National Aeronautics and Space Administration

CBPSS
Fall 2022 Meeting: Biological and Physical Sciences (BPS) Division Program Status & Planning

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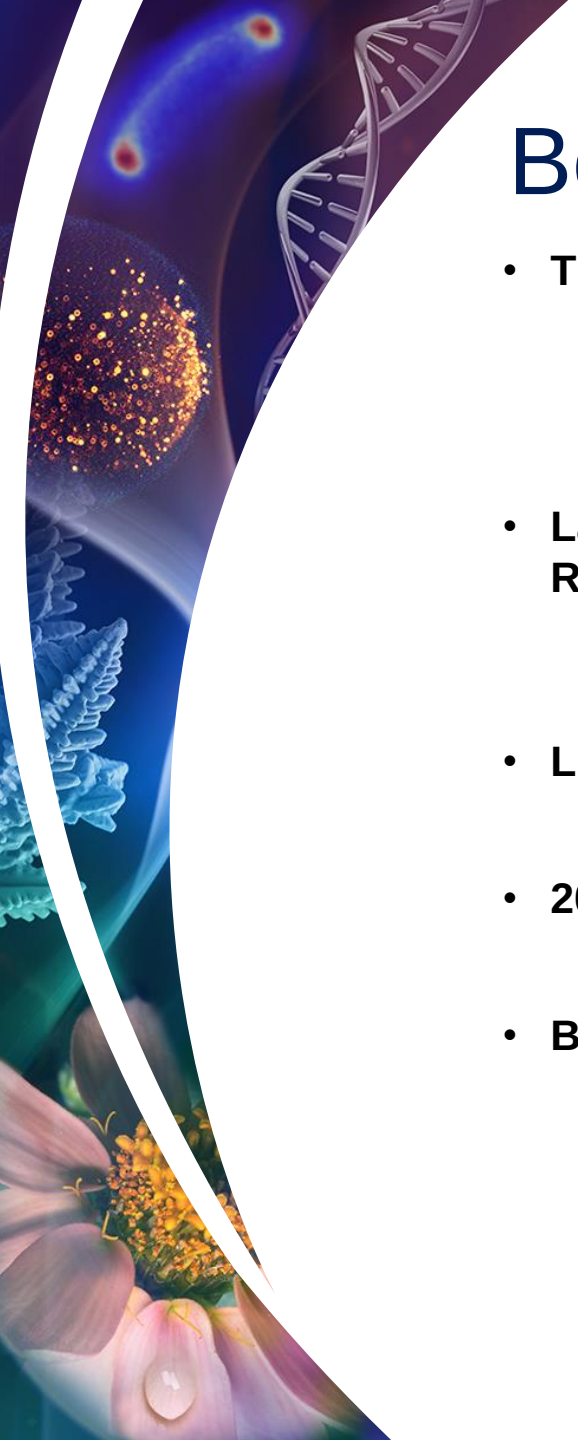
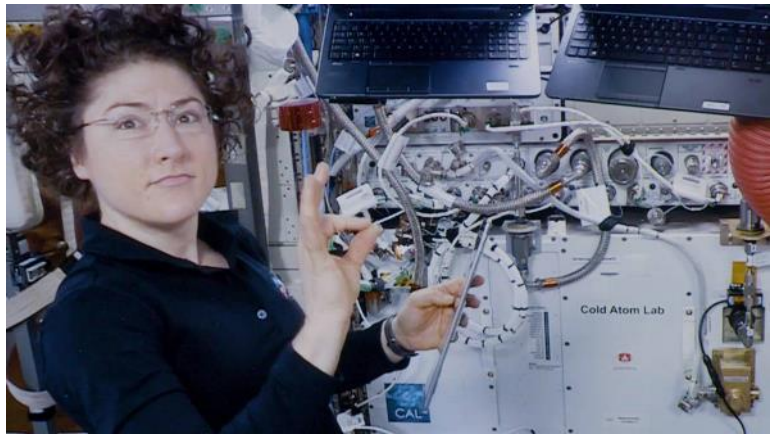
October 19, 2022

