# Designing and testing a technology demonstrator in microgravity

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# Background


PhD in Aerospace Engineering Sciences

→ Low-gravity magnetohydrodynamics
→ Touchless electrostatic potential sensing
→ President-elect of ASGSR Students

"la Caixa" Foundation · Fundación Rafael del Pino · AFOSR Air Force Office of Scientific Research · NASA · JPL Jet Propulsion Laboratory California Institute of Technology · ASGSR

# Background

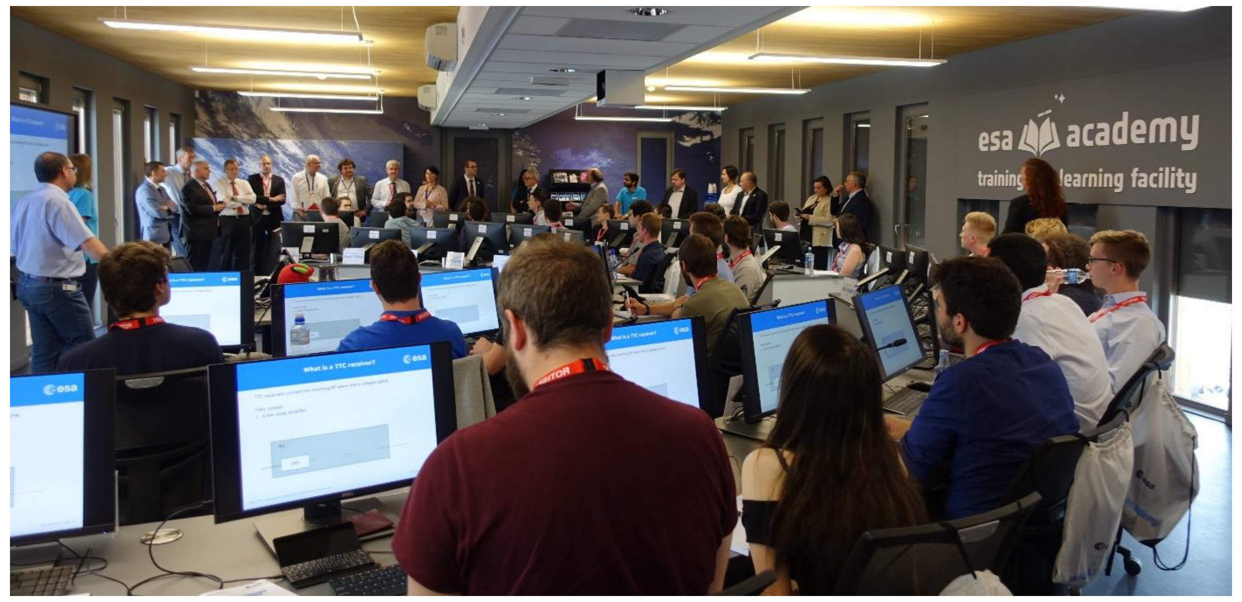

UNIVERSIDAD DE SEVILLA

BSc Aerospace Eng., MSc Aeronautical Eng.

POLITECNICO
MILANO 1863

MSc Space Eng.

education
esa




Microgravity research, ESA/ELGRA Summer School

# Research

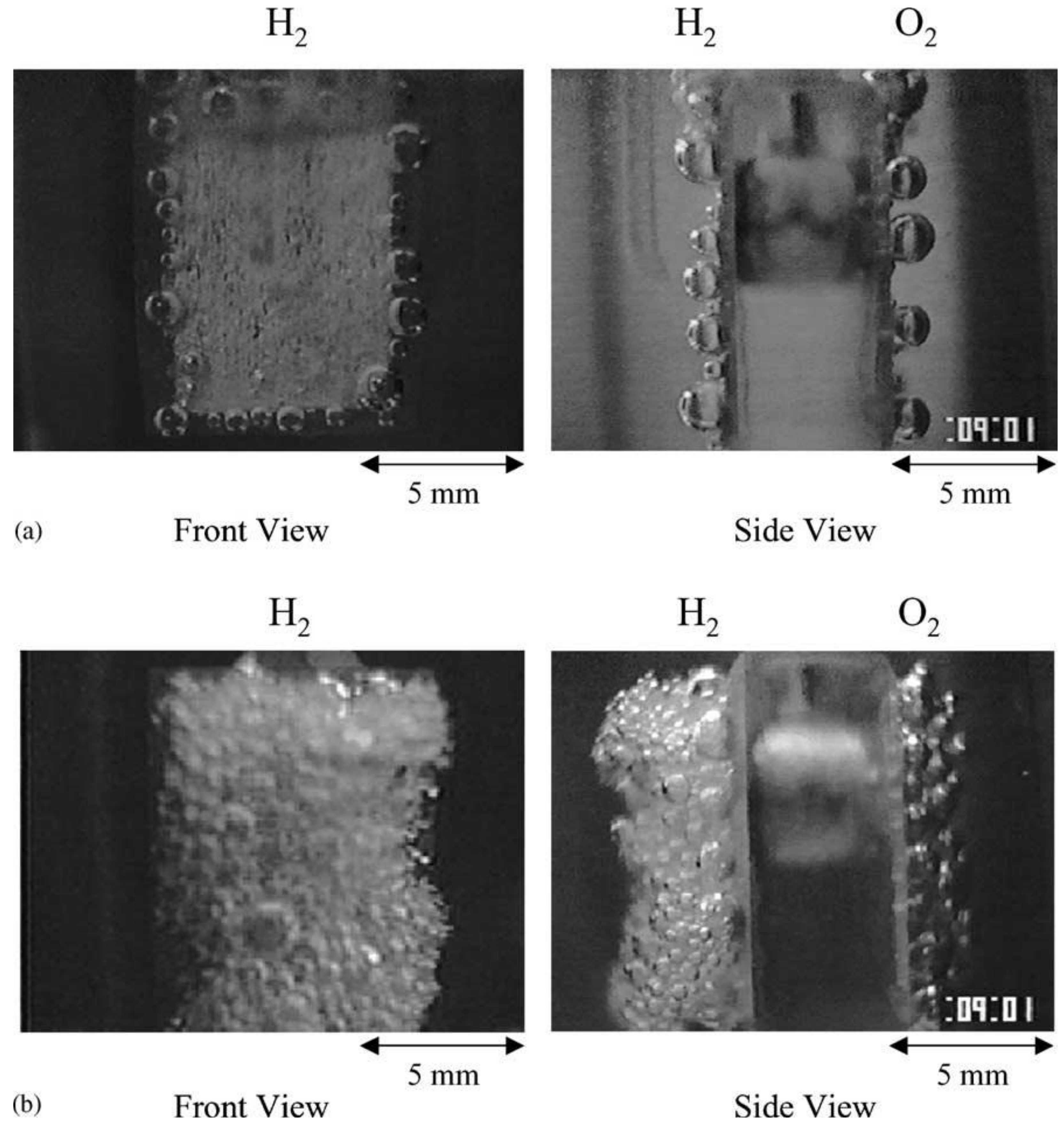
# What is a technology demonstrator?

| | |
|---|---|
| TRL 9 | System proven in operational environment |
| TRL 8 | System complete and qualified |
| TRL 7 | **Integrated pilot system demonstrated** |
| TRL 6 | **Prototype system verified** |
| TRL 5 | **Laboratory testing of integrated system** |
| TRL 4 | **Laboratory testing of prototype component or process** |
| TRL 3 | **Critical function, proof of concept established** |
| TRL 2 | Technology concept and/or application formulated |
| TRL 1 | Basic principles are observed and reported |

