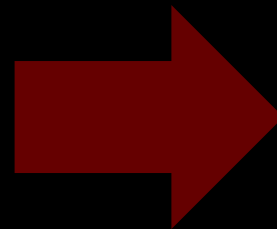




Next step is...



Microsatellites



Cubesats





High pressure component

vs. Regulation

Xenon  
2.3 kg



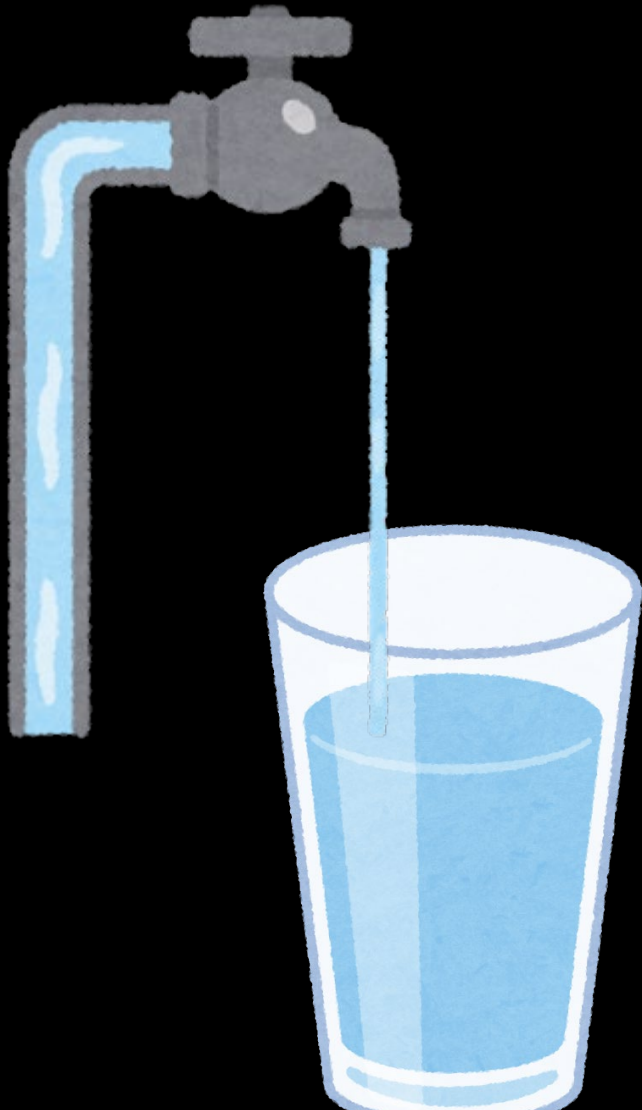
High-pressure  
gas system (dry)

4.5 kg

vs. Safety review



# Our proposal for cubesats: Water Propellant



Liquid

in room temperature and pressure

Safe, as you drink it

In-situ

resource utilization in the near future

# AQUARIUS [əkwəriəs]

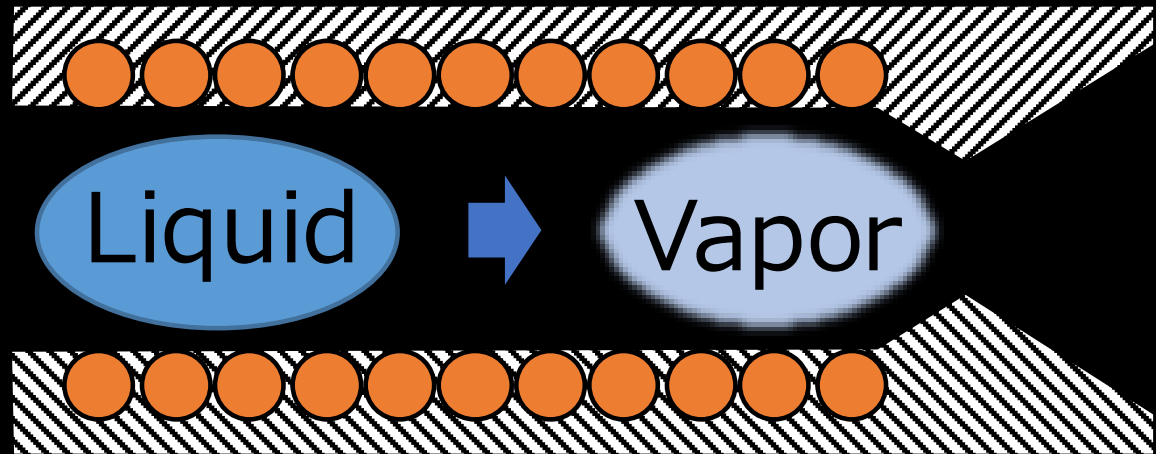
AQUA ResIstojet propUlsion System

AQUARIUS-2.5U



AQUARIUS-1U



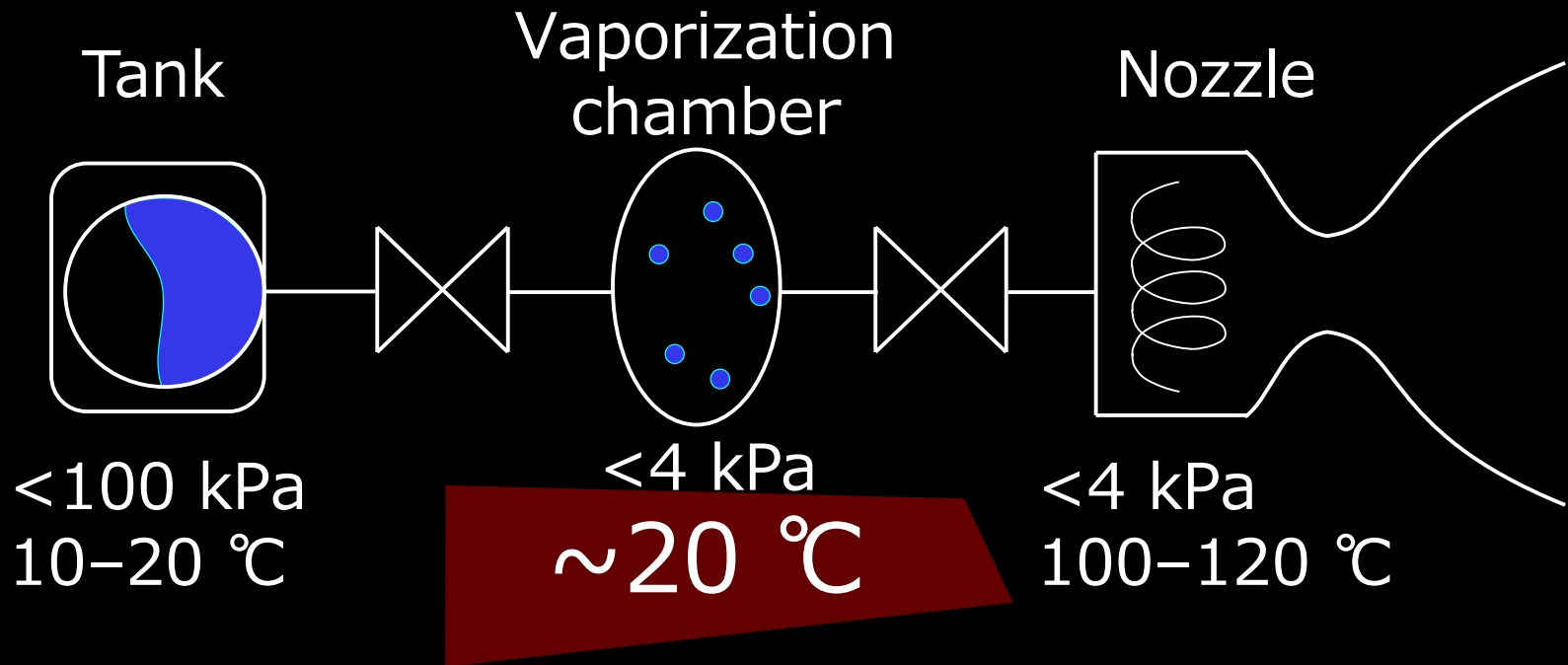


# Water resistojet thrusters

Water is vaporized and heated up at a single chamber and the final temperature is 500 – 1000 K.

- Gas/Liquid two phase flow
  - Heating up to  $\sim 1000$  K
- ➡ Complicated physics
- ➡ High power & Thermal insulation

