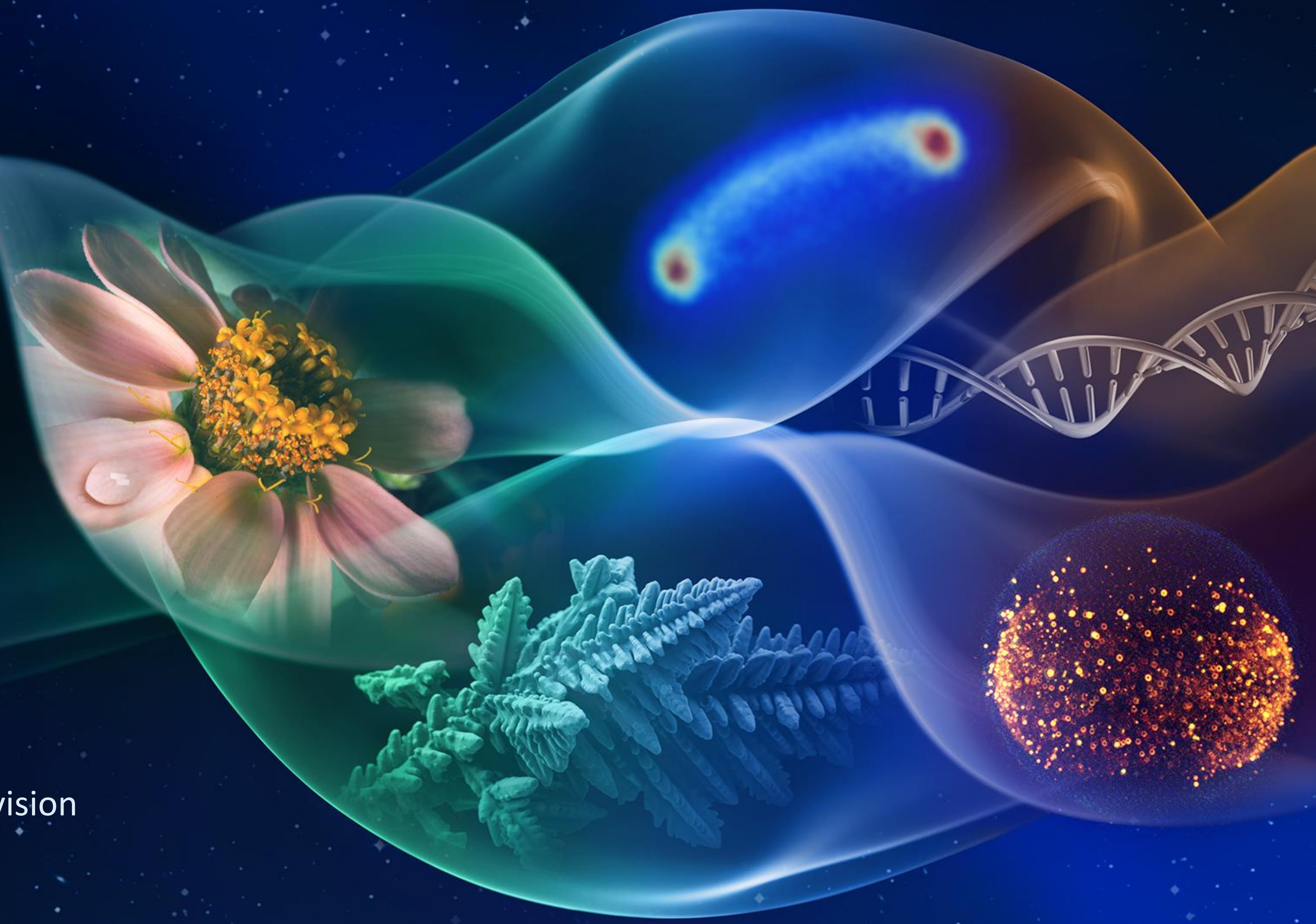
National Aeronautics and Space Administration

