MARTIAN METEOROLOGY: WEATHER FORECASTING EVA FROM AN ANALOG MARTIAN HABITAT. Buckner, D. K. Buckner[1], P. De Leon[1], FNU Anamika[1], P. G. Henson[1], [1]University of North Dakota, Space Studies Department, Clifford Hall Room 512, 4149 University Ave Stop 9008, Grand Forks, ND 58202, denise.buckner@und.edu.

Introduction: Human habitation of extraterrestrial bodies, particularly Mars, is an important future step in the exploration of the Solar System [1]. Terrestrial analog habitats provide valuable sites for research supporting these ventures, for enhanced understanding of human factors, tool and system ergonomics, and Extravehicular (EVA) operation mission design [2].

For a Martian habitat to provide long-term life support for crews, the ability to locally and autonomously monitor weather conditions is key. Dust storms pose a unique and serious challenge to crews, obstructing vision and communication capabilities with Earth and orbiting satellites, threatening life support systems, and hindering EVA operations. Because dust obstructs communications and dust storms are often unpredictable and can form with little warning, in situ forecasting capabilities are important.

The thin Martian atmosphere precludes the use of UASs for weather monitoring, and satellite systems are costly and will be of little use when heavy dust covers the planetary surface. However, weather balloons provide an ideal platform for forecasting, as they are low cost, user friendly, require no fuel, traverse high altitudes, and can carry a wide variety of light, low cost, accurate sensors and cameras for data logging and retrieval. Fabrication of sensor arrays and camera systems within the habitat requires minimal time, so crews can quickly prepare versatile systems, even when dust storms are imminent. With simple tool modifications, crews can quickly fill and launch these payloads on board balloons in close proximity to the habitat for maximum safety and convenience.

Mission Overview: This poster discusses three EVA tests to explore feasibility of balloon operations and weather forecasting with small, three member crews in the Inflatable Lunar/Mars Analog Habitat (ILMAH) at the University of North Dakota (Figure 1). This student-designed and built habitat supports ongoing crewed mission research with the goal of studying life support systems and EVA operations.

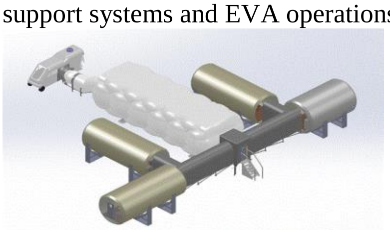

Figure 1: The University of North Dakota's ILMAH.

For these mission, crews fabricated and programmed sensor arrays and cameras within the habitat, then filled and launched the payloads while suited during EVA operations. One crewmember stayed inside the habitat and served as mission control and communications captain, while two other crewmembers performed the EVA operations. Following the launch, sensors logged atmospheric data, including temperature, pressure, humidity, and dust concentration for both real-time and later analysis.

Past Work: This poster is a follow-up to a presentation given at LPSC 2018 discussing the first EVA test of the system. Since then, two additional crewed tests have been conducted, with each subsequent test implementing new tools, sensors, and operational procedures for enhanced autonomy. Analysis of the literature finds no prior attempts to launch weather balloons during any analog habitat studies. This poster discusses the system design and mission operations from three EVAs conducted with unique crews, along with future work for long-term implementation in upcoming missions and applications to the Martian environment [3].

Test I (Mission IV): This mission was designed to demonstrate feasibility of autonomous weather monitoring. Hardware and software used could reasonably operate in the Martian environment. Procedures and human performance were other key elements.

Payload design: While inside the habitat, the crew fabricated a radiosonde to fly on the balloon; this device measures temperature, pressure, and humidity. The payload consisted of this radiosonde, plus an Iridium GPS unit and Go Pro cameras to track the path of the balloon and gather images from above.

