National Aeronautics and Space Administration

NASA Moon to Mars Updates and Division Space Labs Goal

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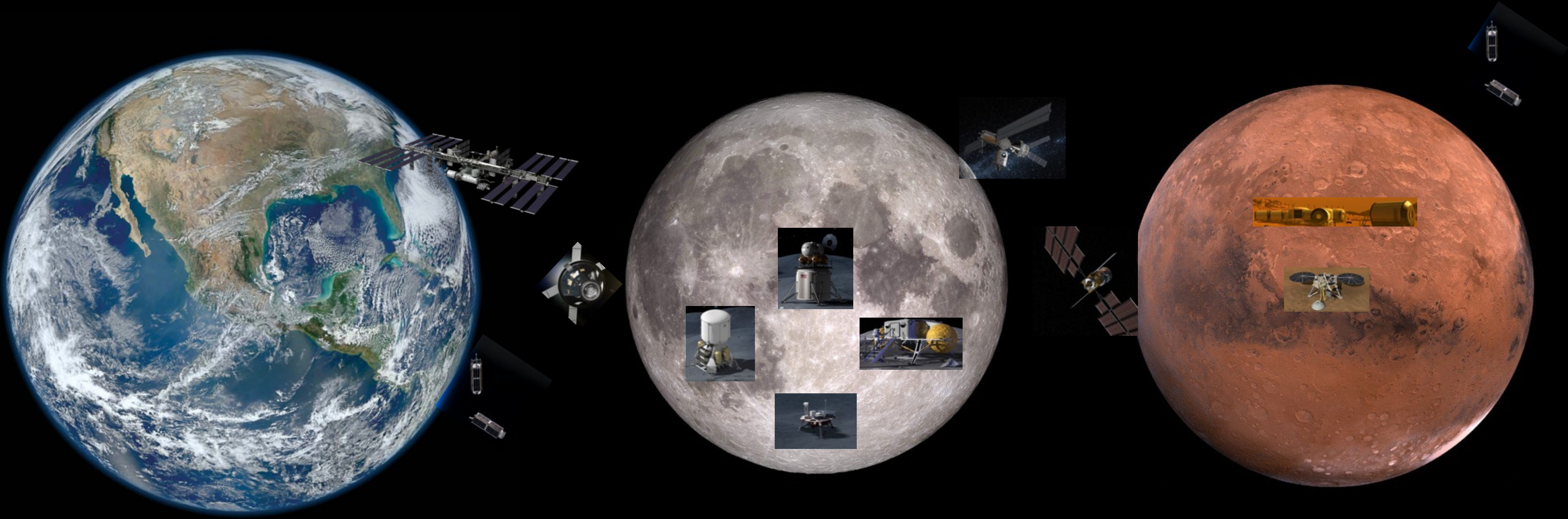
NASA Headquarters | Washington, DC

Oct. 9, 2024 | Committee on Biological & Physical Sciences in Space

BIOLOGICAL AND PHYSICAL SCIENCES
ADVANCING THE FRONTIERS OF SPACE EXPLORATION



Earth-based and LEO research and technology to advance lunar exploration and habitats development

Lunar research and technology to advance Mars exploration and habitat development

Opportunities

Lunar Surface Science Solicitation:
Released by NASA SMD Exploration Science Strategy and Integration Office
All solicitations include funding for the science, instruments, and project management by the proposal team

1) **F.13 Lunar Terrain Vehicle Instruments**
    1) $44 million – at least 2 proposals will be selected
    2) South Pole; delivered to the Moon before the launch of Artemis V
    3) U.S-led and Foreign-led proposals eligible
    4) Currently in Step-1 proposal phase – Due Oct. 23, 2024
    5) Step-2 proposals due Dec. 23, 2024

2) **F.12 Artemis IV Deployed Instruments Program**
    1) $25 Million – at least 1 proposal selected (or more if the total cost does not exceed the total maximum funding of the program
    2) Draft solicitation released for community comments – Due Oct. 15, 2024
    3) South Pole – for lunar surface only
    4) U.S.-led and Foreign-led proposals eligible
    5) Selectin candidate payloads for Artemis IV payload manifest

3) **PRISM Stand Alone Landing Site Agnostic Instruments Call (Commercial Lunar Payload Services) 2024**

Opportunities

Lunar Surface Science Solicitation:

In planning:

- **PRISM 4 solicitation**
- **A4 Hand-Held Instruments RFP**
- **NASA Planetary Sciences Division Solar System Exploration Virtual Research Institute Cooperative Agreement 5**
  - Large science teams
  - Multi-year ground-only research investigations
  - Draft late fall 2024

