# HRP and SLPSRA Lunar Gateway Utilization

National Aeronautics and Space Administration

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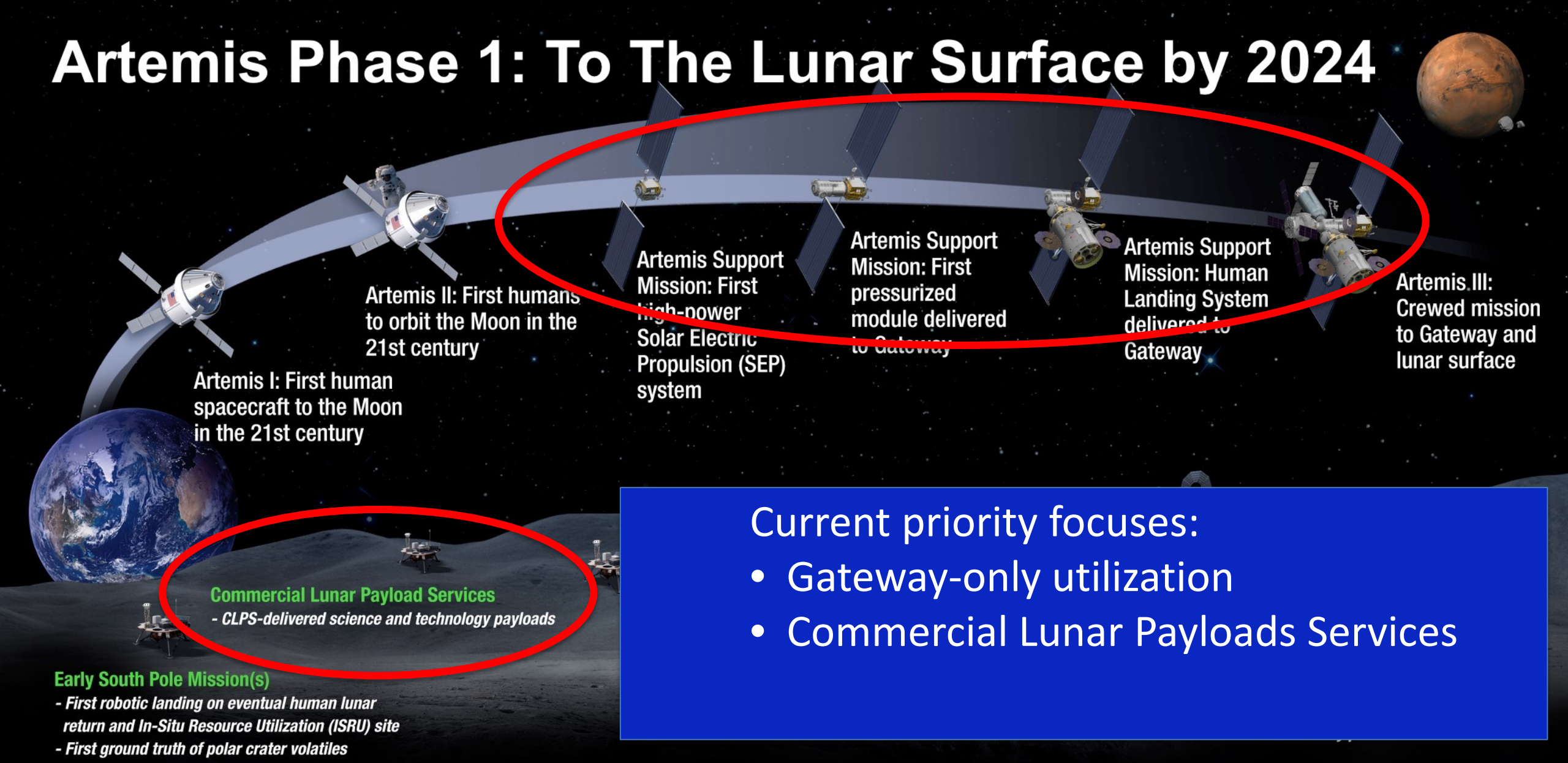
# Artemis Phase 1: To The Lunar Surface by 2024