## Electrodes

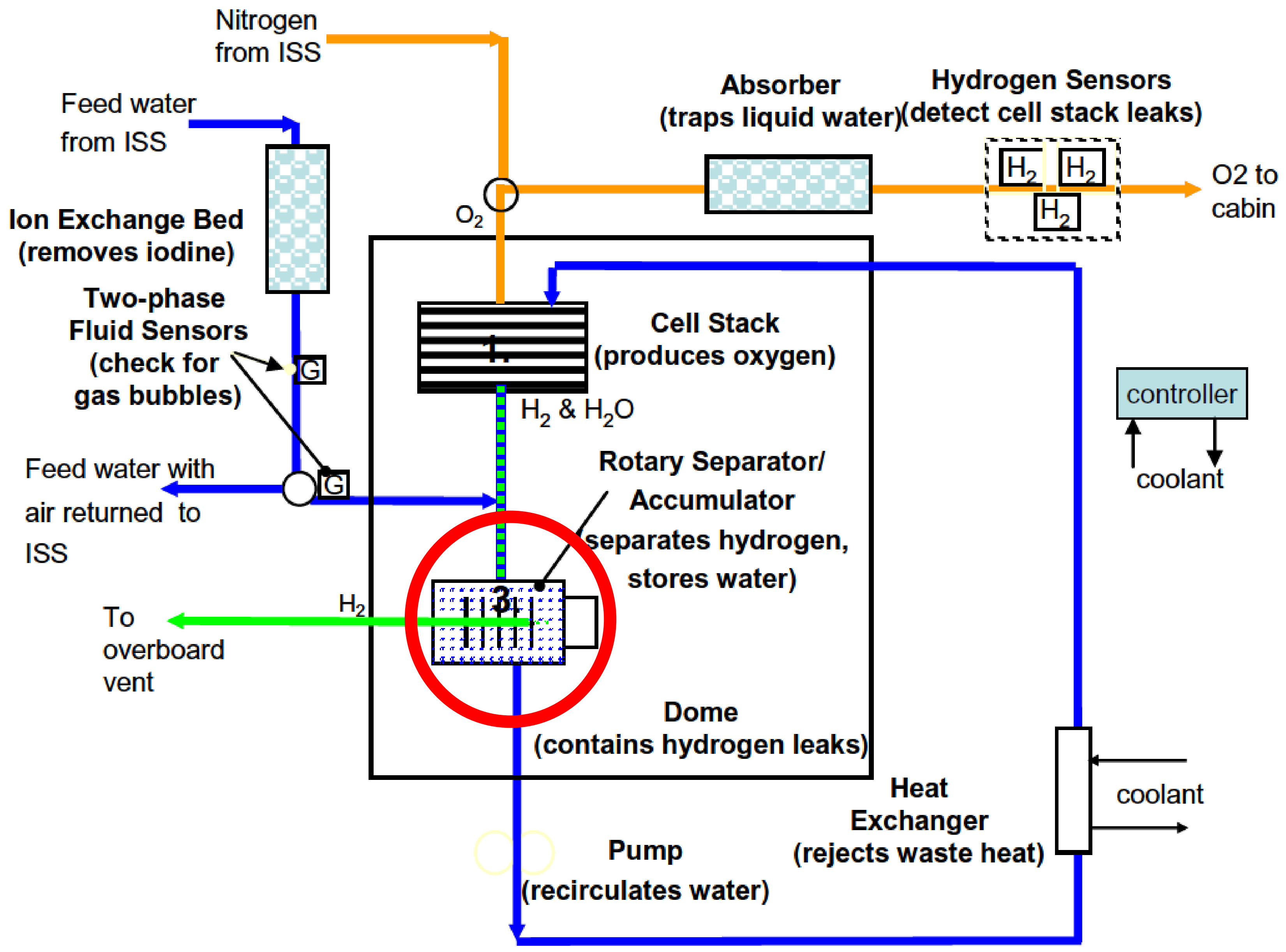
Terrestrial

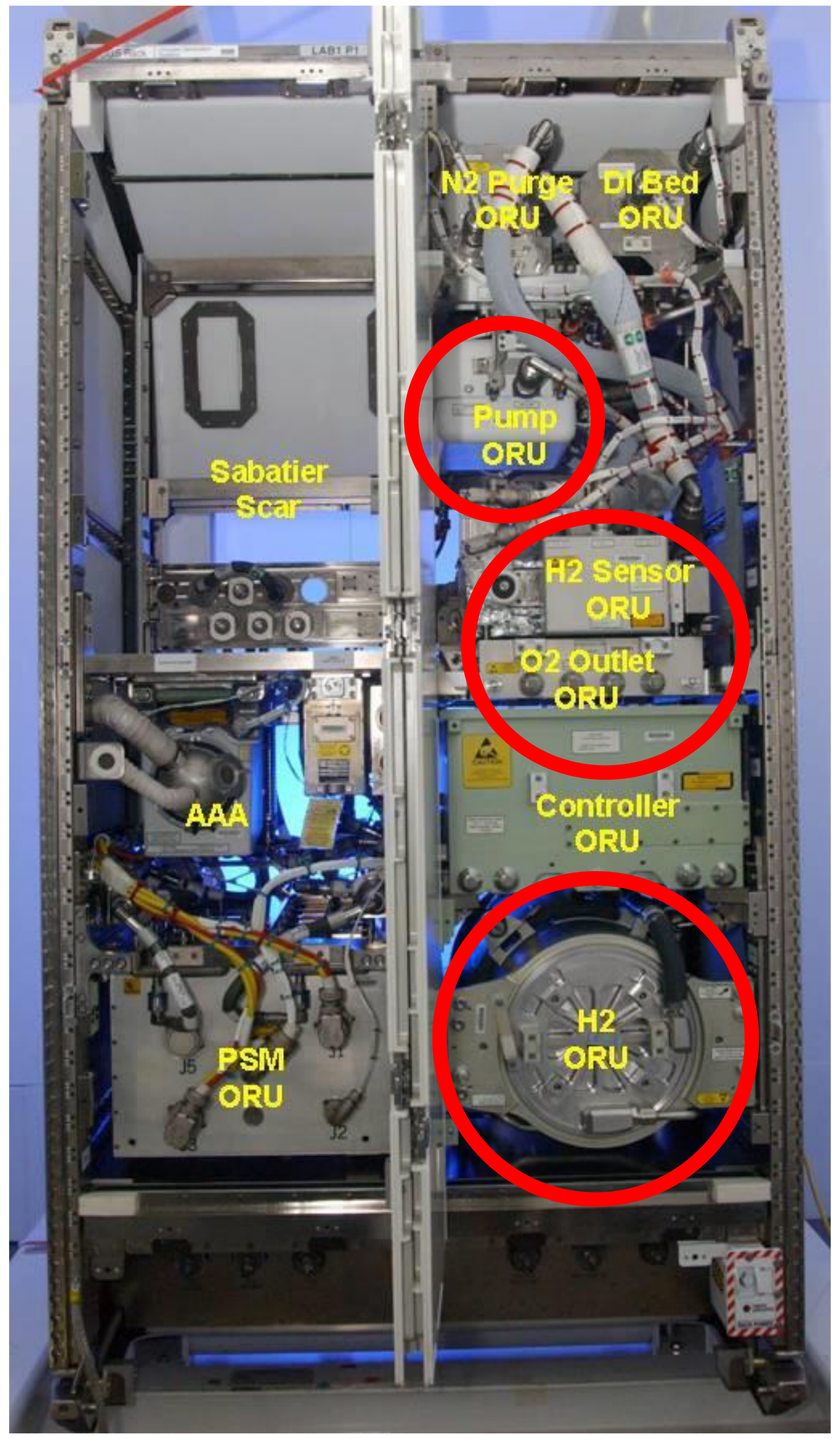
Microgravity




*H. Matsushima et al., Water electrolysis under microgravity. Part 1. Experimental technique, Electrochimica Acta (48), 4119-4125, 2003*

## ISS Oxygen Generation Assembly

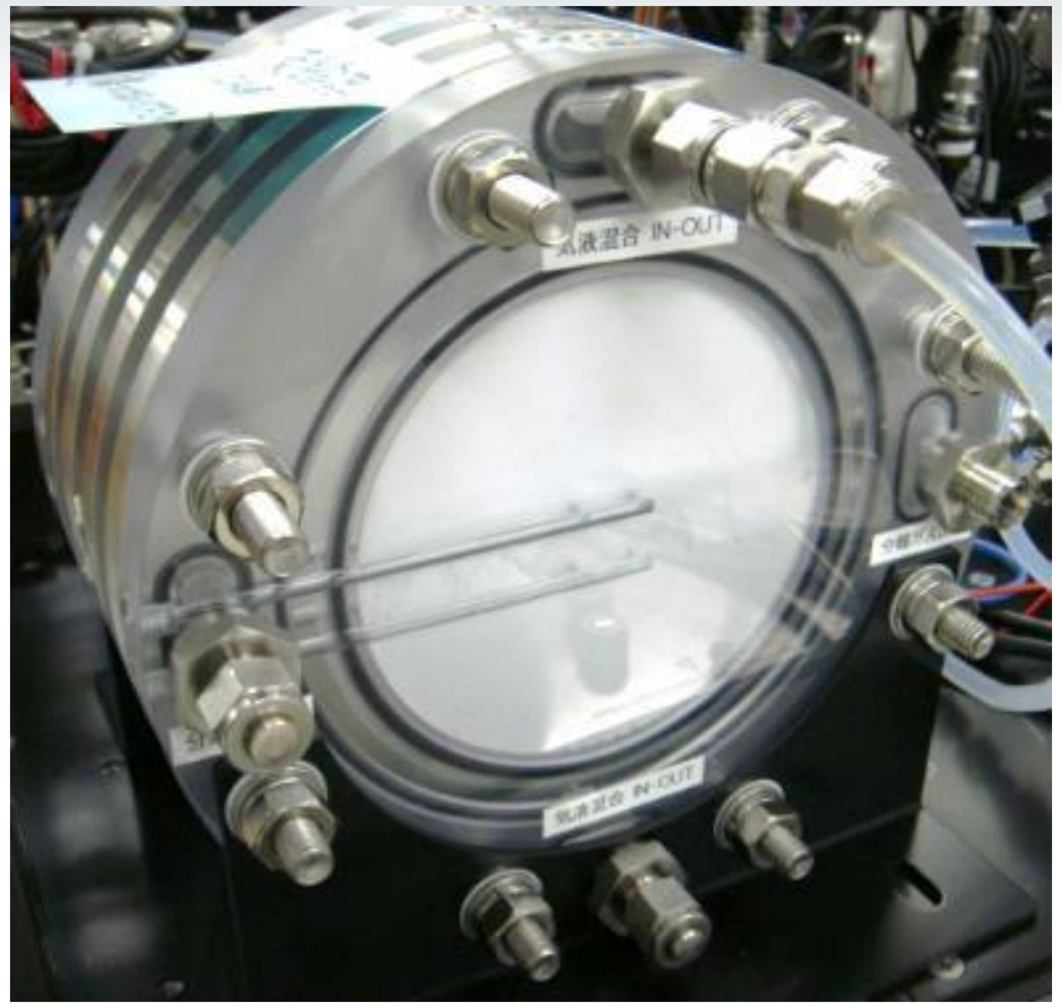



*R.J. Erickson et al., International Space Station United States Orbital Segment Oxygen Generation System On-orbit Operational Experience, AE Int. J. Aerosp. 1(1):15-24, 2009*