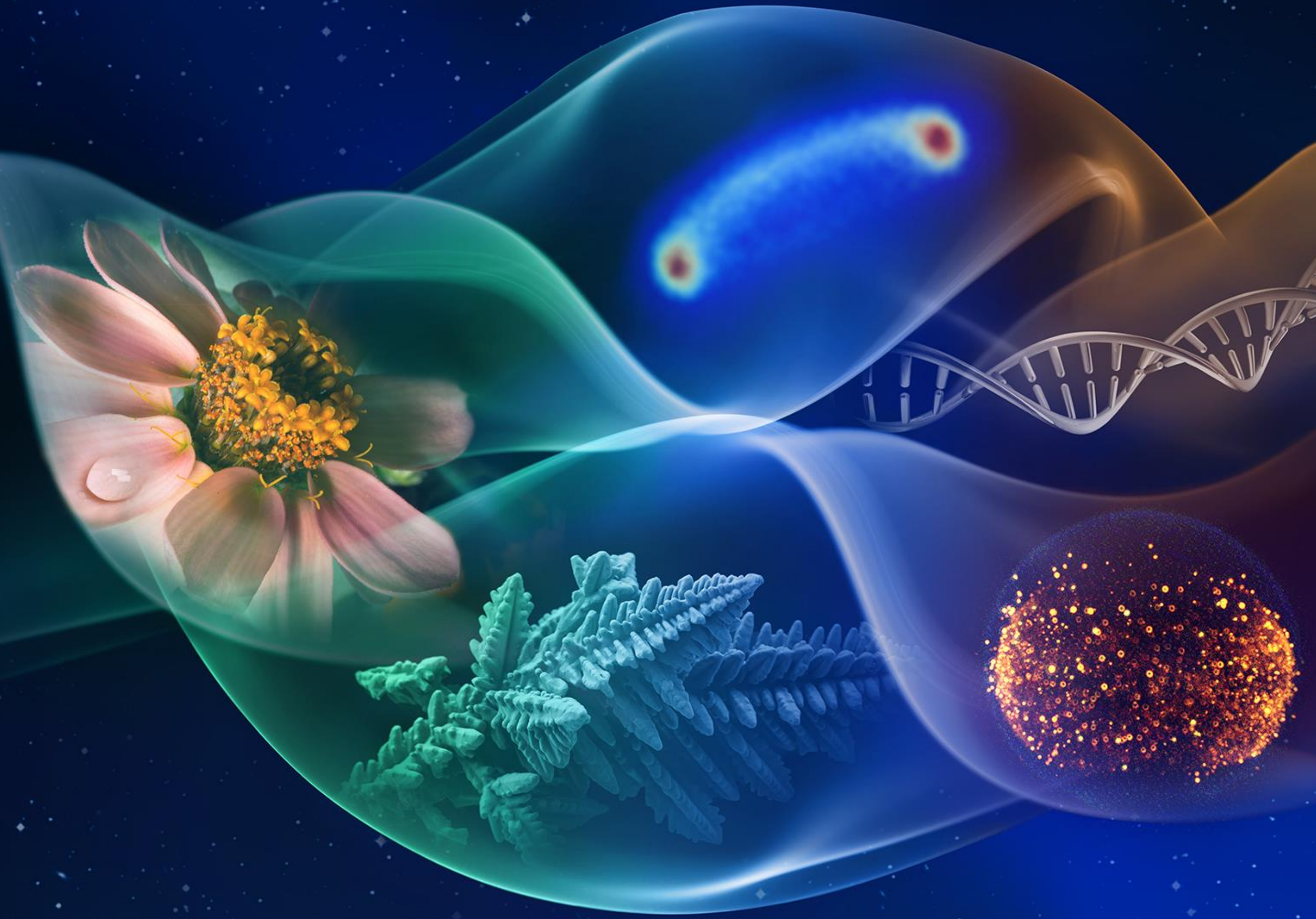
NASA

BPS
BIOLOGICAL AND PHYSICAL SCIENCES

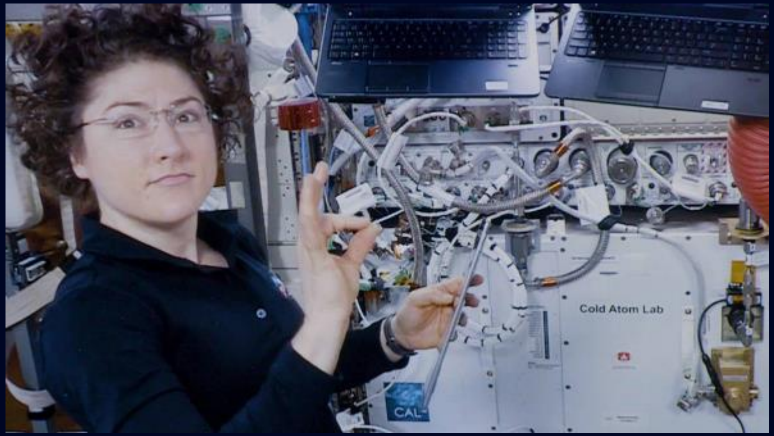


Craig Kundrot
Director, Biological and Physical Sciences Division
NASA

Overview



BPS Vision



Example of Physical Sciences research: Studying quantum gasses

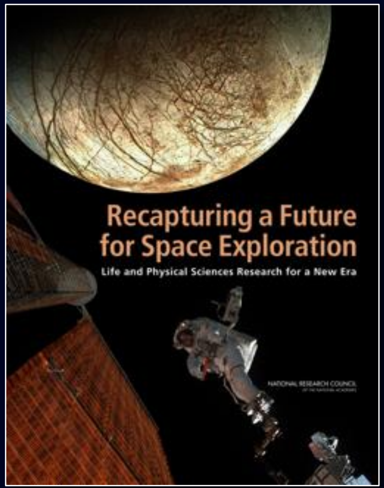
We use spaceflight environments to study biological and physical systems.

