DISABILITY AND SPACE: TESTING ACCOMMODATIONS FOR A MIXED-ABILITY CREW. S. Wells-Jensen[1], J. L. Molaro[2], E. Virre[3], A. B. Kapusta[4], A. D. Voelker[5], G. T. Whitesides[6], T. Bailey[7], B. Deroko[8], M. A. Deming[9], M. Fauerbach[10], S. Gifford[11], S. Jha[12], J. C. Johnson[13], P. A. Johnson[13], A. A. Mardon[13], C. A. L. O'Brien[14], H. R. Zucker[9]. [1]Bowling Green State University. [2]Planetary Science Institute (jmolaro@psi.edu). [3]University of California San Diego. [4]ThinkSpace Consulting, [5]SciAccess, Inc., [6]Virgin Galactic, [7]Yuri's Night, [8]Otis College of Art and Design, [9]Unaffiliated, [10]Florida Gulf Coast University, [11]Washington University, [12]Zephyrus Research, [13]University of Alberta, [14]The Ohio State University.

Introduction: Space flight has traditionally been the exclusive domain of non-disabled individuals, as the prevailing understanding has been that disabled people lack the capacity to function in extreme environments, to perform rigorous or dexterous physical activity, or to operate effectively as part of a team in high-risk situations.

These mistaken assumptions are perpetuated by the lack of accessible pathways to science and engineering careers, which leads to a decreased representation of disabled individuals in the STEM fields.

However, with the proper accommodations and targeted training for both disabled and non-disabled crew members, disabled professionals can become trusted and essential members of crews working not only on the ground as mission support but also as astronauts aboard orbital and deep space missions.

The most serious barrier to full participation is the lack of research into what accommodations are necessary to realize these goals. On October 17, 2021, Mission: AstroAccess (MAA) [1] launched a group of disabled scientists, athletes, artists, and veterans on a ZERO-G Corporation parabolic flight simulating weightlessness. These "Ambassadors" carried out investigations to test accessibility accommodations that may assist future disabled astronauts operate in the extreme environment of space. Here we describe the demonstrations performed during the flight and learning outcomes.

Broad Goals: MAA has three broad goals to: (1) demonstrate that disabled individuals can successfully operate in a weightlessness, (2) test strategy and technology-based accommodations to enhance functionality in weightlessness, and (3) influence the policies of public and private space entities surrounding requirements for astronaut candidacy.

MAA Team: The mission is an initiative of SciAccess [2], an organization dedicated to advancing disability inclusion in STEM fields and led by co-author Voelker. The volunteer team is comprised of ~50 individuals at a wide range of career levels in academic, public, and private space-related sectors, with some members representing one of a network of 30+ partner organizations, including Yuri's Night, Disabled American Veterans (DAV), Gallaudet University, the MIT Media Lab, the San Francisco Lighthouse for the Blind, and the American Institute of Aeronautics and Astronautics (AIAA). The team was organized into several committees, including Flight Operations which was led by author Molaro. Molaro is the Director of Disabled for Accessibility In Space (DAIS) [3, 4], a peer networking group for disabled space professionals.

Ambassadors and Disabilities: In addition to the ground team, twelve "Ambassadors" (Fig. 1) with a variety of backgrounds were selected to fly. We specifically recruited individuals with disabilities in three categories: blind/low vision, deaf/hard of hearing, and mobility disabilities. Three Ambassadors had low vision with varying degrees of light perception, and one was fully blind. Two Ambassadors were deaf. The remaining six Ambassadors had various types of mobility disabilities. Of these six, four used wheelchairs and had limited to no control over lower limbs, and three of them used leg or arm prosthetics.

The demonstrations planned for each Ambassador during the flight were drafted by Flight Operations with input from both disabled team members (including mission and committee leadership) and team members with relevant expertise in disability issues prior to the Ambassador selections. Once selected, plans were finalized with input from the individual Ambassadors.

Figure 1. Ambassadors in front of the ZERO-G plane before boarding. From left to right is (top row) Mary Cooper, Sheri Wells-Jensen, Eric Shear, Apurva Varia, Sina Bahram, Zuby Onwuta, Mona Minkara, Viktoria Modesta, (bottom row) Sawyer Rosenstein, Dana Bolles, Eric Ingram, and Ce-Ce Mazyck.