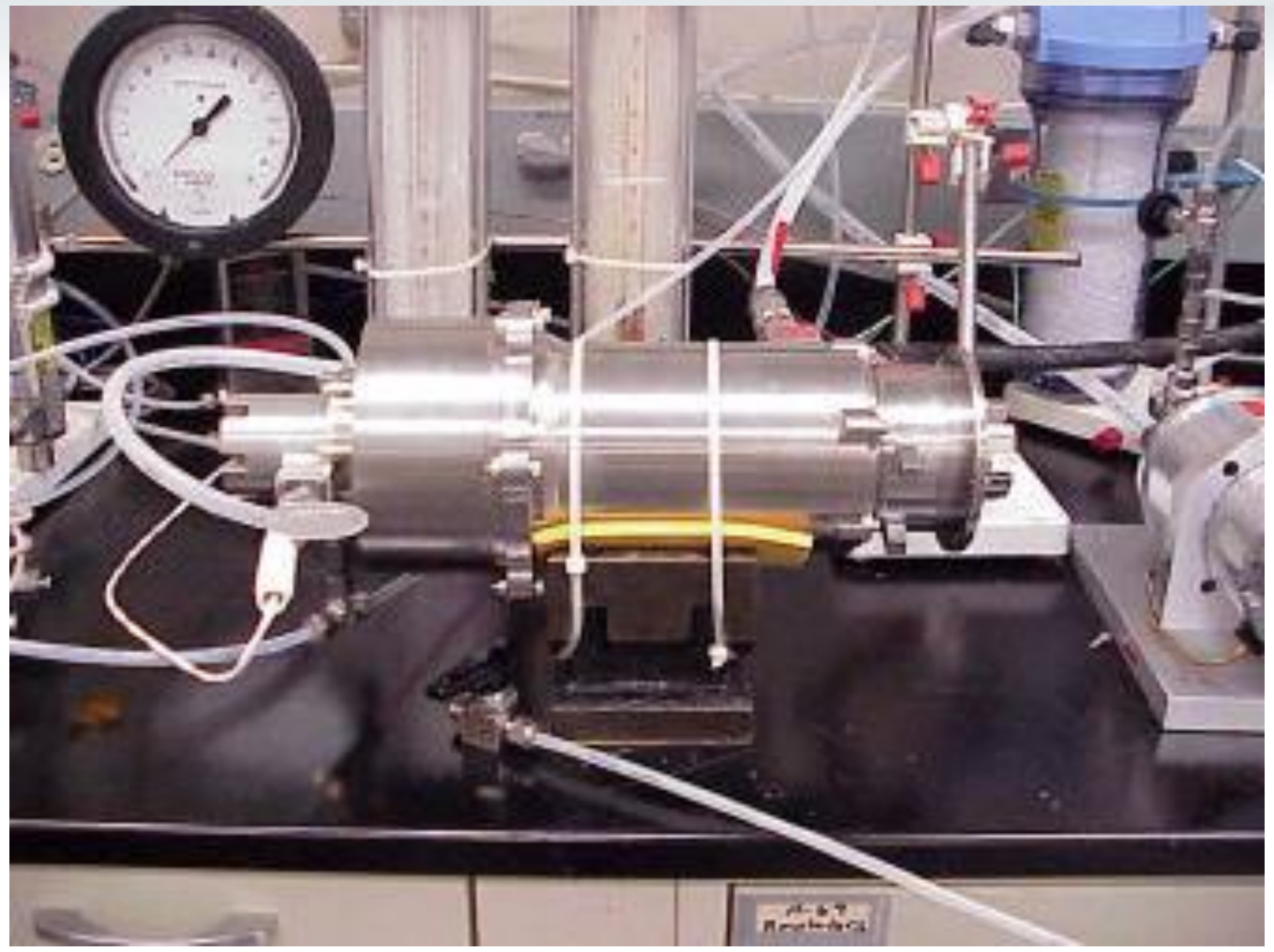
# Phase separation technologies

## Membranes



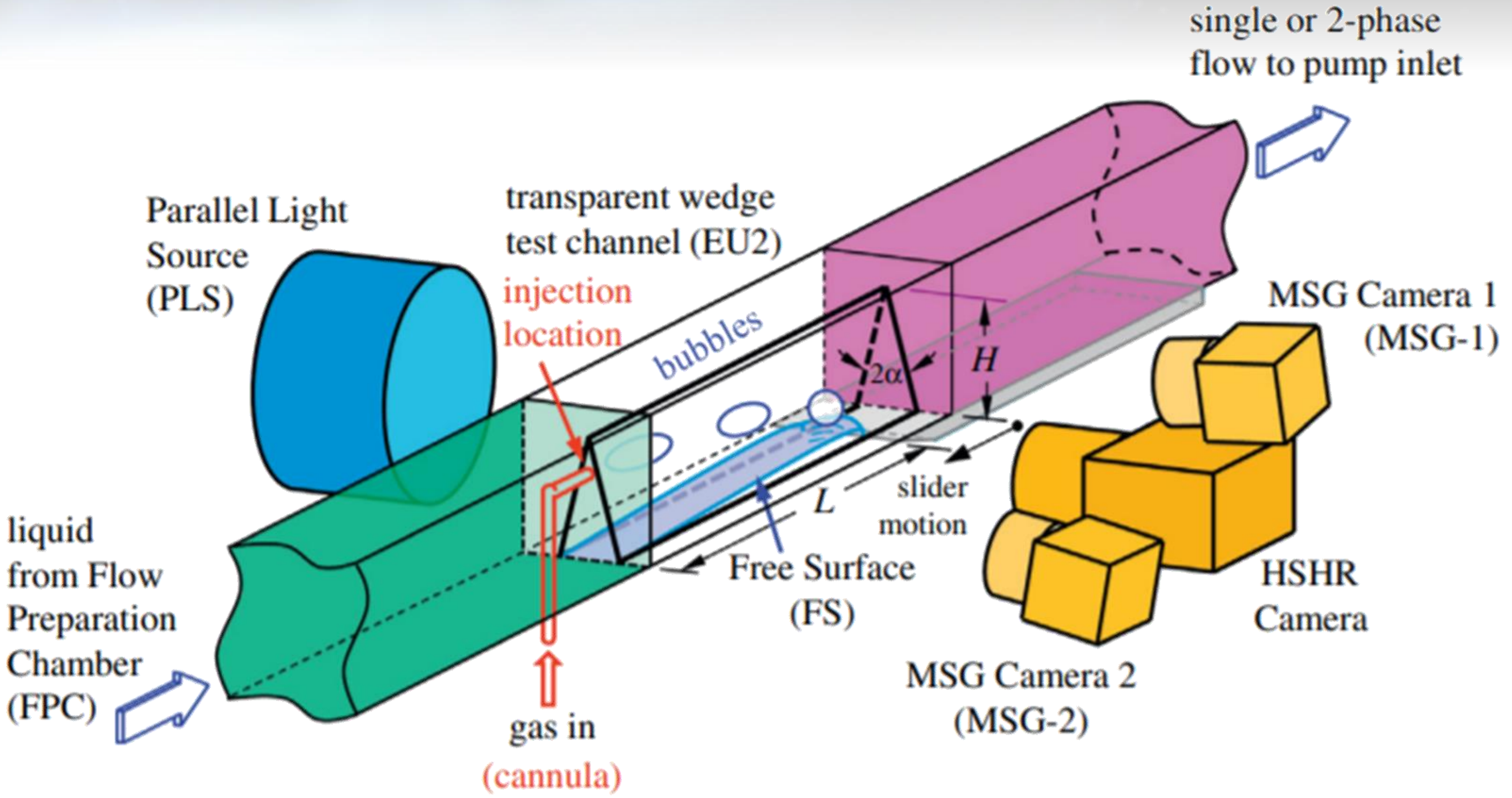
M. Sakurai, and T. Terao, Study of Water Electrolysis Under Microgravity Conditions for Oxygen Generation – Applied to a Ground Demonstration system and Development of New Systems, 46th Int. Conf. on Env. Sys., 10-14 July 2016, Vienna Austria

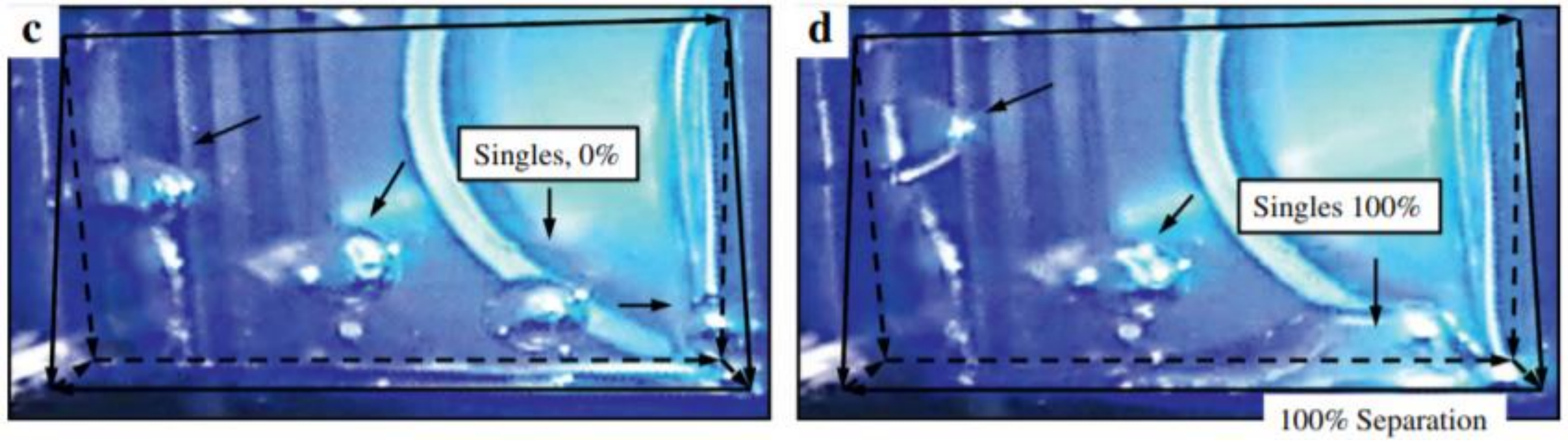
## Rotary devices



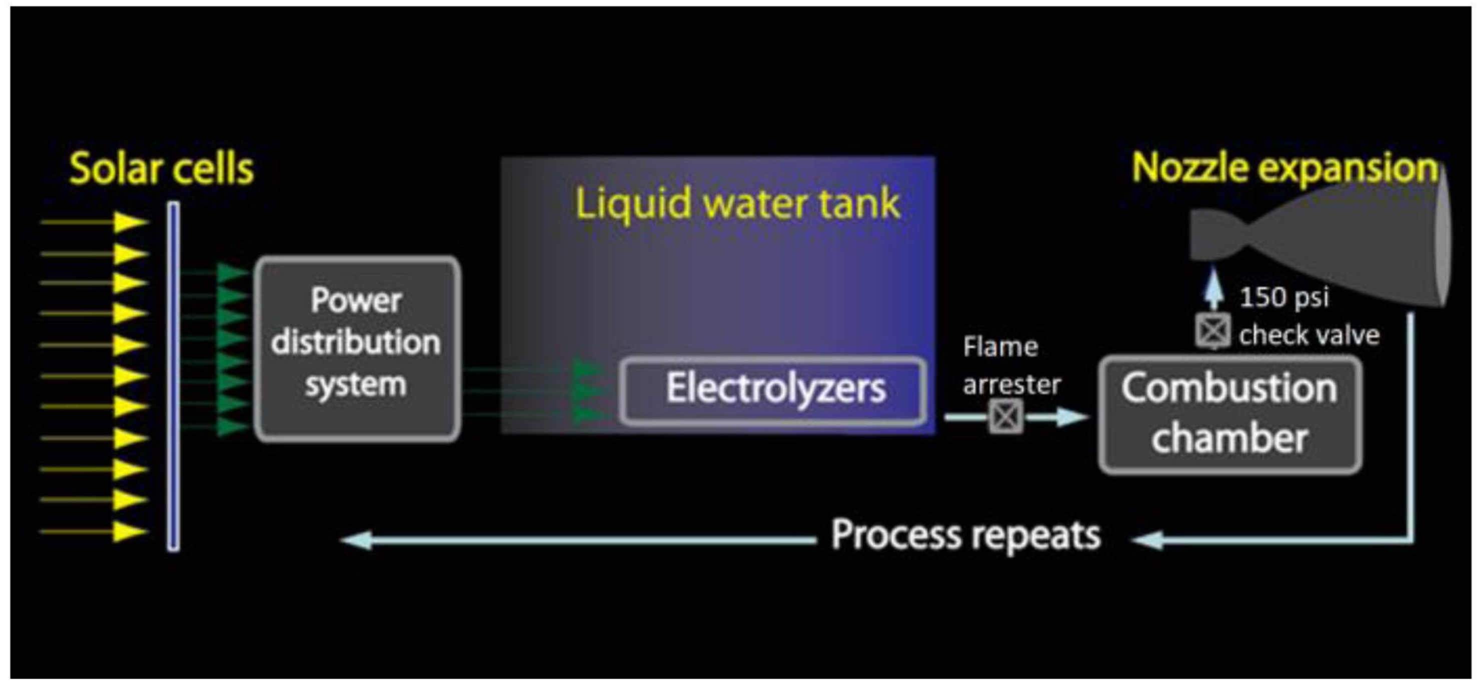
D. J. Samplatsky, and W. Clark Dean, Development of a Rotary Separator Accumulator for Use on the International Space Station

## Conduit geometries




F. Jenson et al. "Passive phase separation of microgravity bubbly flows using conduit geometry", International Journal of Multiphase Flow 65 (2014), 68-81




## SC Spinning

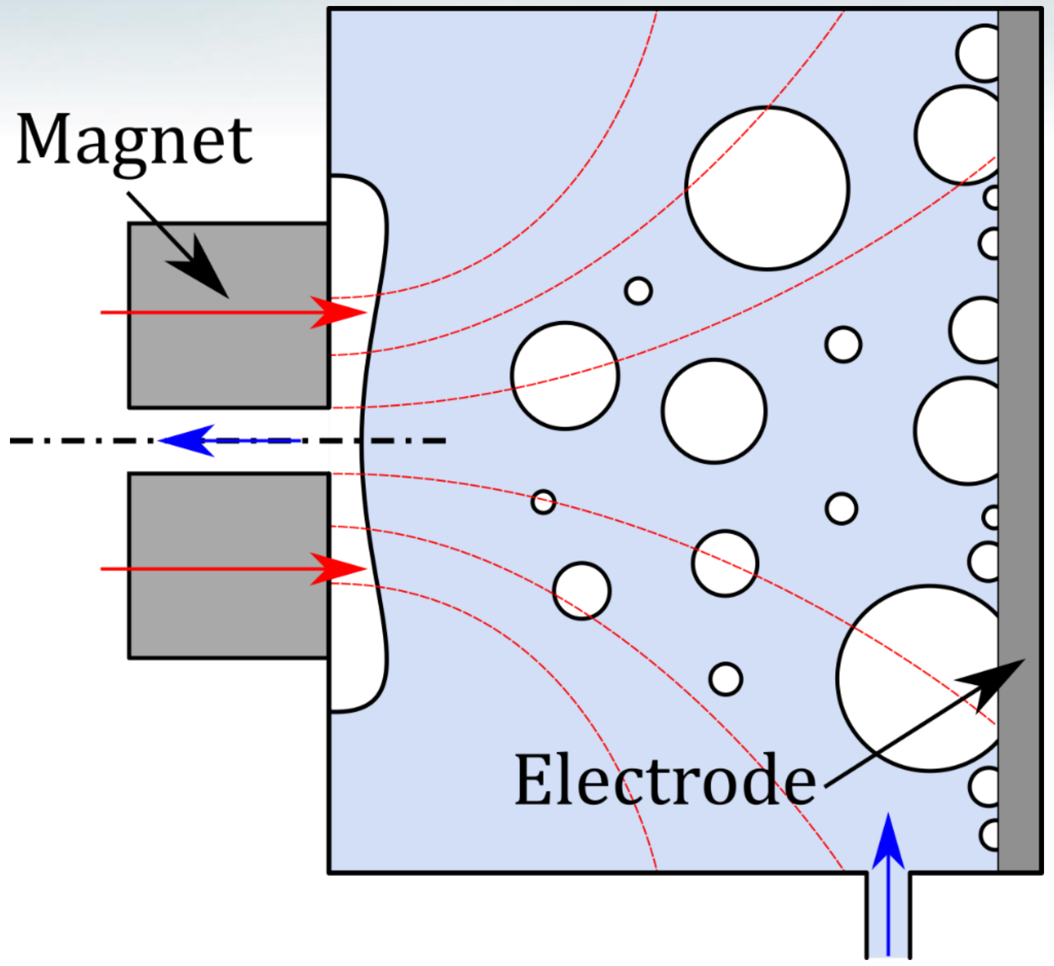
K.P. Doyle and M.A. Peck, Water Electrolysis Propulsion as a Case Study in Resource-Based Spacecraft Architecture, IEEE ASE Systems Magazine (34) 9, 4-19, 2019