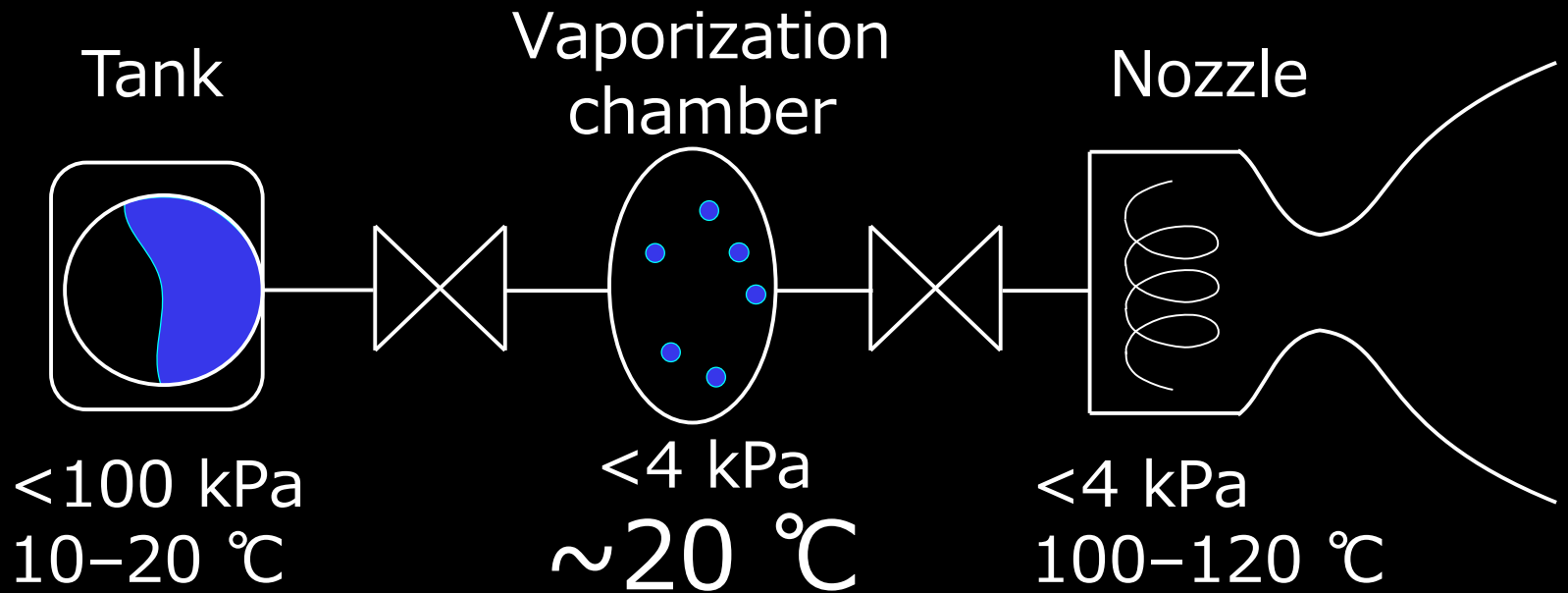
# Water resistojet thruster AQUARIUS



## Vaporization at $T \sim 20 \text{ }^{\circ}\text{C}$

Enabling energy harvesting  
Separation of vaporization and heating

# Water resistojet thruster AQUARIUS



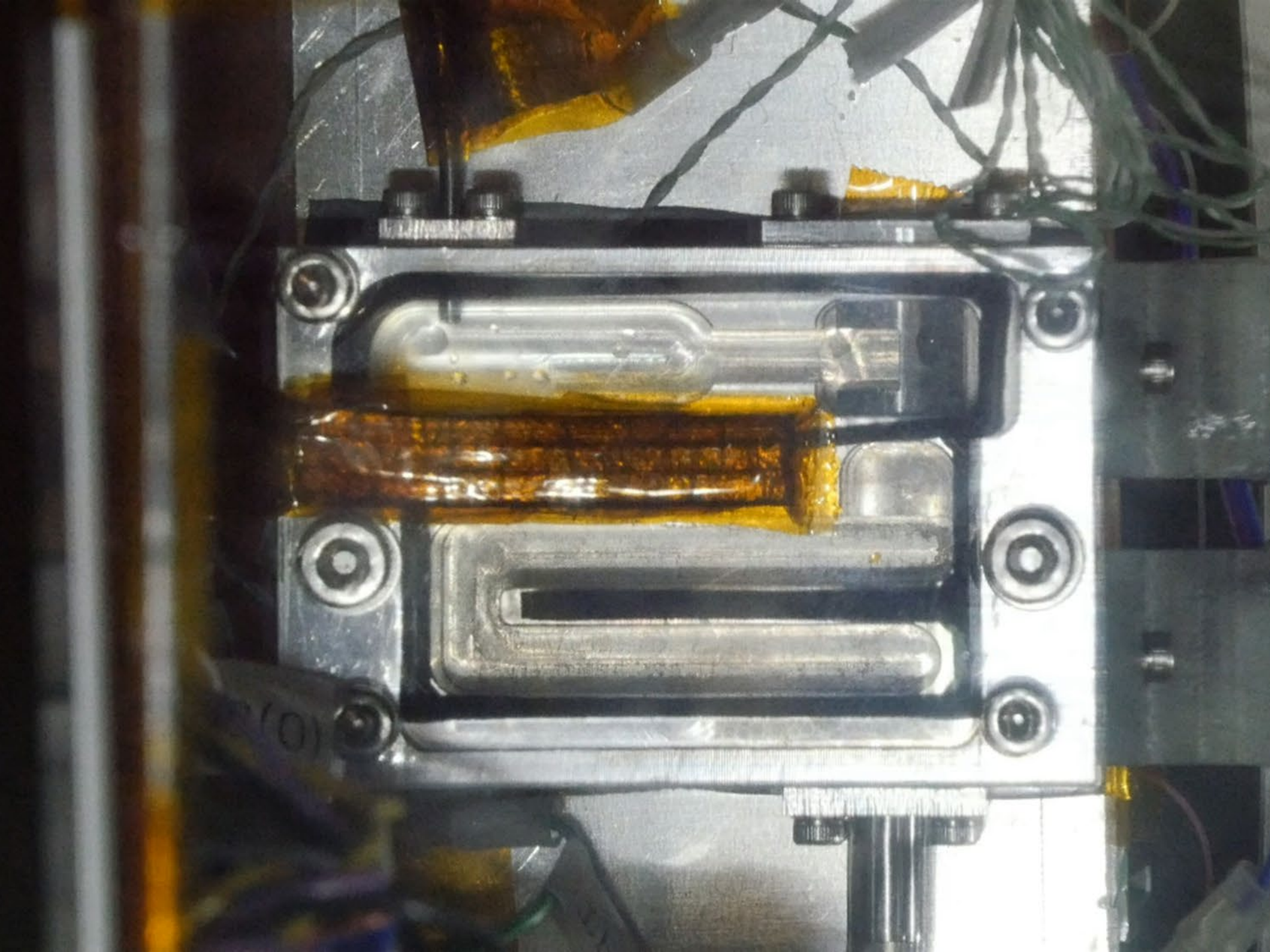
## Energy harvesting

Communication

OBC/PCU

Ion thruster







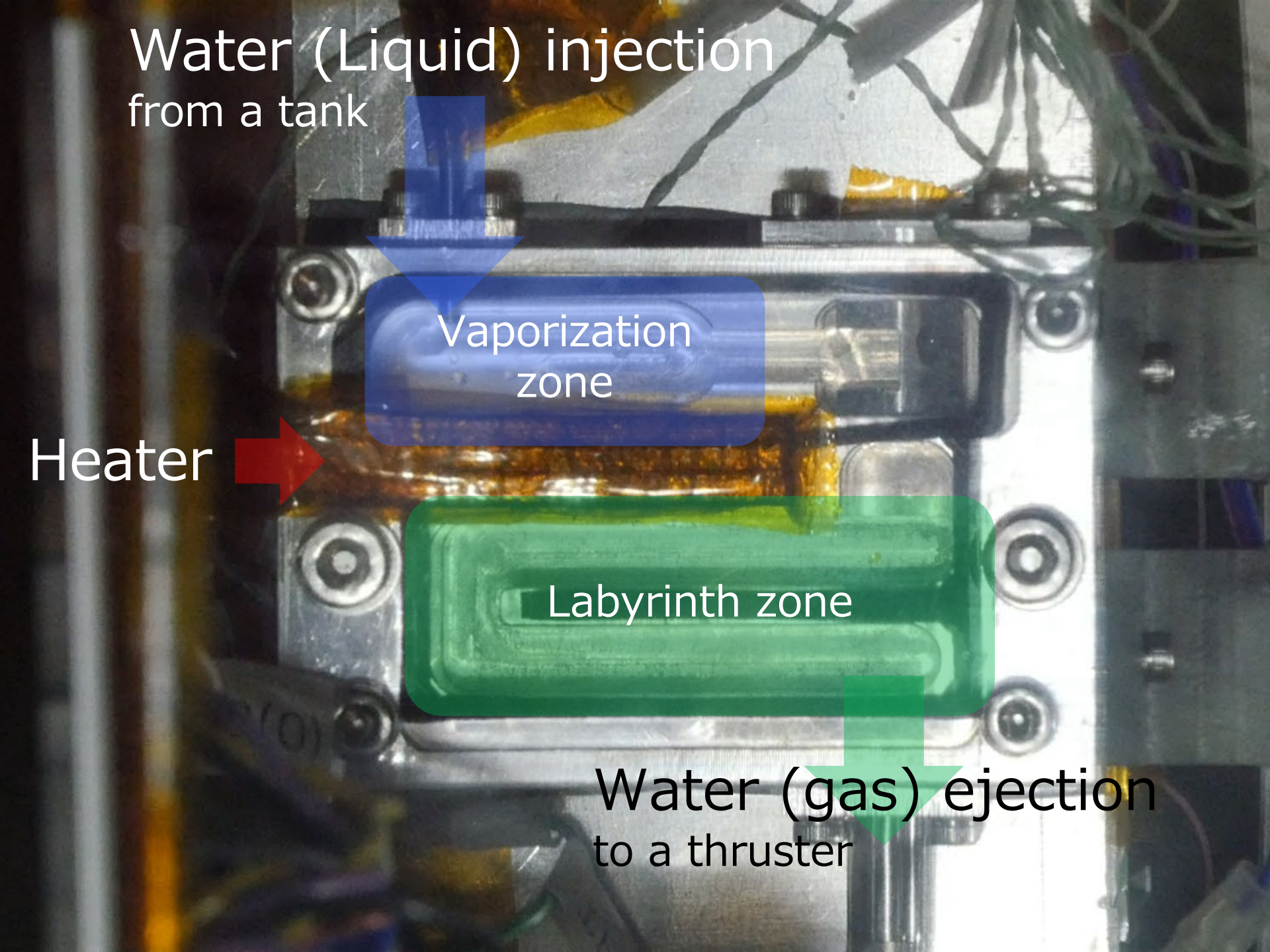
Water (Liquid) injection  
from a tank

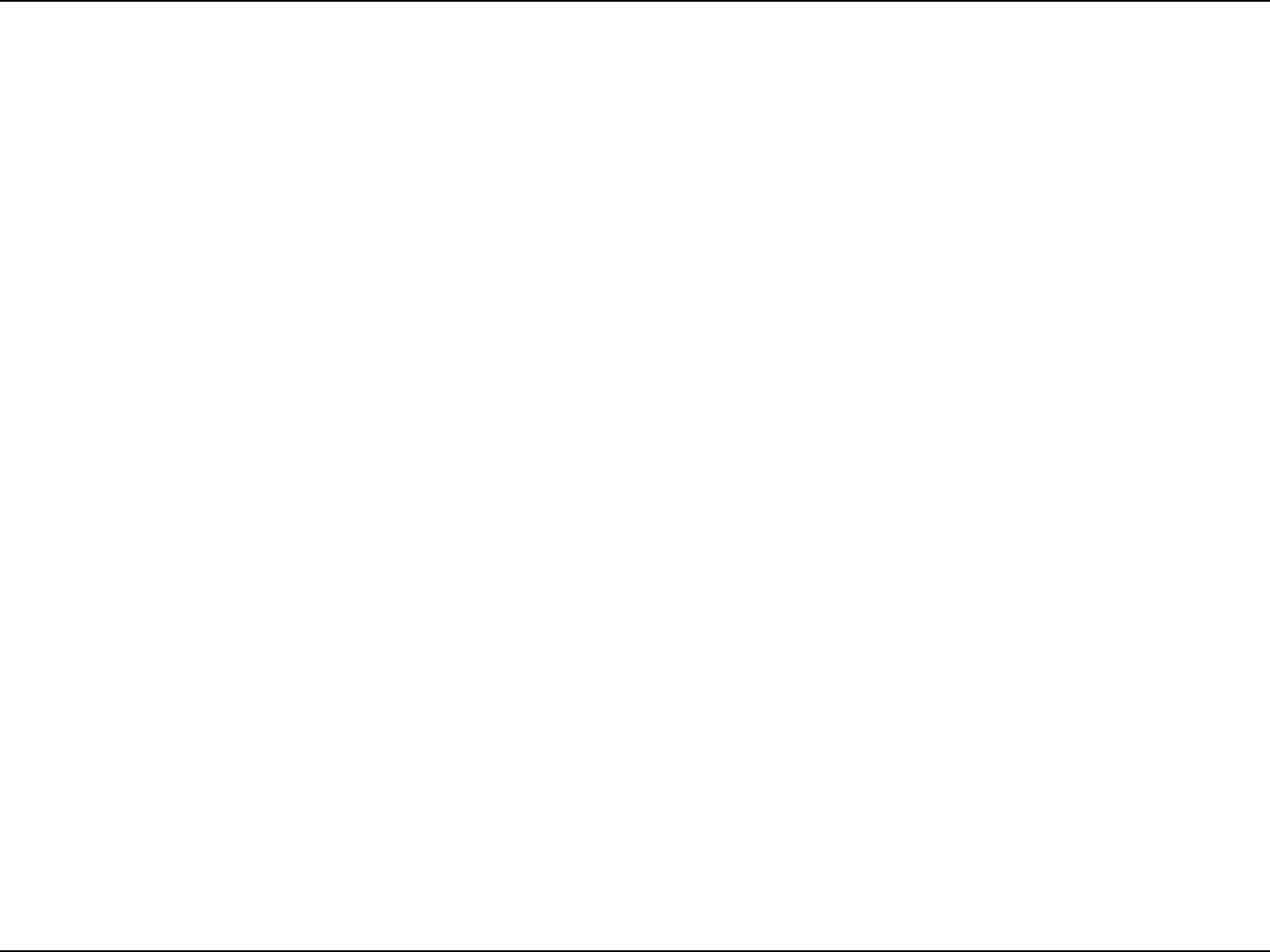
Vaporization  
zone

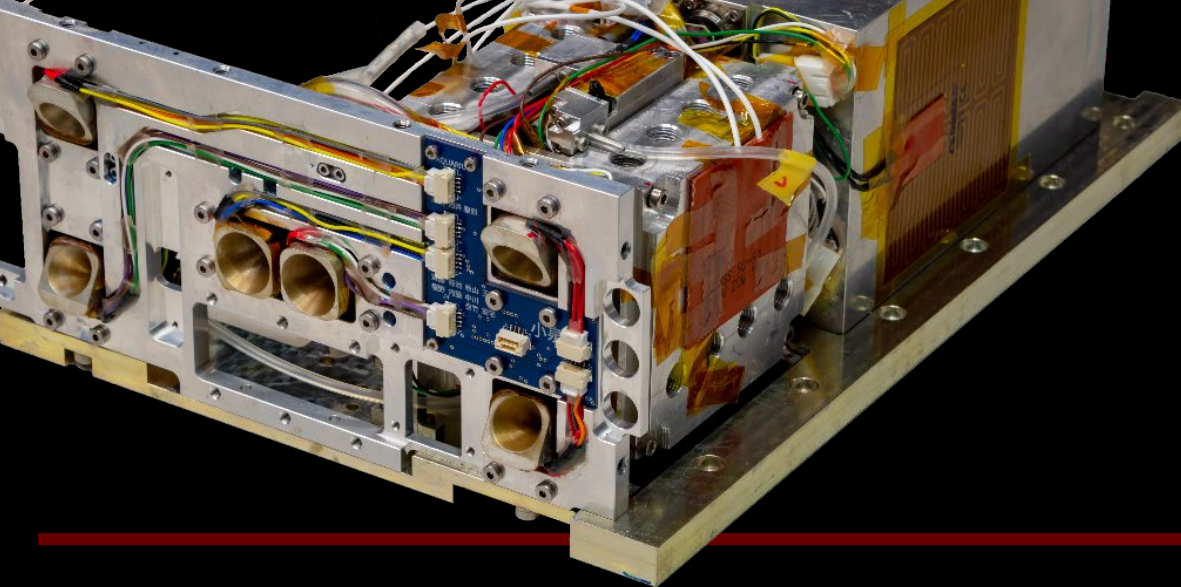
Heater

Labyrinth zone

Water (gas) ejection  
to a thruster







---

AQUARIUS-2.5U

*Propulsion*

AQUARIUS-1U

---

EQUULEUUS (6U)