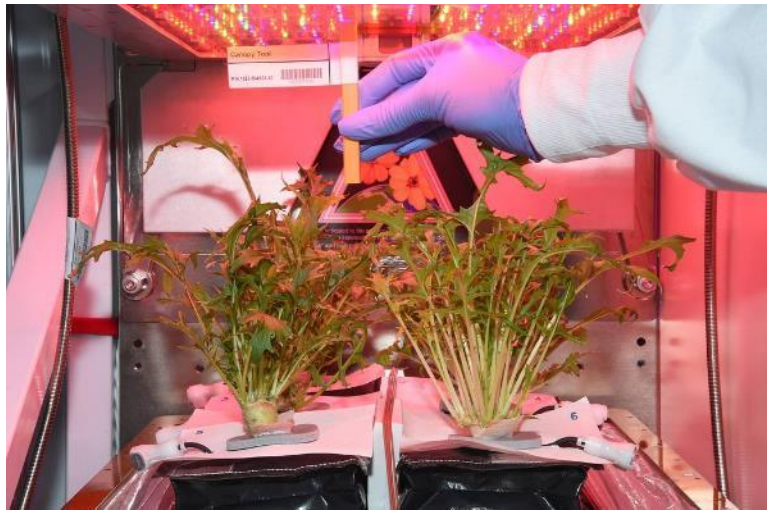


Bottom Line Up Front

- **The current funding level supports**
  - Two focus areas: Quantum Science and Thriving in Deep Space (TIDES)
  - Completing projects already started in response to the 2011 Decadal Survey
  - Continuing to expand Open Science and IDEA activities
- **Laying the foundation to use the proposed budget increase in President's Budget Request(PBR) for FY23 for a commercial initiative**
  - Aim to increase the pace of research and research demand in LEO in some research disciplines such as biology, biomedical, soft matter, and materials science
- **Limited physical sciences investigations beyond Quantum Science**
  - Lack robust flight and ground programs in fluids, combustion, materials, and soft matter
- **2032 Decadal Survey scheduled for June 2023 release**
  - No budgetary wedge to respond
- **Beyond low-Earth orbit activities are underway**
  - Payload selected by ESSIO to land via CLPS lander
  - Payload on Artemis I
  - Science selected for Artemis II, however insufficient funding for hardware
  - Resource allocation reservations for Gateway and Artemis III+, however insufficient funding for hardware



Example of Physical Sciences research:
Studying quantum gasses



Example of Space Biology research:
Growing plants in space

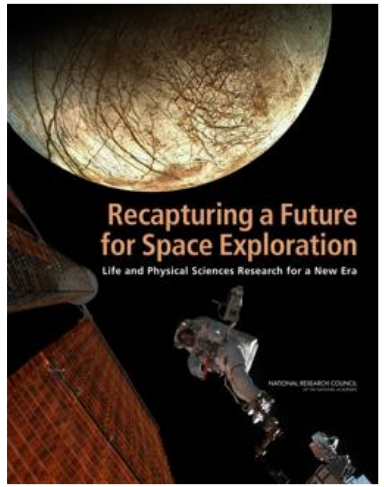
BPS Vision

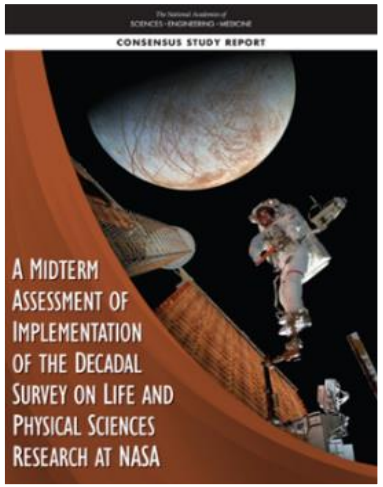
We use spaceflight environments to **study biological and physical systems.**

Examining phenomena under extreme conditions **helps us better understand how they function.**

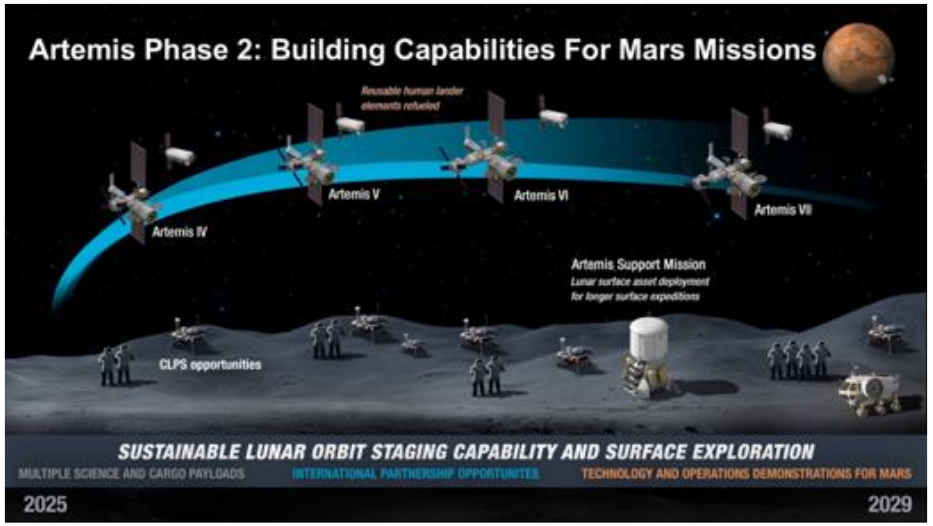
This understanding contributes to significant scientific and technological advancements that

- **make fundamental advances in science,**
- **enable space exploration, and**
- **benefit life on Earth.**





Decadal Survey



Artemis Missions

BPS Mission

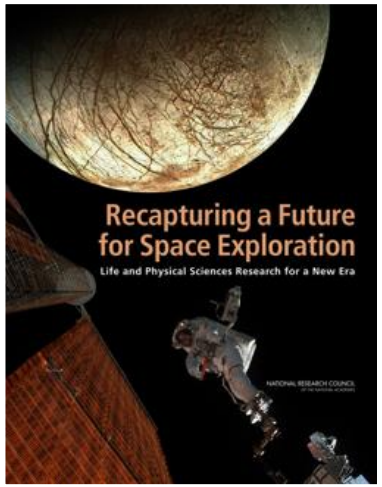
Pioneer Scientific Discovery

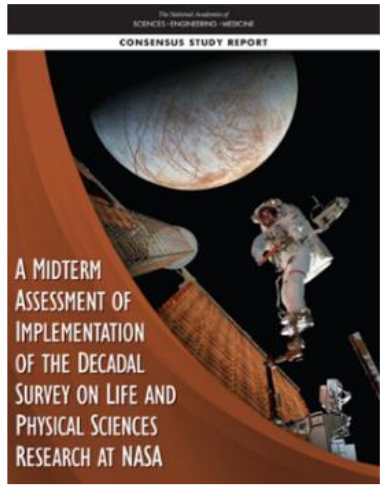
- Proactively seek out new ways to expand fundamental scientific knowledge
- Provide expertise and support to others seeking to utilize space

