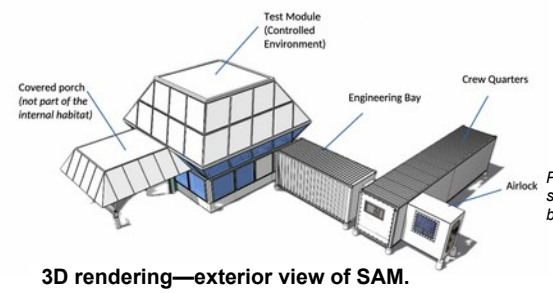
A Space Habitat Surgical Bay Design and Development Project

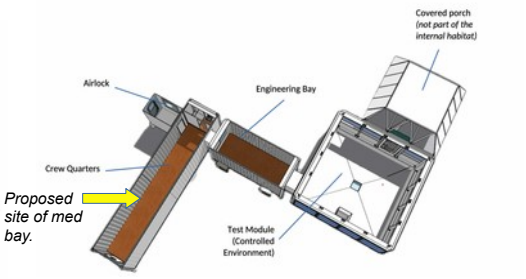
A surgical bay for other-world habitats with immediate implementation at the Space Analog for the Moon & Mars (SAM) Biosphere 2, University of Arizona

Overview

Project Name	A Space Habitat Surgical Bay Design and Development Project
Project Manager	Kai Staats, Director of Research at SAM
Project Dates	August 2024 to 2026
Background	All long-duration space stations in low Earth orbit have existed in the context of a relatively rapid return to Earth. For critical medical emergencies, a crew member could be stabilized and evacuated to Earth within a matter of hours. While return from a Lunar habitat is 3-5 days to Earth, return from Mars will be no less than seven months, more than three years for full crewed missions. Medical and surgical issues in exploration class missions will require on-orbit or in-hab medical management to increasing degrees of capacity in relation to the distance from Earth. Our team recently completed a 100-year survey of medical and surgical care paradigms in military, expeditionary, remote and spaceflight medicine. We recognize that advances in innovation, technology, training, and expertise have improved patient outcomes. However, care capabilities decrease with tightly constrained medical systems.
Objective	Through professional collaboration, we propose developing a fully-functional medical and surgical bay ("med bay") at the hermetically sealed and pressurized space analog and research facility SAM, using an iterative design process guided by NASA requirements and commercial needs, incorporating contemporary technology and innovation. The primary focus is surgical innovation, simulation, training, and education related to space.
Location	The Space Analog for the Moon and Mars (SAM) Biosphere 2, University of Arizona, Oracle, AZ.
Working Group	The Space Surgery (Med Bay) Working Group at SAM is an inclusive group of self-assembled medical and non-medical professionals and industry partners seeking collaboration with a common interest in achieving the goal of developing a medical and surgical bay. The first meeting of the working group was held by video conference in September 2024. In the second meeting in November 2024, a list of action items and tasks were established to start working in parallel for design and development of the med bay with realizable waypoints and deliverables. (List of individuals on page 5.)
Target Audience	Space medicine and engineering professionals.



3D rendering—exterior view of SAM.



3D rendering—interior view of SAM.

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Project Specifics

Scope	The proposed med bay would be a demonstration of a comprehensive, compact, full-featured, low-resource, and readily deployable research-grade medical and surgical bay capable of dealing with potential issues that may arise during long-duration missions, focusing on: • General/trauma surgery and dental care scope of care. • Validation of functionality through hands-on procedure and equipment demonstration and training.
Research Goals	1. To conduct and facilitate high-quality scientific research and ground-based experiments, both in and out of analog missions, specifically related to space medicine and surgery. 2. To understand current and future capabilities and limitations in both deep space procedural and critical care surgery. 3. To develop a standard for medical bay capabilities criteria to be adopted by space fairing companies and government entities. 4. To partner with academic, government, and corporate aerospace entities for the ongoing development of real-world medical procedures, facilities, and training for human space exploration.
Development Plan	• Establish a formulaic means to assess the capabilities of a medical bay design. • Determine a “Conditions List” starting with the NASA IMPACT document. • Determine equipment and supplies required for management of these conditions. • Determine mass/volume/power required for working space, equipment, & supplies. • Design, mock-up, and build-out. • Determine knowledge, skill, and training requirements to be successful with the selected resources.
Design & Decision Criteria	The proposed design for a medical and surgical bay at SAM will be: • Guided by existing NASA requirements and commercial needs. • Interdisciplinary and multi-disciplinary collaboration. • Contemporary, incorporating technology and innovation that is portable, regenerable, contactless, and wearable when applicable. • Compact, readily deployable, and low-resource–designed to fit within confines of a Mars transit vehicle while housing the necessary components, equipment, and supplies for management of urgent and emergent medical surgical conditions. • Multiple-use functional in the context of systems and tools. • Full-featured, capable as a military field station or forward surgical team (FST). • Focused on a general and trauma surgery and dental scope of care. • Potential reference for terrestrial applications, particularly management and minimization of hospital waste.
Constraints	Fixed facility. Ongoing research projects.