*Satellite*

AQT-D (3U)

2020 End by SLS

*Launch*

3Q 2019 ISS Deploy

1.2-kg Water

*Propellant*

0.4-kg Water

Start, 2016 Apr

*Development*

Start, 2017 Dec

4 mN / 70 s

*Thrust/Isp*

4 mN / 70 s

---



Water resistojet thruster

# AQUARIUS-2.5U

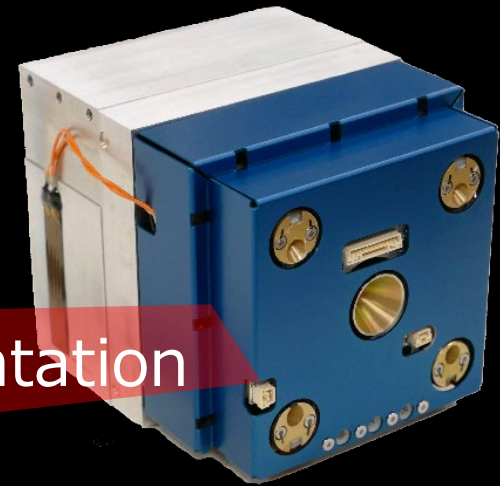
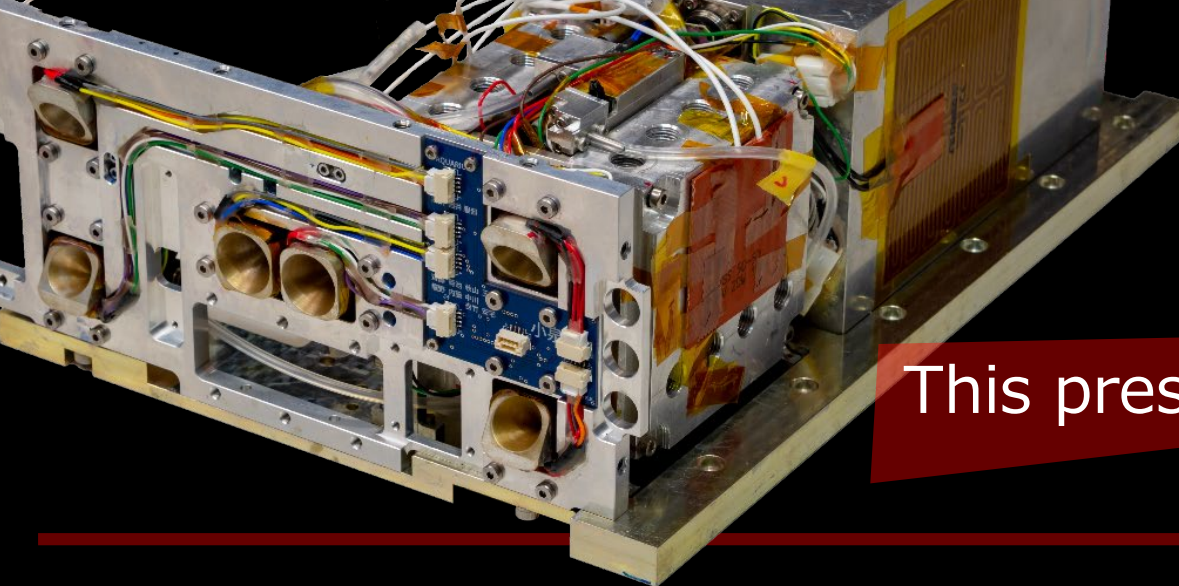
*drives*

Next presentation

SLS cubesat:

# EQUULEUS

[EQUilibriUm Lunar-Earth point 6U Spacecraft]



This presentation

AQUARIUS-2.5U

*Propulsion*

AQUARIUS-1U

EQUULEUUS (6U)

*Satellite*

AQT-D (3U)

2020 End by SLS

*Launch*

**3Q 2019 ISS Deploy**

1.2-kg Water

*Propellant*

0.4-kg Water

Start, 2016 Apr

*Development*

Start, 2017 Dec

4 mN / 70 s

*Thrust/Isp*

4 mN / 70 s



# AQT-D: AQUA Thruster-Demonstrator

The ISS-Deployed CubeSat for a Demonstration of the Water Micro-Propulsion System

[Home](#) [AQT-D](#) [AQUARIUS-1U](#) [Team](#) [Acknowledgment](#) [Contact](#)

## Team

Principal Investigator  
(originally planned speaker)



**Jun Asakawa,**  
**Ph.D.**



**Kazuya Yaginuma,**  
**Ph.D.**



**Yuichi Nakagawa**



**Yoshihiro Tsuruda,**  
**Ph. D.**



**Kota Kakiyara**



**Kanta Yanagida**



**Shuhei Matsushita**



**Mikihiro Ikura**

More info for project

Electrical Engineer

Software Engineer

Thermal Engineer

Lab director

Ph. D. Student

Ph. D. Student

(what you see now)



**Yusuke Murata**



**Hiroyuki Koizumi,  
Ph.D.**

Lab of  
(spea

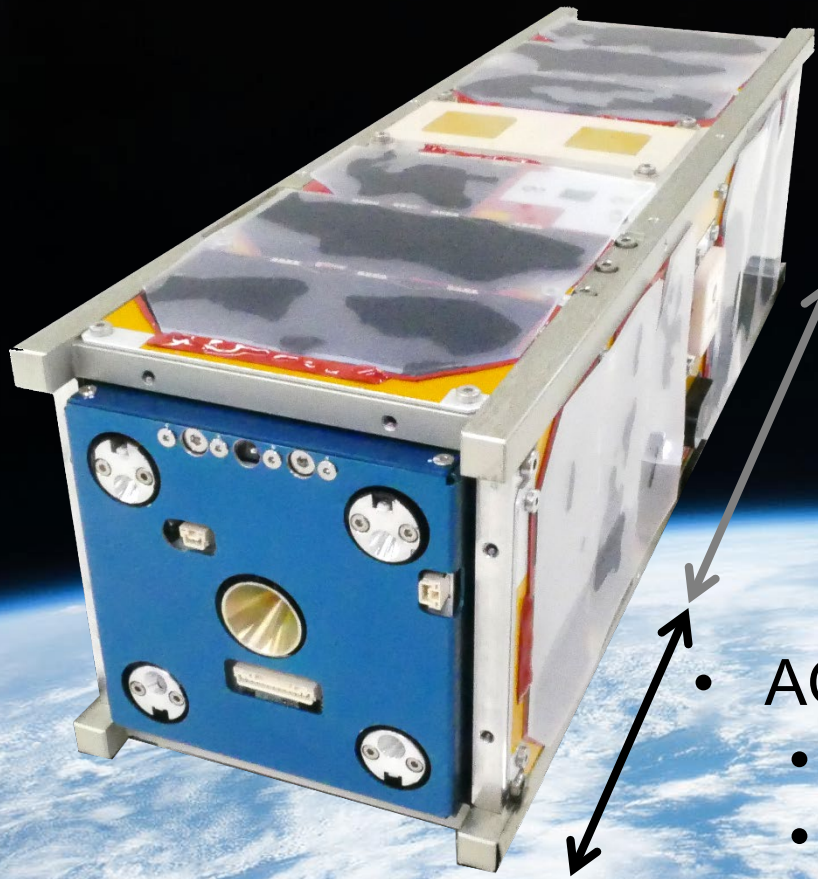






# AQT-D

## AQua Thruster - Demonstrator



- AQT-D
  - ISS-Deployed CubeSat
  - Launch Date : 2019 Middle
  - Mass : 3.7 kg
- 2U Bus System
  - 3-Axis Attitude Control
  - S-band Communication
- AQUARIUS-1U
  - 0.5U Water Tank
  - Multi-Nozzle System (translation & attitude)





# AQT-D

## *Missions and Features*

- Technical Demonstration of AQUARIUS
  - Vaporization Chamber Technique
- Direct Thrust Measurement in Orbit
- Long Time Operation of Thruster
  - Total Operation Time: 15 hours
  - $\Delta V = 54$  m/s (LEO alt. change: 190 km)
- Mission Policy
  - Control the unexpected recontact with



AQT-D

*Safety Requirement for ISS deployment*

- **HRL (Hazard Response Level) = 0** <sup>\*1\*2</sup>

Water propulsion system is certified by JSC

- THL (Toxic Hazard Level) = 0
- BSL (Biosafety Level) = 0
- Flammability Level = 0

- **Non-Fracture Part**

- Not Pressure Vessel <sup>\*3\*4\*5</sup>
- Maximum Pressure < 15psia (=103 kPaA) <sup>\*4\*5</sup>
- Stored Energy < 14240 ft-lbs (=19310 J) <sup>\*4\*5</sup>