Enable Exploration

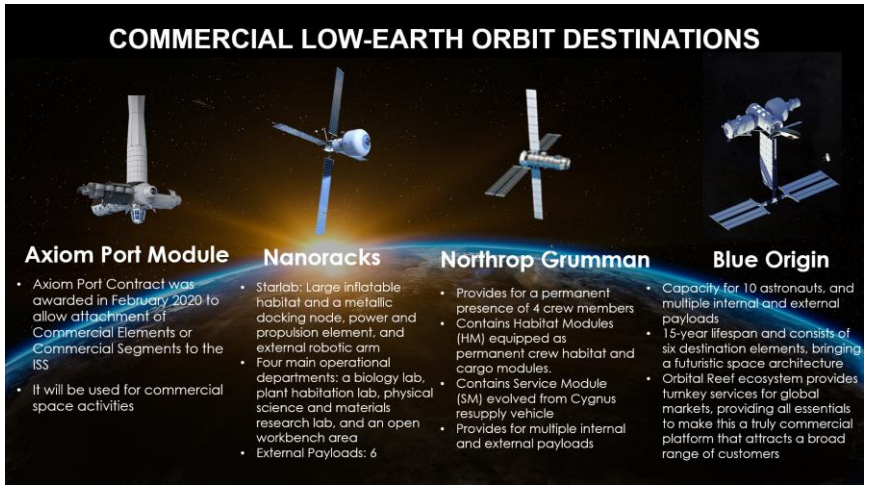
- Anticipate and investigate critical areas for scientific knowledge and technology development
- Deliver results to other NASA organizations and industry

Planning for Change





Decadal Survey



Commercial LEO Destinations

- **Decadal Survey**
  - Scheduled for release June 2023
  - Prioritize recommendations; estimate budgets; schedule implementation
    - Coordinate with SOMD, ESDMD, STMD; OGAs; industry; academia; international partners
  - Establish Program Analysis Groups for high priority recommendations
    - Roadmaps, analysis of alternative approaches

- **Commercial Space**
  - Sub-orbital: Discussing use of Flight Opportunities Program and Sub-orbital Crew Program for commercial initiative
  - Orbital: Discussing potential BPS requirements with CLD developers directly and through SOMD Commercial LEO Development Program and SOMD ISS Program
  - BPS needs and priorities await Decadal Survey

Biological & Physical Sciences Advisory Committee (BPAC)

- **Charter**
  - To provide advice and make recommendations to the Director on programs, policies, plans, and priorities and their implementation
  - To provide a regular forum for broad discussion of BPS science and the role of BPS science within and outside NASA
  - Will evaluate BPS annually for progress against its NASA performance objectives
  - BPAC Chair is a member of the SMD Science Committee that advises the AA
  - Source of advice and an informal ‘sponsor’ of Program Analysis Groups that together provide timely input to help BPSD plan and execute its programs
- **Diverse representation**
  - Disciplines: Animal Biology, Microbiology, Plant Biology, Combustion, Fluid physics, Fundamental Physics, Soft Matter, Materials Science, Translational Science, Exploration
  - Modes: Ground-based analogs, Suborbital, LEO, BLEO, Data Analysis/Big Data, STEM/Education
  - Organizations: Academic-R1*, Academic-R2*, NASA Center, Other Res Org, Industry/Commercial Space, OGA
  - Inclusive of under-represented populations, varying stages of career, geographical locations

BPS Program

- **What's Changed**
  - New commercial initiative to develop transformative research capabilities with commercial space industry to dramatically increase pace of research
  - Develop Private Astronaut Mission capability to fly hyper-specialized scientist for up to 30 days to conduct fast-paced, transformative research
  - Developing use of human commercial platforms: suborbital and new Commercial LEO Destinations

- **What's the Same**
  - Lead new transformative research in two key focus areas: Quantum Science and Thriving In DEep Space (TIDES)
  - Complete research in development for other 2011 Decadal Survey recommendations
  - Maintain core capabilities and open science platforms

BPS Strategy and Priorities

- **Launch Commercially Enabled RapId Space Science" (CERISS) initiative (budget increase in PBR for FY23)**
  - Develop transformative research capabilities with commercial space industry
  - Increase pace of research by 10- to 100-fold and research demand in low Earth orbit (LEO)
  - Pave way for Scientist Astronaut Missions and autonomous experiments beyond LEO

- **Continue "base" program (FY22 funding level)**
  - Maintain focus on and fund new research for
    - Quantum science
    - TIDES (Thriving in Deep Space)
  - Fulfill other 2011 Decadal commitments in development; no funding for new research in these areas
  - Engage diverse audiences (open science and outreach)
  - Maintain core capabilities