# The diamagnetic force

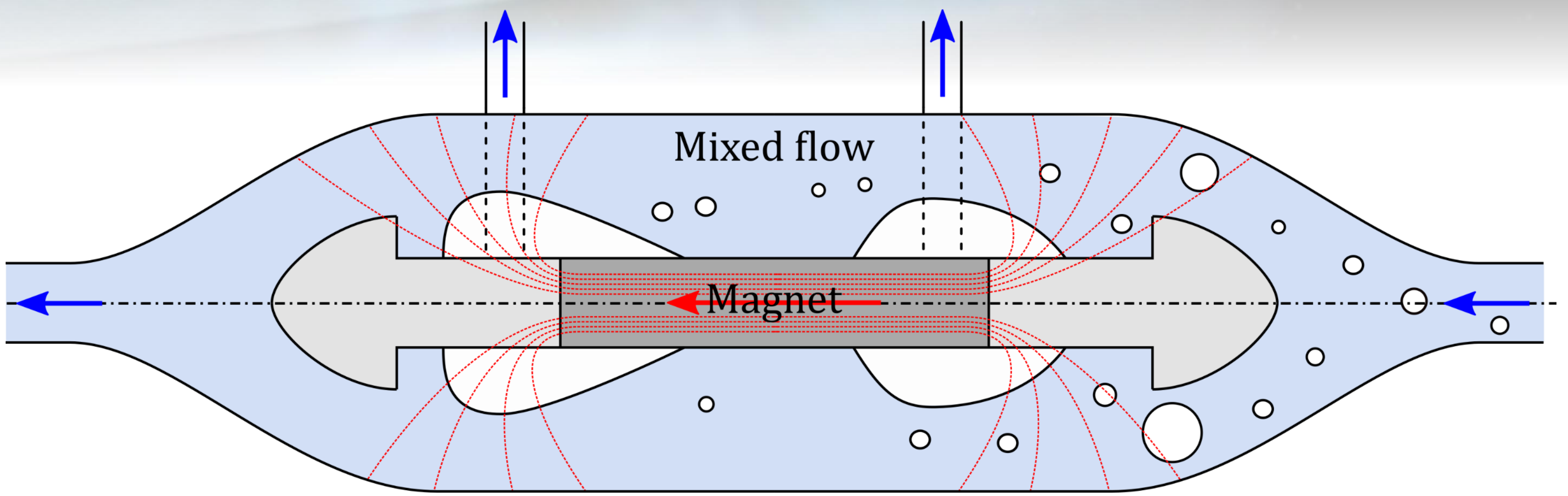

https://youtu.be/KlJsVqc0ywM

# Concept: diamagnetically enhanced electrolysis

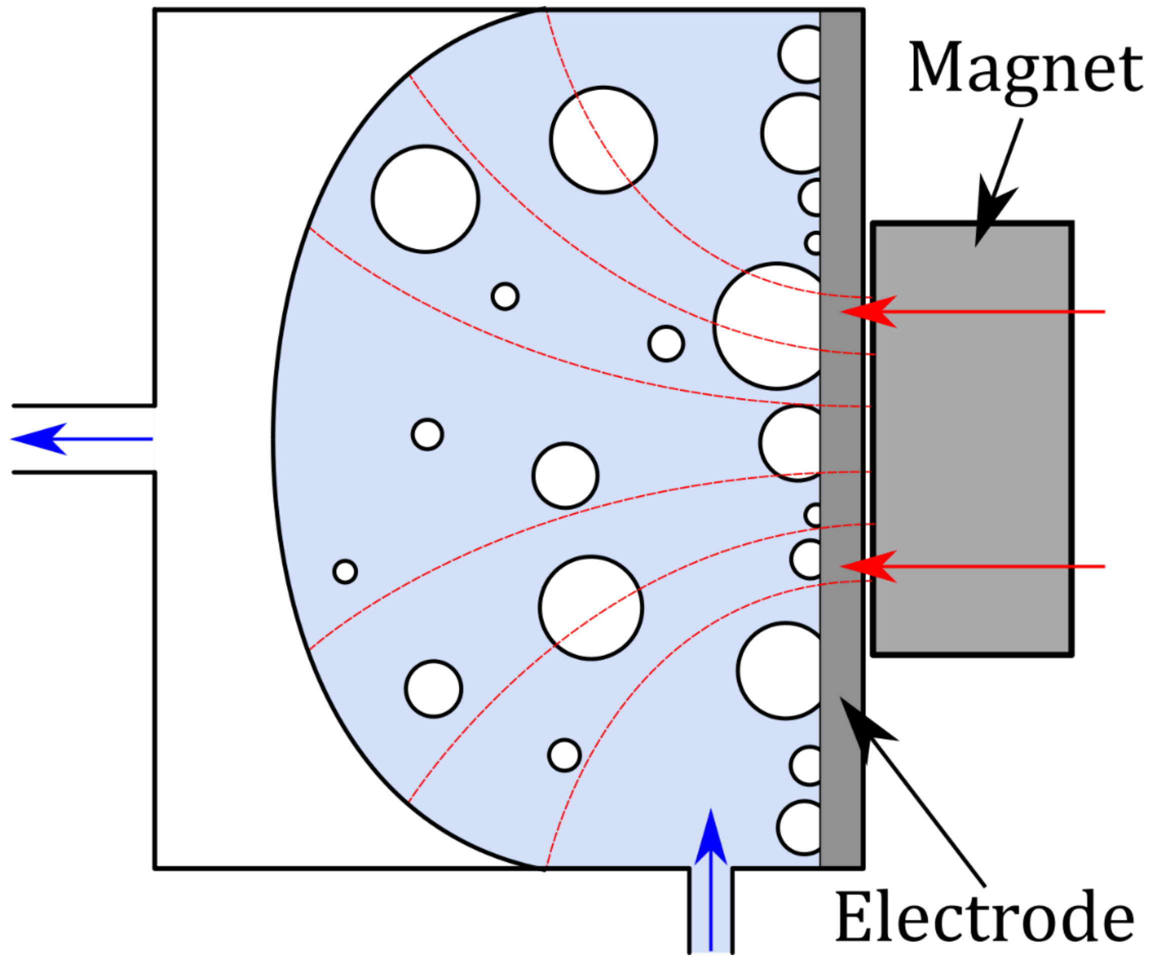
Diamagnetic electrolysis



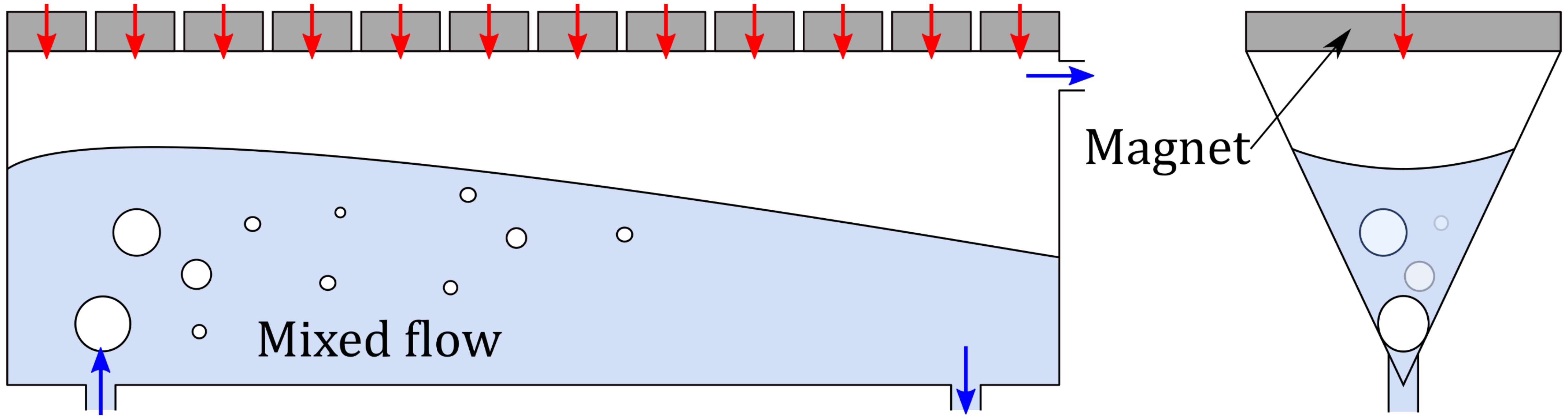

Magnetic phase separation




Para/ferromagnetic electrolysis

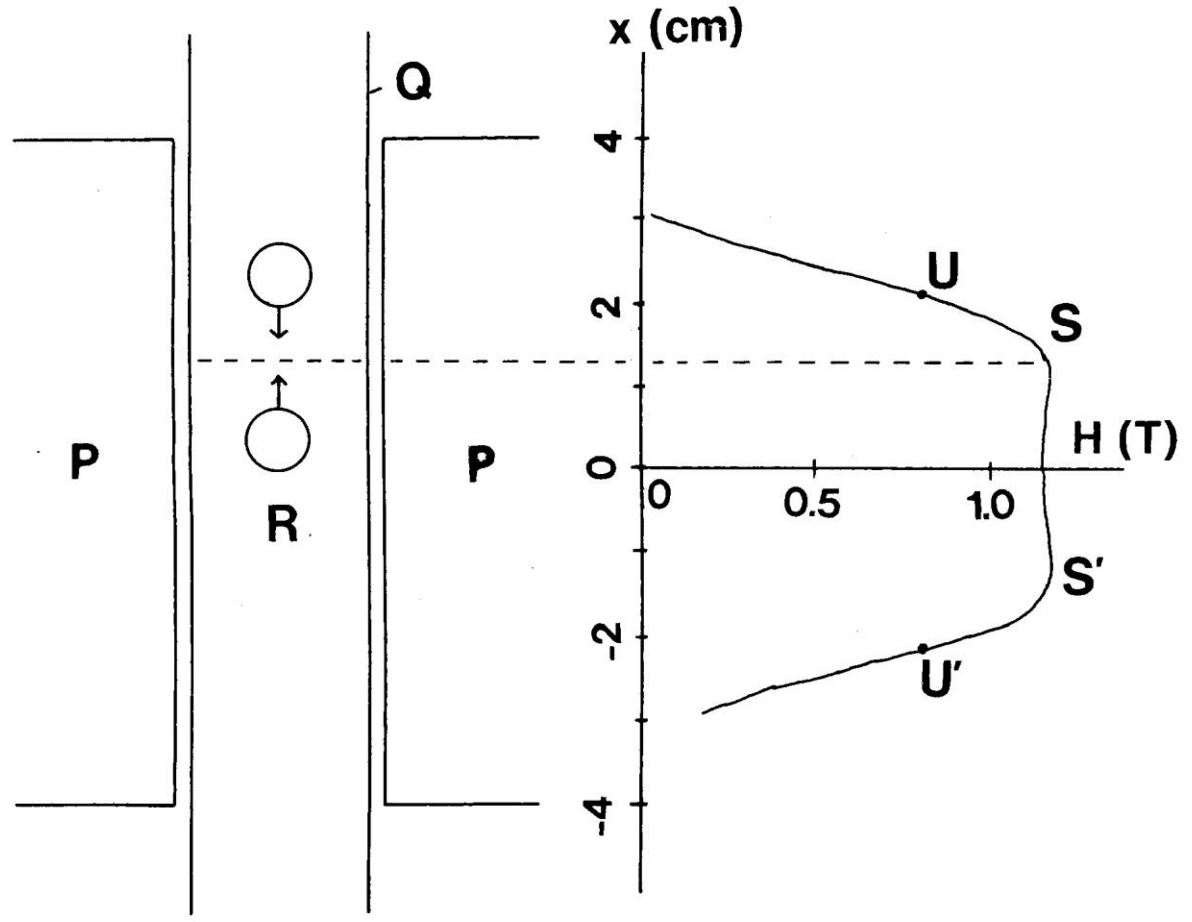