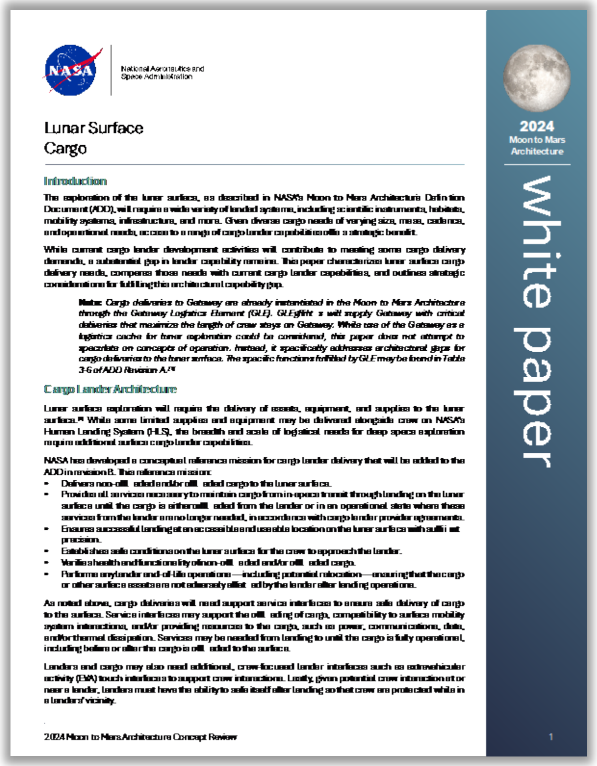
Lunar Exploration Analysis Group (LEAG) Executive Committee Search

- **LEAG announced call for Executive Committee positions for**
  - Community Liaison, Biological and Physical Sciences
  - Note: These liaisons are not representatives for the NASA SMD Divisions but are representative of the community itself
- **Closed September 30, 2024**

National Academy of Sciences Special Study on Human Exploration of Mars

- Requested by the NASA Science Mission Directorate and Exploration Systems Development Mission Directorate

New White Papers



National Aeronautics and Space Administration

2024 Moon to Mars Architecture

white paper

Lunar Surface Cargo

Introduction

Cargo Lander Architecture

2024 Moon to Mars Architecture Concept Review

Lunar Surface Cargo

This paper characterizes lunar surface cargo delivery needs, comparing them with current cargo lander capabilities, and outlining strategic considerations for filling capability gaps.

Lunar Mobility Drivers and Needs

This paper outlines current lunar mobility capabilities expressed in the Moon to Mars Architecture and characterizes gaps where future demand for mobility services exist.

National Aeronautics and Space Administration

2024 Moon to Mars Architecture

white paper

Lunar Mobility Drivers and Needs

Introduction

Mobility Needs

2024 Moon to Mars Architecture Concept Review

Read the White Papers Here:
https://www.nasa.gov/moontomarsarchitecture-whitepapers/

Architecture Workshops

2024 Industry and Academia Workshop
National Academy of Sciences

2024 International Partner Workshop
National Academy of Sciences

Yearly Architecture Workshops

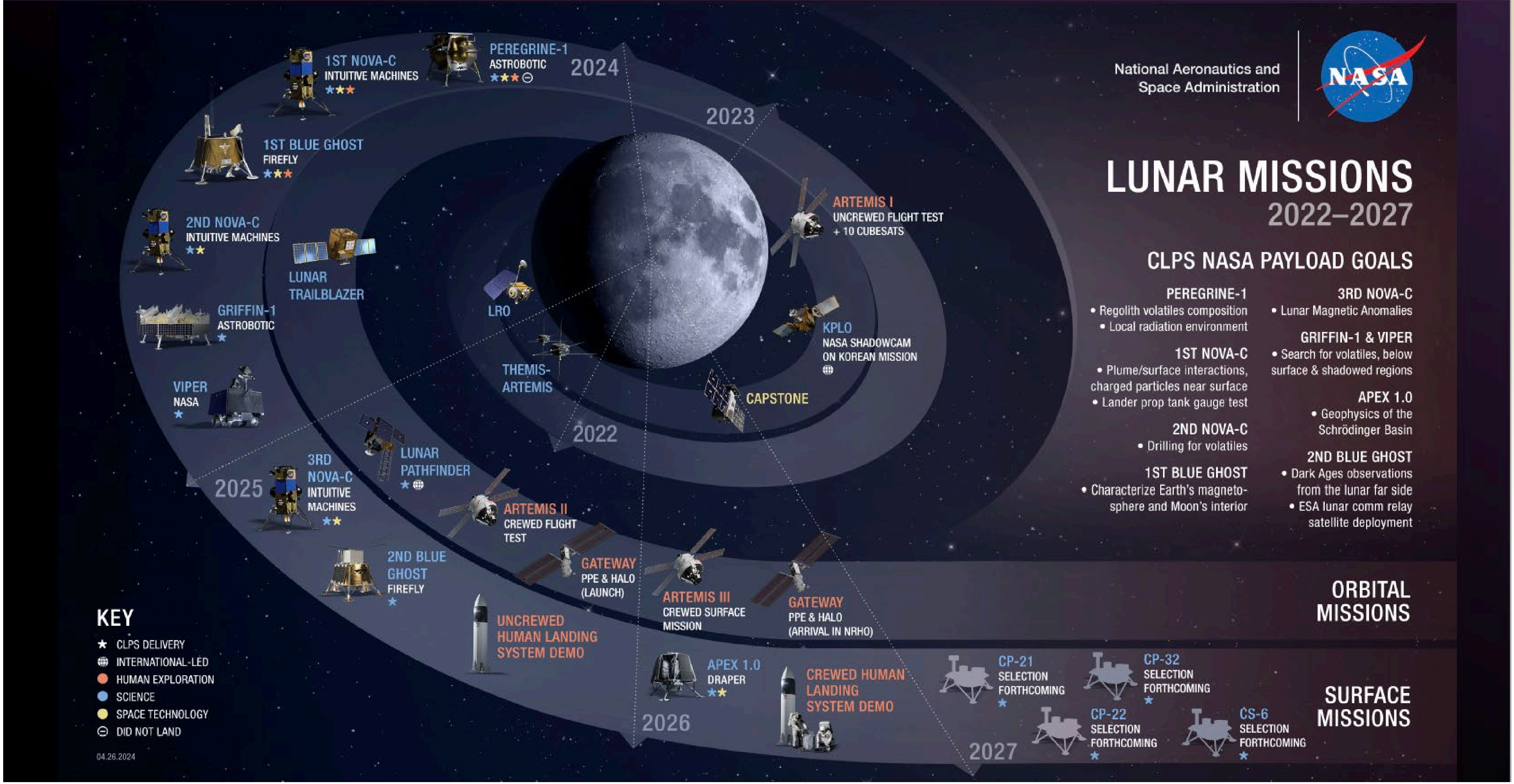
2025 workshops tentatively scheduled for February 11 to 13 in Washington, D.C.

