NEEMO 16: EVALUATION OF TECHNIQUES AND EQUIPMENT FOR HUMAN EXPLORATION OF NEAR-EARTH ASTEROIDS.

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Introduction: NASA Extreme Environment Mission Operations (NEEMO) is an underwater spaceflight analog that allows a mission-like operational environment and uses buoyancy effects and added weight to simulate different gravity levels. The 13-day NEEMO 16 mission was performed at the Aquarius undersea research habitat (Fig. 1).

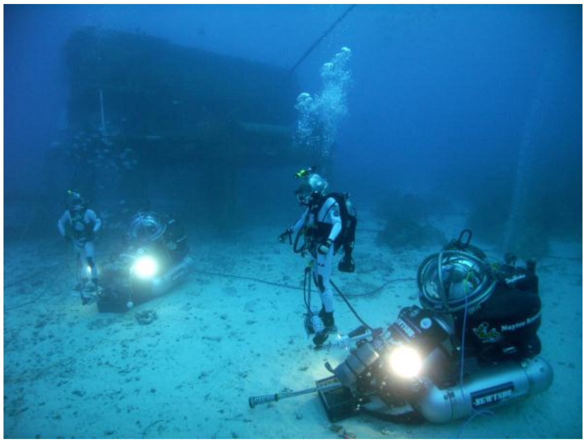

Figure 1. The Aquarius undersea habitat (background) and Deep Worker submersibles (foreground w/ crew) used during the NEEMO 16 mission. Photo credit: NASA/M.Widick.

The mission focused on near-Earth asteroid (NEA) exploration techniques to provide key input to NASA's Capability Driven Framework [1], including evaluation of different combinations of vehicles, crewmembers, tools, and equipment that could be used to perform exploration tasks on a NEA surface (Fig. 2).

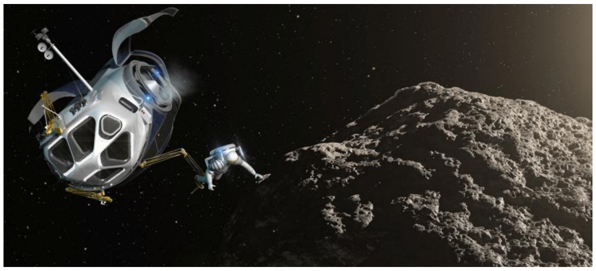

Figure 2. Depiction of an MMSEV with a crewmember performing extravehicular activity (EVA) in a foot restraint on an astronaut positioning system (APS) near a NEA. Image credit: NASA.

The effects of representative communication latencies associated with NEA missions were also studied during the mission.

Methods: Four subjects were weighed out to simulate zero gravity and evaluated different techniques and tools to perform a NEA exploration circuit on the sea floor outside Aquarius. Subjects completed tasks including float sampling, rock chip sampling, core sampling, soil sampling, geophysical array deployment, and large instrument deployment (Fig. 3); lessons learned from previous analog tests were incorporated [2].

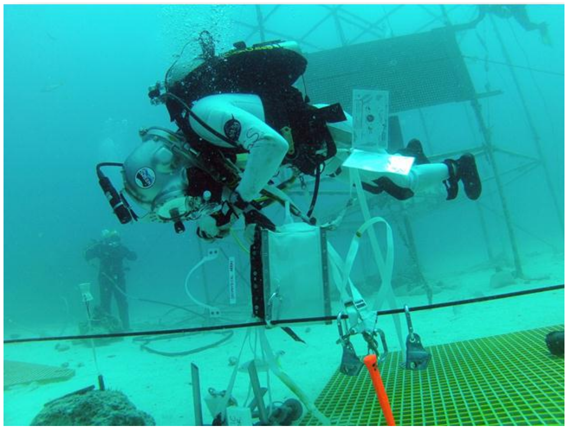

Figure 3. EVA crewmember in NEA exploration circuit working with sample/tool bags while attached to translation lines. Photo credit: NASA.

Tasks were completed using translation lines, a rotational/translational boom, EVA jetpack, and a foot restraint on a Deep Worker submersible representative of the Multi-Mission Space Exploration Vehicle (MMSEV) [3,4].

A one-way communication latency of 50-seconds between a NEA and mission control was simulated throughout the mission. Subjective data included acceptability, simulation quality, capability assessment ratings, and comments. Photo and video were also collected.

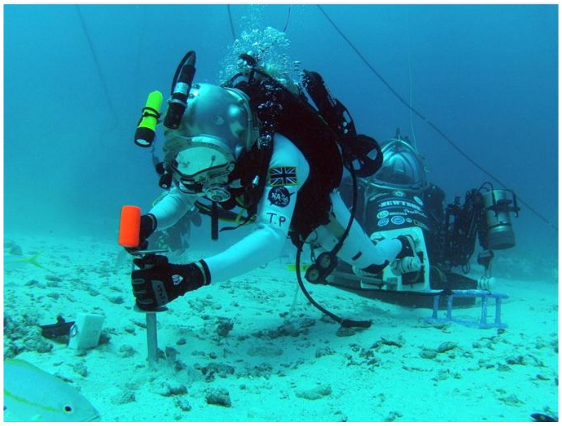

Figure 4. EVA crewmember hammering geophysical array anchor while attached to a foot restraint on the Deep Worker submersible (MMSEV analog). Photo credit: NASA/M.Widick.

Results: The only method rated as totally acceptable for performing all the NEA exploration tasks was using a foot restraint on an MMSEV (Fig. 4). EVA jetpacks and methods that used anchoring to the NEA surface (boom and translation lines) were found to be acceptable for a limited set of tasks. Technology development should include a vehicle with an APS and EVA foot restraints, EVA jetpacks, and possibly an EVA boom that could be anchored to an MMSEV or to the surface. Follow-on unsuited testing was performed on the Active Response Gravity Offload System (ARGOS) at NASA Johnson Space Center during NASA's Research and Technology Studies 2012 (RATS12). Further insight may be gained with additional testing of NEA exploration techniques in a reduced gravity analog with spacesuits and increased fidelity vehicles and equipment. Also, communication tool and just-in-time training improvements were also identified to better handle both nominal and contingency operations with NEA-like communication latency.

References: [1] Anon. (2011). "Human Space Exploration Framework Summary", National Aeronautics and Space Administration. [2] Chappell S. P. et al. (2012) *Global Space Exploration Conference*, Washington, DC. [3] Abercromby, A. F. J. et al. (2012) *Acta Astronautica*, *doi:10.1016/ j.actaastro. 2012.02.022*. [4] Abercromby, A. F. J. et al. (2012) *Global Space Exploration Conference*, Washington, DC.