Combined phase separation

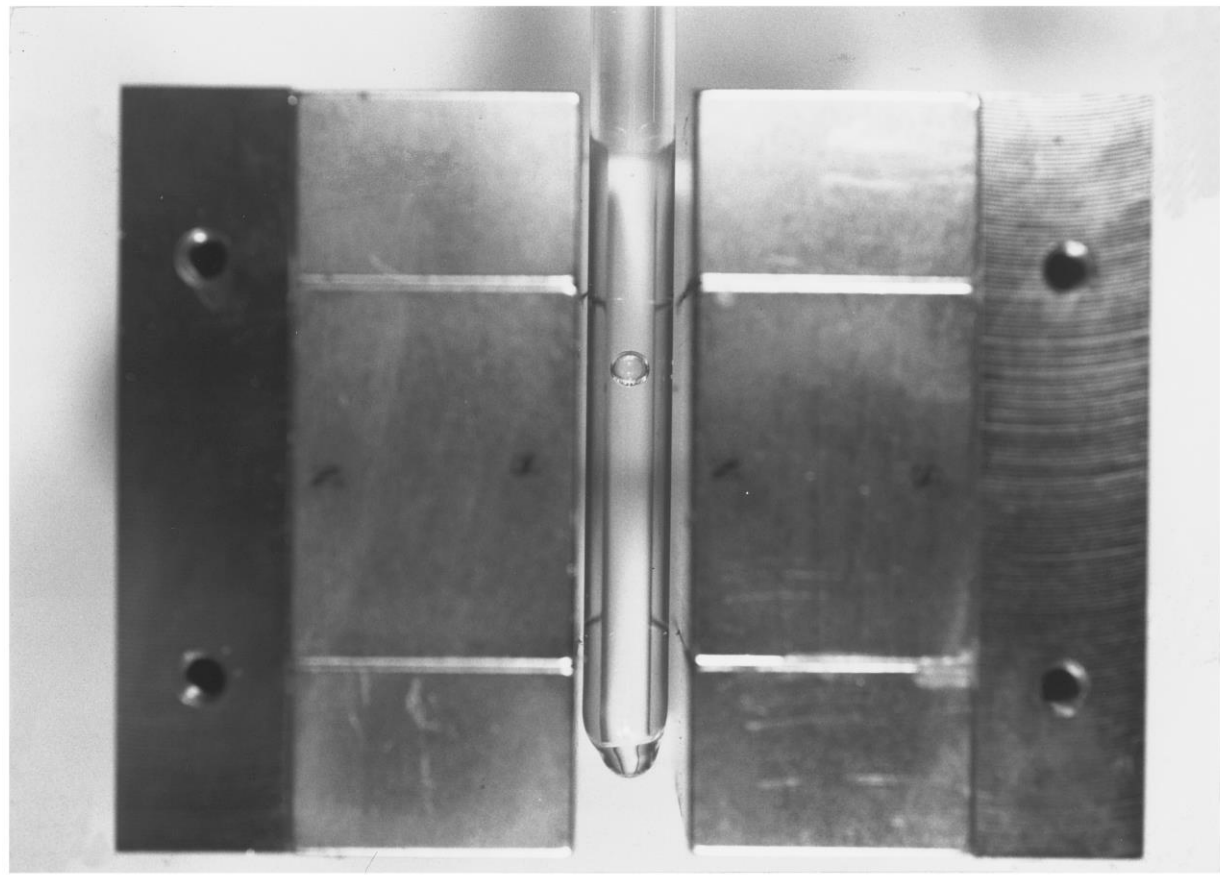



*Á. Romero-Calvo et al., "Diamagnetically enhanced electrolysis and phase separation in low-gravity", Journal of Spacecraft and Rockets, 2021 (accepted for publication)*

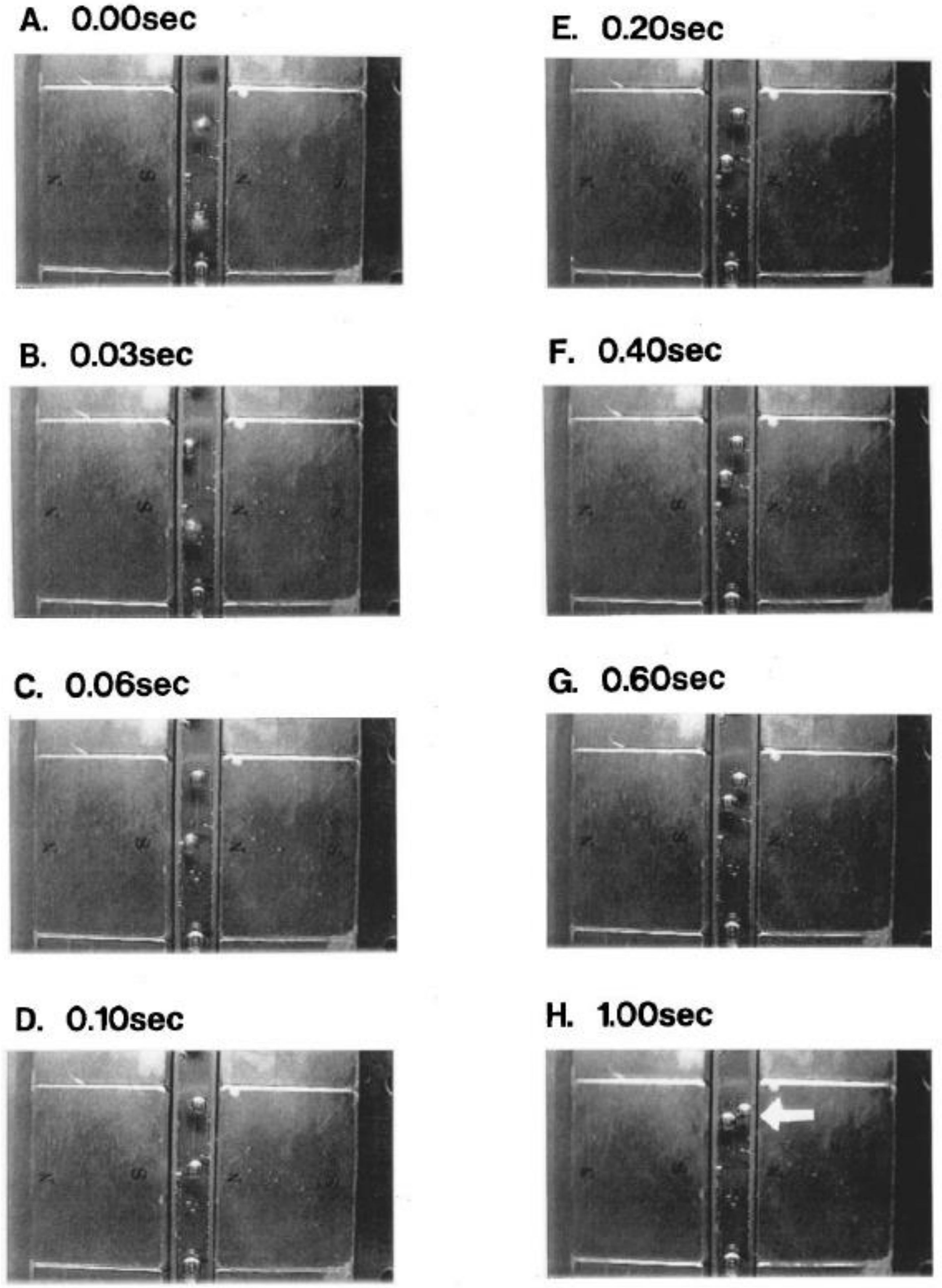
# Previous experiments (TRL 3 – proof of concept)