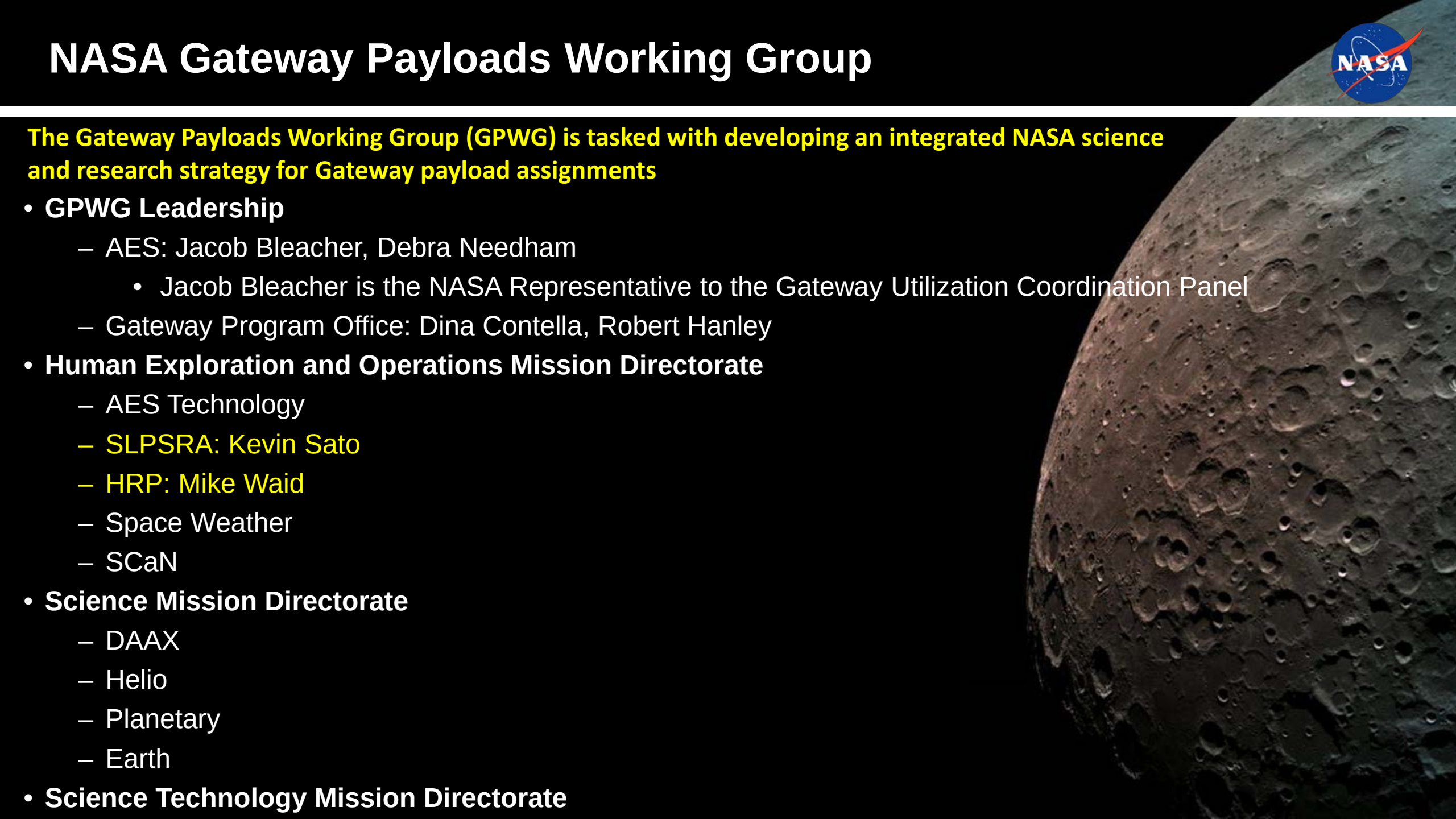

Current priority focuses:

- Gateway-only utilization
- Commercial Lunar Payloads Services

**LUNAR SOUTH POLE TARGET SITE**

2020 2024

# NASA Gateway Payloads Working Group



**The Gateway Payloads Working Group (GPWG) is tasked with developing an integrated NASA science and research strategy for Gateway payload assignments**

- **GPWG Leadership**
  - AES: Jacob Bleacher, Debra Needham
    - Jacob Bleacher is the NASA Representative to the Gateway Utilization Coordination Panel
  - Gateway Program Office: Dina Contella, Robert Hanley
- **Human Exploration and Operations Mission Directorate**
  - AES Technology
  - SLPSRA: Kevin Sato
  - HRP: Mike Waid
  - Space Weather
  - SCaN
- **Science Mission Directorate**
  - DAAX
  - Helio
  - Planetary
  - Earth
- **Science Technology Mission Directorate**