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Project Design Considerations

Physical	• Known design and capabilities aboard the ISS, navy submarines, military field settings. • Anticipated conditions, needs, and uses for LEO, cislunar transit, Moon habitation, Mars transit habitation. • Type of habitat: orbital or surface, with SAM immediately focused on surface habitation. • Functionality: efficient, lightweight, compact, deployment in multi-functional area. • Use: research, simulation, education, training. • Materials: 80-20 aluminum support with stainless and/or easy-clean plastic laminate surface. • Cost: TBD • Estimated time to completion: working prototype by the close of 2025 • Estimated time to use: Q2 2026
Operational	To function as a research-grade operating room, the following must be considered: • Creation and maintenance of a contained and/or sterile environment. • Adequate fluid and waste management. • Electronic medical record keeping. • Training and skills maintenance. • Restraint and organization system innovations and technology for potential use in lower gravitational fields (e.g. Moon) and microgravity (e.g. on-orbit, cislunar and Mars transfer).
Components: ***Equipment, Supplies, & Medications***	Basic components for conducting procedures and individual components are based on current operating room (OR) designs and layout. Unlike current ORs with dedicated areas of hospitals, the med bay will be a multi-purpose use area, at least initially, due to low volume of space in early habitats. Components must be compact and lightweight to overcome payload restrictions, ideally electrically isolated from the craft, potentially vibrationally as well.
Components: ***Reusables, Consumables, & Disposables***	While some practices in healthcare may need to be a part of the med bay for maintenance, they may be deleterious to the planet and will definitely have to be addressed when considering simulation for off-world habitation and commercial space stations. These include but are not limited to the following: • Single-use instrumentation. • Recyclable and non-recyclable packaging. • Single-use personal protective equipment. • Chemicals used to clean and maintain hospital environments.

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Project Timeline

Concept & Team Development	August – September 2024 • Initiated concept; held first virtual team meeting
Partner Engagement	October – December 2024 • First paper drafted; potential industry partner engaged
Research & Design	January 2025 • In-person design workshop at Biosphere 2 July – November 2025 • Work on publications • Compile and order list of equipment, materials • Plan for representative mission
Build Prototype	November – December 2025
Research & Testing	January – May 2026 • Representative mission • Build training modules, simulation scenarios
Fund-raising	Ongoing

Conclusion

Project Outcome	Improved understanding of current and future capabilities and limitations in procedural and critical care surgery in small spaces, applicable to any transit vehicle or habitat on the Moon or Mars, through surgical simulation, training, and education.

SAM at Biosphere 2, Oracle, AZ.

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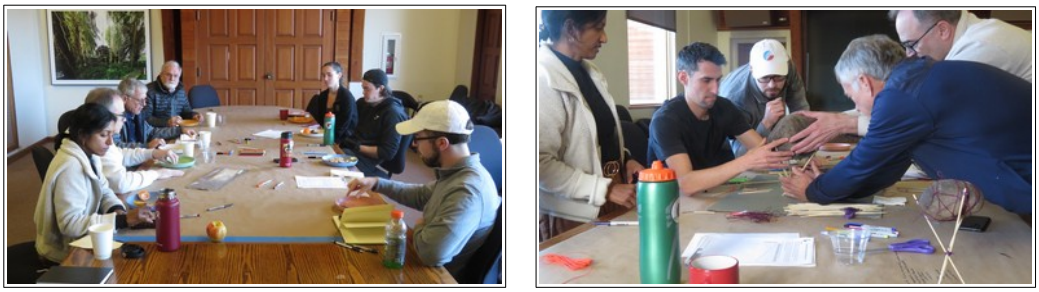
Working Group

(In alphabetical order by last name)

- **Michael Hodapp, DDS—**Experienced NASA dental consultant. Active with AsMA Ad Hoc Committee on Commercial Spaceflight.
- **Thomas Hoffman, DO—**Former naval flight officer & NASA flight surgeon; board certified in Family Medicine. AsMA Fellow; active AsMA Ad Hoc Committee on Commercial Spaceflight.
- **Connor MacRobbie—**PhD candidate, Mechanical Engineering at University of Waterloo; experience in space work, building design and hospital codes.
- **Madelyn MacRobbie—**PhD candidate, MIT and Harvard Medical School, Medical Engineering & Medical Physics, AeroAstro track. Summer intern at SAM.
- **Mira Milas, MD—**Endocrine surgeon at Banner University Medical Center, Phoenix. Executive Director of Arizona Program for Exploration (APEX) Medicine and Surgery Fellowship.
- **Bindhu Oommen, MD, MPH—**Board certified general surgeon; consultant and med bay lead at SAM; Member of AsMA, Space Surgery Association, OSMED, and WEM.
- **Eric Petersen, MD, MS—**Trauma & acute care surgeon, surgical intensivist, and aerospace medicine specialist at Banner University Medical Center, Phoenix; Program Director of APEX Medicine & Surgery Fellowship. SpaceX flight surgeon; continues to work as a contractor for launch/landing missions with SpaceX.
- **Kai Staats, MSc—**Director of Research at SAM. Led the development of SIMOC, a research-grade computer simulation and educational interface to a Mars habitat. Veteran developer of platforms for research and science. Co-founder and CEO of Linux operating system; author of Karoo GP machine learning algorithm used at LIGO.
- **Kaleigh A. Stabenau, MD—**Otolaryngologist, UC Irvine. Assistant Program Director for APEX. Flight surgeon & consultant for SpaceX, Axiom, and VAST.
- **Trent Tresch—**Served as a co-director for SAM habitat. Leads the UA Center for Human Space Exploration (CHaSE) initiatives, teaching spacesuit operations and spacecraft egress.
- **David Wexler, MD, PhD**—Retired otolaryngologist, UMASS School of Medicine & UMASS Space Science Laboratory; prior Air Force specialist physician & graduate of the USAF School of Aerospace Medicine primary course. Active with AsMA's Ad Hoc Committee on Commercial Spaceflight.



Med Bay Working Group—Design Workshop at Biosphere 2, January 2025.

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