https://socialforms.nasa.gov/Architecture-Updates

Subscribe to Updates

Lunar Discovery and Exploration Program (LDEP) Update

July 10, 2024 10

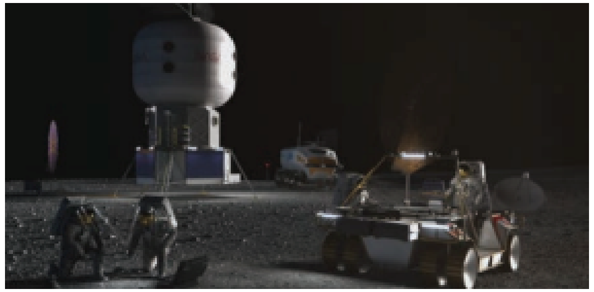


ARCHITECTURE SEGMENTS

HUMAN LUNAR RETURN

Initial capabilities, systems, and operations necessary to re-establish human presence and initial utilization (e.g., science) on and around the Moon.

Orion, SLS, EGS, Gateway, HLS, Deep Space Logistics, xEVAS, CPNT



FOUNDATIONAL EXPLORATION

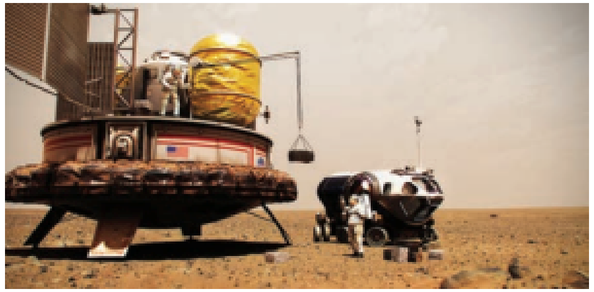
Expansion of lunar capabilities, systems, and operations supporting complex orbital and surface missions to conduct utilization (e.g., science) and Mars-forward precursor missions.

LTV, PR, MPH, Large Cargo

SUSTAINED LUNAR EVOLUTION

Enabling capabilities, systems, and operations to support regional and global utilization (e.g., science), economic opportunity, and a steady cadence of human presence on and around the Moon.

Power, ISRU, Expanded mobility/habitation,



HUMANS TO MARS

Initial capabilities, systems, and operations necessary to establish human presence and initial utilization (e.g., science) on Mars and continued exploration.

Transportation, EDL, Ascent, Science Ops, Return needs

FY 2025 President's Budget Request Moon to Mars Manifest

FY	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Exploration Systems Development Mission Directorate			**Artemis II** (Sep. 2025) Crewed Flight SLS Block 1/ Orion/ML1	**Artemis III** (Sep. 2026) Crewed Flight SLS Block 1/ Orion/ML1 HLS Crewed Lunar Demo xEVA Surface Suits *HLS Uncrewed Lunar Demo* *Gateway PPE/HALO Launch*	*Gateway PPE/HALO Arrival in NRHO*	**Artemis IV** (Sep. 2028) Crewed Flight SLS Block 1B/ Orion/ML2 I-Hab to Gateway Gateway Logistics Services Sustaining HLS Crewed Lunar Demo xEVA Surface Suits *Sustaining HLS Uncrewed Lunar Demo*		**Artemis V** (Mar. 2030) Crewed Flight SLS Block 1B/ Orion/ML2 ESPRIT to Gateway Sustaining HLS Crewed Lunar Demo xEVA Surface Suits LTV	**Artemis VI** (Mar. 2031) Crewed Flight SLS Block 1B/ Orion/ML2 Airlock to Gateway Gateway Logistics Services Gateway External Robotics System TBD Sustaining HLS Services xEVA Surface Suits	**Artemis VII** (Mar. 2032) Crewed Flight SLS Block 1B/ Orion/ML2 Gateway Operations TBD Sustaining HLS Services xEVA Surface Suits Pressurized Rover
Space Operations Mission Directorate	DSN Upgrades (DLEU) Completed DSS-36 [Canberra]	Completed DSS-24 [Goldstone]	DSS-34 [Canberra] DSS-56 [Madrid]		Lunar Communications Relay and Navigation Services (LCRNS)–Increment Increment Alpha	Lunar Exploration Ground Sites 1-3 DSS-54 [Madrid] Increment Bravo	Increment Charlie	Ongoing Science, Human Research Program, and Technology Development in LEO (ISS transition to CLD)		
Science Mission Directorate CLPS Flights Outlined	LRO Mars 2020:	ESCAPADE Attempted: TO 2-AB Completed: TO 2-IM TO 19D	TO 20A: VIPER HERMES ready for integration ESA Lunar Pathfinder delivered for launch AVATAR (Artemis II) TO PRIME-1 Lunar Trailblazer TO CP-11	Artemis III Surface Science Instruments MMX (MEGANE/ P-Sampler) TO CS-3&4 TO CP-12	LRO continued ops TO CS-06 TO CP-21 TO CP-22	Artemis IV Surface Science Instruments TO CS-6 TO CP-31	Rosalind Franklin Mission (RFM) Launch, Landing TO CP-41 TO CP-42 TO CP-51 TO CP-52 TO CP-61 TO CP-62	Artemis V Surface Science Instruments Artemis LTV Science Instruments	Artemis VI Surface Science Instruments	Artemis VII Surface Science Instruments
Space Technology Mission Directorate	MOXIE; MEDA DSOC	CFM SpaceX TP Flight Demo	Surface Robotic Scouts (CADRE) TO PRIME-1: Drill; Nokia LTE/4G Comm; IM Deployable Hopper CFM ULA TP Flight Demo PPE SEP qual. environ. complete CFM Eta Space TP Flight Demo	CFM Lockheed Martin TP Flight Demo NEP Concept Design	DRACO Demonstration	TO LIFT-1: Lunar Surface Power Demo (i.e., RFC, VSAT, Wireless Charging); Lunar Surface Scaled Construction Demo 1; ISRU Pilot Excavator; ISRU Subscale Demo	SEP qual. complete			Fission Surface Power demo delivered for launch TO LIFT-2: Lunar Surface Scaled Construction Demo 2; Autonomous Robotics Demo; Deployable Hopper 2; ISRU Subscale Demo 2