Challenges

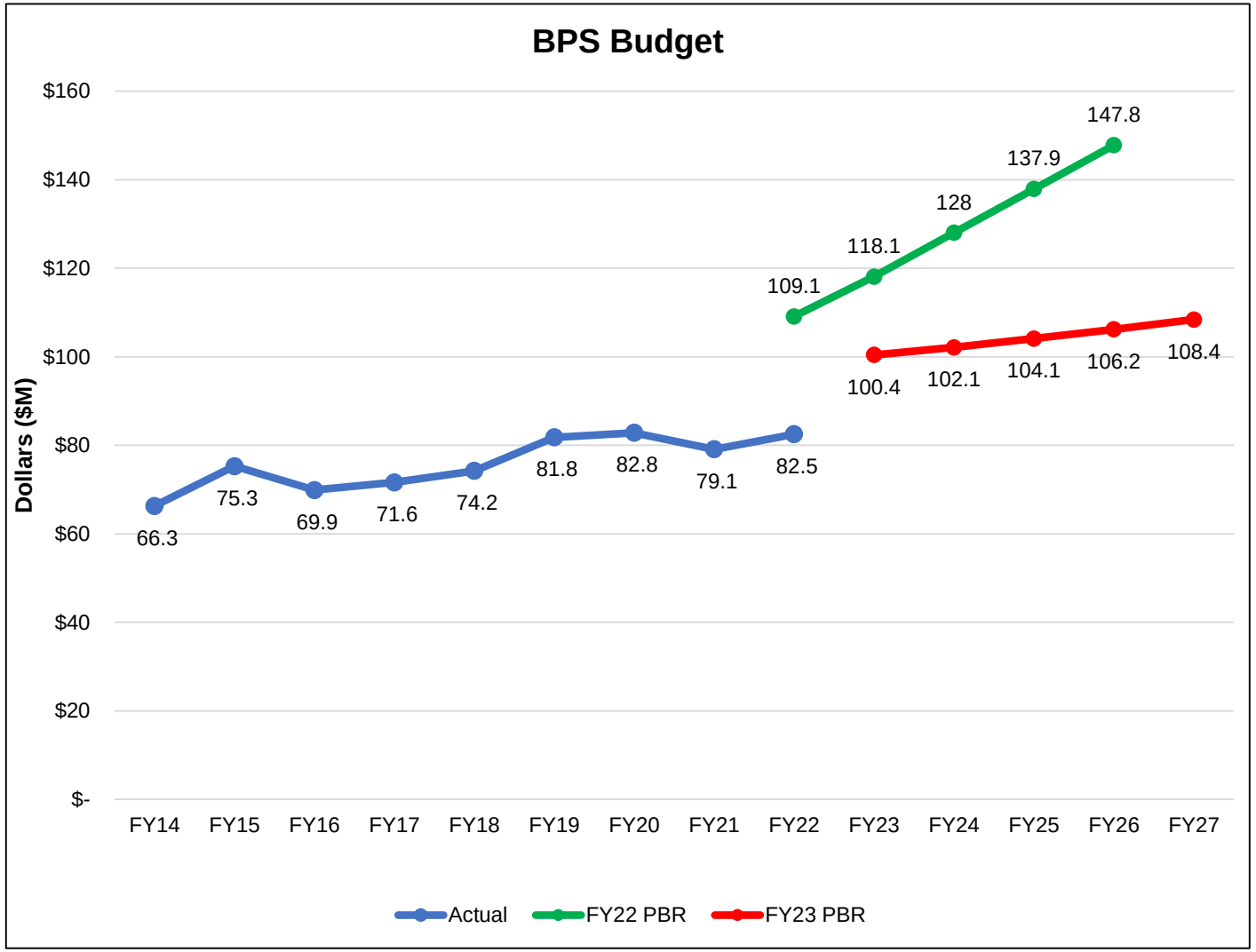
- **LEO research**
  - ISS resource predictability (e.g., crew time, up-mass, cold stowage) due to Decadal Science's lowest priority
- **Dynamic environment and needs with flat budget profile**
  - **ISS to be decommissioned in 2030;** BPS LEO research must transition to CLDs
    - ISS mission integration and operations subsidy transitions to zero in FY25 (~$10M)
    - BPS's extensive re-use of hardware on ISS will go away
    - BPS budget will likely need to cover integration, launch, and operations costs on CLDs
  - **Artemis Era:** New vehicles require new payloads
    - Orion, Gateway, Commercial Lunar Payload Services (CLPS), Human Landing System (HLS)
    - Concurrent development of BPS research and platforms
  - **Decadal Survey** will recommend highly transformative keystone capabilities and campaigns; reuse of hardware is unlikely

Top Risks

- **FY23 budget impacts**
  - If Congress appropriates less than the FY23 PBR, implementation of commercial (CERISS) and base program focus areas will be impacted
  - Delayed research on station
- **Upgrades to the Alpha Magnetic Spectrometer on the International Space Station (ISS) could delay execution of the BPS research portfolio by one year, reducing use of ISS from 7 years to 6, and costing up to $12M**
- **Uncertainty around future LEO facilities**
  - CLDs may not provide access for BPS investigations that do not have a broad multi-user base
  - NASA allocation of purchased resources from CLDs may prioritize BPS Decadal Science in its lowest category, as has been done on ISS.