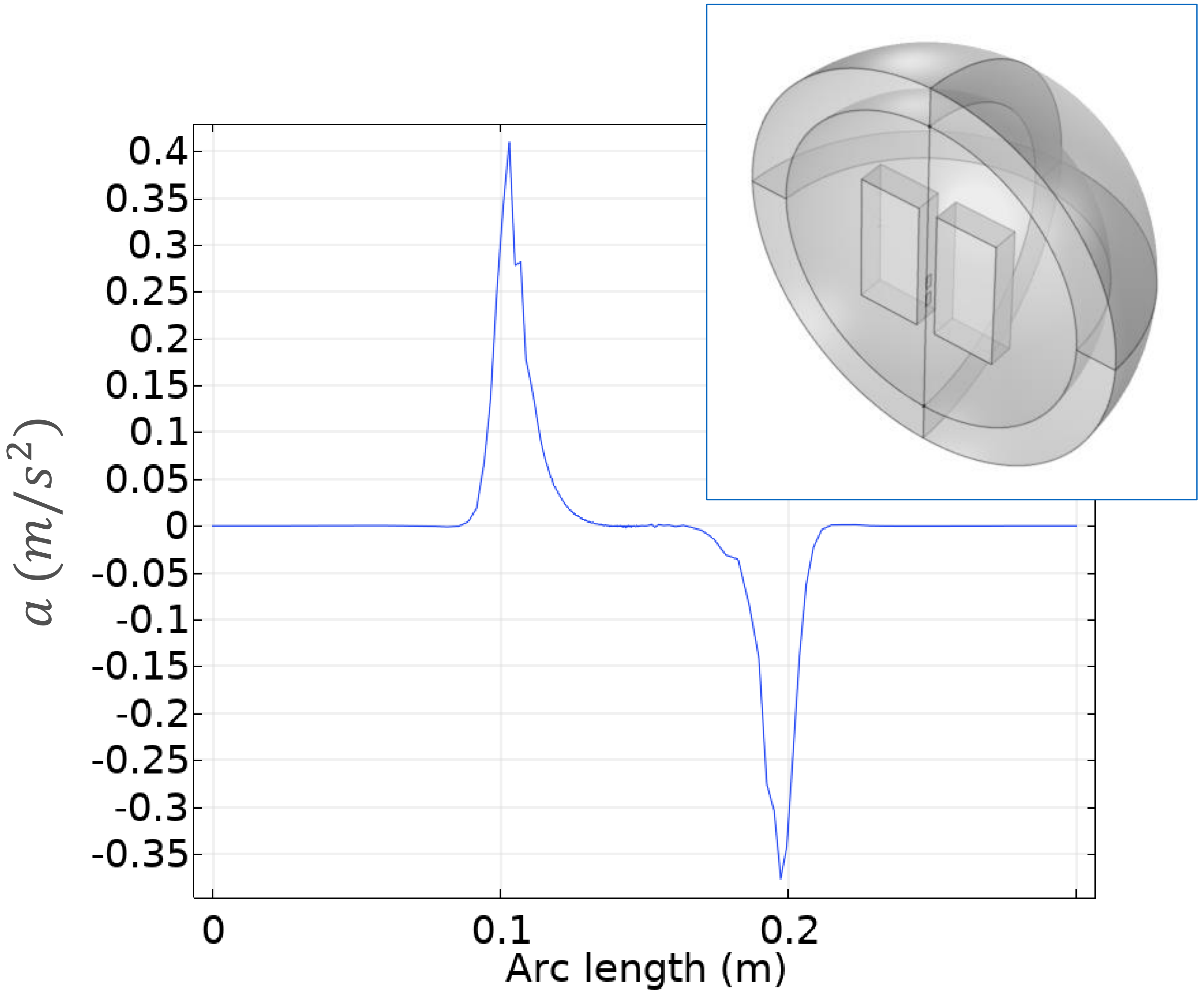



(a)



(b)

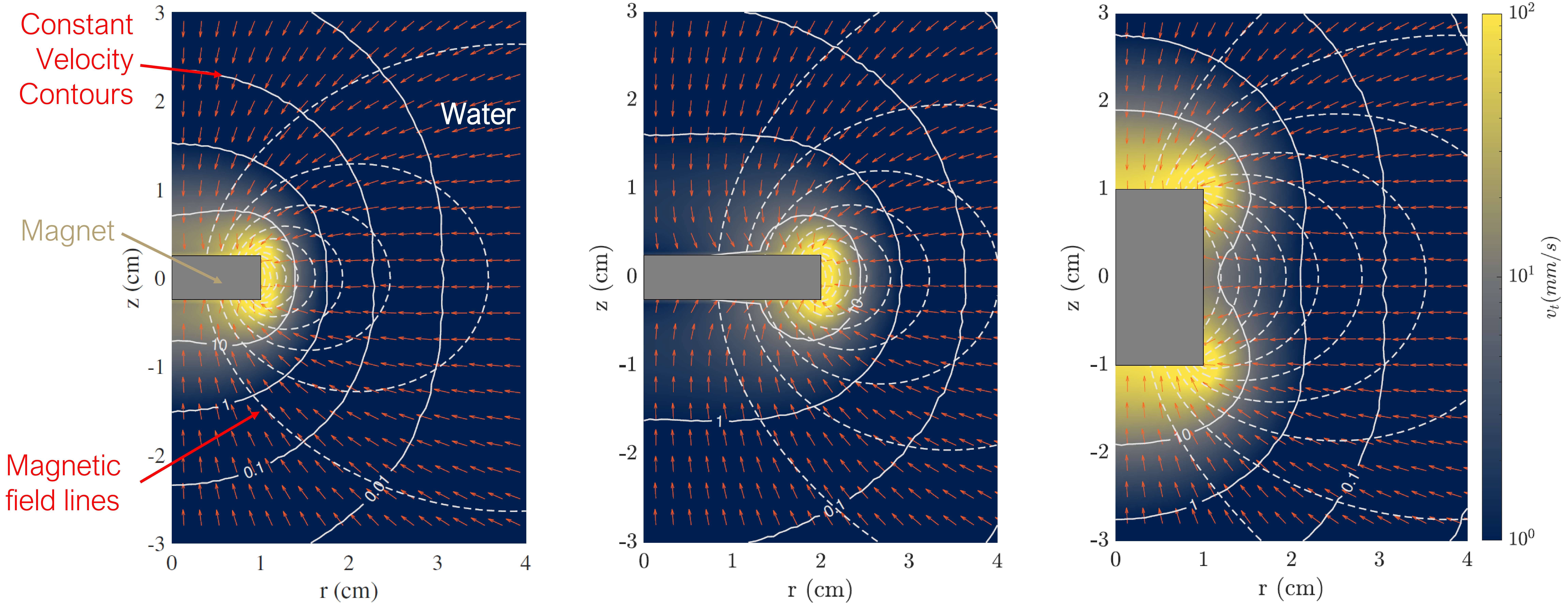



N. I. Wakayama, Magnetic buoyancy force acting on bubbles in nonconducting and diamagnetic fluids under microgravity, Journal of Applied Physics 81, 2980 (1997)

# Simulation: terminal (steady-state) velocity

1 mm radius $O_2$ bubble in water in microgravity




(a) Base configuration (b) Radially extended (c) Axially extended

# What we expect…

https://youtu.be/BxyfiBGCwhQ

- Magnetic acceleration of $10^{-3} - 10^{-2}\ \mathrm{m}/s^2$
- 1.25 cm radius sphere rotating at ~3.5 rad/s → Maximum buyoyancy accelerations of $\sim 5 \cdot 10^{-4}\ \mathrm{m}/s^2$ (increases with $r^2$)
- Should work! (hopefully)

# Technology demonstrator:
# ASGSR Ken Souza program 2020

# Step 1: Requirements

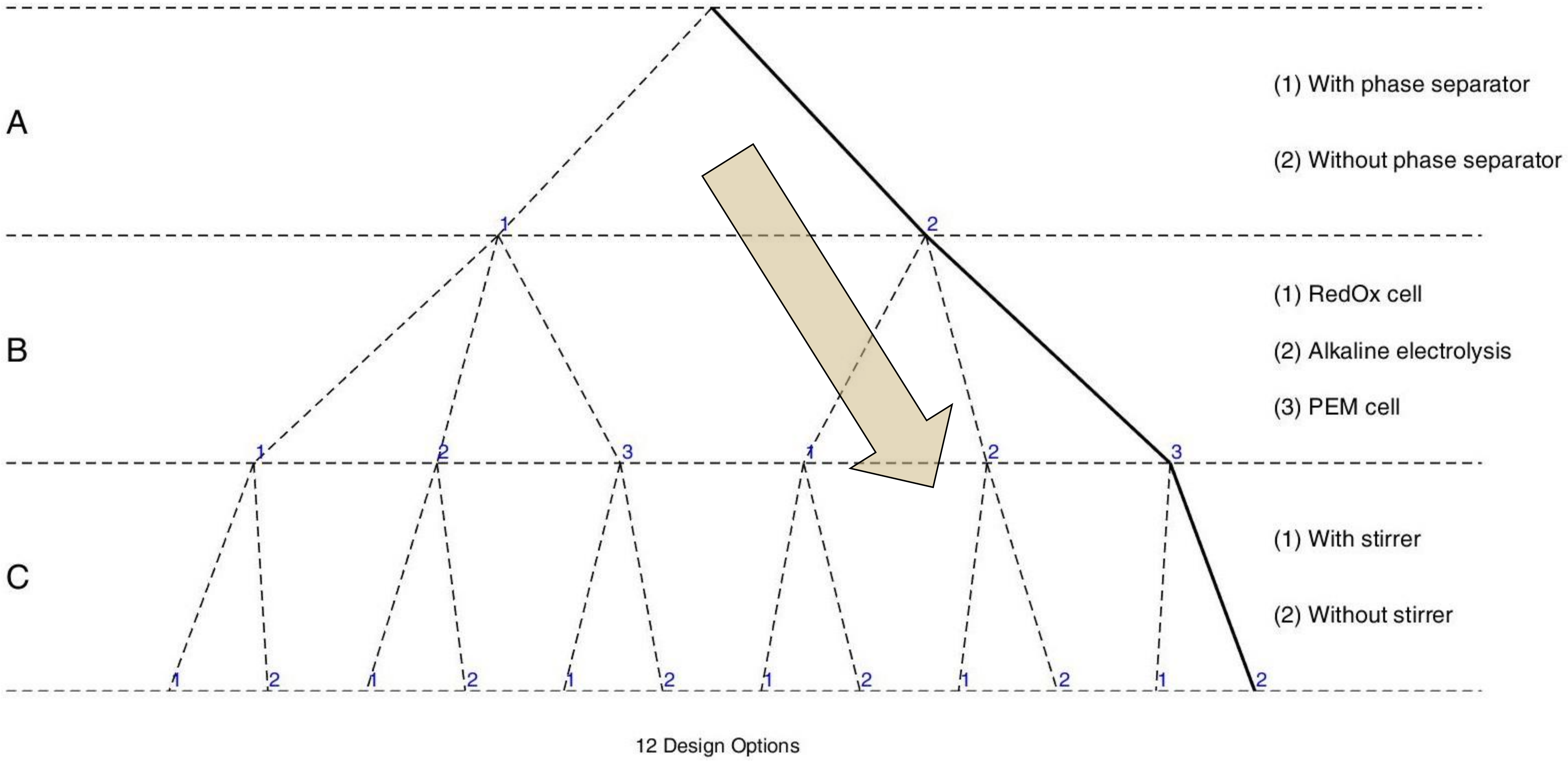

Blue Origin’s New Shepard mini-payload requirements:

- May contain **up to 150 ml of approved non-hazardous liquids**
- Contains **no significant hazards** (**chemical**, biological, stored energy, or RF transmitters).
- Hardware dimensions shall not exceed **10x10x20 cm**
- Total mass shall not to exceed **0.5 kg**.
- Capsule provides **5V and 0.9 A of power** and **mission data via USB** connector from **~5m before launch** to ~5m after landing
- Payload shipment to be received no later than **L-2 weeks**

