IAF HUMAN SPACEFLIGHT SYMPOSIUM (B3)
Human and Robotic Partnerships in Exploration - Joint session of the IAF Human Spaceflight and IAF Exploration Symposia (6-A5.3)

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THE ZENOLITH: A ROBOTIC ASSISTANT FOR HUMAN ORIENTATION AND PSYCHOLOGICAL TETHERING IN MICROGRAVITY

Abstract

Humans have been creating tools to navigate space and time throughout history. These tools are necessitated by the fact that exploration and navigation of unfamiliar territory is both logistically and psychologically challenging. Space exploration is no exception. As the NASA document "Psychology of Space Exploration" (Vakoch, 2011) states, "Astronauts live and work in highly unusual and challenging environments where they must withstand multiple stressors. Their abilities to maintain positive psychological outlooks...are crucial for personal well-being and mission success." Inspired by these industry concerns and the critical nature of behavioral health to human space exploration, we have designed and flown the first Zenolith: a robotic aid to human perception and orientation for the orbital context.

Encouraged by the success of the SPHERES project (Saenz-Otero A., Miller D.W., 2008), we drew from the history of navigational tools and the nature of confined space craft—with its relative lack of windows—to create a device that can maintain its orientation in microgravity in relation to a distant location. The Zenolith consistently indicates a configured set point that is meaningful to the astronaut living in architectures that provide limited opportunities to connect visually with their larger context. This expanded sense of orientation aims to provide "psychological tethering" to a point of interest (e.g. in relation to a location on Earth, a celestial object, or a mission destination) using directionality as a prompt. For instance, an astronaut may configure the device to maintain a pointer to their family's home while on orbit.

This paper introduces the technology of the Zenolith and the design decisions made during its development, culminating in an operational test in microgravity during a 2021 parabolic flight. We describe the attitude control system, composed of three reaction wheels, controlled by a proportional–integral–derivative (PID) system, which relies on an inertial measurement unit (IMU) to provide orientation feedback. Finally, we summarize data and insights gathered from the test flight, as well as testing and validation procedures we hope will be useful to similar free-float parabolic experiments.