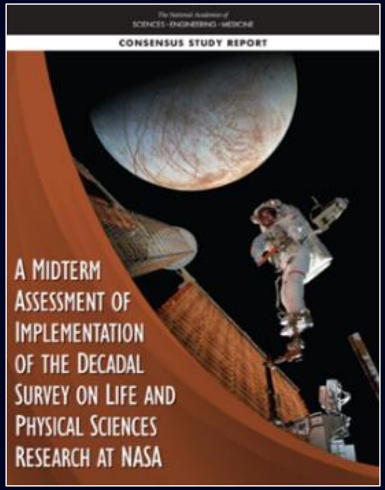
Examining phenomena under extreme conditions can help us better understand how they function.

Example of Space Biology research: Growing plants in space

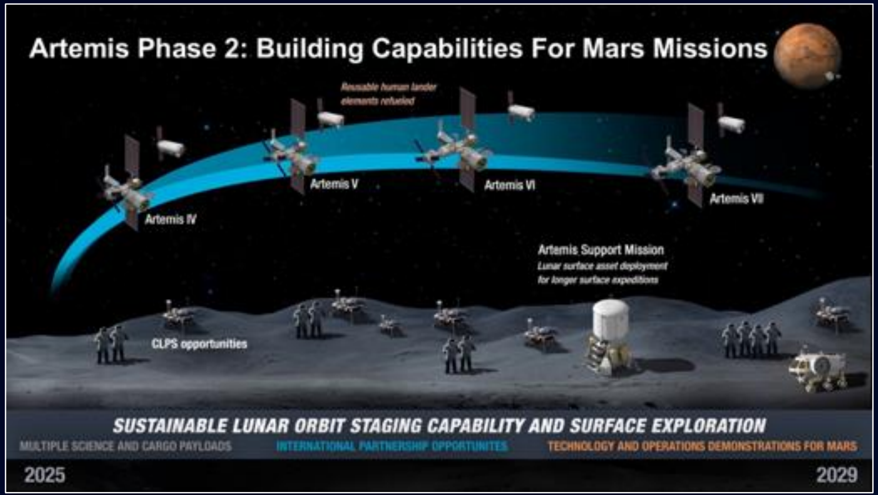
- This can contribute to significant scientific and technological advancements that
  - make fundamental advances in science,
  - enable space exploration, and
  - benefit life on Earth.

