ISS Technology Demonstrations for Future Spaceflight Medical Systems

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Throughout the history of human spaceflight, crewmembers have experienced various in-flight medical conditions including illness and injury. Planned missions to the Moon and Mars will require capabilities to maintain the health of future space travelers. Mass, power, and volume available in the vehicles and habitats for these missions will be severely constrained; resupply of resources will be limited or non-existent, as will opportunities for evacuation to Earth. Furthermore, ground-based support will be hampered by communication latencies and blackouts. These vehicle and mission constraints will necessitate a medical system that has been efficiently planned, providing on-board procedural guidance in addition to a variety of medical devices and consumable resources. Medical capabilities required for the diagnosis and treatment of potential medical conditions during future spaceflight missions may include real-time health monitoring, medical imaging, and biomarker analyses (e.g., blood or urine). Terrestrial medicine shares these needs, thus many of these medical capabilities could likely be satisfied by Commercial-Off-The-Shelf (COTS) devices and methodologies; however, in some cases the unique space environment and increased mission duration will drive the need to modify technologies and the way care is provided.

NASA's Human Research Program (HRP) Exploration Medical Capability (ExMC) Element and Mars Campaign Office's Exploration Medical Integrated Product Team (XMIPT) are working together to decrease medical risk during exploration missions. Flight-tested medical diagnostic and treatment technologies are necessary to effectively manage medical conditions relevant to exploration missions while meeting vehicle constraints, integrating with medical decision-support tools, and enabling increasingly Earth-independent operations. Several projects have leveraged the ISS as a testbed for exploration, including 1) in-situ blood analysis, 2) medical inventory, 3) intravenous fluid generation, and 4) autonomous medical procedure guidance.

Management of several in-flight medical conditions, such as bacterial and viral infections and acute radiation syndrome, is dramatically improved with ability to assess blood cell populations, electrolytes, and metabolites. In December 2020 and January 2021 ExMC performed an ISS technology demonstration (Tech Demo) of the HemoCue® WBC DIFF analyzer (HemoCue, Brea, CA), a COTS device that was modified to enable functionality in a spaceflight environment. This Tech Demo marked the first time that hematology measurements were successfully performed real-time in microgravity. Also modified and demonstrated was the

reusable Handheld Electrolytes and Lab Technology for Humans (rHEALTH) ONE analyzer (rHEALTH, Bedford, MA), which uses flow cytometry and sheath-based hydrodynamic focusing methodologies. The rHEALTH ONE ISS Tech Demo in May 2022 demonstrated test results obtained in-flight matched those on the ground.

NASA currently relies on crew self-reporting to manage and maintain medical inventory on ISS. The ability to maintain an accurate inventory becomes more critical during long duration missions since the crew will need to be increasingly autonomous in finding and utilizing medical items, including those scenarios when alternative treatments need to be considered due to limited or no resupply. HRP's Medical Consumables Tracking (MCT) project was developed by ZIN Technologies, Inc. (Cleveland, OH), and demonstrated real-time tracking of medical supplies aboard the ISS between December 2016 and July 2018. The MCT system design utilized Radio Frequency Identification Device (RFID) technology to perform automated inventory and was installed in the Crew Health Care System (CHeCS) Resupply Stowage Rack (RSR).

The challenge of limited shelf life, exacerbated by the lack of resupply opportunities, affects a plethora of medical system components including consumables, pharmaceuticals, and intravenous (IV) fluid. In 2010, ExMC funded ZIN Technologies, Inc. (Cleveland, OH), to develop the Intravenous Fluid Generation (IVGEN) system. IV fluids were successfully generated with IVGEN using the potable water supply on ISS during ISS Expedition 23. The XMIPT is in the process of developing a miniaturized version of the original IVGEN hardware for a future Tech Demo aboard the ISS.

Current ISS medical operations rely heavily on preflight training and real-time remote guidance, both of which become impractical or impossible for exploration missions. The primary goal of the Autonomous Medical Officer Support (AMOS) Software Tech Demos on ISS was to confirm telemedical proof-of-concept for autonomous medical imaging in an operational setting. This novel software tool shifts emphasis from preflight training and real-time remote guidance to in-flight just-in-time instruction, a new and necessary paradigm for crew medical autonomy. AMOS introduces a novel, streamlined skill management concept for exploration missions featuring comprehensive training and guidance modules for ultrasound examinations using the ISS Ultrasound 2 (a modified GE Vivid-q™; General Electric HealthCare, Chicago, IL). With no prior crew training or remote guidance, two Tech Demos on the ISS (April 2020 and June 2022) resulted in high quality, clinically useful image sets.

We will provide a review of historical, current, and planned medical devices and technologies considered for inclusion within future spaceflight medical systems and summarize hardware development activities and medical device tech demos conducted on the ISS.