Ground Station and Communications: The ground station consisted of a 10 element diamond Yagi antenna atop a tripod sitting outside the habitat, connected to a radio receiver and PC inside the habitat. Data was transmitted from the radiosonde over HAM radio frequency. (Figure 2)

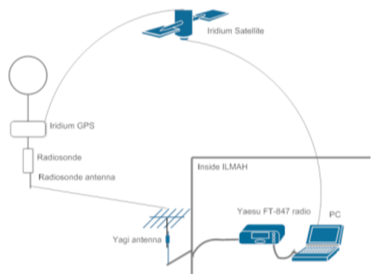

Figure 2: Diagram of communication system between payload, supporting systems, and ground station.

Tool design: A number of typical tools used to fill weather balloons were altered to interface with spacesuits. A tool belt was designed to hold the tools and keep them close to the crewmembers.

Procedural operations design: The procedural design for this mission was based off of balloon launches conducted on Earth, modified for the analog habitat environment. The crewmember inside the habitat communicated with the two crewmembers outside the habitat via radio headsets.

Overview: Key elements include instrumentation fabrication, payload design, communication systems, specialized tools, operational procedures, communication between crewmembers, and data analysis. The crew successfully fabricated the sensors and payload, filled and launch the balloon, and tracked location. Procedural design was successful and operations ran as planned.

Test II (Mission V): Additional sensors were implemented for enhanced forecasting capabilities.

Payload design: To test versatility, the crew fabricated additional sensors, cameras, and position transmitters and incorporated them into the payload. (Figure 3)

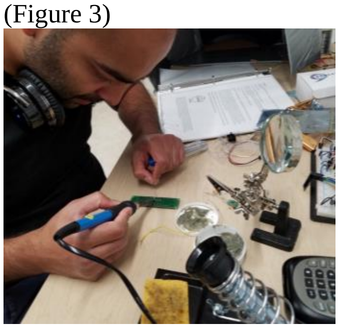

Figure 3: Sensor fabrication conducted by crewmember within the ILMAH EVA and electrical engineering laboratory facilities.

Ground Station and Communications: Past system was used again without major updates.

Tool design: Updates implemented for user friendliness and increased ergonomics.

Procedural operations design: Focus on increased autonomy, with mission operations initiated and managed by Capcom.

Overview: Expanded sensor array demonstrated versatility of mission concept and provided feasibility of a multi-faceted forecasting system with real-time modifications in payload capabilities, depending on conditions the crew needs to measure or monitor.

Test III (Mission VI): Just-in-time training via video communications was implemented, additional sensors were integrated (including dust sensor and cameras), and improved tool design enabled fully autonomous operational procedures.

Payload design: Focus was placed on payload miniaturization; important elements included a small temperature/pressure/humidity array, dust sensor, camera, and GPS.

Ground Station and Communications: Data logging for later data retrieval and analysis replaced radiosonde payload, due to past system communication breakdown.

Tool design: Updates included new fill tools for balloon stabilization. (Figure 4)

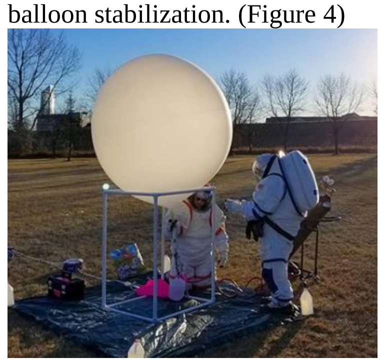

Figure 4: Fill tool updates, including balloon stabilization cage, enabling full crew autonomy during fill procedures.

Procedural operations design: This test focused on increased autonomy, streamlined EVA procedures, and implementation of just-in-time training, where Earth-based mission control led the in-habitat crew through fill procedure training via remote video communications.

Overview: Miniaturization of payload elements improved fill and launch operations, just-in-time training resulted in improved crew knowledge and recall during EVA operations, and full autonomy during EVA procedures was achieved.

Future Work: Future work includes development of a reliable communication system between payloads and crew, further expansion of sensor array capabilities, and eventual modification for implementation in a Martian environment.

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References: [1] National Aeronautics and Space Administration (2015) *NASA's Journey to Mars Pioneering the Next Steps in Space Exploration.* [2] Robinson, D. K. R. et al. (2008) *Acta Astronautica, 62(12)*, 721-732. [3] States News Service. (2017) *States News Service: Space Station Takes Shape*, July 4.