BPS Mission





Decadal Survey



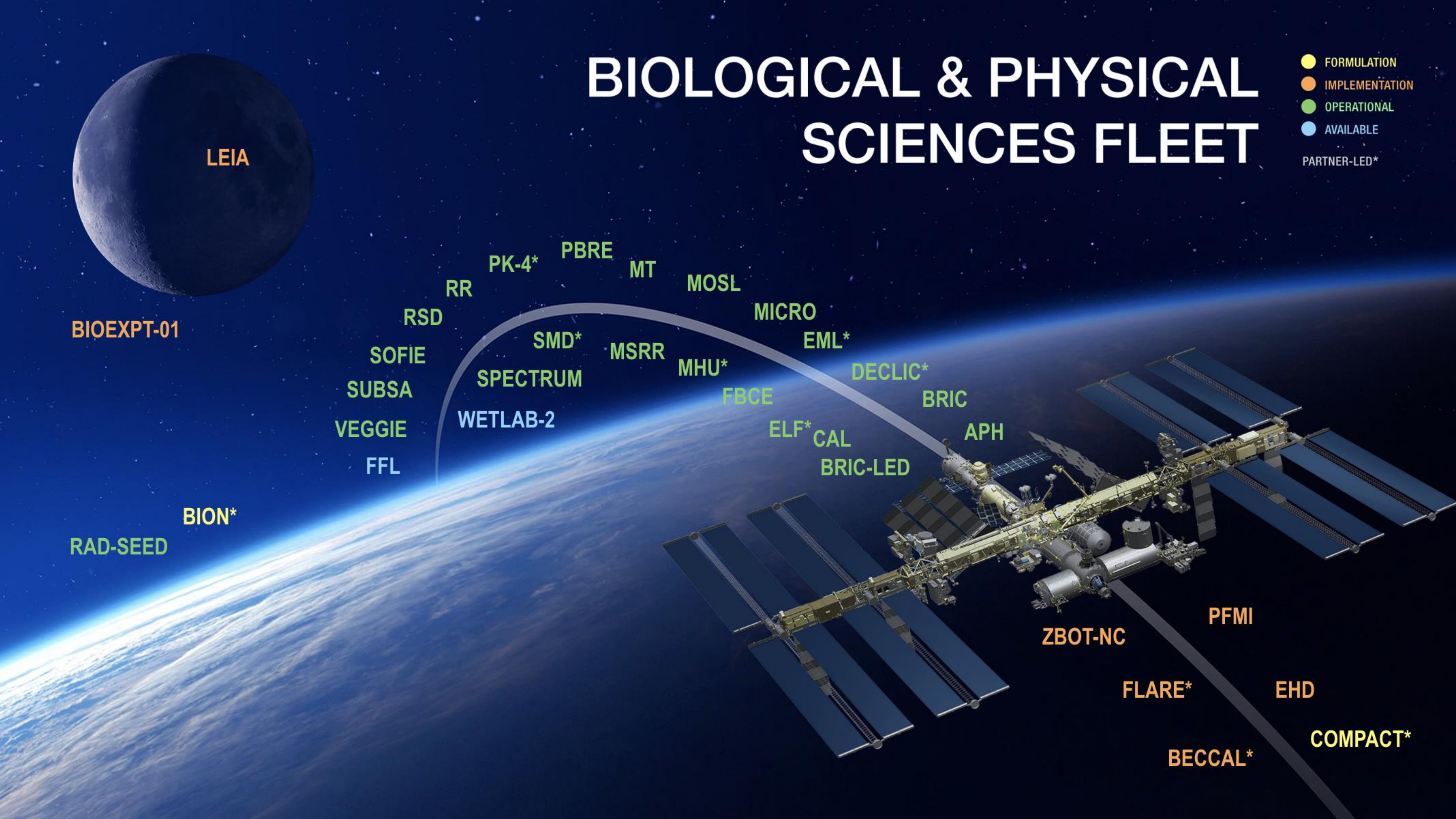
Artemis Missions

Pioneer Scientific Discovery

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

Enable Sustainable Exploration

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



BIOLOGICAL & PHYSICAL SCIENCES FLEET
FORMULATION
IMPLEMENTATION
OPERATIONAL
AVAILABLE
PARTNER-LED*
LEIA
BIOEXPT-01
RR
PK-4*
PBRE
MT
MOSL
RSD
MICRO
SMD*
MSRR
EML*
SOFIE
MHU*
DECLIC*
SPECTRUM
SUBSA
FBCE
BRIC
WETLAB-2
VEGGIE
ELF*
CAL
APH
FFL
BRIC-LED
BION*
RAD-SEED
PFMI
ZBOT-NC
FLARE*
EHD
COMPACT*
BECCAL*

BPS Employs Many Research Platforms

*Future Platforms


CubeSat


International Space Station


Free Flyers (BION)

