**Gateway Logistics Mission for Artemis IV:**

**Opportunity for a Keystone Biological and Physical Science Mission for Next Decade and Beyond**

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By

**Jamie S. Foster, Ph.D.**

Department of Microbiology and Cell Science

University of Florida

Space Life Sciences Lab, Merritt Island, FL, USA

Email: [jfoster@ufl.edu](mailto:jfoster@ufl.edu)

Co-authors (listed alphabetically)

Lynn Harrison, Ph.D., Molecular and Cellular Physiology, Louisiana State University; lynn.clary@lsuhs.edu

Douglas Matson, Ph.D., Mechanical Engineering, Tufts University

Douglas.Matson@tufts.edu

Rich Boling, Redwire Corporation

RBoling@techshot.com

Dave Reed, Redwire Corporation

DReed@techshot.com

Andrew C. Schuerger, Department of Plant Pathology, University of Florida

schuerg@ufl.edu

**Abstract**

Currently, NASA is developing the Artemis Program, a series of missions to return humans to the Moon that includes the Gateway Lunar orbiting platform. However, to make these missions more affordable, NASA has restricted the potential upmass to only include those materials needed for basic crew support, thereby limiting potential science outcomes and shortening mission timelines. As a result, these minimalist approaches are short-sighted and will not enable the capabilities and time needed to make ground-breaking scientific advances that would help render Artemis a sustainable, long-term program. In this paper, we describe the opportunity for a Gateway Logistics Mission to support the minimum needs for Artemis IV, and additionally, provide a significant amount of dedicated capability for science, thereby potentially creating a dedicated Biological and Physical Sciences (BPS) Mission to support foundational scientific research over the next decade.

**1. The Problem: Lack of BPS-Related Science Opportunities on the Early Artemis Missions**

With the current mission configurations and budgetary constraints, the opportunities for BPS-related science to be conducted on Artemis I - IV are minimal [1, 2]. Only a few kgs of upmass have been allocated for experiments aboard the Orion capsule for these initial flight opportunities, such as BioSentinel microfluidics cards for radiation exposure on yeast aboard the unmanned Artemis I. Additionally, on Artemis II, there will be opportunities for only a few experiments limited to the 6-unit and 12-unit CubeSats totaling only a few dozen kgs of science upmass. On Artemis III, with the focus on a lunar lander, there will also be mass limitations for scientific experimentation. Additionally, due to cost restrictions, a logistics mission may not be flown to the Gateway to support Artemis IV, forcing the focus of that mission to be limited, leaving a great deal of un-used upmass for cargo and supplies that could be dedicated to extending the mission duration and adding science and technology payloads for the crew to perform groundbreaking research in the unique environment of deep space [1, 3, 4]. With these upmass limitations on the Orion spacecraft *the opportunities for BPS-related science on* *the early Artemis missions* *are extremely limited over the upcoming decade*. Without significant scientific discoveries or advancements in technological capabilities to help justify the costs and capture the interest of the American people, the continuation and progression of a long-term Artemis Program for a sustainable human presence on the Moon is at risk.

**2. Unique Opportunity to Expand Artemis IV as a BPS-Focused Science Mission**

To address the limitations for BPS-related science on Artemis missions over the next decade, ***the current configuration of the Artemis IV mission could be modified to dedicate the majority of a logistics mission for Gateway to BPS-related science,*** thereby enabling thousands of additional kgs of additional upmass that would: 1) extended the crew timeline for visiting Gateway and, 2) deliver numerous hardware and utilization payloads ***for a dedicated BPS-related research mission.***