Icons are representative only, and may not reflect final configurations, not to scale | Icons represent the fiscal year in which an event occurs | Based on FY 2025 President's budget request

Flammability of Materials on the Moon (FM^2)

- Lunar surface ground truth of materials flammability data from drop tower-based partial gravity studies that also used the exploration atmospheric environment conditions

- Obtain new flammability data on different materials

SpaceX Starship Uncrewed Demonstration

Artemis III Science

- NASA has chosen the first science instruments designed for astronauts to deploy on the surface of the Moon
- Once installed near the lunar South Pole, the three instruments will collect valuable scientific data about the lunar environment, the lunar interior, and how to sustain a long-duration human presence on the Moon
- Lessons learned from these experiments will help prepare NASA to send astronauts to Mars

LEMS **Lunar Environment Monitoring Station**

LEAF **Lunar Effects on Agricultural Flora**

LDA **Lunar Dielectric Analyzer**

LEAF

Lunar Effects on Agricultural Flora

Summary: LEAF will apply system biology and engineering to investigate the effects of the lunar surface environment on the short-term organism-wide physiological responses of model space crops.

Science Goals:

- Grow resilient model space-crops in lunar & Earth environments
- Compare crop phenotypes in lunar and Earth environments:
  1. Seed germination & clonal reproduction rates
  2. Crop morphology (size, orientation, and color) and growth
  3. CO_2 consumption and O_2 production
- Identify genome-wide biomolecular deviations in lunar grown crops
- Define future science hypotheses regarding crop potential for life support via photosynthetic gas exchange & nutrient production

PI: Christine Escobar, Space Lab Technologies LLC

Co-Sponsorship between ESSIO and Division

Where are we going?