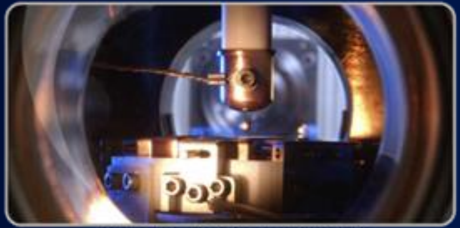

*Lunar Gateway


*Commercial Lunar Lander Services


Drop Tower


Parabolic Flight


Sounding Rocket
Sub-orbital Vehicle


Electrostatic Levitator


*Human Landing System


Rodent Unloading


Centrifuge


Balloon Flight

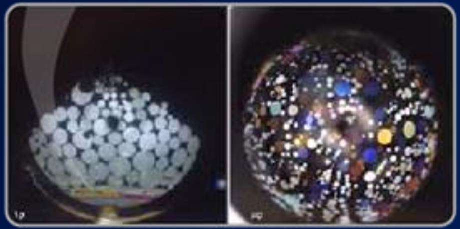

NASA Space Radiation Lab


NASA Isolation Chamber


NSF Polar Station

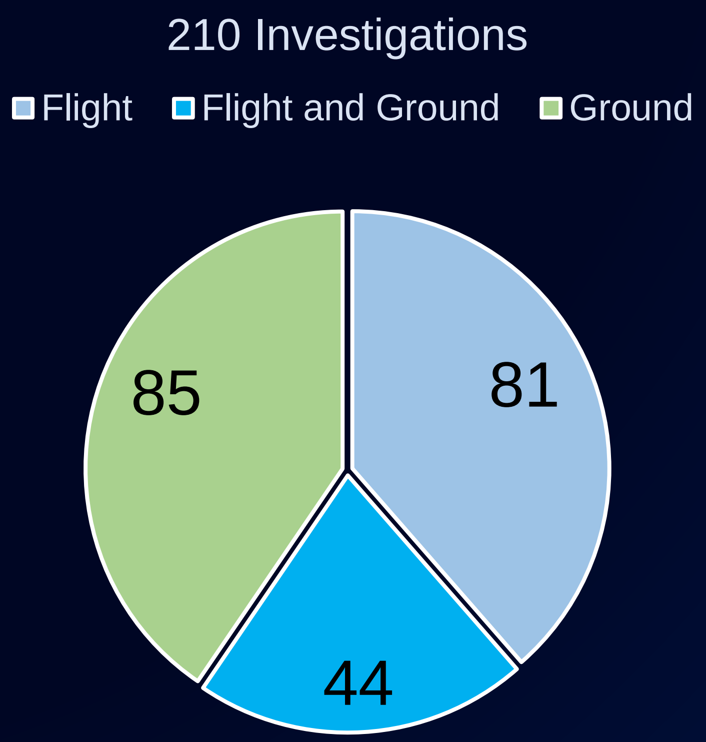

Russian Isolation Chamber


Gravity Vector Averaging


Physical Sciences
Informatics


GeneLab

BPS Investigations Span Many Disciplines



- Animal Biology
- Plant Biology
- Microbiology
- Combustion
- Fluid Physics
- Materials Science
- Soft Matter
- Fundamental Physics

