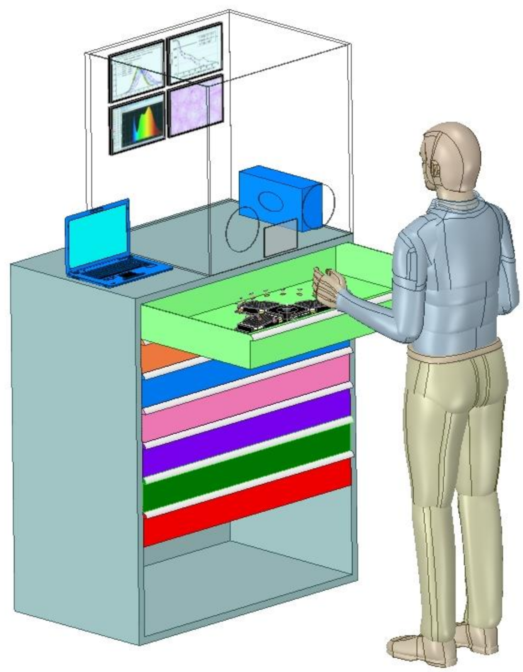
GATEWAY BIOBOX: A COMPACT, MULTI-PURPOSE BIOLOGICAL HARDWARE SUITE FOR IN SITU EXPERIMENTS AND ANALYSES IN DEEP SPACE. D. J. Smith[1], M. Parra[1], M. Lane[2], E. A. Almeida[1], and the Space Biosciences Research Branch[1], [1]NASA Ames Research Center, Mail Code: SCR, Moffett Field, CA, 94035, david.j.smith-3@nasa.gov, macarena.p.parra@nasa.gov, e.almeida@nasa.gov, [2]NASA Kennedy Space Center, Prototype Laboratory, Mail Code: NEL, Kennedy Space Center, FL, 32899, michael.a.lane@nasa.gov

Introduction: A look across the history of NASA life science payloads (including International Space Station experiments and all predecessor studies on the Space Shuttle and Mir) reveals that most biology experiments were simple: packaged into containers, transported to orbit, then activated to grow in the microgravity environment and eventually returned to the ground after cryopreservation or fixation. Although some basic reporter genes or growth patterns could be elucidated or imaged on orbit (depending on the specimen), more sensitive biological analyses and assays typically occurred days, weeks, or even months later in ground laboratories once samples were transported back to Earth – i.e., not in the space environment. *This paradigm for biology experiments must change with the Deep Space Gateway*.

Encouragingly, four spaceflight missions launched to the ISS in 2016-17 demonstrated a new suite of instruments designed to generate molecular datasets on orbit. With proven functionality of Wetlab-2 [1], miniPCR [2], RAZOR [3], and the Biomolecule Sequencer (BSeq) [4], research teams demonstrated that end-to-end biological experiments can be conducted in space. A new era of biological research in spaceflight can now be planned and empowered by on-orbit, flexible analyses using miniaturized, efficient molecular machinery for lysing cells or tissues, extracting and purifying biomolecules of interest, amplifying and identifying genes, and even preparing libraries for nucleic acid sequencing. Leveraging universal features of these successful in-flight instruments as well as ISS legacy systems for performing biological experiments in space, we propose the "*Gateway BioBox"*, a multi-purpose, adaptable hardware suite that will prepare NASA for beyond low Earth orbit expeditions where fundamental biology questions must be examined without reliance upon sample return.

Gateway BioBox: With volume, mass, and power limitations in the Deep Space Gateway habitat inevitable, a compact, multi-purpose biological research hardware suite will be needed. The Gateway BioBox is a compilation of NASA's smallest & nimblest biological tools and hardware systems that will allow for a wide range of specimen cultivation and analysis, from the most sensitive molecular measurements to cell and tissue biology assays performed routinely in Earth laboratories. It adapts elements of ISS hardware already flown (e.g., MSG, Wetlab-2, BSeq, Bioculture, etc.) and adds 1-g gravity controls plus ancillary equipment and environmental sensors that will be useful for a variety of conceivable life science investigations.



The BioBox will accommodate specific model organism categories in each individually-controlled, stacked drawer that can slide out for experimental manipulations. For instance, a single drawer could be dedicated to either bacteria, fungi, human cell cultures, fruit flies, or plant seedlings. Inside each drawer of the BioBox would be a standard set of environmental control devices (e.g., LEDs) and sensors (e.g., dosimeters, thermocouples, relative humidity monitors, etc.). Specimens would be able to grow in microgravity conditions and/or attach to a centrifuge positioned inside the drawer capable of spinning liquid media containers (e.g., 96-well plates) or solid media containers (e.g., agarose petri dishes) used for experimental growth. BioBox drawers will be programmable or manually adjustable through a user-friendly master control panel, allowing each model organism to grow at experimentally optimal conditions. Microfluidic cards from small spacecraft (i.e., cube-sats [5]) could also be installed inside drawers for miniaturized and automated life science experiments requiring a stable, powered and controlled environment. Above the BioBox drawers computer tablets can provide a simple crew interface, as well as a workbench for preparing and processing samples inside a sterilizable glovebox. State-of-the-art tools would be inside the glovebox. Today, that might include Wetlab-2's Sample Preparation Module, fluid transfer and de-bubbling devices, and real-time quantitative PCR thermocycler [1]. An automated library preparation tool and miniaturized sequencer [4] would also provide multi-purpose analytical functions for most life science investigations. Specific BioBox instruments should be down-selected later in order to acquire industry-leading, miniaturized capabilities that cannot be readily predicted at this time. At the bottom of the BioBox will be a dedicated refrigerator for storing reagents used for biological assays at 4 °C.

BioBox Resources. Mass (50-100 kg); Power (0.2-0.5 kW); Cost ($10M); Volume (0.5-2 m^3); Crew Time (could involve either autonomous or crew-tended operations); Location (inside Deep Space Gateway crew habitat); Other Resource Needs (periodic re-supply of reagents, supplies, and model organisms).

Need for the Facility: Despite decades of ISS research, our understanding of combined and potentially synergistic effects of deep space radiation and microgravity is nearly non-existent. The Gateway BioBox would enable model organism studies investigating biological responses and mitigations for long-duration, low-dose deep space radiation which cannot be reproduced on ISS or on Earth. Serving as a core facility for the Deep Space Gateway, the BioBox could support research projects examining a wide array of exploration knowledge gaps, including multigenerational growth patterns; symbioses; pathogenesis; microbiome relationships with human and plant health; bone, skeletal, and vascular changes; T-cell and immune system responses; and medical countermeasures (drug benefits, radiation mitigation, adaptation, and effects of artificial gravity).

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