BPS Budget

- **Planned budget growth to be deployed to CERISS initiative**
- **BPS's $5-10M/year ISS Mission Integration and Operations subsidy ends in FY25**
- **OMB requested growth in FY24+ is ~2%**

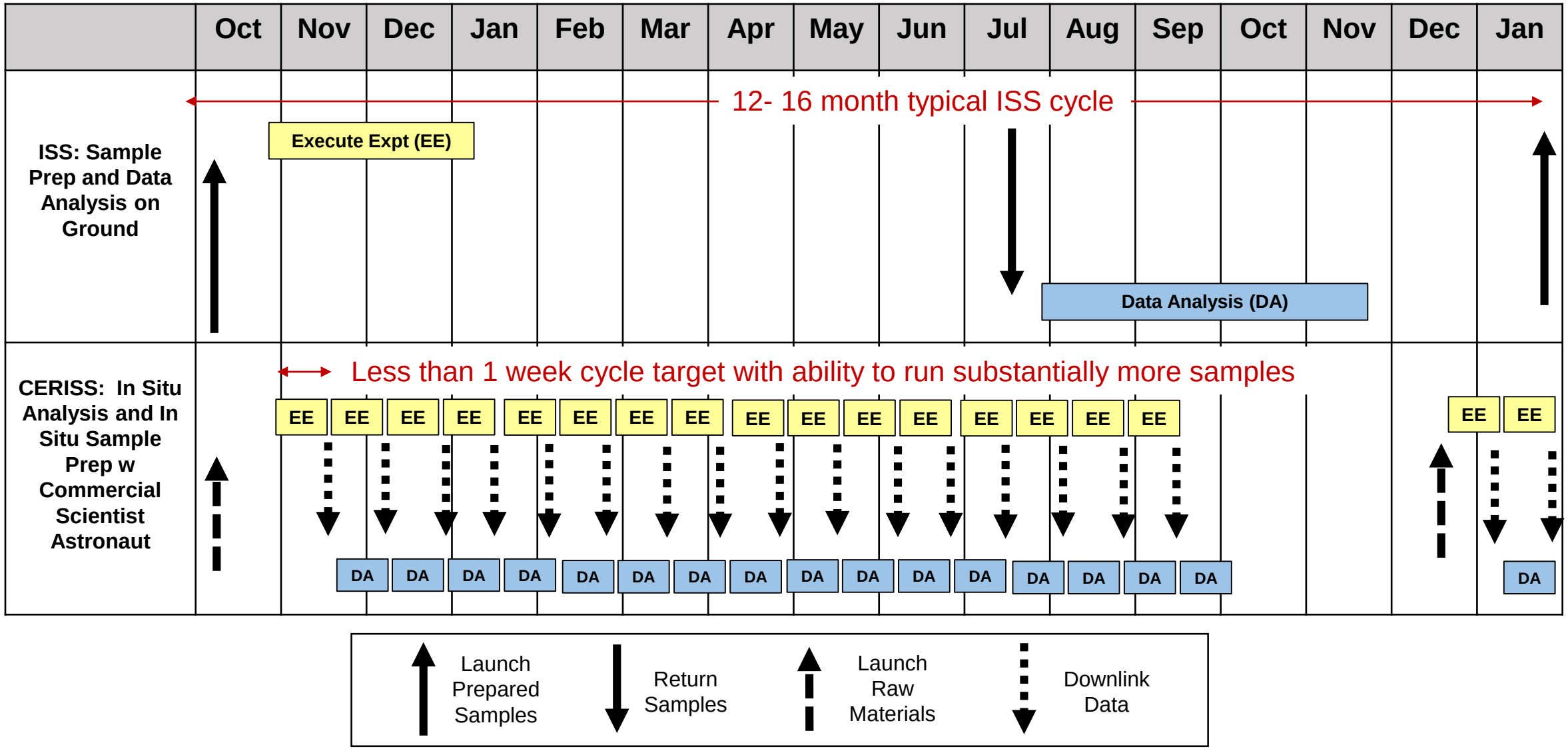


Commercial Initiative: CERISS

Commercially **E**nabled **R**ap**I**d **S**pace **S**cience (CERISS) | Overview

- **Focus Area**
  - Develop transformative research capabilities with commercial space industry to dramatically increase pace of research
- **Long-Range Goals**
  - Conduct Scientist Astronaut Missions (SAMs) on the ISS and Commercial LEO Destinations
  - Develop automated hardware for experiments beyond low Earth orbit (e.g., lunar surface)
- **Motivation**
  - The pace of ISS research is too slow for OGAs and industry; it takes years to plan, develop, launch, operate, return samples and begin the cycle again.
- **Context**
  - New capabilities for platforms and payload are being developed now by commercial space in preparation for the transition from ISS in 2030
  - There are gaps in the development of capabilities for in situ analysis and in situ experiment preparation
  - Private Astronaut Missions provide a new mechanism for hyper-specialized researchers to conduct research in LEO
- **Benefits**
  - 10- to 100- fold faster pace of research for a wide range of research sponsored by BPS, NASA Human Research Program, OGAs, and industry
  - Increases demand for R&D in low Earth orbit, facilitating growth of commercial space industry