\*1 JSC-26895

\*2 SSP-50005

\*3 JMX-2011303

\*4 SSP-52005

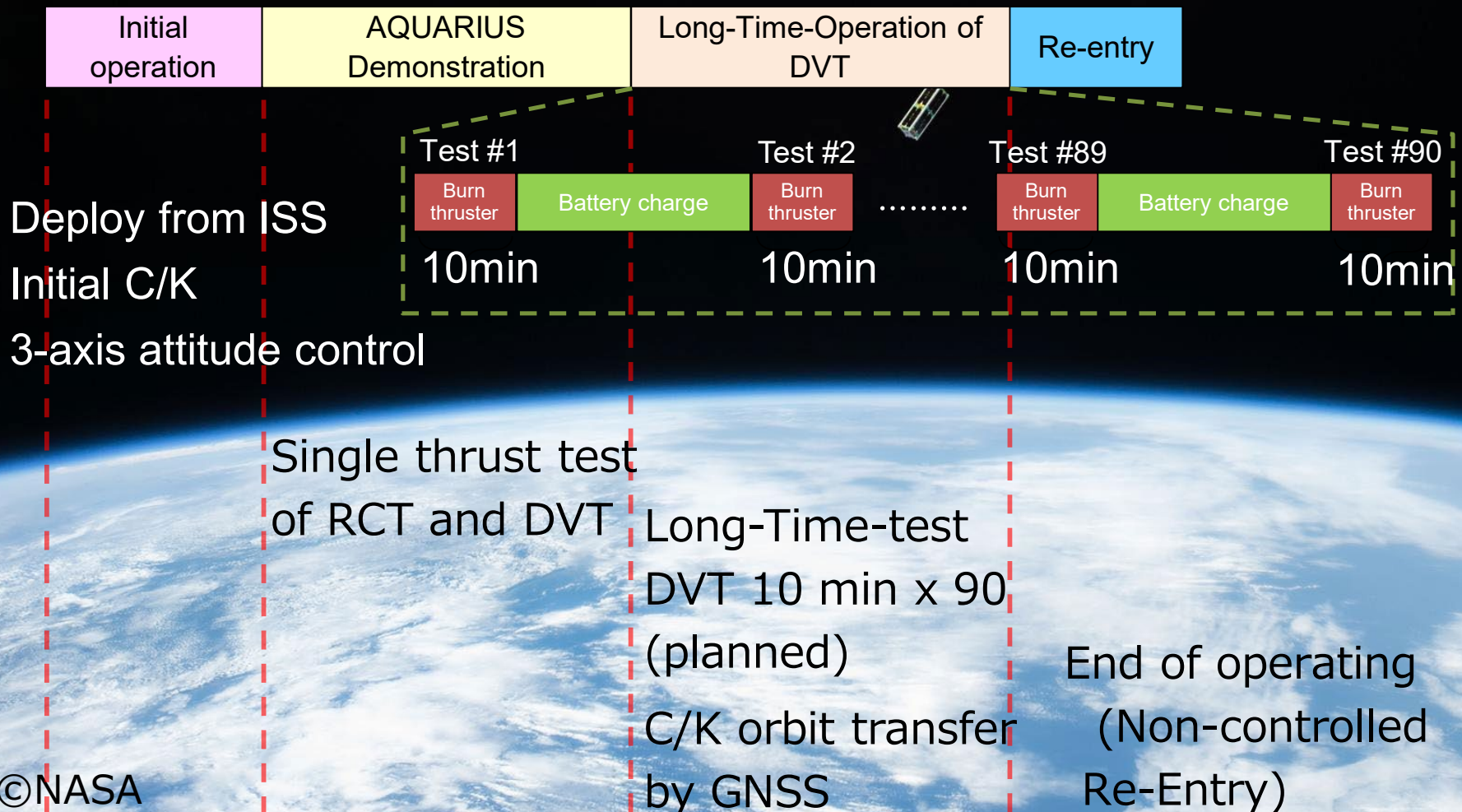
\*5 NASA-HDBK-5010



# AQT-D

## Mission Scenario of AQT-D

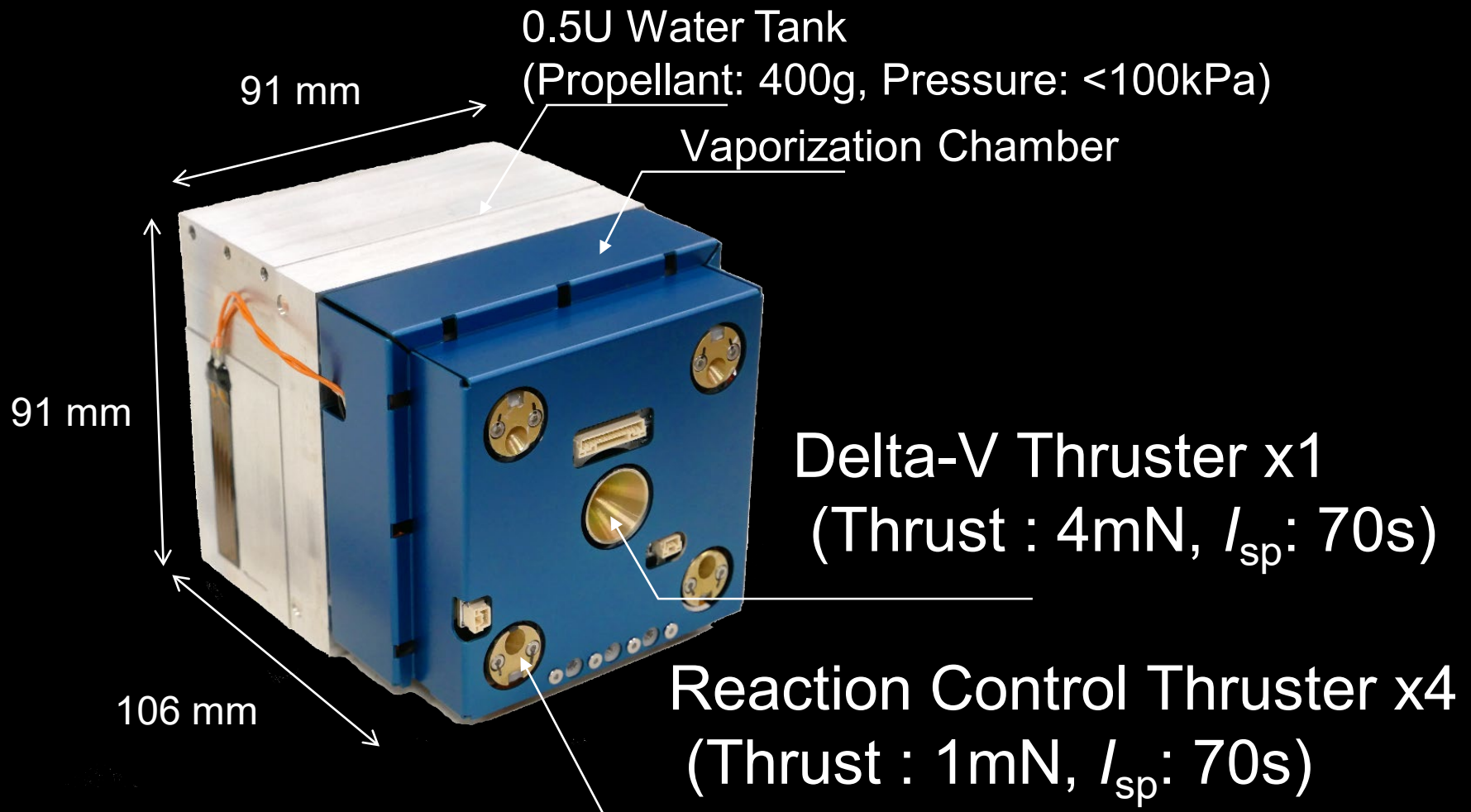
1<sup>st</sup> month    2<sup>nd</sup> / 3<sup>rd</sup> month    After 4<sup>th</sup> month