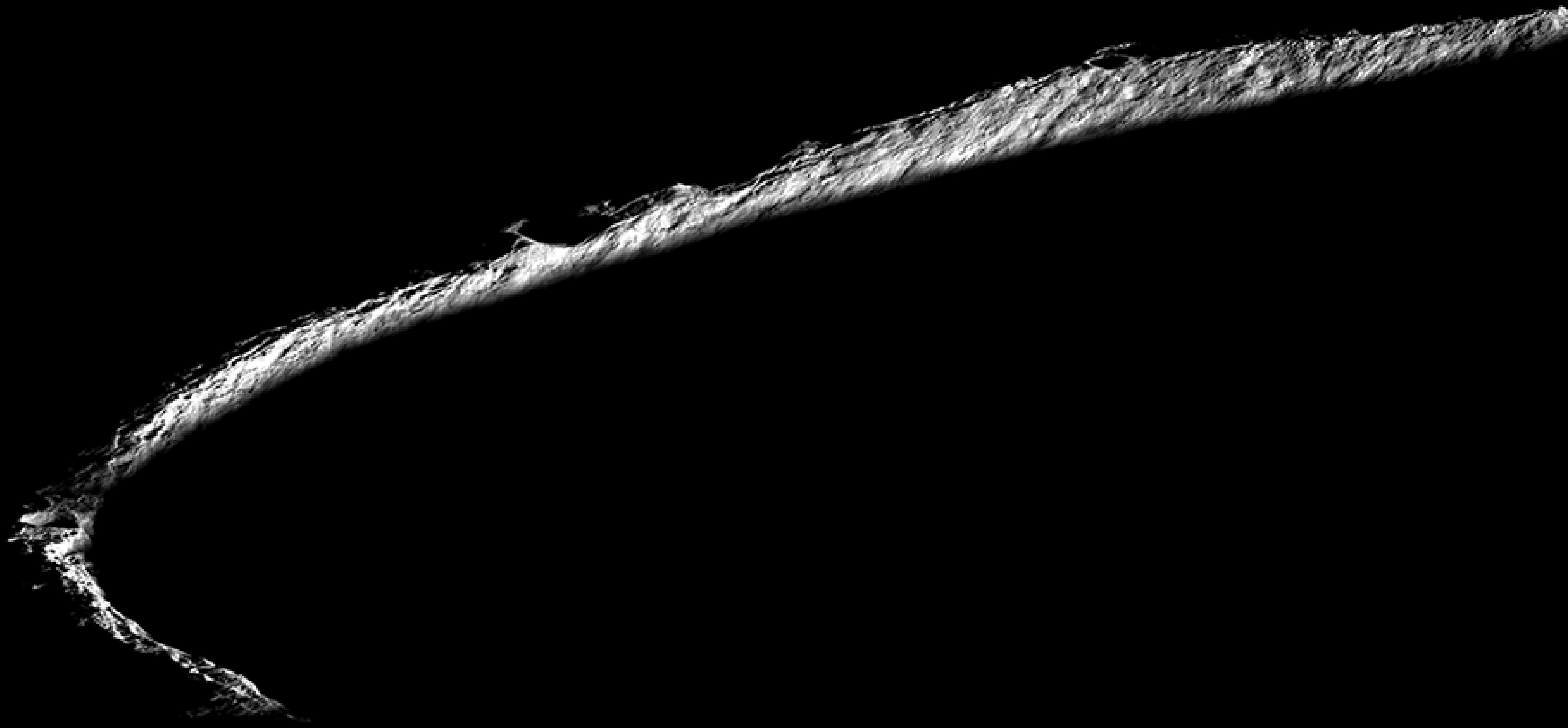


Image Credit: NASA/ASU

National Aeronautics and
Space Administration

NASA Division Space Labs Goals Update

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Oct. 2024 | Committee on Biological & Physical Sciences in Space

Space Labs Overview

Space Labs Goal Overview

- **Goal Focus:** Spaceflight strategy and tactical implementation, and flight opportunities for Biological and Physical Sciences () Program Science

- Based on and incorporates all Goal roadmap capabilities & needs as well as Science Program objectives & priorities
  - **Goals:** Space Crops, Precision Health, Quantum Leaps, Foundations
  - **Programs:** Space Biology, Physical Sciences, Fundamental Physics, and Commercially Enabled RapId Space Science (CERISS)

- Incorporates the National Academies 2023-2032 Decadal Survey Report for biological and physical sciences research recommendations and findings

Thriving in Space

Revolutionary research in extraordinary places.

