Developing a Molecular Biology Toolkit for Spaceflight using 3D-Printed Plasticware

Mission Assignment

During spaceflight, the microgravity environment significantly alters the *physics of fluid dynamics*, making the behavior of fluids, such as water, quite different and more intriguing than on Earth. Without the downward pull of gravity, water doesn't fall; instead, it forms floating orbs that hover in the air (**Fig. 1**)[1]. This occurs because in microgravity the forces that cause water to stick together, known as surface tension, play a dominant role. However, in certain physical configurations, surface tension also causes fluids to distribute and adhere across surfaces, such as the behavior of water when attempting to wring out a towel in microgravity (**Fig. 2**)[2] or the use of chopsticks to stretch out a liquid droplet (**Fig. 3**)[3].

Fig 1: Water droplet in microgravity.

Fig 2: Wringing a wet towel in microgravity.

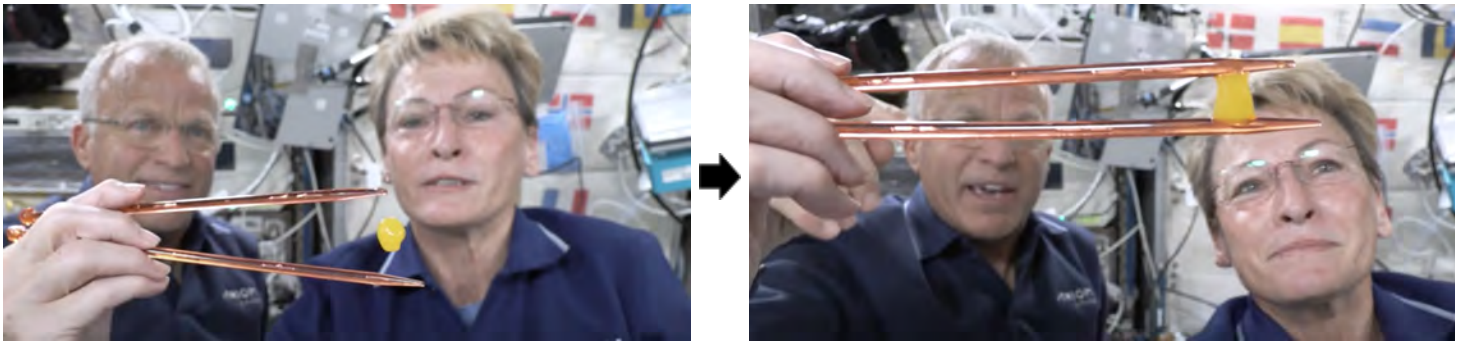

Fig 3: Catching a droplet of juice with a pair of chopsticks and using the surface tension with the chopsticks to stretch the juice droplet.

Molecular biology experiments in particular are challenging to perform in microgravity. These experiments use aqueous solutions for extraction, purification, and sequencing of nucleic acids (**Fig. 4**)[4], which are essential tasks for monitoring genome integrity and cellular health risks during spaceflight. Specifically, the types of plastic hardware used for storing and mixing aqueous solutions are prone to leakage and escape of fluids from their container. The mission of **SERA Flight-2** on **Blue Origin's New Shepard** is to design novel plasticware for molecular biology experiments to solve the fluid leakage problem.

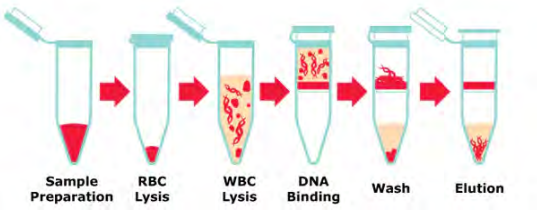

Fig 4: Example of a molecular biology protocol for DNA extraction.

Plasticware Re-Design Competition Options

Plasticware designed for handling fluids in the International Space Station (ISS) has undergone significant redesigns to accommodate the challenges of microgravity. Space-optimized plasticware incorporates features such as surface tension-based channels, tightly sealing lids, and specially contoured shapes (**Fig. 5**)[5,6]. These innovations ensure that astronauts can effectively manage liquids for drinking, experiments, and daily tasks, without the risk of spillage and contamination that could endanger the station's delicate operational ecosystem.

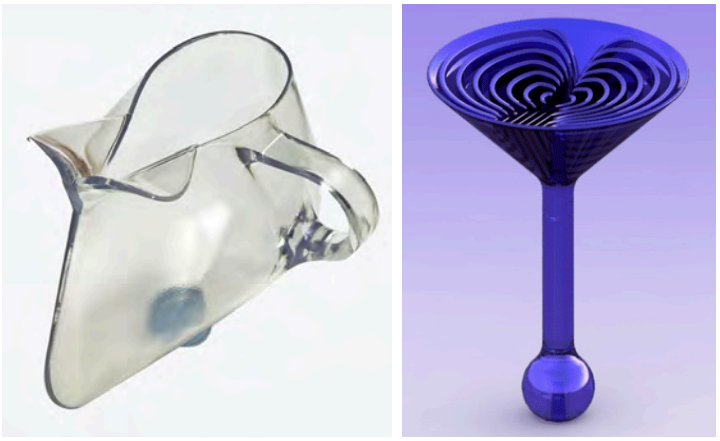

Fig 5: A coffee cup (left) and martini glass (right) designed for microgravity.

