

**NASA EXTREME ENVIRONMENT MISSION OPERATIONS (NEEMO).** M.L. Reagan<sup>1</sup>, W.L. Todd<sup>2</sup>, B.A. Janoiko<sup>1</sup>, M.L. Gernhardt<sup>1</sup>, J.E. Poffenberger<sup>3</sup>, S.A. Chappell<sup>3</sup>, D.A. Coan<sup>3</sup>, T.G. Graff<sup>4</sup>, K.E. Young<sup>5</sup>, K.H. Beaton<sup>3</sup>

<sup>1</sup>NASA Johnson Space Center, 2101 E NASA Pkwy, Houston, TX 77058, [marcum.l.reagan@nasa.gov](mailto:marcum.l.reagan@nasa.gov), <sup>2</sup>Booz Allen Hamilton, 2525 Bay Area Blvd, Houston, TX 77058, <sup>3</sup>The Aerospace Corporation, 2310 E. El Segundo Blvd. El Segundo, CA 90245, <sup>4</sup>Jacobs, 2224 Bay Area Blvd, Houston, TX 77058, <sup>5</sup>NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, MD 20771

**Introduction:** NASA is preparing to land the first woman and first person of color on the Moon within the next decade, and ensuring the success of these missions will depend on our preparation on the ground in multiple ground-based lunar environment analogs. To achieve this, NASA has used full mission class analogs, of which NASA Extreme Environment Mission Operations (NEEMO) is the longest continuously running example.

**Discussion:** NEEMO is NASA's long-standing undersea high-fidelity spaceflight mission analog. It focuses on exploration science, EVA techniques and tools, and maturing ISS IVA flight hardware and operations concepts. NEEMO crews are composed of groups of US and International Partner (IP) astronauts, engineers and scientists who live, work and explore in a challenging environment analogous to the environment experienced currently on ISS and what is expected for future deep space exploration destinations.

NEEMO missions are conducted at Aquarius Reef Base (ARB), which includes a shore base in Tavernier, FL, and the world's only undersea research station, the Aquarius habitat, which is located 5.4 miles (9 kilometers) off Key Largo in the Florida Keys National Marine Sanctuary. ARB is owned and operated by Florida International University (FIU). Aquarius was selected due to its remote and extreme location and its ability to provide the unique isolation and risk factors that spaceflight presents.

NEEMO missions allow for evaluations of end-to-end EVA and Science exploration concepts of operations with a crew that is *in situ* in a true extreme environment. They also allow for evaluations of flight hardware and ops tools that are either pondered or destined for ISS or Gateway in the near future.

NEEMO missions feature flight-like interactions between the crew and a Mission Control Center (MCC) and Science Team, which in turn allows evaluation of mission and science operations decision making and communications techniques. One reason NEEMO missions are of such high fidelity is that so many of the participants are experienced human spaceflight end operators. The majority of crewmembers are trained astronauts, and many of the MCC operators have credentials as current or former certified ISS MCC operators (e.g., CapCom, EVA Officer, etc.). Mission products are generated daily by the ground team and are modeled on ISS products (but modified as needed). A planning team manages the constantly evolving mission

timelines in response to the ever-changing constraints and opportunities.

During NEEMO missions, suited EVA crewmembers (using diving helmets) have clear voice communications with each other, the habitat, and the MCC and Science Team back on shore. Each EVA crewmember also sends helmet cam video to the habitat and MCC and Science Teams. Appropriate communications latencies are inserted for the destination being simulated as well.

NEEMO missions are made possible by a broad collaboration of participants. Astronauts from all of the ISS partner agencies are eligible for crew assignment. Often the crew includes a NASA scientist, doctor or engineer with a particular skill to contribute. Sometimes crewmembers come from external entities – generally institutes or universities. Objectives come from a wide variety of sources as well, from within NASA, IPs, government agencies, academia, commercial companies and research institutes. A typical NEEMO mission is a collaboration between at least 5 NASA centers.

To date, 23 NEEMO missions have been conducted since 2001, and NEEMO 24 is planned for 2022.

**Conclusion:** NEEMO is a high-fidelity mission analog conducted in an extreme subsea environment. It features experienced end-operators in human spaceflight, from the astronaut crewmembers to key personnel staffing Mission Control.

**Acknowledgments:** The authors wish to thank FIU and NASA's HEO SEI/Strategic Analysis and Exploration Integration and Science Directorate organizations for the continued support that makes the NEEMO Project possible.



Figure 1: NEEMO aquanauts on an exploration EVA.