# AQUARIUS-1U

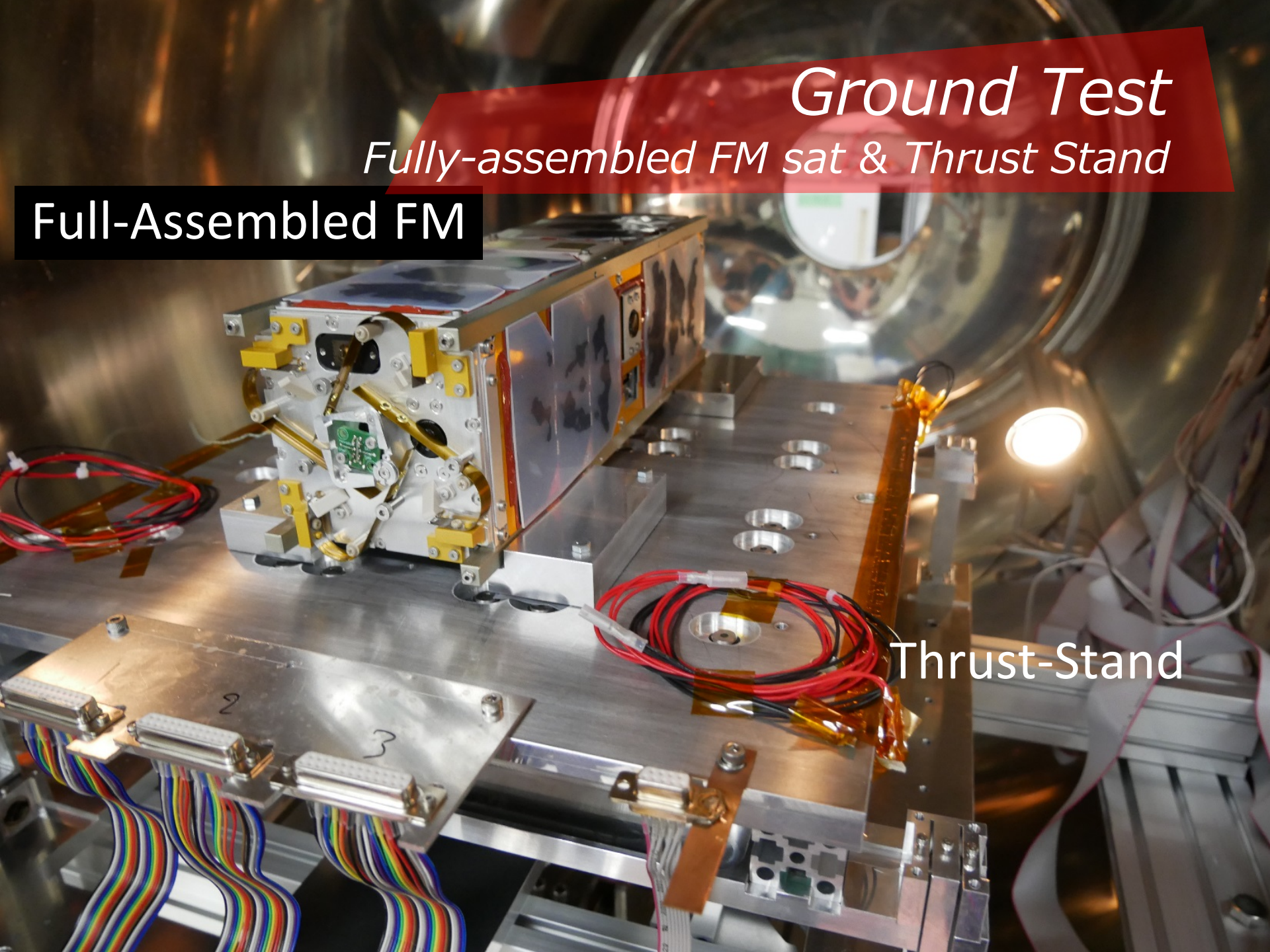
*Delta-V Thruster x1 + RCS Thruster x4*



# *Ground Test* *Fully-assembled FM sat & Thrust Stand*

Full-Assembled FM

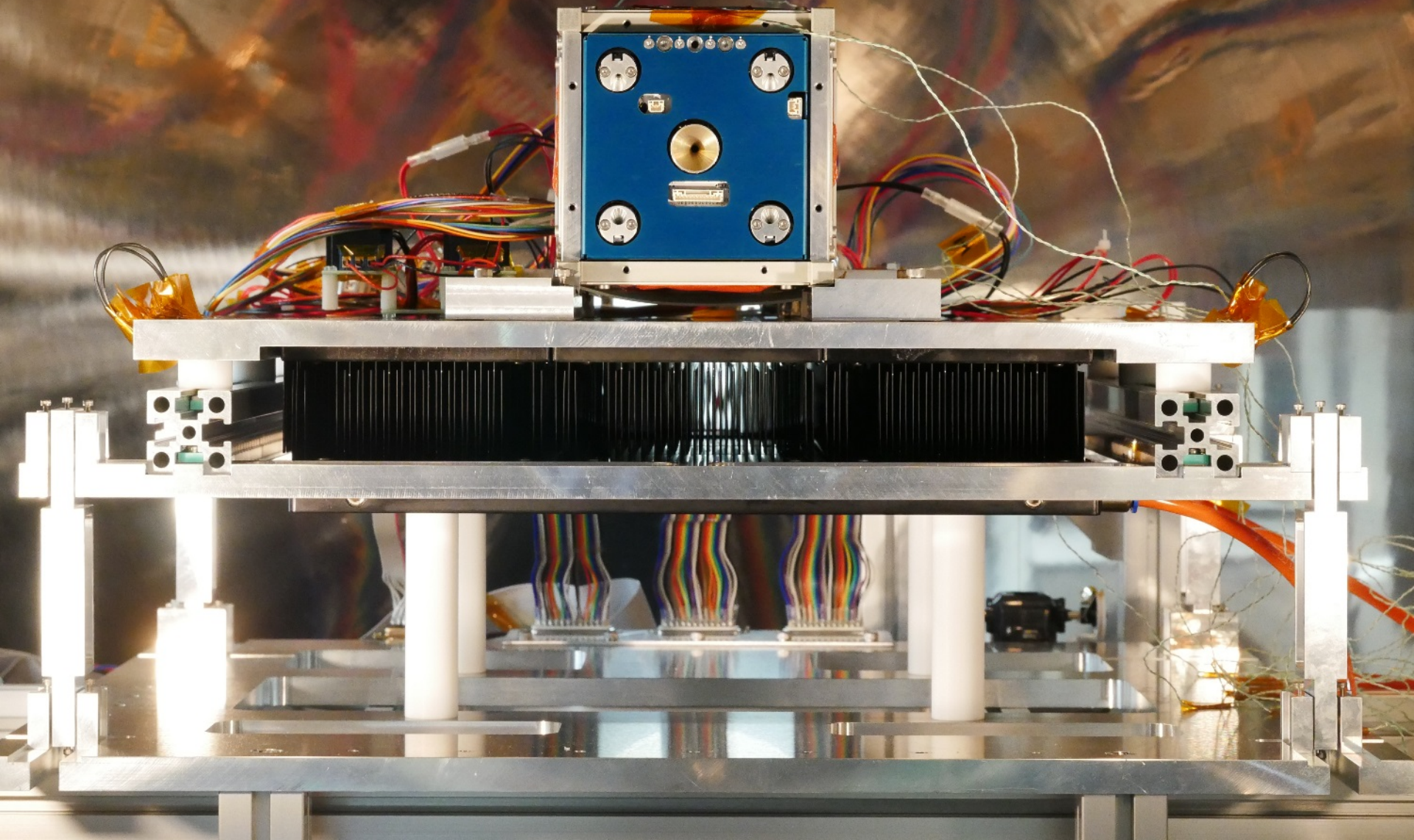
Thrust-Stand





# *Ground Test*

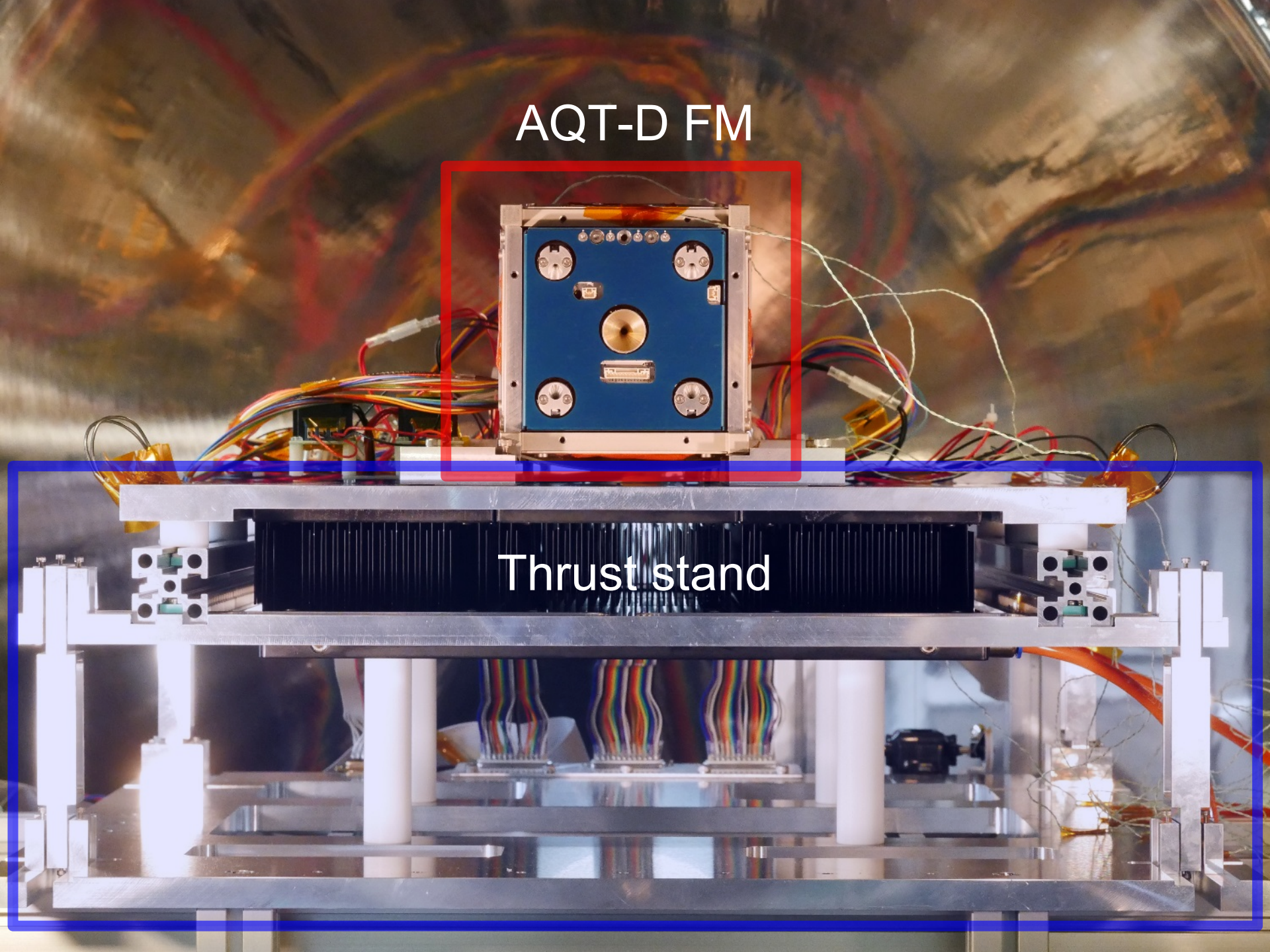
## *Fully-assembled FM sat & Thrust Stand*

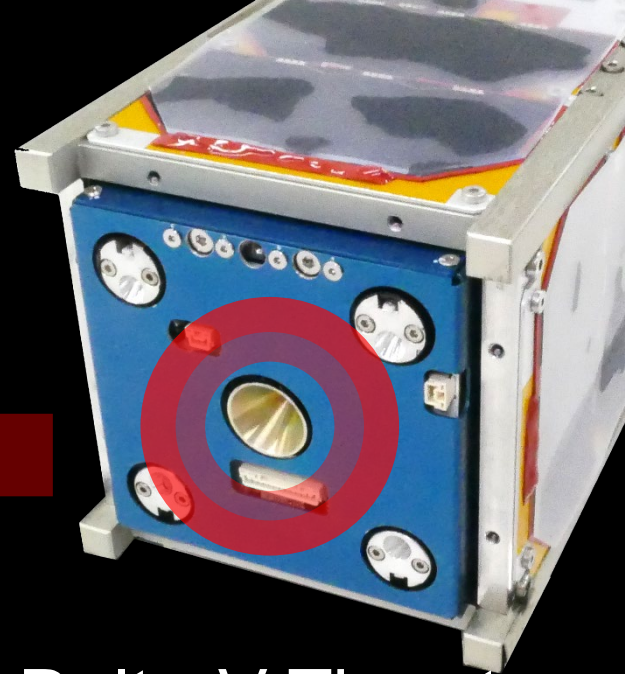
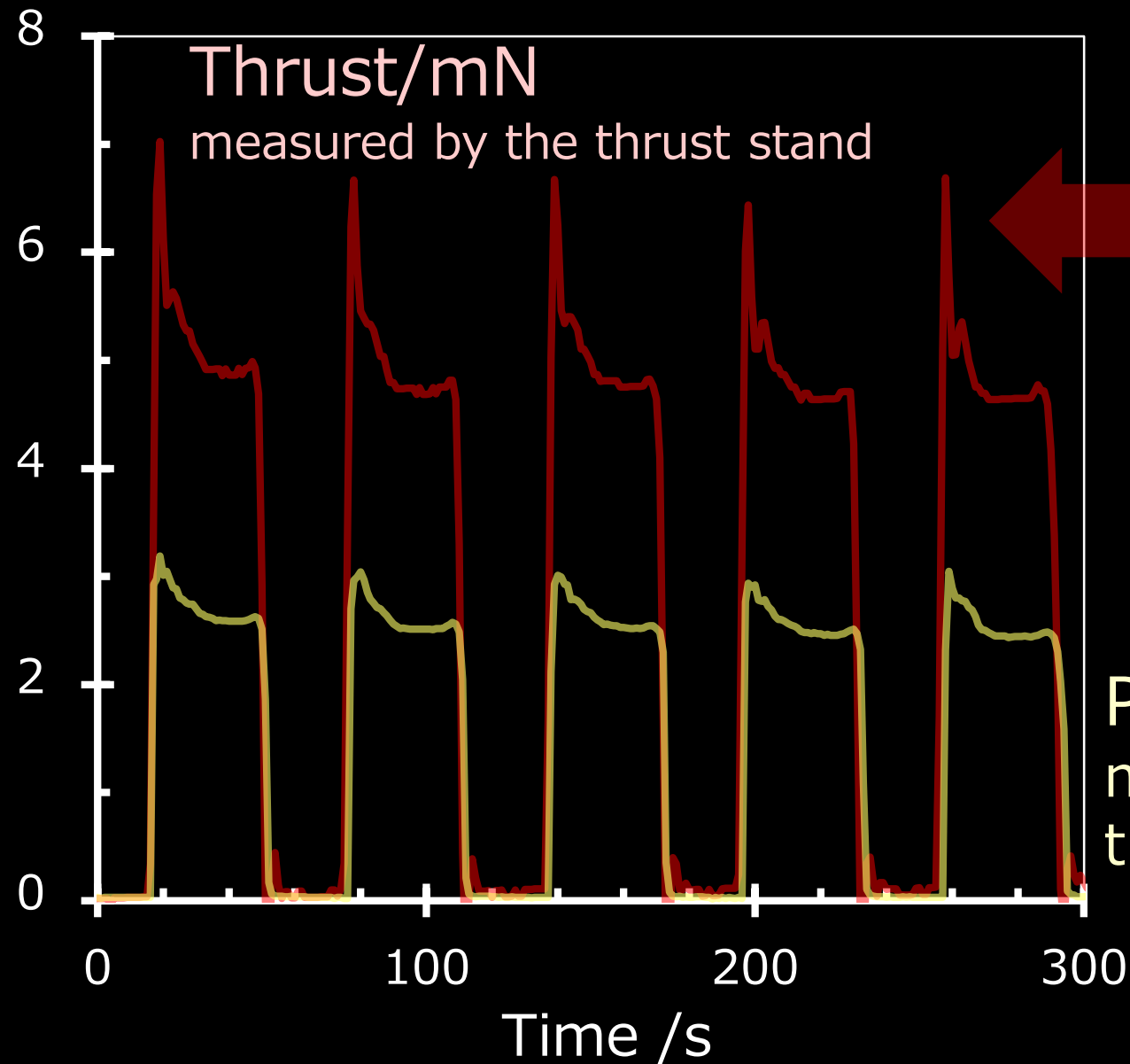