# HRP/HHP Human System Candidate Test Objectives

HSRB Approved List 10/2018

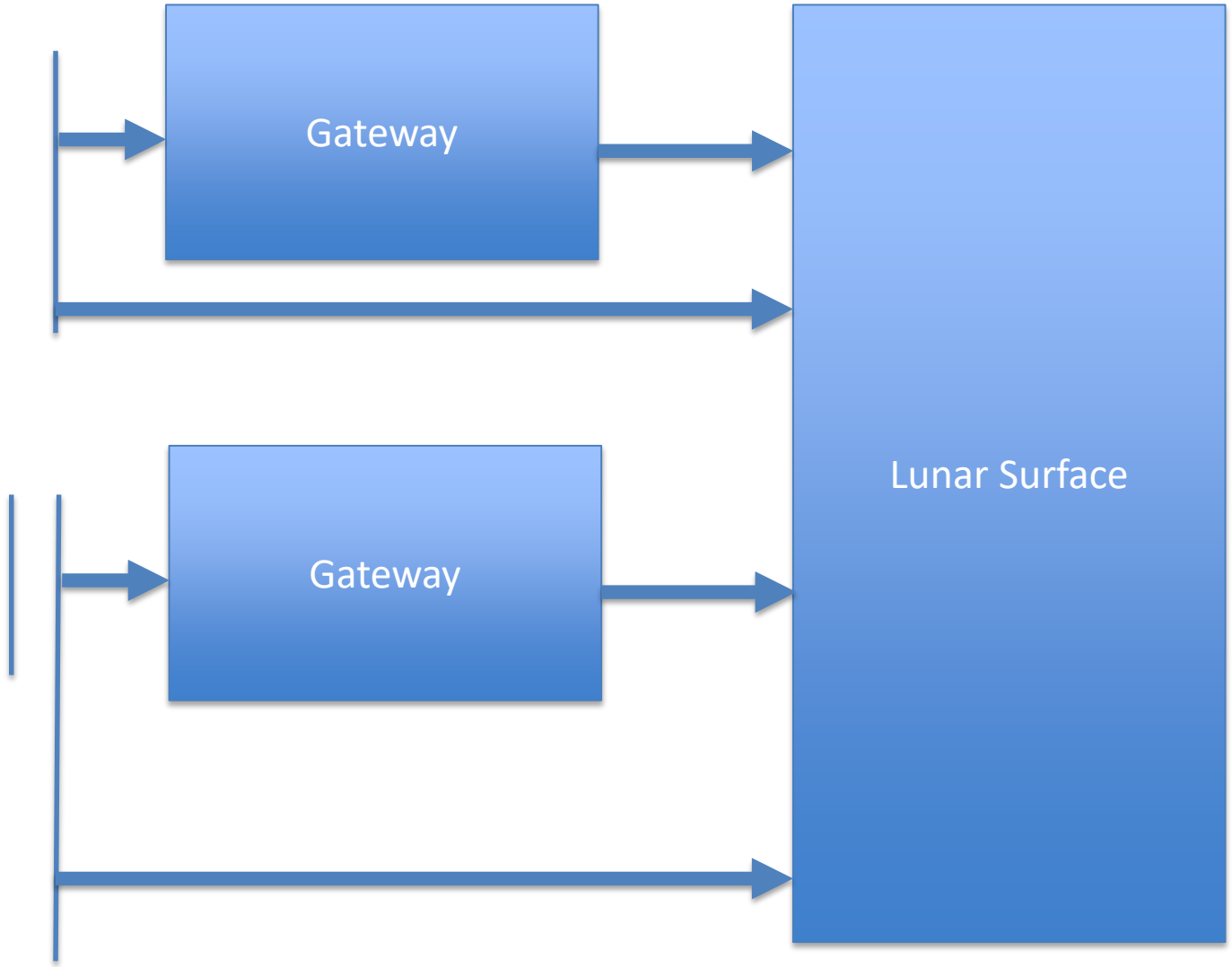
| CTO # | CTO Title |
|---|---|
| HS-01 | Validate the execution of progressively Earth-independent nominal medical and behavioral health operations |
| HS-02 | Validate the execution of progressively Earth-independent simulated contingency medical and behavioral health operations |
| HS-03 | Validate the capability to provide a safe and effective pharmacy for progressively Earth-independent operations |
| HS-04 | Validate the capability to monitor, prevent, and treat behavioral health outcomes asynchronously (time-delay) during progressively Earth-independent operations |
| HS-05 | Validate the capability to store, process, and analyze in-situ biological samples to facilitate progressively Earth-independent crew health and performance operations |
| HS-06 | Validate the capabilities required for providing physiological countermeasures to maintain crew health and for monitoring countermeasure efficacy |
| HS-07 | Validate the capability to deliver a food system adequate for crew health and performance in support of progressively Earth-independent operations |
| HS-08 | Validate crew interfaces with the habitat and related systems for adequate crew health and performance during progressively Earth-independent operations |
| HS-09 | Validate the capability to provide and maintain a crew habitable environment and the capability to monitor its quality via in-situ analysis throughout progressively Earth-independent operations |
| HS-10 | Validate SPE radiation protection capabilities |
| HS-11 | Validate autonomous space weather monitoring and early warning capabilities for progressively Earth-independent operations |
| HS-12 | Validate deep space radiation protection plans to mitigate the effects on crew health and performance |
| HS-13 | Validate crew training proficiency across multiple performance domains for progressively Earth-independent operations |
| HS-14 | Validate the ability for crew to operate robotic agents remotely with varying levels of time-delay and Earth-independence |
| HS-15 | Validate the adequacy of progressively Earth-independent crew problem-solving and decision-support information systems |
| HS-16 | Validate the efficiency and effectiveness of methods and processes for flight crew to maintain and repair systems in support of progressively Earth-independent operations |
| HS-17 | Validate the efficiency and effectiveness of multimodal crew/system interactions, communication, and alerting |
| HS-18 | Validate the integration of spaceflight data with crew health and performance systems for progressively Earth-independent operations |
| HS-19 | Evaluate and validate the effects of an Exploration Atmosphere (8.2psia/34% O2) on crew health and performance |
| HS-20 | Evaluate and validate operational implementation of the Exploration Atmosphere EVA prebreathe protocol, procedures, and human factors |
| HS-21 | Evaluate and validate intermittent G exposure countermeasures, via centrifugation of humans during extended periods of weightlessness |
| HS-22 | Evaluate the impact of systems design on crew performance and trainability |
| HS-23 | Evaluate unobtrusive methods for measuring human performance |
| HS-24 | Evaluate the synergistic biological impacts of the deep space environment and countermeasures on health and performance in order to validate predictive models |
| HS-25 | Evaluate the effects of the deep space environment on food-related microbes and plants for crew health and performance |
| HS-26 | Evaluate the effects of refrigeration and freezing stowage on food and nutrition over long durations in the deep space environment |
| HS-27 | Evaluate the effects of ambient stowage on food and nutrition over long durations in the deep space environment |