CERISS Dramatically Improves Pace of ISS Research



CERISS | Approach

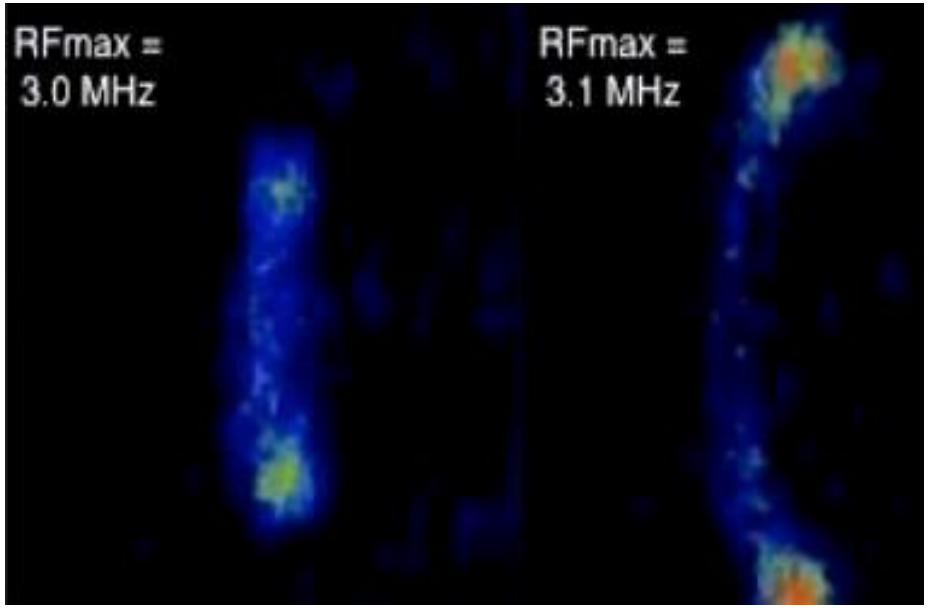
- **Develop and deploy in situ analysis and in situ preparation capabilities in low Earth orbit for use by all astronaut types (NASA, PAM, SAM)**
  - Conduct gap analysis with Space Operations Mission Directorate and issue RFIs
    - RFI 1: Targets industry to describe existing state-of-the-art capabilities and capabilities in development
    - RFI 2: Targets research community to describe Decadal Survey priorities that would benefit the most
  - RFP: Compete contracts for the development of in situ analysis and in situ preparation capabilities
  - ROSES: Compete research grants for using and refining capabilities
    - Ground-based
    - Commercial suborbital flight (crewed), as needed
  - ROSES: Compete research grants to use capabilities in low Earth orbit operated by NASA and/or private astronauts
    - Initially on ISS, then on Commercial LEO Destinations

- **Develop plans for BPS missions building on in-situ capabilities**
  - Scientist Astronaut Missions (SAM)
    - Use Private Astronaut Mission (PAM) capability to fly hyper-specialized scientist for up to 30 days to conduct fast-paced transformative research
    - Initially on ISS, then on Commercial LEO Destinations
  - Automated experiments beyond low Earth orbit
    - Artemis Commercial Lunar Payload Services, Gateway, and Human Landing System
    - Deep Space Free-Flyers

Quantum Research

Quantum Science | Overview

- **Focus Area**
  - Properties of quantum matter/quantum gases
- **Long-Range Goal**
  - High-precision tests of General Relativity and Quantum Mechanics
  - Direct gravitational detection of Dark Matter and Dark Energy
- **Motivation**
  - 2011 Decadal Survey Priority FP3, 2018 Midterm Assessment Recommendation 5-12
  - 2017 NASA Fundamental Physics Standing Review Board Report
  - 2018 National Quantum Initiative
  - Cold Atom Lab results on ISS
- **Context**
  - Conduct high-precision experimental space physics
    - Studies of quantum matter and spacetime using space laboratories
      - Test-mass or specimen under study is in the laboratory
      - Einstein Equivalence Principle, Gravitational Physics, Physics beyond the Standard model, Quantum Matter
- **Benefits**
  - Potential innovations in sensors, computing, memory, and communications



Quantum Matter condensate bubbles enabled by microgravity using Cold Atom Lab aboard the ISS. (PI: Nathan Lundblad)

Quantum Science | Approach

- **Extend CAL operations through FY26 with closeout in FY27**
  - Complete potassium-rubidium dual species studies
- **Provide Science Module 3B (SM-3B) to maintain reliability**
  - Add mesoscale trap to increase atom numbers 2- to 3-fold
  - Replace current driver assemblies to enable studying weakly bound multiple atom systems
- **Continue current grants, including CAL PI science through FY23, with final reports in FY24**
- **Future grants**
  - Establish broad community through annual ROSES solicitation of ground-based investigations starting in FY22
  - Solicit flight investigations through ROSES solicitations in FY22, FY24, and FY26
- **BECCAL**
  - Technology maturation supporting collaboration with DLR on the Bose-Einstein Condensate Cold Atom Laboratory (BECCAL)
  - FHA Spring 2026

Astronaut Christina Koch works on Cold Atom Lab aboard the ISS

Thriving In DEep Space (TIDES)

Thriving in Deep Space (TIDES) | Overview

FOCUS AREA 2

- **Focus Area**
  - Determine the mechanisms of how animal models and plants respond to deep-space stressors in combination
- **Long-Range Goal**
  - Enable sustainable, long duration human exploration of the solar system
  - Discover new biological processes in animals and plants
- **Motivation**
  - 2011 Decadal Survey Priorities P1-3, AH2-5,8,14-15, CC8-9, 2018 Midterm Assessment Recommendation 5-9,11
- **Context**
  - Enable sustainable human exploration of space by understanding human physiology in flight and how to provide crop plants on missions
  - Identify responses to combined effects of space radiation, microgravity, altered atmospheres, etc., common across spectrum of model organisms
  - Progress from unicellular organisms to vertebrate animals and crop plants
- **Benefits**
  - Identify potential biomarkers and countermeasures for crew health and performance
  - Enable crop plant production for micronutrients and improved behavioral health
  - Test utility of spaceflight for identifying mechanisms in aging and disease
  - Improve terrestrial controlled-environment agriculture

Arabidopsis thaliana plants grown in lunar regolith by University of Florida researchers, Dr. Robert Ferl and Dr. Anna-Lisa Paul

TIDES | Overview

FOCUS AREA 2

Understand Fundamental Mechanisms

Use model organisms to determine how animals/humans respond to deep-space environments.

