BIOLOGICAL OBSERVATORY AT THE DEEP SPACE GATEWAY. D. L. Hamill, NASA Langley Research Center (doris.l.hamill@nasa.gov).

Introduction: The NASA Life Sciences Research Capabilities Team (LSRCT) has been discussing deep space research needs for the last two years. The LSRCT supports a large number of abstracts in addition this one, reflecting a full range of desirable life science research. NASA's programs conducting life sciences studies – the Human Research Program, Space Biology, Astrobiology, and Planetary Protection – see the Deep Space Gateway (DSG) as enabling opportunities to investigate biological organisms in a unique environment that cannot be replicated in Earth-based laboratories or on Low Earth Orbit science platforms.

The LSRCT discussions have estimated that the life sciences' needs for deep space exposure greatly exceed that expected capacity of the DSG. This paper describes an innovative idea that has been under discussion by LSRCT members for addressing these needs, an approach that appears to be compatible with a commercial business model.

The DSG Life Sciences Capacity Problem: The entirety of what humanity knows about the effects of deep space exposure on living systems comes from the very few men who spent a very few day there during the Apollo program. The many unknowns that remain certainly contain keys to ensuring crew health and safety during extended exploration missions and may uncover entirely new science. The details of research needs are described in other LSRCT member abstracts but are summarized below to underscore the volume and importance of deep space, life science investigations.

There is no way on the ground or in LEO to simulate the effect of long duration, low dose deep space radiation combined with microgravity. Issues of microbial and microbiome evolution in an isolated system under deep space conditions are entirely unknown. There is no information whatsoever on plant growth in deep space nor how habitable ecosystems including plants might react to the deep space stress. There is no information on the stability of food and pharmaceuticals in the deep space environment. Hypothesis-driven studies of radiation and microgravity effects may help scientists understand them in enough depth to develop countermeasures with low system impact, like pharmaceuticals. Observational studies beyond the Earth's magnetosphere may reveal entirely new biological responses and mechanisms. Deep space provides an opportunity to expand understanding of the possibility of extraterrestrial life and the implications for planetary protection. Exposure of living specimens to the deep space environment offers an enormous potential for discovery, understanding, and exploration risk reduction.

Unfortunately, realizing this potential requires far more capacity than the DSG can provide. DSG was envisioned from the start as a platform for testing systems, operations, and human accommodation for deep space, with science utilization taking opportunistic advantage of any capability that might be available in meeting those challenges. It was never envisioned as a robust laboratory like ISS.

Hypothesis-driven studies typically require a large number of organisms. A minimum of twenty specimens are needed just to distinguish an observed phenomenon from random chance. Countermeasures for human use typically require scores or even hundreds of individual specimen exposures to demonstrate their safety and effectiveness above chance. Furthermore, human countermeasures and investigations of the effects of deep space on complex behaviors require complex animal models, typically rodents, which place a great demand on experiment volume, power, upmass, downmass, consumables, and upkeep.

DSG's life sciences research capacity is subject to two main constraints.

First, crew access will be limited to a month or two every year or two, and ISS experience suggests that crew time devoted to utilization is likely to be highly restricted even then. Second, the locker volume available to all utilization, biological and otherwise, will be modest compared with the needs for it.

The DSG can make many years of exposure time available for experiments that do not need crew attention. Some additional research could be enabled by relatively simple robotic support. High-value research with complex animal models and plants would need more advanced robotic technology, which could emerge through innovation and commercial spin-in if a need for it is established. However, justifying the investment in such technology and equipment would require far more utilization than could be accommodated by the few DSG lockers that might be allocated to life sciences.

A Biological Observatory: The solution to the utilization volume problem could involve docking a separate, special-purpose module, specially outfitted for life science research, to one of the docking ports to serve as a dedicated biological observatory. Three potential scenarios for the Biological Observatory are offered here.

The module could be configured as a visiting vehicle, perhaps based on a vehicle designed to serve as a logistics module. While the crew and their logistical support vehicle are not at the DSG, an observatory module outfitted with experiments and specimens could dock on the logistics module's port. DSG would provide communication, power and cooling, GN&C, and an environment compatible with life. The Biological Observatory would provide the resources needed for transit, experiment locker accommodations, robot interfaces, and supplemental ECLSS. Expensive or heavy multi-purpose equipment for robotic tending of the module experiments would be permanently based on the DSG. Before a new crew's logistics vehicle arrived, specimens could be robotically sacrificed, preserved, and off-loaded as appropriate. The module would be detached then reentered, destroyed, or sent to a station-keeping position for redocking after the logistics module departs. The crew could prepare the samples for return or do any delicate manual work (e.g. harvesting organs, sectioning) needed to capture the experimental information remotely.

Alternatively, the Biological Observatory could be permanently attached to a port in the node and equipped to accommodate lockers and the robotic equipment needed for individual experiments. Experiment lockers would come up on the logistics module, either on a dedicated flight during the quiescent (unmanned) period, to be offloaded and installed robotically, or as part of the crew's logistics for manual installation. This permanent module would allow the multi-year exposures that are key to several critical research questions associated with deep space exploration.

It is possible that an untended, isolated vehicle with living specimens could produce a contaminated environment unsuitable for human occupation. If this proves to be a concern, the observatory could be a separate vehicle attached to but isolated from the habitable DSG modules. The vehicle would have its own environment and ECLSS but rely on the DSG for power, communication, GN&C, etc. Crewmembers, appropriately protected, would gain access to it for experiment change-out or data collection via a tunnel, perhaps an inflatable one, attached to the EVA airlock, which would be suitably configured to provide isolation by, for example, purging with sterile air after crew access.

The exact conops and design of the Biological Observatory would be a matter for studies and trades. The central idea, however, would be a module that supplements the capacity of the baseline DSG specifically to support biological specimens for long-duration exposure and robotic tending in the absence of crew. It would have the flexibility to accommodate a variety of experiments and both plant and animal specimens.

A Commercial Business Model: It is entirely feasible that the Biological Observatory could be provided on a commercial business model, with its space leased to NASA investigators. In the 1990s, SpaceHab pioneered a commercial research business model aboard its Shuttle-based research module. It not only offered locker volume with access to space, but also provided integration services and leased some equipment, for example protein crystal growth chambers. The same kind of business model could provide a Biological Observatory on DSG to minimize the need for NASA to invest in expensive facilities while its resources are committed to developing the exploration gateway.

Commercial logistics transport to ISS already has the ability to accommodate living specimens and return cargo intact; commercial crew transport will provide a human-compatible environment that could be used on the Biological Observatory. The DSG architecture anticipates the availability of commercial logistics transport. These vehicles, modified to accommodate experimental lockers and robotic tending, could minimize the commercial investment needed provide the Biological Observatory while providing companies a new revenue stream from previous investments.

Because of the technology risk, NASA may be required to provide the robotic tending or at least underwrite the development and validation of the technology. The commercial business model will provide the vendor with an incentive to transition NASA's technology to improve the capabilities of the module and to work on simplifying the integration timeline and documentation.

Conclusion: The needs of living specimens are sufficiently unique, and the opportunities for breakthrough life science research are sufficiently abundant that the baseline capabilities of the human-tended DSG will never meet them. Something like the Biological Observatory described here would be necessary to take full advantage of the deep space exposure opportunities that the DSG provides to life scientists.