From UF to Zurich: Bridging Space Biology, Engineered Tissues, and Human Health through a Transatlantic Parabolic Flight Campaign

Deep Thakkar[1], Ronald Masse[2], Devin Mair[1], Nondita Datta[2], Thomas Quinlan[3], Alexa Cooney[1], Julian Tobon[4], Manyun Chen[5], Jitender Lamba*[4], Thomas E. Angelini*[6], Yousong Ding*[5], Amor Menezes*[2], Maddalena Parafati*[1], Nils Averesch*[3], and Siobhan Malany*,[1,7,]

[1]*Cellular and Systems Pharmacology, College of Pharmacy, University of Florida,*
[2]*Mechanical and Aerospace Engineering, Herbert Werthiem College of Engineering, University of Florida*
[3]*Microbiology and Cell Sciences, Institute of Food and Agricultural Sciences, University of Florida*
[4]*Pharmacotherapy & Translational Research, College of Pharmacy, University of Florida*
[5]*Medicinal Chemistry, College of Pharmacy, University of Florida*
[6]*Physics, College of Liberal Arts and Sciences*
[7]*Director, In-Space Biomanufacturing Hub*
**Authors contributed equally*

The accelerating use of low-Earth-orbit platforms to investigate human physiology, biological systems, and space biomanufacturing has created opportunities to study how altered gravity, mechanical forces, and fluid dynamics influence biological processes across multiple scales. These studies have relevance not only to space exploration but also to cardiovascular, metabolic, regenerative, and disease biology, where changes in fluid transport, cellular mechanics, tissue organization, and intercellular signaling can influence physiological function. Consequently, constrained access to spaceflight, coupled with the planned retirement of the International Space Station and the gap in transition to commercial platforms are expected to further constrain access to microgravity environments, increasing the need for alternative testing platforms. Ground-based systems like random positioning machines and rotating wall vessels cannot fully capitulate the conditions of true microgravity because of shear stress and enhanced convection. Parabolic flights provide an important intermediate platform for technology development and validation by generating repeated periods of true free-fall microgravity.

Recognizing this need, the University of Florida In-Space Biomanufacturing Hub (UF In-Space Bio Hub) organized the ACE2SPACE 26 parabolic flight campaign where three principal investigators, one post-doctoral researcher and two students performed experiments on two flights in the second week of September. The campaign encompassed a broad range of biological and engineering domains: bacterial membrane stability for engineered *E. coli*, enzymatic catalysis for bioproduction of radioprotective agents, space biomanufacturing of plastic using *Cupriavidus necator*, intracellular & intercellular fluid dynamics, soft material organoid encapsulation, CHIP mutations in hematologic cancer cell lines, hypercoagulation in in-vitro lung alveolar models, vascularized hiPSC derived cardiac organoids for regenerative medicine, and 3D tissue models for skeletal muscle physiology. Collectively, these experiments span microbial physiology, cellular and membrane biophysics, fluid dynamics, cancer biology, coagulation, cardiovascular and tissue physiology, regenerative medicine, and biomanufacturing, illustrating the broad utility of microgravity as an experimental environment.

Parabolic flights provide approximately 20–25 seconds of microgravity per parabola (10–30 minutes of cumulative microgravity per flight). The brief duration of each parabola and the limited time between parabolas require experimental systems to be compact, robust, and operationally efficient. Furthermore, the wide range of biological models—including microbial systems, mammalian monolayer cultures, suspension cultures, and three-dimensional tissue models, coupled with the diversity of analytical readouts, necessitate the development of specialized hardware. Through this campaign, the hub supported student-led hardware development efforts tailored to these requirements, integration, and flight operations, providing them direct exposure to microgravity research while helping cultivate the next generation of space life scientists.

Beyond individual experiments, ACE2SPACE 26 demonstrates how parabolic flight can serve as a multidisciplinary platform for investigating biological responses to altered gravity, ranging from microbial membrane dynamics and biomanufacturing to cardiovascular, coagulation, metabolic, and tissue physiology. The campaign further highlights the value of collaborative access models and international partnerships in expanding opportunities for microgravity research and accelerating the development of technologies and biological models relevant to both space exploration and human health on Earth.

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