# Gateway Phase 1
# HRP Payloads Summary

| Payload | Function |
|---|---|
| Cargo Transfer Bag Science | Expose pharmaceutical formularies to the deep space spaceflight (or vehicle) environment [radiation, CO2, etc.] to evaluate degradation and toxicity over time |
| Use existing Gateway systems/ops | Unobtrusively measure crew operational performance tasks in deep space |
| Use existing Gateway systems/ops | Unobtrusively measure team-task performance in deep space: Gateway crew interactions with Lunar lander party |
| Wearable device (e.g. watch) | Unobtrusively monitor sleep-wake patterns, activity levels, and circadian rhythms in deep space environment and on lunar surface. |
| Pocket-size Notebooks | Collect, preserve, and return saliva dry book samples to enable biomedical Immune Science in deep space |
| Optical Coherence Tomography device | Evaluate retina using Optical Coherence Tomography (OCT) in deep space environment<br>(Proposed but not currently planned at this time) |

# Original Comprehensive Utilization Concept

- **Disciplines and Science Elements**
  - **Space Biology**
    - Microbiology
    - Cell biology
    - Plant biology
    - Animal biology
    - Developmental, Reproductive and Evolutionary Biology
  - **Physical Sciences**
    - Materials
    - Fundamental Physics
    - Fluid physics
    - Complex fluids
    - Combustion
    - Materials
    - Biophysics



# Gateway Phase 1 Biological Science Utilization

1) **Deep Space Research Platform**
   - **Possible lunar environment analog**

2) **Mars Transit and Orbit Analog**

(Science locations and utilization are expected to expand during later phases, given resource and capability expansions)

**Science**

a) Microbiology
b) MoBE
c) Seed Dormancy
d) Small invertebrates

**Utilization Timeframe**

a) Crew presence
b) Gateway dormant

**Key Enabling Science Return**

- Crew health and safety
- Characterize microbial response, acclimation, and adaption to the deep spaceflight environment
- Characterize MoBE function and behavior under optimal and sub-optimal growth conditions during Gateway occupancy and dormant period environments
  - Risk evaluation
  - Countermeasures
  - Effectiveness of environment manipulation and cleaning to control microbial growth
  - Biocorrosion and biofouling
- Comparative microbial study between Gateway and ISS data