We do not have microgravity-compatible redesigns for common laboratory plasticware in molecular biology. This complicates in-flight performance of molecular biology experiments, such as those performed on the ISS[7,8,9,10] and those slated for Blue Origin's Orbital Reef[11]. Complications include longer experiment times (i.e. increased crew time allocation) and environmental contamination with laboratory reagents.

In this mission, competitors will (1) re-design common laboratory plasticware, providing CAD files to create 3D printed plasticware, and (2) test this plasticware during the microgravity period of a New Shepard flight. The three laboratory plasticware items selected are: 1.5mL microfuge (i.e. Eppendorf) tubes, (2) 10mm Petri dish (12mL volume), and (3) a 2mL cryovial (**Fig. 6**).

Fig 6: 1.5mL microfuge tube (left), 10mm Petri dish (middle), and 2mL cryovial (right).

Flight Manifest

To test novel plasticware, each crew member will require the following:

1. Four 5mL screw-top tubes with 4mL of water in each.
2. Two 20mL syringes filled with 15mL water each.
3. Go-Pro Camera
4. Set of novel 3D printed plasticware.
5. One P1000 pipette
6. Two P1000 pipette tips
7. Absorbent towel

Total Water Volume: 46mL of water per crew member.

Flight Hardware

Per Crew Member

1 	**2** 	**3** 	**4** 
5 	**6** 	**7** 	

References

1. *Flight Engineer Jessica Meir Observes a Floating Sphere of Water - NASA*. www.nasa.gov/image-article/flight-engineer-jessica-meir-observes-floating-sphere-of-water/. Accessed 16 Apr. 2024.
2. Canadian Space Agency. “Wringing out Water on the ISS - for Science!” *YouTube*, 16 Apr. 2013, www.youtube.com/watch?v=o8TssbmY-GM.
3. Perseid Foundation. “Surface Tension | Living in Space Educational Content.” *Www.youtube.com*, 6 Sept. 2023, www.youtube.com/watch?v=eg7JVPZB3OY&t=132s. Accessed 16 Apr. 2024.
4. Millipore Sigma. *How Do You Separate DNA from Blood?* www.sigmaaldrich.com/US/en/technical-documents/technical-article/genomics/dna-and-rna-purification/how-proteinase-k-can-be-used-in-blood-dna-extraction-application.
5. Rochester Institute of Technology. “NASA: Capillary Cup.” *Vignelli Center for Design Studies*, www.rit.edu/vignellicenter/product-timecapsule/nasa-capillary-cup.
6. Cosmic Lifestyle Group. “Zero Gravity Cocktail Project.” *Kickstarter*, 2 Apr. 2015, www.kickstarter.com/projects/spacemansam/zero-gravity-cocktail-project.
7. Boguraev, Anna-Sophia, et al. “Successful Amplification of DNA Aboard the International Space Station.” *Npj Microgravity*, vol. 3, no. 1, 16 Nov. 2017, pp. 1–4, www.nature.com/articles/s41526-017-0033-9, https://doi.org/10.1038/s41526-017-0033-9. Accessed 9 Jan. 2023.
8. Burton, Aaron S., et al. “Off Earth Identification of Bacterial Populations Using 16S RDNA Nanopore Sequencing.” *Genes*, vol. 11, no. 1, 9 Jan. 2020, p. 76, https://doi.org/10.3390/genes11010076. Accessed 30 July 2021.
9. Castro-Wallace, Sarah L., et al. “Nanopore DNA Sequencing and Genome Assembly on the International Space Station.” *Scientific Reports*, vol. 7, no. 1, Dec. 2017, www.ncbi.nlm.nih.gov/pmc/articles/PMC5740133/, https://doi.org/10.1038/s41598-017-18364-0.
10. Stahl-Rommel, Sarah, et al. “Real-Time Culture-Independent Microbial Profiling Onboard the International Space Station Using Nanopore Sequencing.” *Genes*, vol. 12, no. 1, 16 Jan. 2021, p. 106, https://doi.org/10.3390/genes12010106. Accessed 27 Feb. 2023.
11. Zea, Luis, et al. “Orbital Reef and Commercial Low Earth Orbit Destinations-Upcoming Space Research Opportunities.” *NPJ Microgravity*, vol. 10, no. 1, 29 Mar. 2024, p. 43, pubmed.ncbi.nlm.nih.gov/38553503/, https://doi.org/10.1038/s41526-024-00363-x. Accessed 3 Apr. 2024.