The Gateway logistics missions have high upmass capabilities (over 5,000 kg per mission) offered by its commercial provider, which combine cost-competitive delivery services with strong heritage systems, to deliver crew consumables and materials to maintain the spacecraft (e.g., Gateway, and the Human Landing System) with minimal level of mission risk. However, the full upmass capability of a logistics mission is not needed for Artemis IV, to perform the minimum operational objectives of the mission. Dedicating a significant portion of this excess capability to BPS-research will help level the priorities for Gateway utilization over the next decade [4]. The current order of priorities for the utilization of Gateway as a mechanism for science and technology demonstration include 1) science with Lunar regolith; 2) human-based research and 3) BPS-related science and technology [4]. BPS-research is not currently a high priority for Gateway utilization, but BPS-research will be needed to make critical contributions to extending and sustaining our human presence into deep space. Examples include plant systems for nutritional supplementation, microbial monitoring and control in deep space habitats, multiphase fluidic control and long-term maintenance of fluid systems, and unique materials development and selection for deep space systems. The lower priority for BPS-research risks the potential progress of the BPS program over the upcoming decade. Therefore, it will become imperative for the BPS program to have a more pivotal role in the early Gateway missions, to advance the fundamental and applied BPS science that’s also needed to advance NASA’s human exploration missions.

Despite Gateway’s potential for high upmass on the Artemis IV mission, a minimalistic approach has been taken by NASA to reduce costs, thereby only the enabling the most basic needs for the crew to install the new iHab module and prepare Gateway for an extended period of uncrewed operations until the next Artemis mission. Due to the lack of funding for a logistical supply mission to Gateway, the crew will be restricted to a period as short as a few days at Gateway and very minimal levels of science will be accomplished on the Artemis IV mission [1].

The anticipated utilization needed to achieve the current order of science priorities is likely more than triple of what has been currently allocated on the early Artemis missions. *Therefore, if SMD were to fund or co-fund a logistical supply mission for Artemis IV, it would represent an opportunity to extend the Artemis IV mission by at least a week and bring thousands of kgs of hardware and science experiments that would facilitate BPS-dedicated science and make this mission the foundational flagship mission for BPS for the decade for Beyond Low Earth Orbit (BLEO) studies.*

**3. Recommendations and Priorities to Create a BPS-Focused Science Mission**

**A. Dragon XL for Artemis IV -** The vehicle that could facility the additional upmass for Artemis IV is the Dragon XL by SpaceX, which is designed to have the capacity for more than 5000 kg of cargo [5]. Currently the Dragon XL is expected to be used as a logistical supply vehicle to support every Artemis mission, beginning on Artemis IV; but due to cost issues there does not appear to be support from HEOMD to begin the Gateway Logistics Services program until Artemis V [1]. Investment by SMD to potentially kick-off the Gateway Logistics Service program on Artemis IV and facilitate a Dragon XL delivery of supplies by midway through the upcoming decadal survey timeline would enable most of the added upmass to be dedicated to BPS-related science research. For example, with the publicly available schematics for Dragon XL, approximately 5000 kgs of cargo and payloads could be delivered as internal, pressurized, cargo or as external, unpressurized cargo. With 1000 kg of that additional upmass dedicated to crew consumables (e.g., food and air), two additional orbits (i.e., 13 days) of Gateway could be added extending the science mission. A smaller portion (~1000 kg) of that could be allocated to HEO for human-related research and the remaining 3000 kgs could be for BPS-dedicated hardware and science.

The current timeline for Artemis IV, estimated to be 2026-2027, would enable the BPS program to enact a robust experimental selection process and potential even enable ground-based studies and EVTs to be completed prior to a flight-based RFP for this BPS-dedicated mission.

**B. Plug and Play with Legacy Hardware -** To facilitate the potentially rapid timeline of a dedicated BPS-mission on Artemis IV, the use of legacy hardware on these one-way logistical support trips could be an efficient way to facilitate science readiness, as the hardware would not have to be re-qualified and would be flight-ready. The Gateway Logistics missions currently require compatibility with both, the legacy payload standards used by ISS, and the new payload standards that will be used by Gateway. Thus, legacy science hardware and payloads from numerous implementation partners (e.g., Techshot, BioServe, Nanoracks) would provide an immediate and valuable opportunity to fly the hardware and conduct experiments beyond the Low Earth Orbit (LEO) as we transition to Gateway standards for downstream Artemis missions. The use of legacy hardware would also enable direct comparisons between the same hardware flown in LEO aboard the ISS and serve as valuable controls for Gateway science experimentation (e.g., radiation impacts) This approach would also help solve the problem of what to do with legacy hardware post ISS and facilitate the proposed timeline of Artemis IV, set for approximately 2026-2027.