Precision Health

Leveraging space to unlock the secrets of aging and disease

Space Crops

Boldly growing where no one has grown before

Quantum Leaps

Unraveling mysteries of the universe

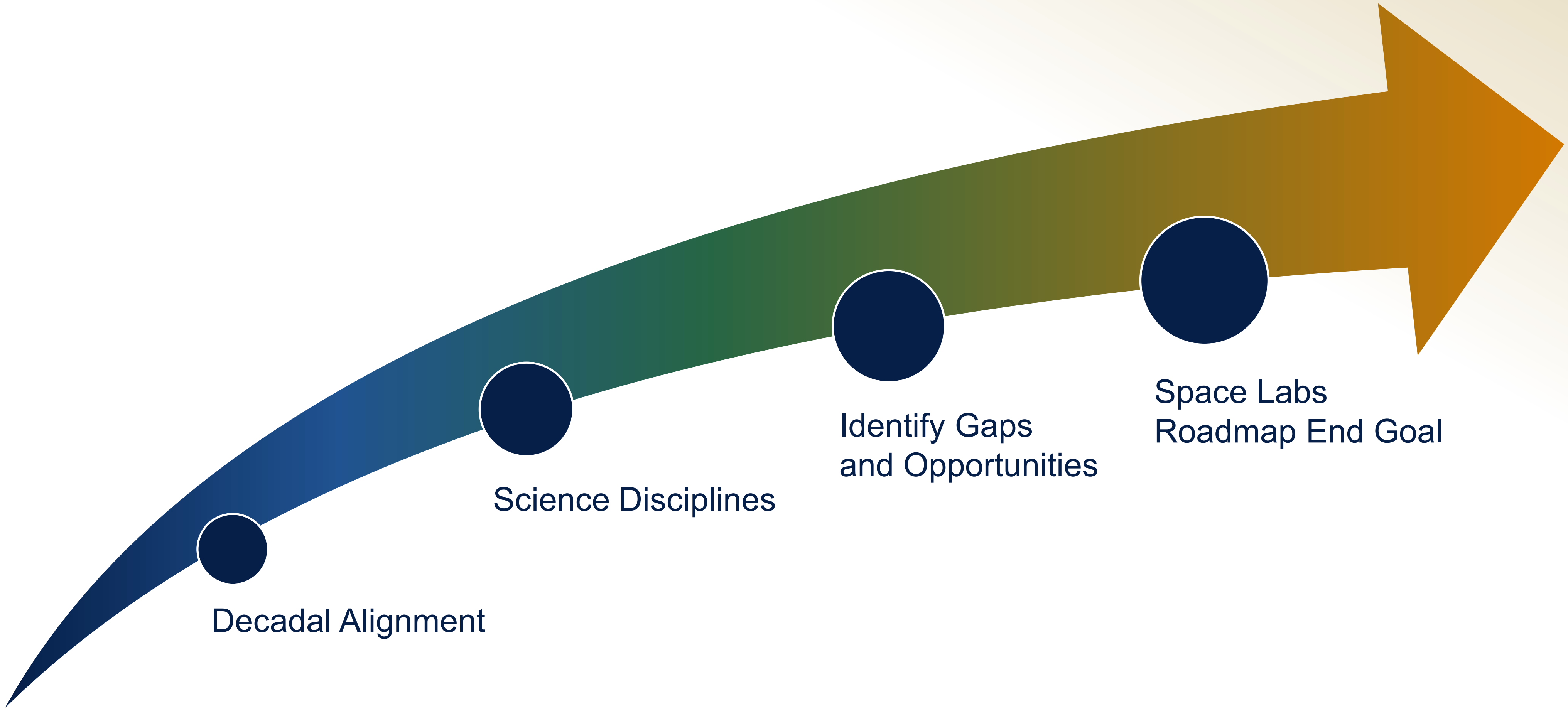
Foundations

Revealing the novel behaviors of fluids, fire, and materials in space

Space Labs

Accelerating the pace and productivity of research

Goal Overview: Space Labs



Decadal Alignment: Space Labs

Traceable to and aligns with the Decadal Survey Report recommendations, findings, and Key Science Questions (KSQ)

Adapting to Space

- Transition to/from space
- Genetic diversity & life history
- Interactions between organisms

Living and Traveling in Space

- Multigenerational effects
- Integration of biological & abiotic systems
- *In situ* utilization
- Behavior of fluids in space

Probing Phenomena Hidden by Gravity or Terrestrial Limitations

- Mechanisms for sensing & responding
- Structure & functionality of materials
- Systems far from equilibrium
- New physics

Research Campaigns:

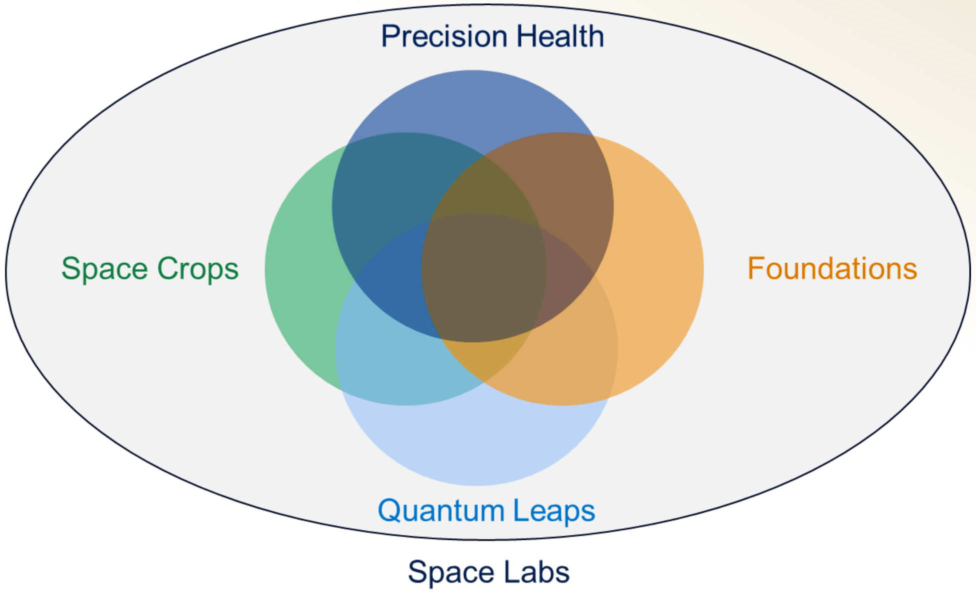
- BLiSS (Bioregenerative Life Support Systems)
- MATRICES (Manufacturing mATeRials & proCEsses for Sustainability in Space)
- PFaST (Probing the Fabric of Space Time)

Note: For beyond low Earth Orbit studies, aligns to the Moon to Mars Strategy and Objectives document and Architecture Definition Document, as well as other community-based objectives and roadmap documents (e.g. Lunar Exploration Analysis Working Group Roadmap and Artemis III Science Definition Team Report)

Science Disciplines: Space Labs

- Incorporates and executes all of the Goals' roadmaps, capabilities/needs, objectives and priorities:

  - **Goals:**
    - Precision Health
    - Space Crops
    - Quantum Leaps
    - Foundations



Identifying Gaps & Opportunities: Space Labs

- What are all known, future, and desired spaceflight platforms and extra-terrestrial surface facilities?
- What and where are the destinations to conduct and address science research?
- What enabling capabilities and needs are necessary to conduct the scientific investigations in space for each Goal? How do we conduct experiments as we've done on ISS and in Earth research labs?
  - Science technology considerations: examples- miniaturization, multiple-use, *in situ analysis,* sample processing, capabilities for crew ops and science experiment continuity, sample and hardware return, cross-platform standardization, experiment iterations in same and multiple platform locations, etc.
  - Lunar surface and Gateway facilities
  - Low Earth orbit facilities (ISS, CLD, free-flyers, suborbital)
  - Deep space facilities
  - CERISS initiative capabilities
- How do each of the Goal roadmaps for spaceflight research map or align to NASA timelines and roadmaps for spaceflight and exploration?
- What partnerships can we leverage?

