Mobile/Modular BSL-4 Containment Facilities Integrated into a Curation Receiving Laboratory for Restricted Earth Return Missions

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NASA robotic sample return missions designated *Category V Restricted Earth Return* by the NASA Planetary Protection (PP) Office require sample containment and biohazard testing upon return to Earth. Since the 1960s, sample containment from an unknown extraterrestrial biohazard have been related to the highest containment standards and protocols known to modern science. Today, this is Biosafety Level (BSL) 4 containment. In the U.S., the *Biosafety in Microbiological and Biomedical Laboratories* publication authored by the U.S. Department of Health and Human Services (HHS): Public Health Service, Centers for Disease Control and Prevention, and the National Institutes of Health houses the primary recommendations, standards, and design requirements for all BSL labs. Past mission concept studies for constructing a NASA Curation Receiving Laboratory with an integrated BSL-4 quarantine and biohazard testing facility have been estimated in the hundreds of millions of dollars (USD). As an alternative option, we have conducted a trade study for constructing a mobile and/or modular sample containment laboratory that would meet all BSL-4 and planetary protection standards and protocols at a fraction of the cost. Mobile and modular BSL-2 and 3 facilities have been successfully constructed and deployed world-wide for government testing of pathogens and pharmaceutical production. Our study showed that a modular BSL-4 construction could result in ~ 90% cost reduction when compared to traditional BSL-4 construction methods without compromising the preservation of the samples or Earth. For the design/construction requirements of a mobile/modular BSL-4 containment, we used the established HHS document standards and protocols for manipulation of agents in Class III Biosafety Cabinets (BSC; i.e., negative pressure gloveboxes) that are currently followed in operational BSL-4 facilities in the U.S.

A mobile BSL-4 negative pressure ISO class 5 cleanroom containment facility could secure a sample return capsule at the landing site. After biocide decontamination procedures, the facility could be transported anywhere in the world by land, sea, or air. The mobile facility could attach to an existing BSL-4 laboratory that could be used to conduct biohazard analyses on a sample subset while the mobile lab could provide primary clean containment of the science samples awaiting biosafety results. A second usage scenario could attach the lab to a dedicated NASA receiving and curation facility that could conduct the primary containment and biohazard testing. Additionally, a third scenario could have the mobile facility remain at the landing site as primary containment and a small sample is transported to an existing BSL-4 facility for biohazard testing. After completion of biohazard testing, decisions could be made to sterilize the sample or transport all or portions to a brick and mortar quarantine storage facility.

A modular BSL-4 negative pressure ISO class 5 cleanroom sample receiving facility could be assembled into any shell building or high bay using the same construction methods as the mobile laboratory. The modular construction could use standard 40 ft (12.2 m) containers, assembled together to create a large lab space with Class III BSC glovebox chains. Manufacturing in a dedicated cleanroom can maintain better control of the engineering, fabrication, assembly, and integration of a facility. Testing and certification could also be conducted at the manufacturing cleanroom facility and then transported and assembled on-site. While a modular BSL-4 facility has never been built, several modular Animal BSL-3 facilities have been successfully constructed world-wide. With added system redundancies, these facilities could be reclassified as BSL-4 laboratories.

Currently, NASA PP Office classifies *Category V Restricted Earth Return* for robotic sample return missions from Mars, Europa, and Enceladus with the caveat that future proposed mission locations could be added or restrictions lifted on a case by case basis as scientific knowledge and understanding of biohazards progresses. This presentation focuses on the design of a mobile/modular BSL-4 Curation Receiving Facility that can meet all current PP and HHS standards and protocols, including redundant systems and critical biological containment/pressurization requirements for future restricted Earth return missions.