+

Build the Blocks to Support Human Life

Understand how model plants, crops, & seeds respond to and can thrive in deep-space environments.

=

Establish a Foundation for Sustained Life on Mars

Develop habitats to enable astronauts' independence from Earth. Stabilize human/animal-plant-microbial ecosystems in the context of multiple deep space stressors.

DEEP-SPACE STRESSORS

Gravity | Radiation | Temperature/Atmosphere | Day/Night/Circadian Cycle | Isolation

PLATFORM PROGRESSION

Ground → Suborbital → LEO/ISS → Gateway → Lunar Surface → Mars Transit → Martian Surface

MODEL ORGANISM PROGRESSION

Unicellular (e.g., yeast, fungi)

Invertebrates (e.g., flies, worms, tardigrades) → Vertebrates (e.g., mice, fish; tissue chips)

Simple model plants (e.g., *Arabidopsis*) → Edibles & others (for micronutrients, etc.)

→ Humans

Ground studies | Space studies | Ground & space studies

TIDES | Approach: Beyond LEO

FOCUS AREA 2

- **Capitalize on near-term opportunities**
  - Commercial Lunar Payload Services: Lunar Explorer Instrument for Space Biology Applications (LEIA)
    - Three Principal Investigators selected through ROSES 2021-E.10
    - Real-time monitoring of several yeast strains
    - Lunar surface radiation and gravity; lunar day (14 days)
    - Based on 6U BioSentinel Small Sat
    - Selected under CLPS PRISM-2
  - Artemis I: BioExpt-01
    - Four Principal Investigators selected through 2018 Space Biology (ROSBio)
    - Yeast, fungi, algae, plant seeds
    - Post-flight ground analysis of spaceflight response of several strains of each organism
    - Microgravity and space radiation; 26-45 days
  - Artemis II: Gateway
    - Placeholders secured for payload mass, volume, power
    - Develop multicellular research capability for Artemis II
  - Artemis III and beyond
    - No funding for payloads (but requesting placeholder allocations of spaceflight resources)
  - Bion M2 (Roscosmos/Institute for Biomedical Problems): paused
- **Implement high priority recommendations from 2023 Decadal Survey**

LEIA Core:
4U BioSensor payload
derived from BioSentinel

TIDES | Approach: LEO

- **Maximize use of International Space Station to characterize biological response to LEO environment**
  - Characterize responses across a wide range of model organisms
  - Compare responses to model organisms in different environments: ground-based analogs, deep space, lunar surface
- **Capitalize on Space Force X37B availability**
  - Several varieties of plant seeds currently on X37B on orbit
  - Post-flight analysis: directed and competed
- **Prepare for transition to Commercial LEO Destinations (CLD)**
  - Transition from ISS starting in 2028; first CLD use could be available in 2024
  - Information exchange through CLD Utilization Forum sponsored by Commercial LEO Development Program Office
  - Planning discussions underway with individual developers
    - Determining which services and capabilities are provided by BPS versus CLDs
    - Determining availability of space for BPS payloads on CLDs
    - Discussing partnering with Axiom Space on Private Astronaut Missions (PAM) as early as 2023

International Space Station

TIDES | Approach: Ground

FOCUS AREA 2

- **Study model organisms in ground-based analogs of space flight to**
  - Develop hypotheses for flight experiments
  - Refine experimental designs for flight experiments
  - Study interactions between controlled spaceflight stressors
- **Develop tissue chips as potential complement to model organisms**
  - Extended life (6 months) chips enables comparison to crew on standard 6-month mission
  - Nine contracts in collaboration with NIH, FDA, BARDA
- **Sustain small R&A program in microbiology**
  - Astrobiology Internal Scientist Funding Model (ISFM) collaborative work packages
- **Plan for post-Decadal Survey expansion of ground test capabilities**