AQT-D FM

Thrust stand

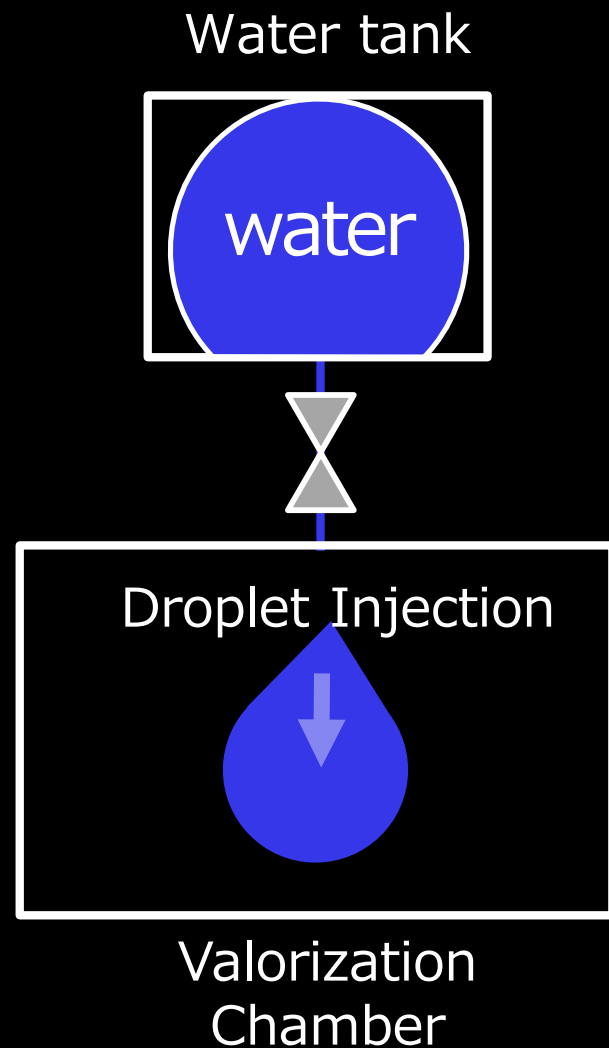
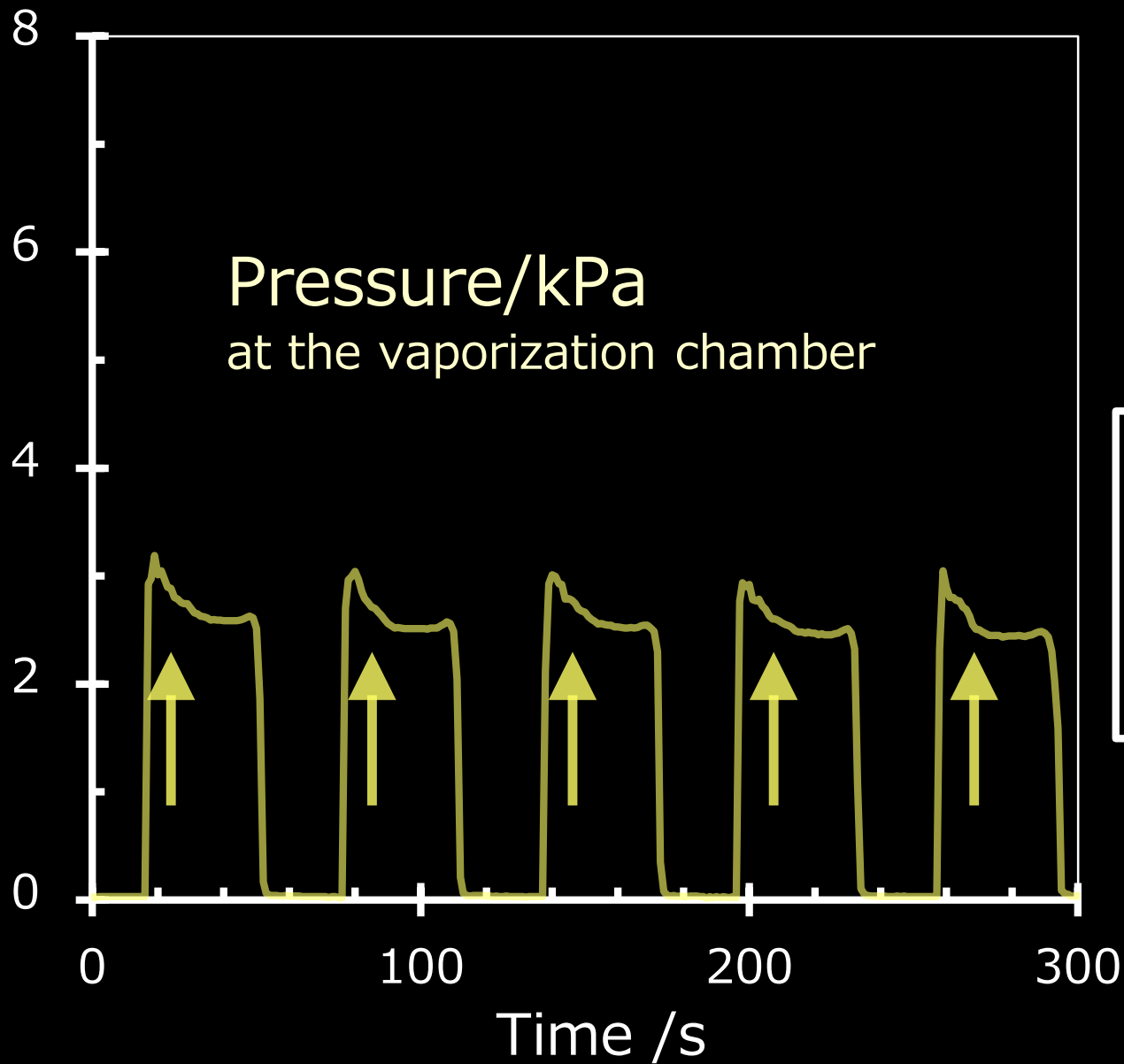


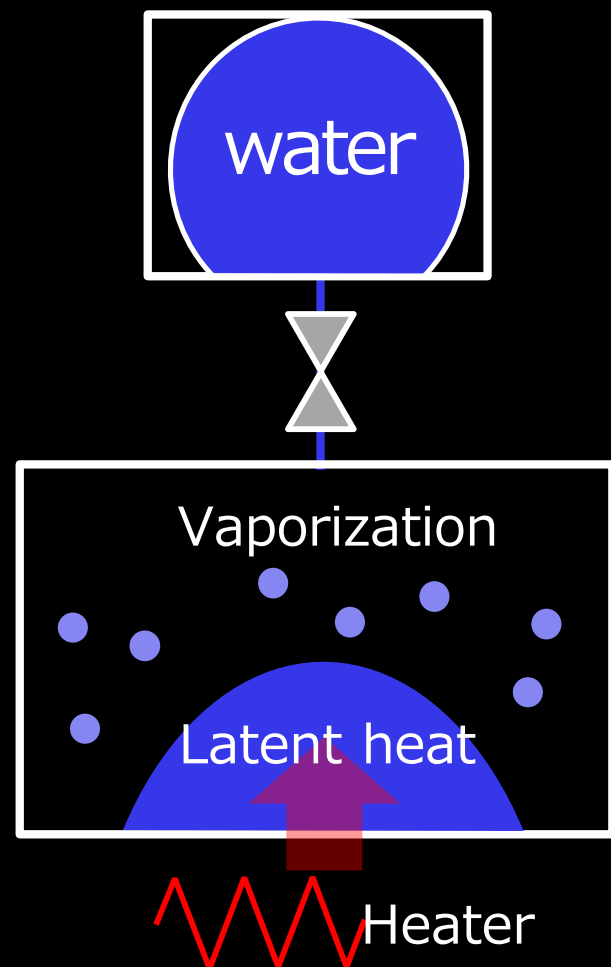
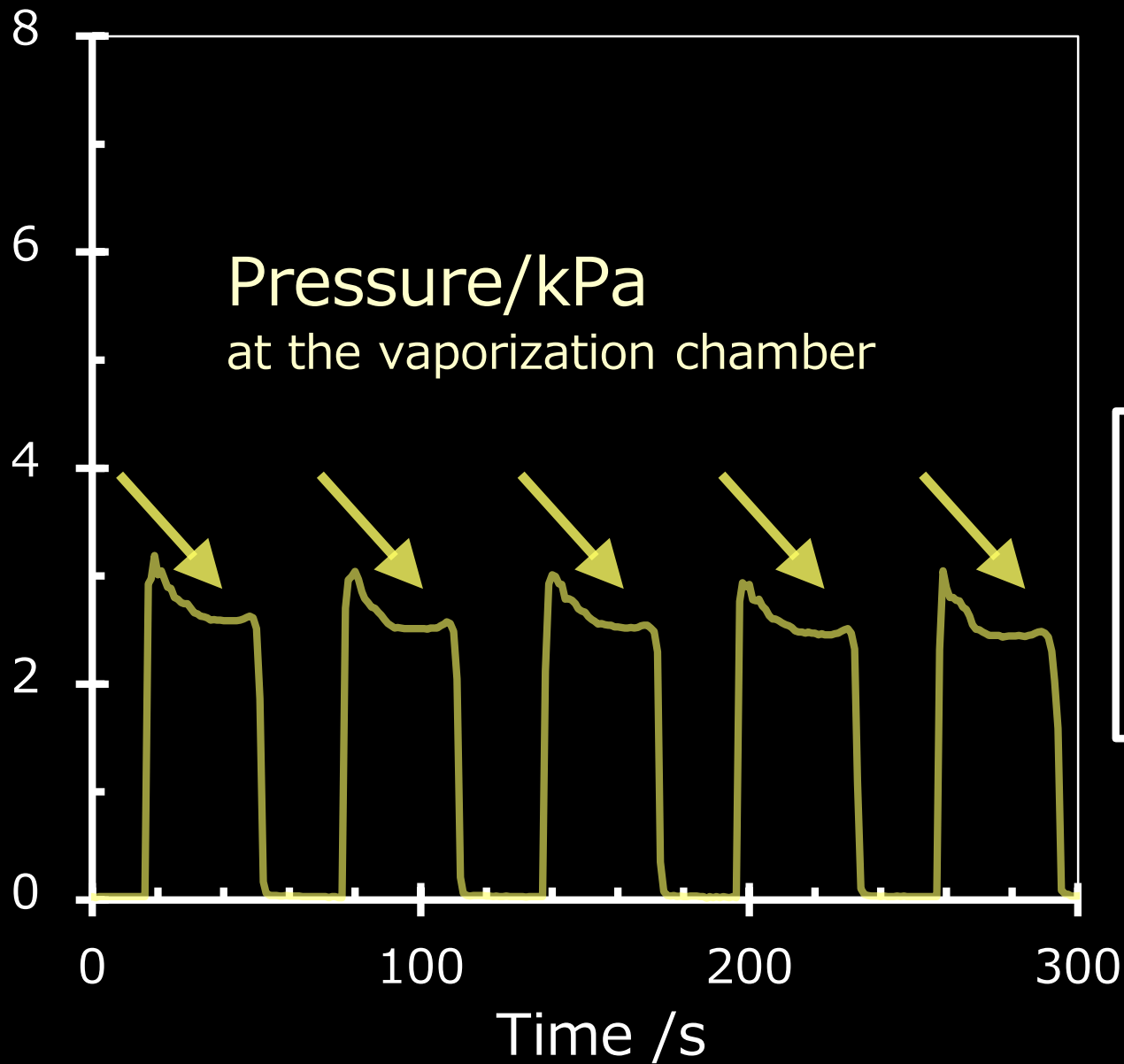