BPS Landscape Highlights: Suborbital, LEO

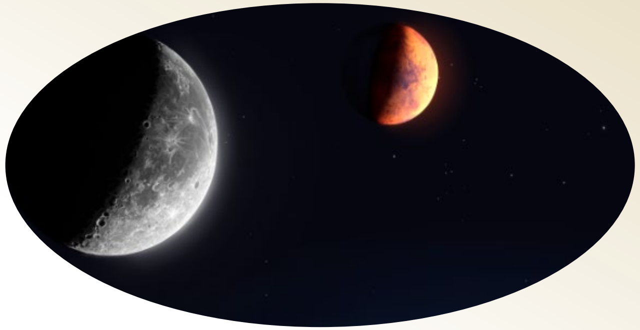
- **Suborbital**
  - Blue Origin flight with scientist payload specialist

- **International Space Station**
  - Past and present research investigations
  - Science delivery on all commercial resupply missions
  - Commercial access to ISS

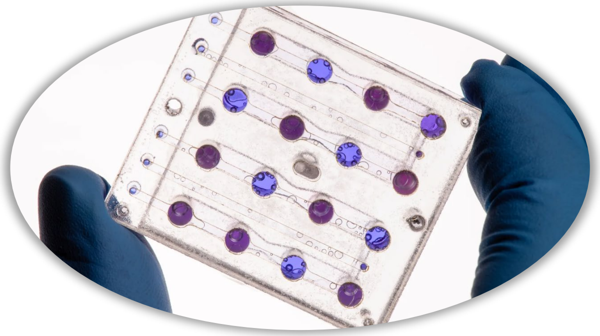
- **Commercial Low-Earth-Orbit Destinations (CLDs)**
  - science capability needs submitted to CLD leads

BPS Landscape Highlights: M2M, Beyond

- **Moon to Mars (M2M)**
  - M2M Architecture Definition Document
  - BioExperiment-01 on Artemis I
  - Regular solicitations for research on the Moon through Artemis and Commercial Lunar Payload Services (CLPS)
  - Science payloads for Artemis II, SpaceX uncrewed demo
  - Artemis III deployed instruments payload
  - CLPS CP-22 LEIA (Lunar Explorer Instrument for space bio Applications)



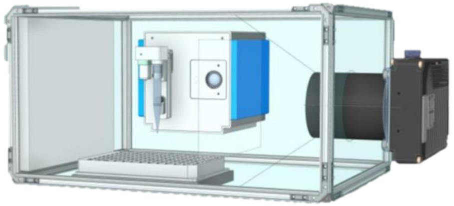
- **Free-flyers**:
  - BioSentinel
  - X-37B for radiation studies



BPS Landscape Highlights: CERISS

Commercially Enabled RapId Space Science (CERISS)

- **CERISS developments and enabling capabilities**
  - Lab capabilities under development (e.g. COTS-modified hardware, commercial hardware for CERISS activity)
  - CERISS RFI Input received from community 2023
  - 2023 TechFlights Award (SMD/STMD partnership)
  - International space agencies and NASA investigating and developing *in situ* analysis capabilities
  - Capabilities development within other Goals (e.g. Space Crops: spectrophotometer; Precision Health: *in situ* analysis studies, tissue chip longevity ground research enabling long duration studies)



Exploration Space Labs

Low Earth Orbit* and Suborbital

Low Earth Orbit
- International Space Station
- Commercial LEO Destinations
- Free-Flyers
  - Small Satellites
  - Large Multi-Payload Satellites

Suborbital
- Balloon Flights
- Sounding Rockets
- Suborbital Flights

*Standard LEO equatorial, polar orbit, high altitude / Van Allen Belts, etc.

Moon

Flight (Lunar Orbit & Surface)
- Orion
- Human Landing System
- Gateway Logistics Module
- Gateway
- Space Launch System
- ESPA Ring Payloads
- Free-Flyers (robotic)
  - Small Satellites
  - Large Multi-Payload Satellites

Lunar Surface
- Human Landing System
- Lunar Terrain Vehicle
- Pressurized Rover
- Multi-Purpose Habitat Lab
- Surface Habitat Lab
- Robotic Rover
- CLPS Landers
- Small Satellite Landers

Mars

Flight (Mars Orbit & Surface)
- Transit Vehicles
- Free-Flyers
  - Small Satellites
  - Large Multi-Payload Satellites
  - Rideshare Payloads

Mars Surface
- Surface Habitat Lab
- Mobile Vehicle
- Robotic Rovers
- Large Robotic Landers
- Rideshare Payloads

Deep Space and Other Destinations*

- Free-Flyers
  - Small Satellites
  - Large Multi-Payload Satellites
  - Rideshare Payloads
- Robotic Vehicles

*Deep space, other worlds, other planetary moons, Lagrange points, heliocentric, etc.

Science Strategy

Division Science Goals

- **Precision Health**
- **Space Crops**
- **Quantum Leap**
- **Foundations**

Defines the Science Strategy to address Decadal recommendations and other science drivers for their Goal, including CERISS applications

- **Input Drivers:** What, Where, When?