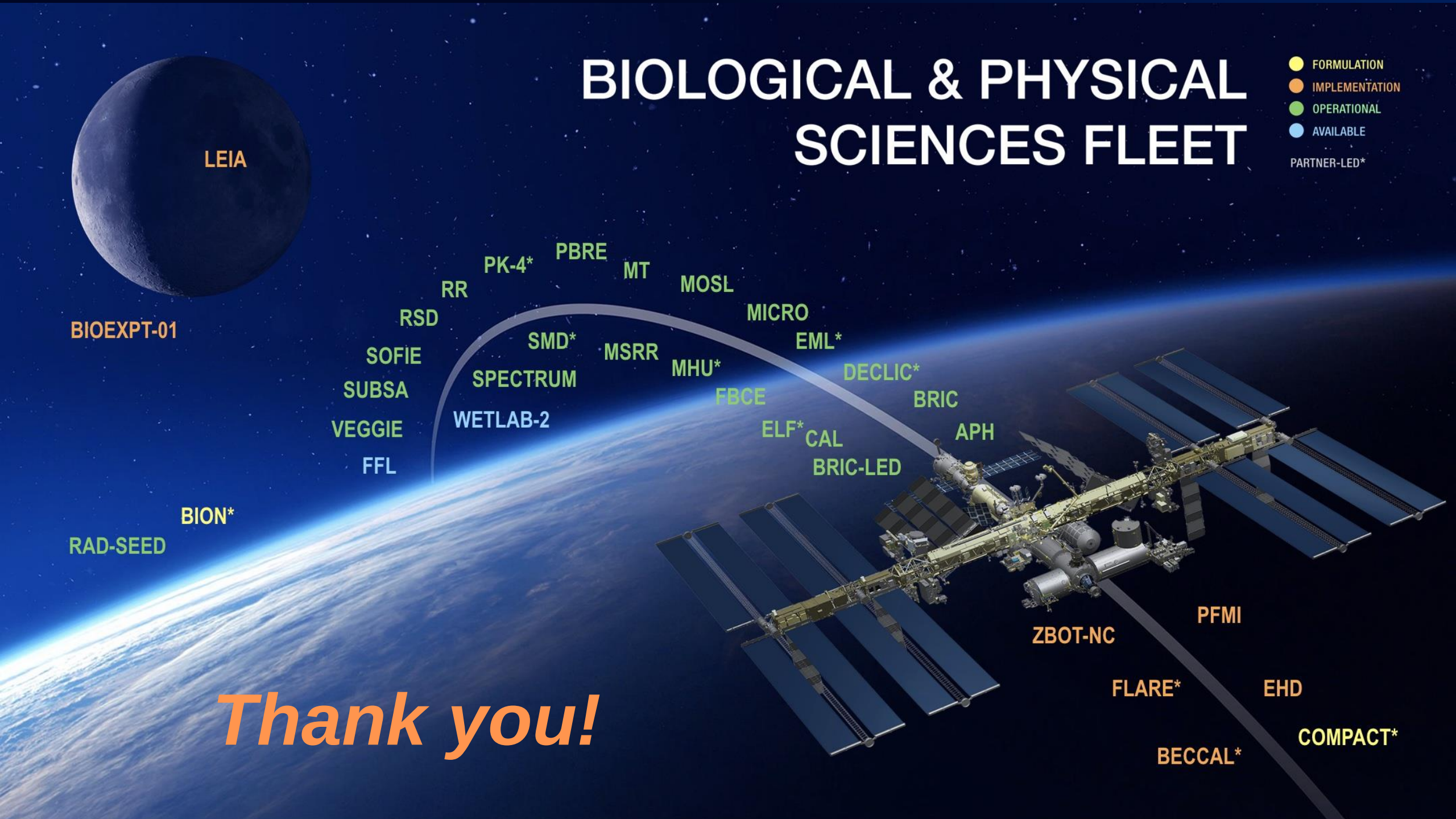
Cross-agency 3D Tissue Chip (microphysiological systems) investigations

Summary

- **If the President's Budget is authorized, BPS is poised to pioneer the use of CLDs to substantially increase the pace of LEO research**

- **The 2023 Decadal Survey will**
  - Identify, recommend, and rank the highest priority, most compelling transformative research activities for BPS to tackle in the next decade
  - Recommend an ambitious program to provide transformative outcomes
  - Provide the building blocks for the next decade of BPS research

- **However, the current President's Budget Request does not allow for a robust response to the Decadal Survey or full utilization of Artemis era platforms**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PFMI
ZBOT-NC
FLARE*
EHD
COMPACT*
BECCAL*
Thank you!

Backup

Glossary

BPS Resources: Glossary			
AA	Associate Administrator	**LMM**	Light Microscopy Module
BARDA	Biomedical Advanced Research and Development Authority	**MPS**	Microphysiological Systems
BECCAL	Bose-Einstein Condensate Cold Atom Laboratory	**NASA**	National Aeronautics and Space Administration
BLEO	Beyond Low Earth Orbit	**NCATS**	National Center for Advancing Translational Sciences
BPAC	Biological and Physical Sciences Advisory Committee	**NCI**	National Cancer Institute
BPS	Biological and Physical Sciences Division	**NIAID**	National Institute of Allergy and Infectious Diseases
CAL	Cold Atom Lab	**NIH**	National Institute of Health
CBPSS	Committee on Biological and Physical Sciences in Space	**OGA**	Other Government Agencies
CERISS	Commercially Enabled Rapid Space Science	**PAM**	Private Astronaut Mission
CLD	Commercial LEO Destinations	**PBR**	President's Budget Request
DLR	*Deutsches Zentrum für Luft- und Raumfahrt* (The German Space Agency)	**RFI**	Request for Information
ESDMD	Exploration Systems Development Mission Directorate	**RFP**	Request for Proposal
ESSIO	Exploration Science Strategy and Integration Office	**SAM**	Scientist Astronaut Mission
FDA	Food and Drug Administration	**SMD**	Science Mission Directorate
ISFM	Internal Scientist Funding Model	**SOMD**	Space Operations Mission Directorate
ISS	International Space Station	**STEM**	Science, Technology, Engineering, and Math
LEIA	Lunar Explorer Instrument for Space Biology Applications	**STMD**	Space Technology Mission Directorate
LEO	Low Earth Orbit	**TIDES**	Thriving in Deep Space