Delta-V Thruster

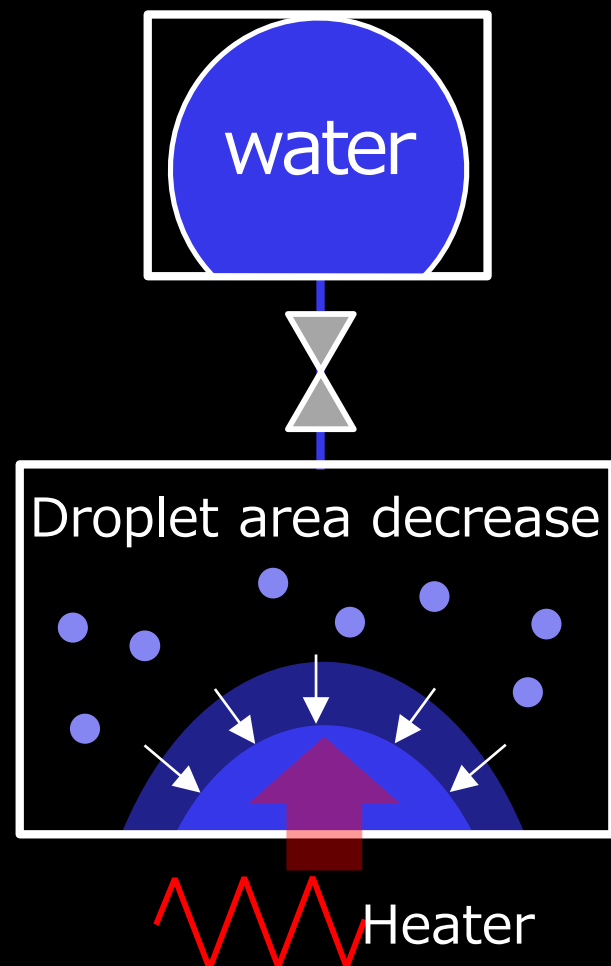
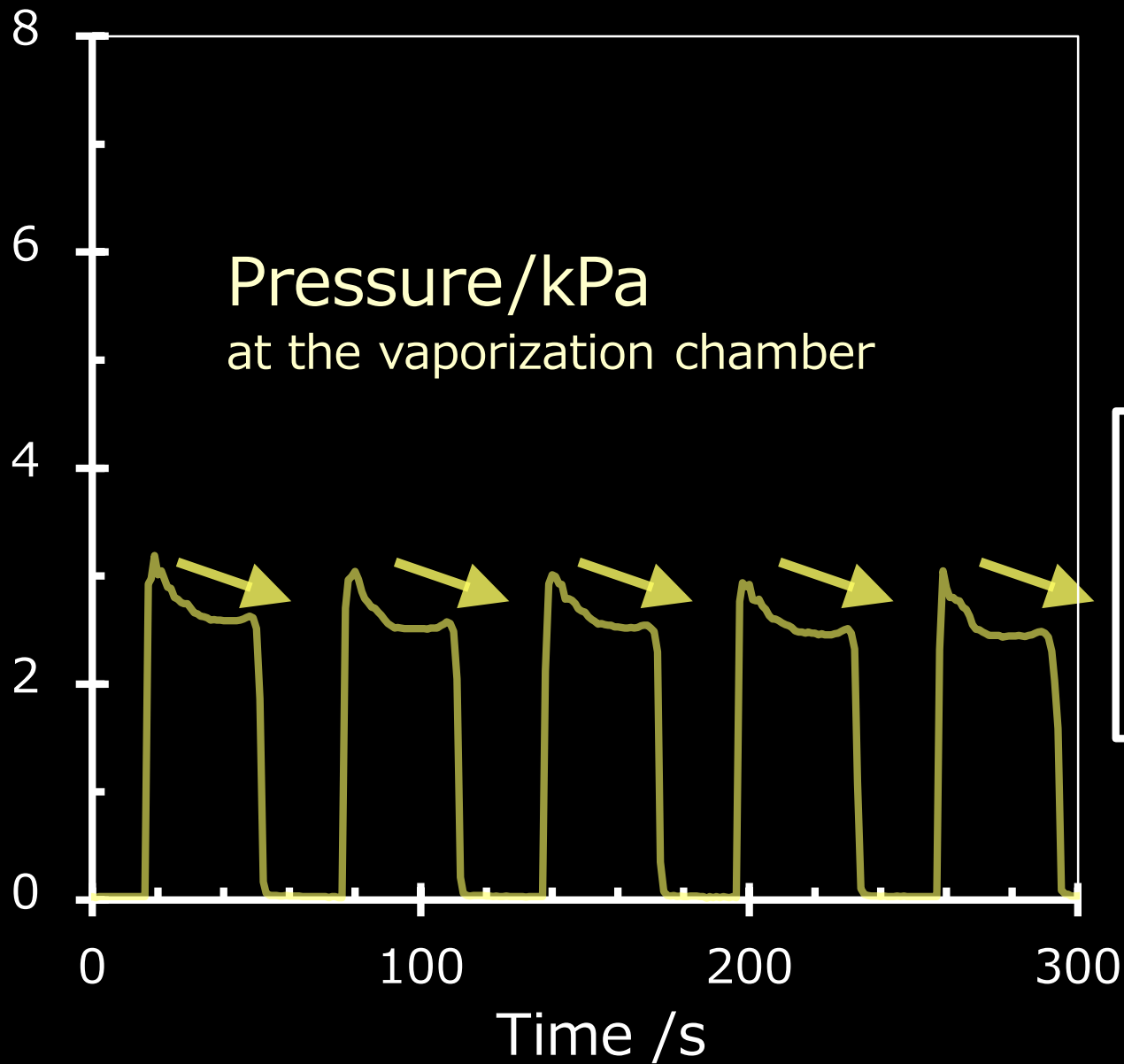
Pressure/kPa  
measured by  
the internal sensor

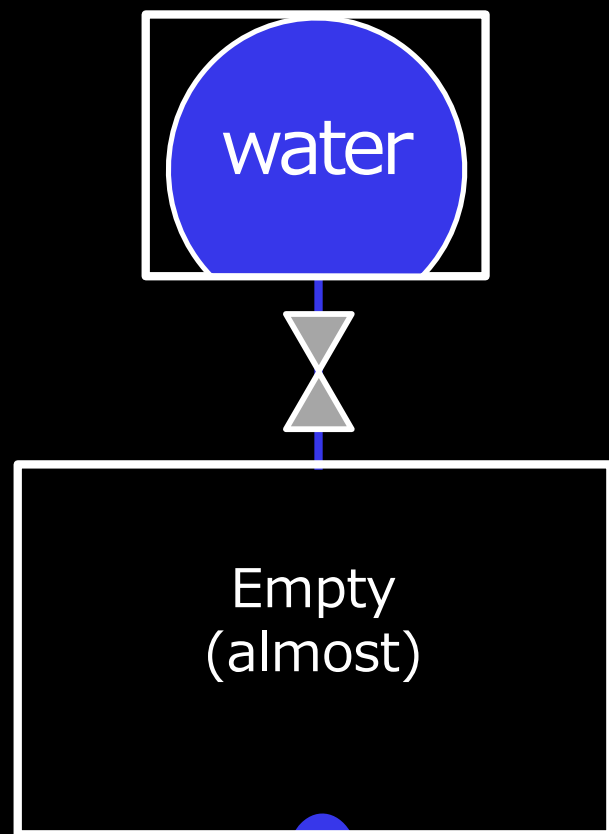
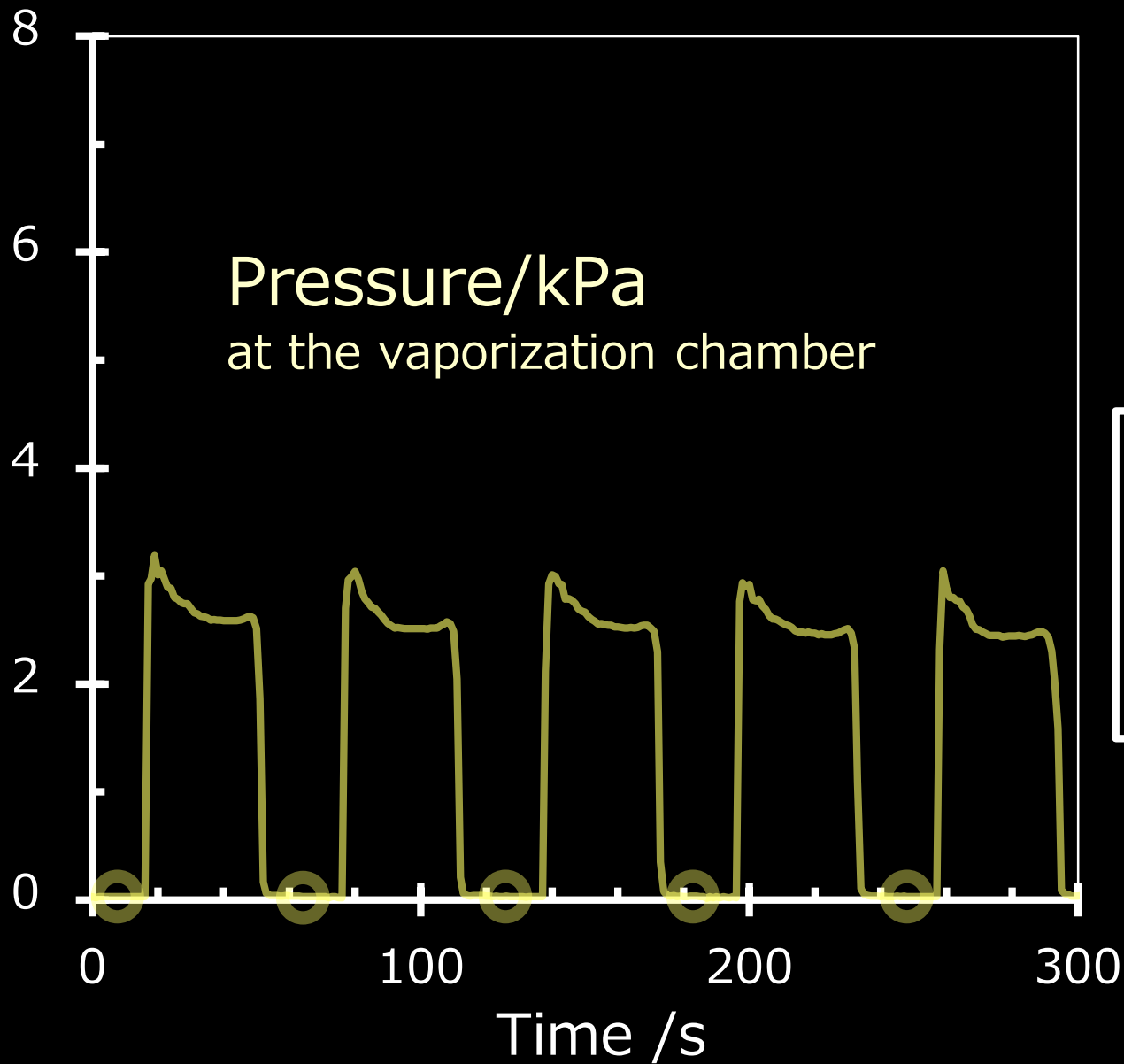






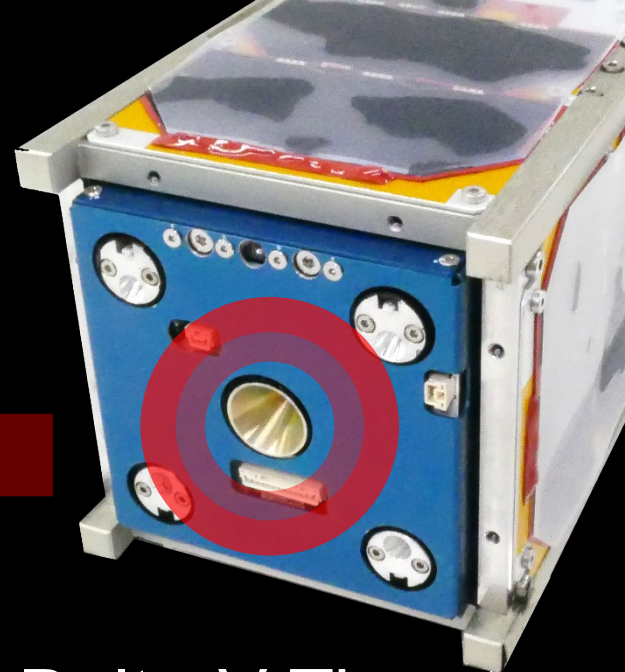
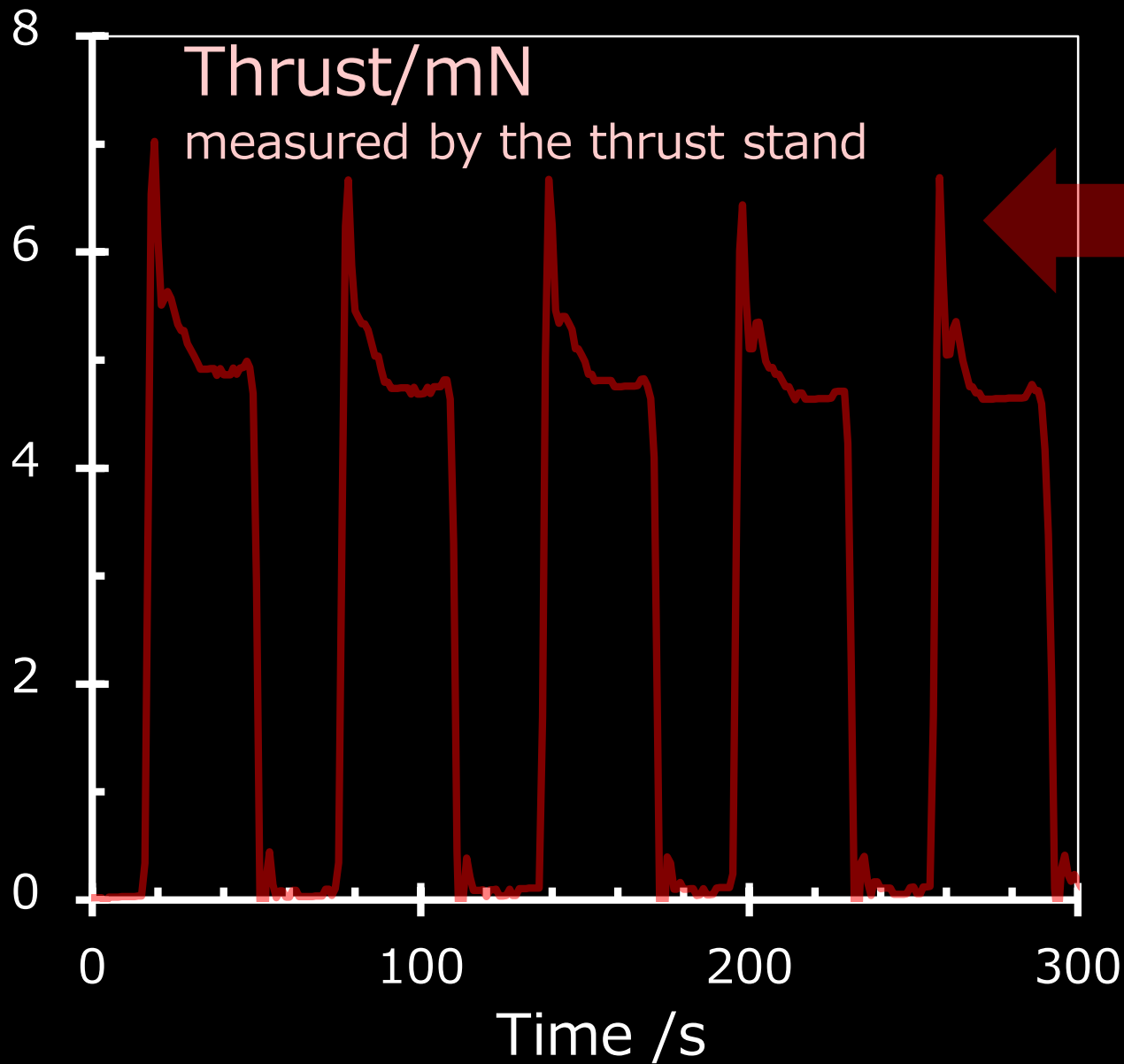