Science Implementation Strategy

Space Labs defines space facilities, capabilities, and timeline strategies for implementing the BPS research investigations

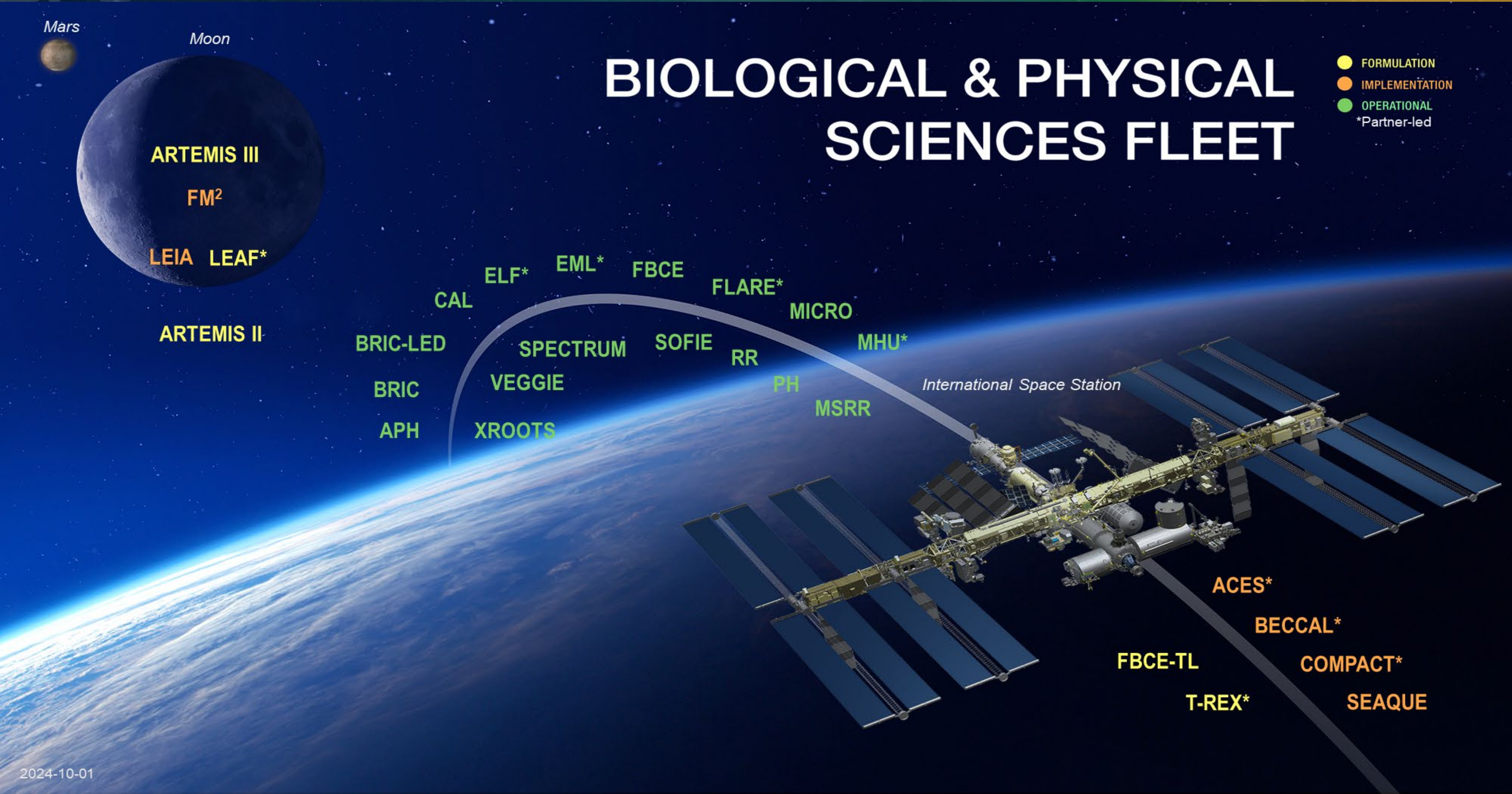
- Map to the current Moon to Mars exploration phases and timeline for the vehicles and facilities
- Map to the vehicle flight cadences
- Map to and define uncrewed vehicles
- Define and map critical vehicle and facility capabilities to timeline
- Identify vehicles that may not exist yet

Space Labs Input Drivers: What, Where, When?

- What is needed to do the science (**major GFE, facility capabilities, and resources to operate scientific research studies**)?
- Where to do the science (**location: facility, platform, geological/space**)?
- When to do the science (**timeline prioritization**)?

BIOLOGICAL & PHYSICAL SCIENCES FLEET

FORMULATION
IMPLEMENTATION
OPERATIONAL
*Partner-led



INVESTIGATIONS → THEMES* → GOALS

Architecting from the Right,

Executing from the Left

THEMES*	GOALS
TISSUE CHIPS ACCELERATED AGING & DISEASE MICROBIOLOGY SYSTEMS BIOLOGY	Precision Health
REGOLITH/SOIL BIOREGENERATIVE LIFE SUPPORT SYSTEMS CROP SPECIES CROP PRODUCTION SYSTEMS	Space Crops
COLD ATOMS/ATOM INTERFEROMETRY QUANTUM ENTANGLEMENT LUNAR LASER RANGING ATOMIC CLOCKS	Quantum Leaps
CRYO FLUIDS & THERMAL MANAGEMENT ~~IN SPACE~~ FIRE SAFETY RECYCLING & SUSTAINABILITY MANUFACTURING & PROCESSING IN SPACE	Foundations
LEO/COMMERCIALLY ENABLED RAPID SPACE SCIENCE GATEWAY LUNAR SURFACE MARS	Space Labs

Draft – subject to change