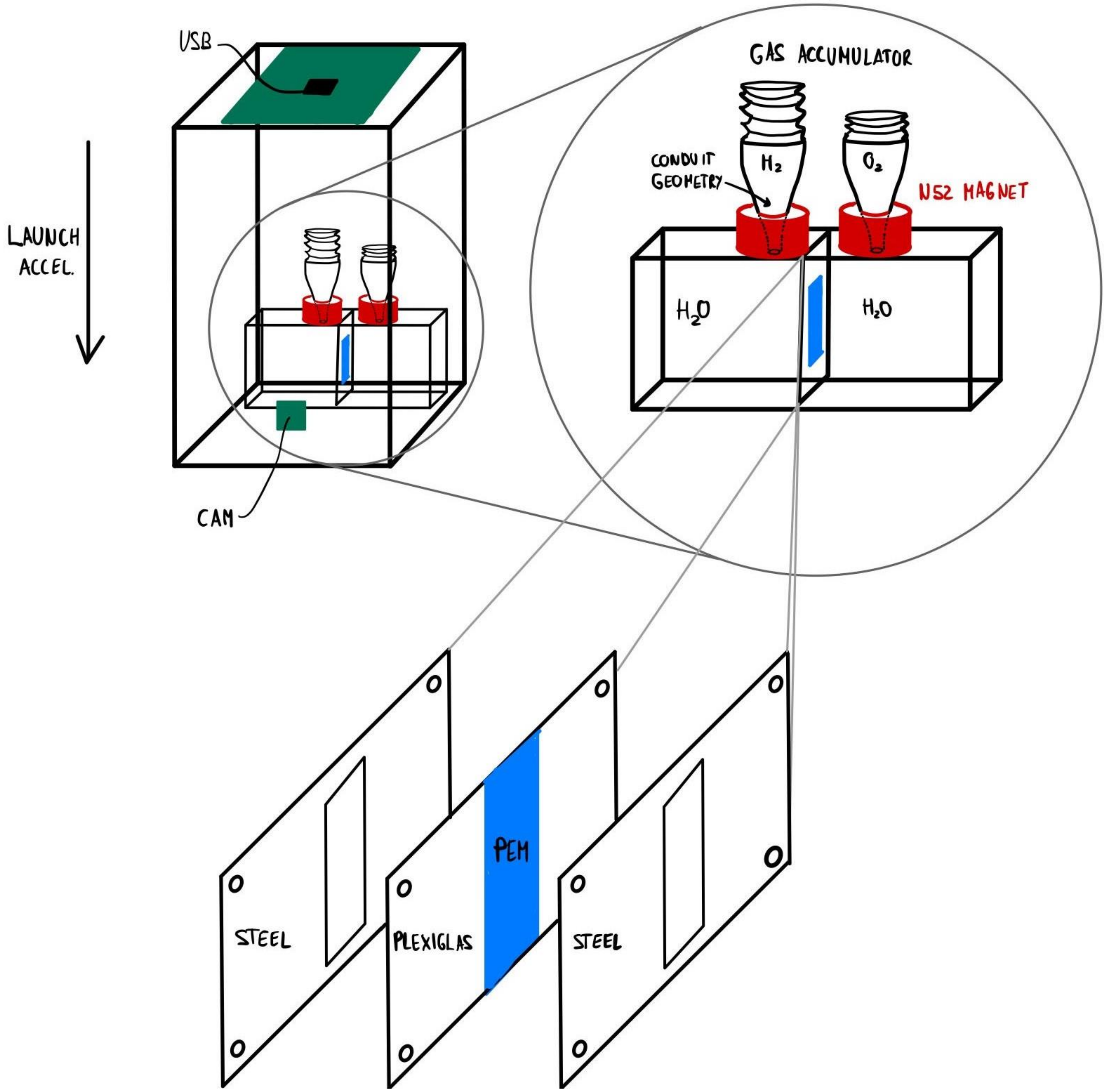
# Step 2: Architecture selection

**Table 1:** Level-1 requirements

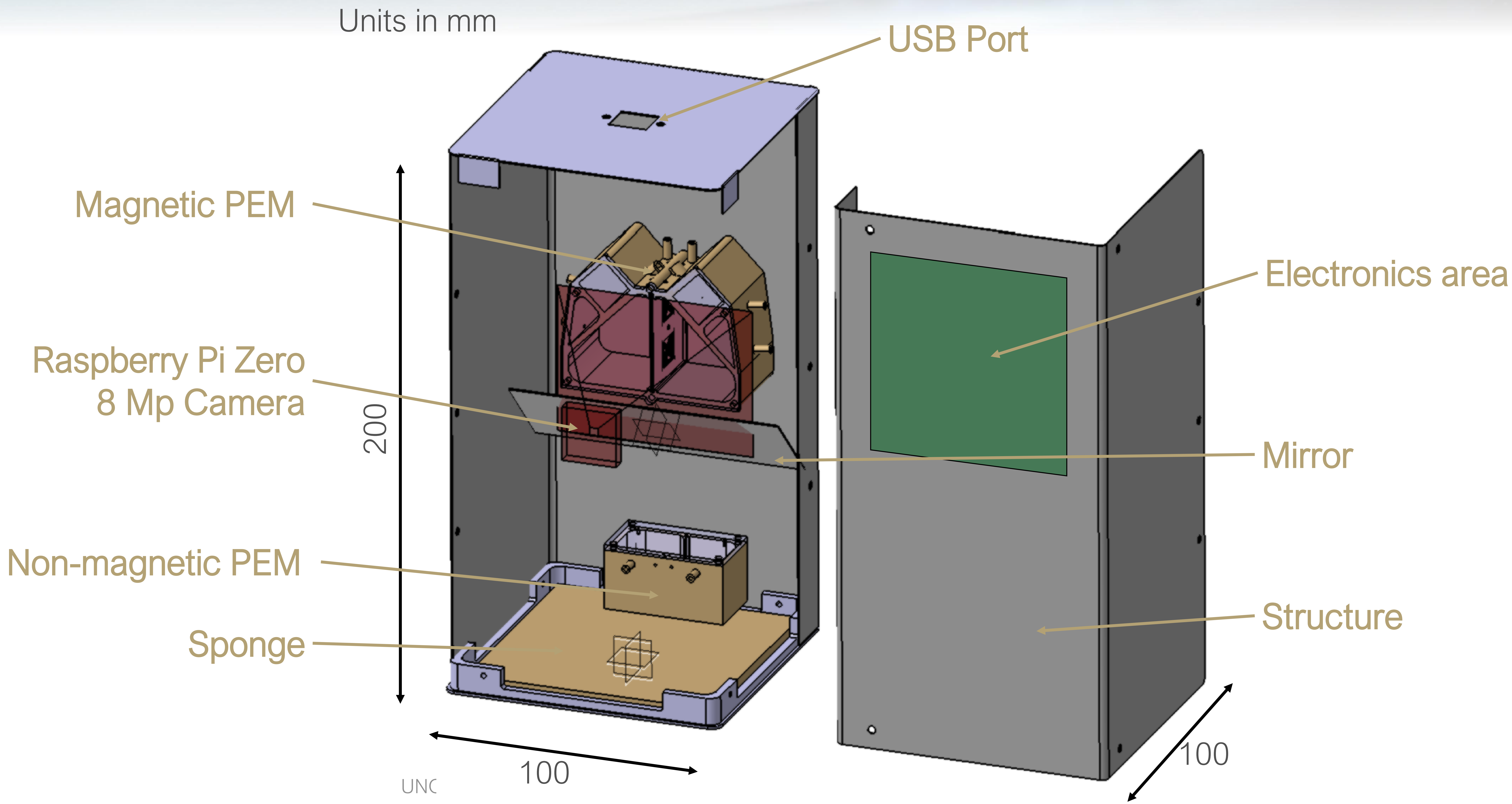
| ID | Requirement |
|---|---|
| L1-001 | The mission shall observe the growth and detachment of $H_2$ bubbles from the surface of a representative electrode subject to an inhomogeneous magnetic field in microgravity |
| L1-002 | The mission shall record the movement of the $H_2$ bubbles after detachment when subject to an inhomogeneous magnetic field in microgravity |
| L1-003 | The mission shall determine whether the $H_2$ bubbles coalesce after detachment when subject to an inhomogeneous magnetic field in microgravity |
| L1-004 | The mission should pursue requirements L1-001-003 for $O_2$ bubbles |
| L1-005 | The mission shall measure the time evolution of the electrolytic cell's current in micro-gravity. |
| L1-006 | The mission shall measure the time evolution of the electrolytic cell's voltage in micro-gravity. |
| L1-007 | The mission should test the magnetically-enhanced liquid-gas separation using conduit geometries. |
| L1-008 | The mission may address the long-term performance of nanostructured electrodes in 1.5 minutes microgravity. |