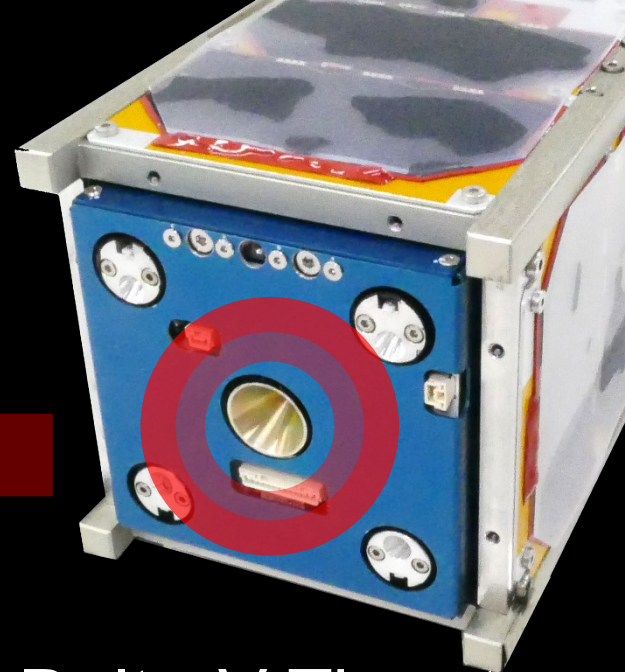
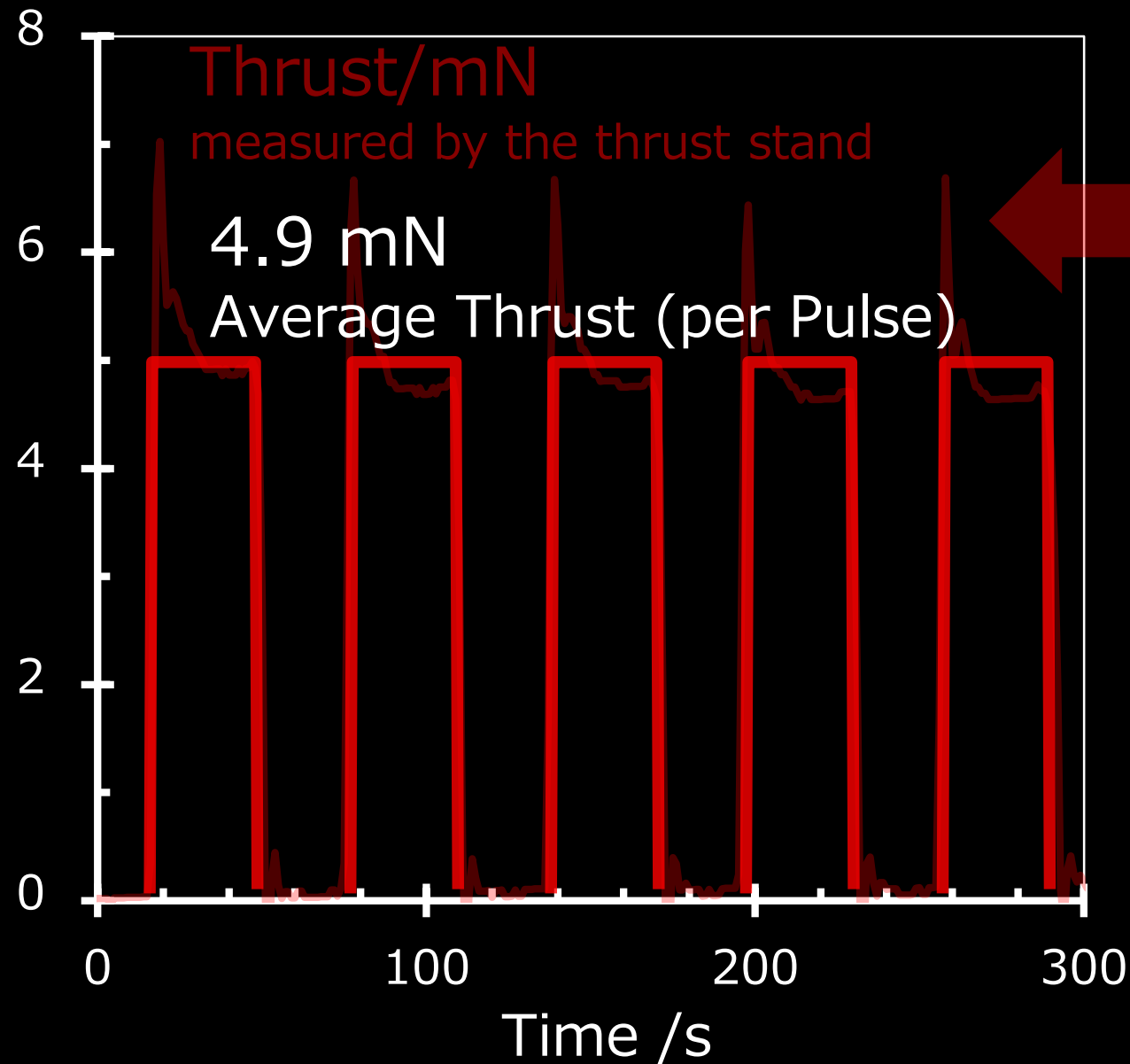




Thrust/mN  
measured by the thrust stand

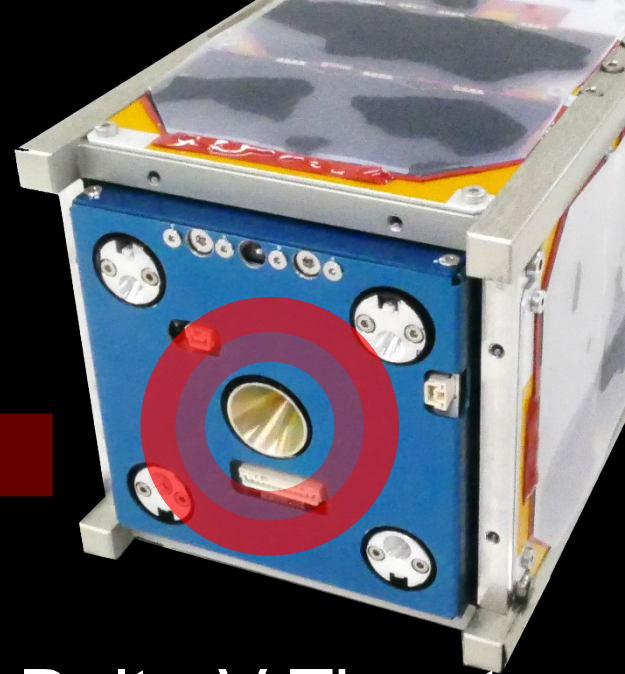
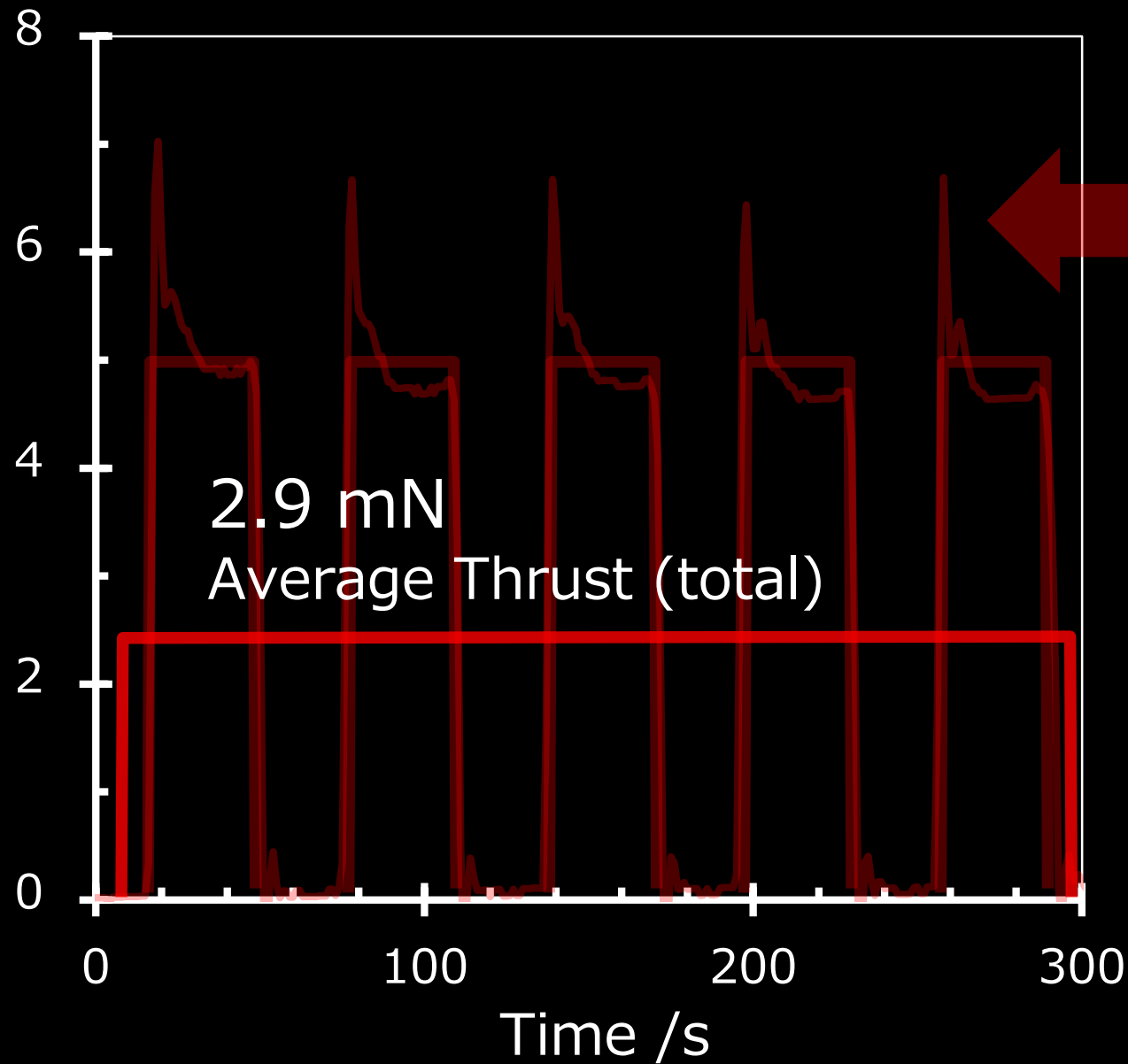


Delta-V Thruster



Delta-V Thruster





Delta-V Thruster

# *Summary and Future Works*

## AQT-D : Aqua Thruster – Demonstrator

- The world's first ISS deployed CubeSat installing water propulsion system.
- Full-integration of FM was completed.
- Good Ground Test Results
- Launch Date : 3Q 2019



*Univ. Exhibit: U12*  
*We will give you more details*

Thank you

Now, we are (almost) finishing the shipping ☺