Flight Plan and Description: The Zero-G aircraft flies in a parabolic trajectory that allows passengers to experience weightlessness. The experience has been likened to the weightless sensation that can occur while riding a roller coaster but is executed in a more controlled and precise manner. Our flight consisted of a set of 15 parabolas, each of which produced ~20-30 seconds of weightlessness. The duration of weightless periods is one of the primary challenges in executing zero-gravity investigations, as it requires any tasks to be executed very quickly. The first three parabolas consisted of two lunar and one martian gravity parabola to acclimate passengers to the physical sensation and prevent motion sickness.

The inside of the aircraft features a few rows of normal airplane seats, with the rest of the cabin open with a padded floor. Yoga mats were attached to the floor in the open area to represent suborbital spaceflight seats and designate "home" locations for each Ambassador. Straps and cords were attached to the walls, floor, and ceiling to use as hand and footholds. Other equipment for demonstrations was staged as needed after the flight took off.

Operational Challenges and Demonstrations: To plan the demonstrations performed on the flight, we explored the following question: What challenges does a weightless environment present to individuals and mixed-ability crews, and what technologies and operational strategies can we use to accommodate them? We focused our efforts on three primary areas of research: navigation, communication, and orientation.

Navigation. How do Ambassadors with any disability safely leave and return to their home positions (i.e., yoga mats)? How do Ambassadors with partial or full paralysis maintain limb control against inertial forces? How do Ambassadors with mobility disabilities station keep in microgravity? Demonstrations included cables and handholds to assist in translation and the use of rigid canes for reach and stabilization. Flight suit modifications were also tailored to individuals to assist in limb control (e.g., a strap to secure legs together) and facilitate access to or stowage of prosthetics (e.g., straps to secure a prosthetic to the body).

Communication. How do deaf Ambassadors receive critical communication from flight crew about changing conditions? Is ASL possible with different (e.g., upside down) or changing (e.g., tumbling) orientations? Does signing impart momentum? Demonstrations included light beacons and haptic (vibration) devices to signal change in gravity status, as well as testing viability of ASL during off-nominal orientation.

Orientation. How do blind Ambassadors collect information to provide location awareness within the cabin? How do blind Ambassadors orient themselves for movement when their position is unknown? Demonstrations included sound beacons for locating the front of the aircraft, haptic devices (as for deaf Ambassadors), tactile markers to indicate directionality on wall surfaces, and haptic devices providing proximity warnings for obstacles.

Demonstration Outcomes: We found that most Ambassadors needed little physical intervention during the flight, commensurate with non-disabled passengers per the ZERO-G flight attendant testimonials, and that all Ambassadors were regularly able to return independently to their yoga mats when coming out of weightlessness. The handholds and cables were useful for all Ambassadors, though canes were found to impart too much momentum. The flight suit modifications were very successful.

Deaf Ambassadors reported that communication via ASL was possible in various orientations, but difficult to test because their hands were frequently in use for station-keeping. The light beacons had limited success for communicating change in gravity because there were not enough in the cabin to ensure one could see them from any orientation. However, Ambassadors reported that the haptic feedback signal was clear regardless of orientation and feel the technology is highly promising. Both the light and haptic devices required a non-Ambassador operator to transmit a signal at the appropriate time. One issue with our implementation was that relay of information from the airplane pilot to device operators resulted in a signal delay, however, this can be overcome by automating the process in future applications.

The sound beacons did not work for blind Ambassadors because the airplane cabin was too noisy to hear them. Future tests could be done by routing sound to crew through noise-cancelling earbuds. Ambassadors attempted to use other people in the cabin as sound markers. However, this proved difficult because they could not tell if the person they were hearing was stationary or in motion. Haptic feedback for navigation had little success largely due to the large number of obstacles (people, walls, etc.) around them (i.e., if a proximity sensor is always going off the information is not useful). Such technology may have promise but needs more innovation and ground testing.

Future Research: We will report our findings and discuss future research directions, including additional flights, further development and ground-testing of promising technologies, and research campaigns aimed at understanding the challenges faced by people with types of disabilities not represented on flight one.

References: [1] Voelker, A. et al., www.astroaccess.org. [2] Voelker, A., et al., www.sciaccess.org. [3] Molaro, J.L. (2021) AGU Fall Meeting, #SH34A-03. [4] Molaro, J.L., www.disabledinspace.org.