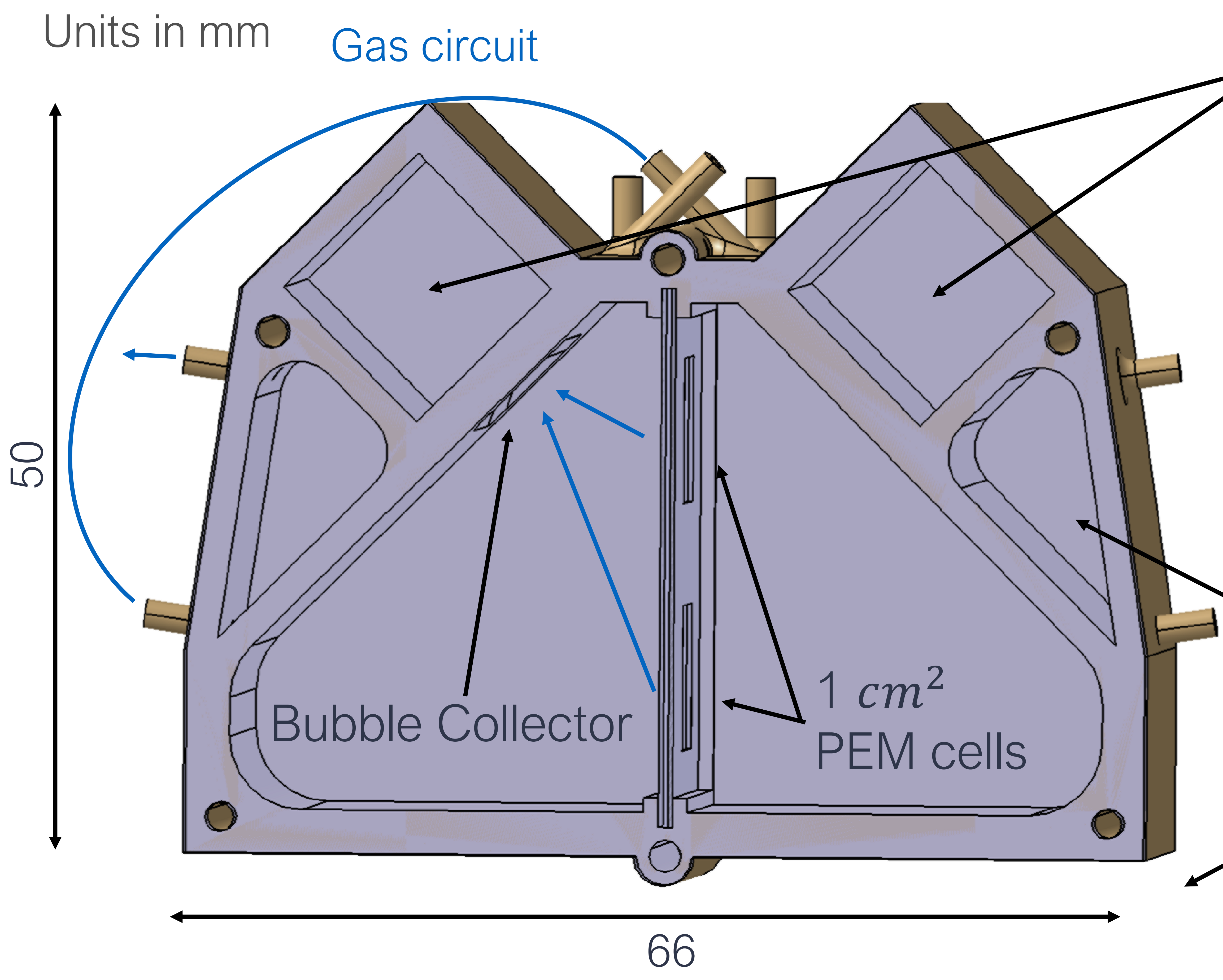
# Step 3: Preliminary design



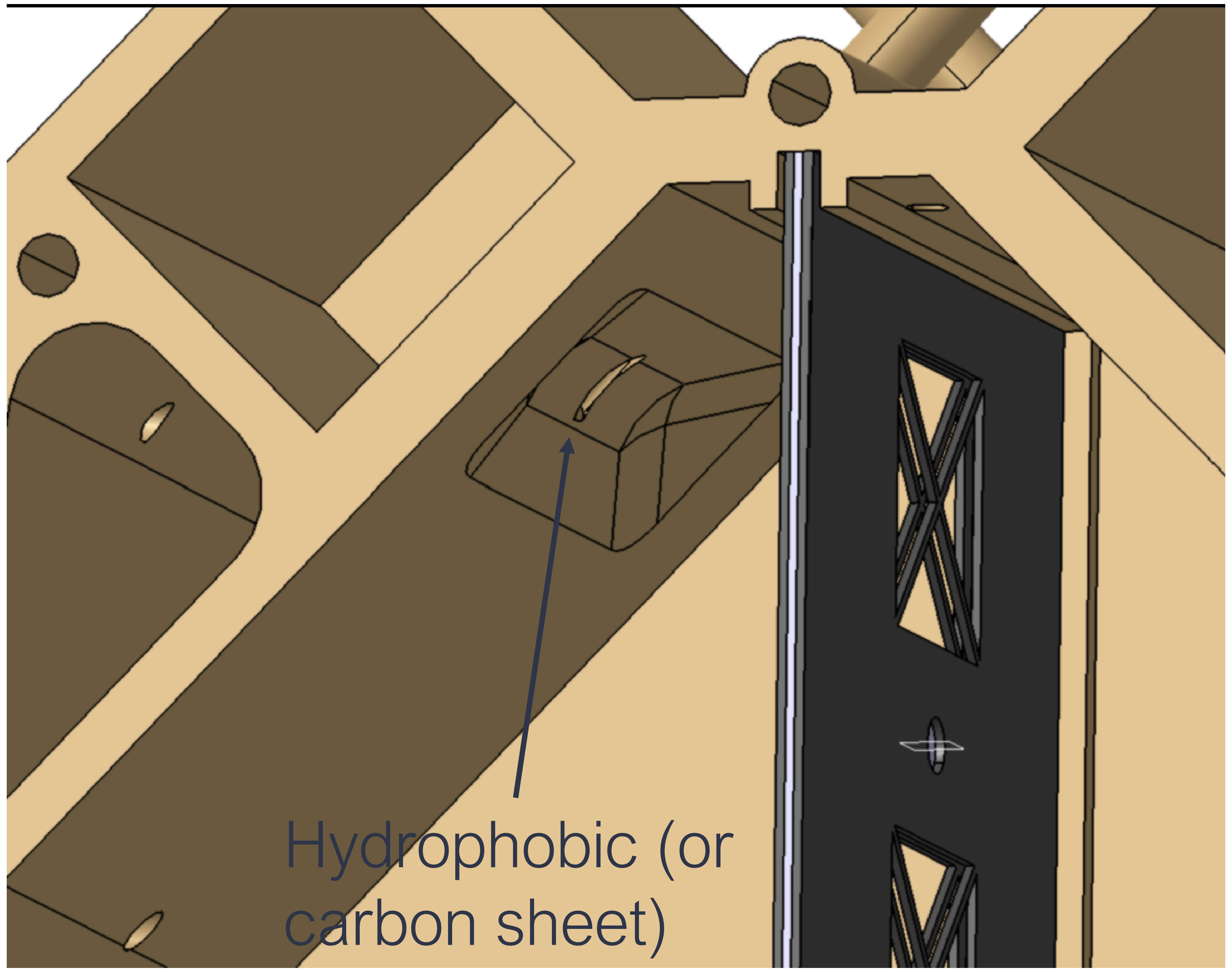
# Step 4: Detailed design (iterative)



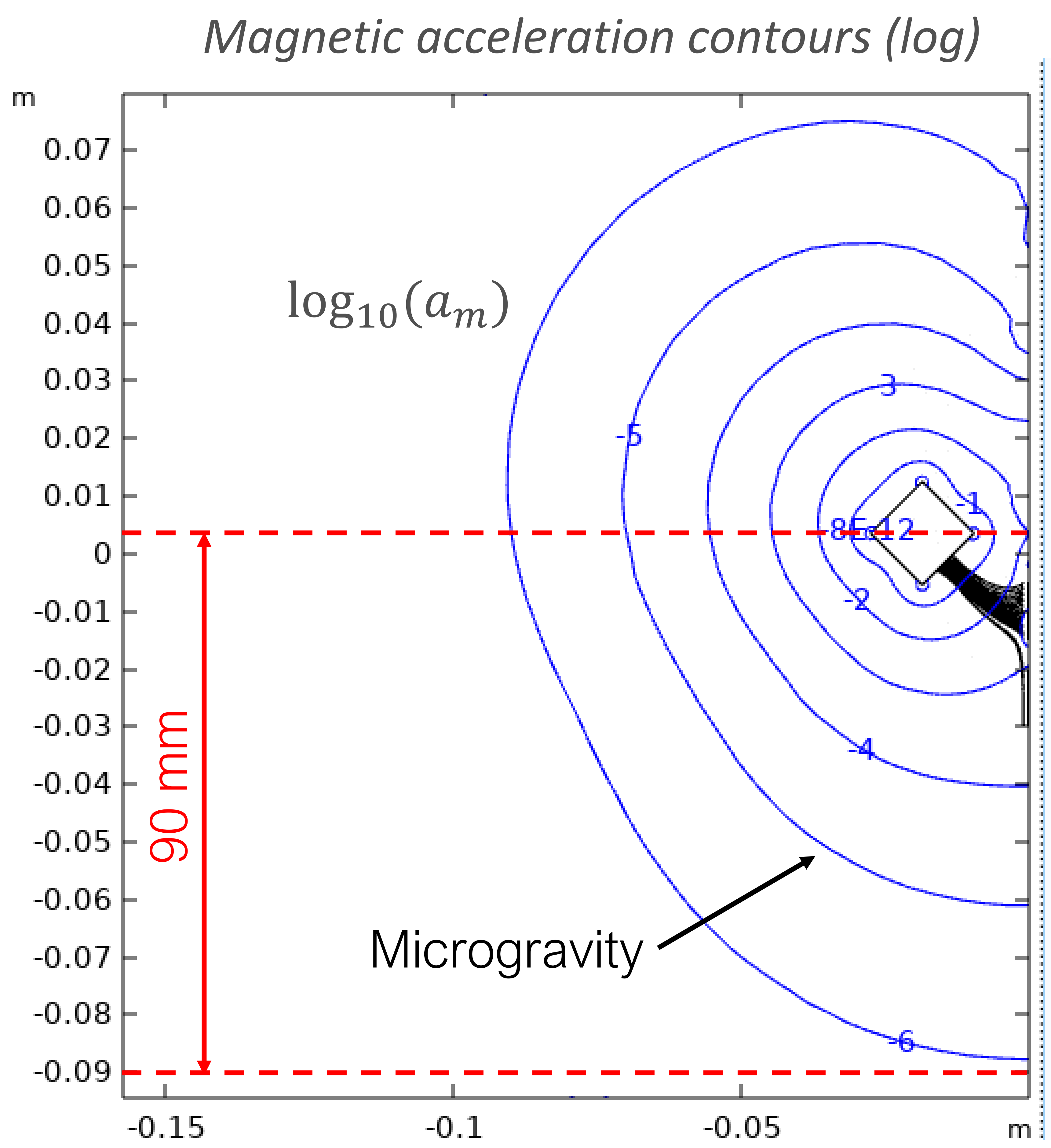
# Electrolytic cell rationale

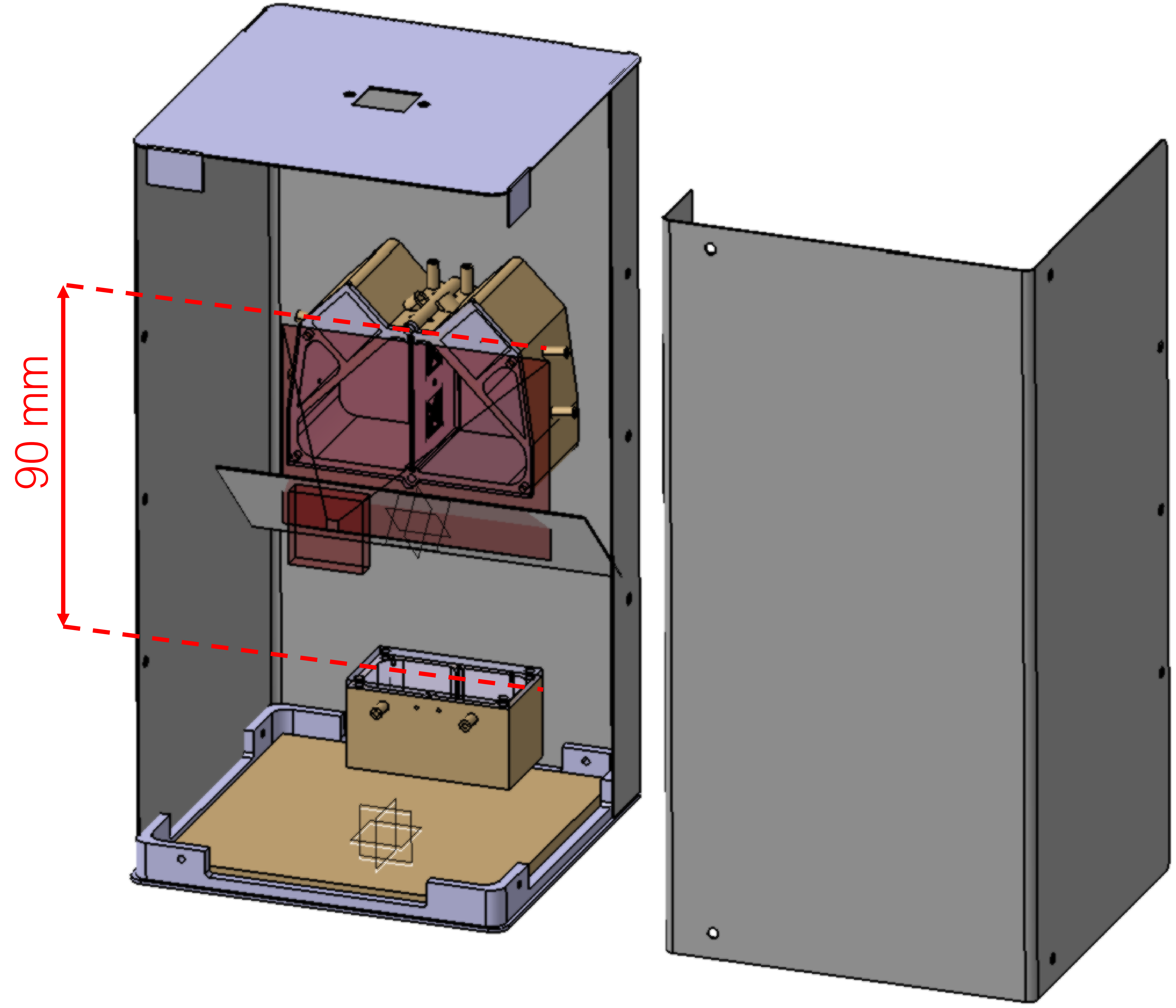



Bubble Collector



# Location of non-magnetic cell



# To conclude…

# Interested in microgravity research?

1. Who are you? What do you want to do?
2. Make a plan
3. Join the global microgravity research community
4. Look for hands-on opportunities
5. Team up
6. Have fun!

# Questions?

*Á. Romero-Calvo et al., "Diamagnetically enhanced electrolysis and phase separation in low-gravity", Journal of Spacecraft and Rockets, 2021 (accepted for publication)*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