**C. Sample Return Pods for Artemis IV** - Additionally, this BPS-focused logistic mission could contain a sample return pod to potentially double the amount of materials being brought back to Earth by Orion. Previous and existing SMD missions have provided sample return from deep space (e.g., Stardust, Genesis, OSIRIS-REX). A BPS-focused sample return pod for Gateway could be attached to the outside of the logistic vehicle and contain enough samples (~100 kg) that could be approximately the size of one or two mid-deck lockers that could be ejected from the logistic vehicle once the tasks were completed and return those samples back to Earth. *SMD-BPS would have the opportunity to be the driver of sample return and get a high level of science in return for this investment.* Future return missions could use the sample return pods increasing overall science research capabilities.

**4. Impact of a BPS-focused Science Mission on Artemis IV on field of space sciences –** Currently, budget cuts to the Gateway Program may mean that logistic vehicles are not part of the Artemis mission program until Artemis V, and even the remaining planned Artemis missions (V – VIII) will have significant challenges meeting the human exploration goals and providing a significant science contribution to SMD-BPS program. However, if SMD was to negotiate and partner with HEOMD to share the costs of a Gateway Logistics Mission aboard Artemis IV, it could allocate a significant portion of the added upmass and additional crew hours for BPS-focused science initiatives. An SMD partnership with HEO and investment into a logistics vehicle for the Artemis IV mission plan would give *SMD the owning share of thousands of kgs of science and hundreds of hours of crew time*.

Gateway is designated for science and there are international commitments in place, therefore an SMD investment into a BPS-focused flagship mission could demonstrated the SMD commitment to Gateway and Lunar sciences. An investment by SMD into a Gateway logistics vehicle for Artemis IV, could drive science forward for the next decade of BPS research beyond LEO. International partner nations, already committed to Gateway, may also desire to collaborate with SMD to support international BPS-science on this mission, further bolstering the visibility and importance of this flagship mission for SMD.

Another positive impact of a dedicated BPS-science mission on Artemis IV is that it would enable the space research community to correlate BPS-research conducted on this proposed mission to previous, or concurrent research, being conducted in LEO. This proposed mission would enable the leveraging of all the available platforms to have a large science footprint on the BPS space research program for the coming decade and beyond.

**5. Estimated Costs**

Costs associated with a Gateway logistic supply mission with Artemis IV would be estimated to be in the $500 million range as it would be the first logistical vehicle for the Artemis program. *Those costs should be shared with HEO* with the expectation that Artemis will benefit considerably from the extended mission and that some of the upmass will be devoted to supporting the crew and Gateway. Furthermore, the following logistics missions (Artemis V and beyond) would be expected to cost less (~$300 million) because they would not require additional design and development, therefore, the Gateway and Artemis Programs would also gain the benefit of sharing the higher cost of the initial mission with SMD.

If Artemis IV flew in 2026 – 2027 that would enable BPS program to have a selection process that could include one or two years of ground-based testing to prepare for science and equipment verification testing as well as the flight.

**6. Concluding statement –** For the Artemis program to be a continued success, NASA’s human exploration goals must extend beyond just landing crew on the Moon and returning them safely to Earth. Clear science and technological advancements must be made that have tangible and relevant connections to the American people. Therefore, optimization of the full capacity of the Artemis program, which includes extended science missions on Gateway are needed. The additional upmass a logistical vehicle on Artemis IV and expansion of sample return capabilities could provide the critical groundbreaking scientific discoveries to perpetuate the Artemis program as a critical learning program to support future missions to Cislunar space and beyond.

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