# Gateway Phase 1
# SLPSRA Early Science

| Science Topic | Study |
|---|---|
| Radiation Environment Characterization (External and Internal) | Characterization of the Cis-Lunar radiation environment inside and outside of the Gateway. Phase 1 Utilization requires ability to downlink the collected data. PPE – external placement; External + internal to the mini-Hab, logistics module, and HLS. |
| Atmospheric/ Environment Characterization | Characterize environment of Gateway Elements, including the mini-Hab, Logistics Module, and HLS: $CO_2$, $O_2$, and $N_2$ gas levels, atmospheric pressure, temperature, vibration, acoustics, humidity; Internal to mini-Hab, logistics module, and HLS. |
| Seed Biology and Viability | Study the viable life span of dry seeds over a long duration in the Cis-Lunar radiation environment under ambient conditions. Conduct fundamental biological studies to understand if and how the deep space environment affects seed viability. Sample return required. |
| Microbial and Invertebrate Biology in Deep Space | Study how microbes and invertebrates adapt to the deep space environment, by analyzing microbial stasis, radiation and general deep space environment effects on stasis and vegetative growth, etc. Can be auto-activated to avoid need for sample return, otherwise sample return required. |
| Microbiology of the Built Environment | Sample collection from surfaces of the Gateway, Logistics Module, and HLS to study the development and dynamics of the microbiome on the Gateway elements. Cold stowage is nice; Sample return required. |
| Microbial Interactions with Materials | Characterize the interaction of microbes (bacterial and fungal) with material coupons of Gateway element building materials and candidate materials for lunar sustainability equipment and habitats. Sample return required. Thermal control required. |

# Gateway Exposure Facility

## External Exposure Platform – ESA

- SLPSRA is investigating the utilization of this platform
  - Space Biology – possible partnership with SMD
    - Based on ISS MISSE studies
  - Physical Sciences - Materials
    - Based on ISS MISSE studies

# Cross-platform Strategy for Exploration-related Biological Sciences


EARTH


ISS


GATEWAY


LUNAR SURFACE


MARS DRM


Crop Production

Research and develop crop system

Research and develop technology for microgravity crop production and reliability for mars transit

Deep space seed viability

Validate mars transit crop system

> 1 Year, Dormancy robotic crop system

Transit and Surface robotic cropping system


Microbiome

Microbiome of the Built Environment (MoBE) under continuous occupancy/turnover

In-situ monitoring technology

MoBE deep space radiation and intermittent occupancy

Lunar surface MoBE

Planetary spread of Earth-origin microbes

MoBE under long duration occupancy without turnover

Planetary Protection applications and surveillance

# Cross-platform Strategy for Exploration-related Biological Sciences

EARTH

ISS

GATEWAY

LUNAR SURFACE

MARS DRM

**Partial Gravity Effects on Organisms**

Hyper-gravity and partial gravity simulations (rodents, invertebrates, microbiology)

→ Centrifuge studies (rodents, invertebrates, nematodes, plants, microbiology, cell biology)

→ *Operational and Resource Challenges*

*TBD: Validation of 1/6 G predicting 3/8 G impacts and radiation/partial gravity interaction*

→ 3/8 G physiology understood before mission

Enabling measurements and samples:

- Radiation monitoring
- Atmosphere (gases and VOCs)
- Environmental monitoring (including vibration and acoustics)

# Example Research Areas for the Lunar Surface

- **Environmental factors and areas of interest**
  - Reduced gravity (1/6-*g*)
    - Flammability, fire safety
    - Two phase flow (pool and flow boiling, packed bed reactors, cryogenic fuel storage and transfer)
    - Soldering, brazing, welding
    - Food crop production
    - Bone loss, muscle loss, cardiovascular deconditioning
  - Deep space radiation & neutron albedo
    - Radiation effects on microbes, plants, crew
  - Lunar regolith and dust
    - Granular materials processing
    - In-situ surface construction, cement/concrete production
    - Metal and/or $O_2$ extraction from regolith
    - Dust mitigation
  - Unattenuated solar spectrum and plant growth
  - Closed habitat ($pCO_2$, $pH_2O$, T, infrequent influx of crew and materials)
    - Microbiome of humans, plants, vehicle
    - Biofilm production, biocorrosion
    - Behavioral health