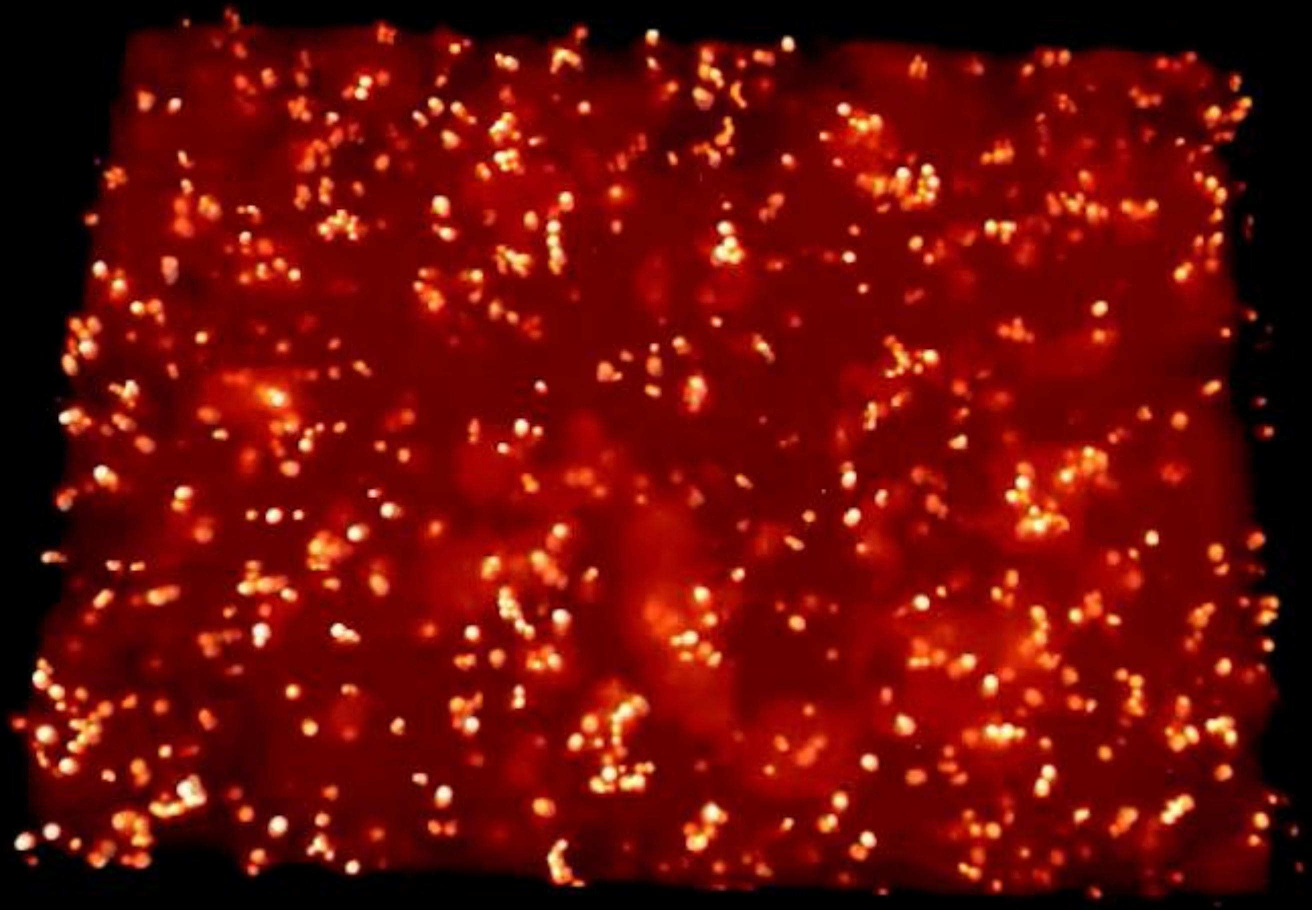
BPS Partners with Govt, Academics, and Industry

DEPARTMENT OF HEALTH & HUMAN SERVICES · USA
BIOMEDICAL ADVANCED RESEARCH AND DEVELOPMENT AUTHORITY BARDA
FDA
CDC CENTERS FOR DISEASE CONTROL AND PREVENTION
NIH NATIONAL CANCER INSTITUTE
NIH National Institute of Health
esa
JAXA
DEPARTMENT OF ENERGY UNITED STATES OF AMERICA
NSF
USDA
NIST National Institute of Standards and Technology
NIH National Center for Advancing Translational Sciences
ИМБП
cnes CENTRE NATIONAL D'ÉTUDES SPATIALES
CSA ASC
ISS U.S. NATIONAL LABORATORY
techshot
Tupperware®
NIH National Institute of Allergy and Infectious Diseases
asi agenzia spaziale italiana
ОСКОСМО
DLR
BIOSERVE SPACE TECHNOLOGIES
REDWIRE
University of Zurich UZH
CNU 충남대학교 CHUNGNAM NATIONAL UNIVERSITY
BOEING
KBR
leidos
snc SIERRA NEVADA CORPORATION
AEGIS AEROSPACE
Florida Institute of Technology
WINSTON-SALEM STATE UNIVERSITY
ZIN Technologies, Inc.
Barrios Technology
TELEDYNE BROWN ENGINEERING Everywhereyoulook™
Stinger Ghaffarian Technologies
TMI TEC-MASTERS Inc.
MAYO CLINIC
UF UNIVERSITY of FLORIDA

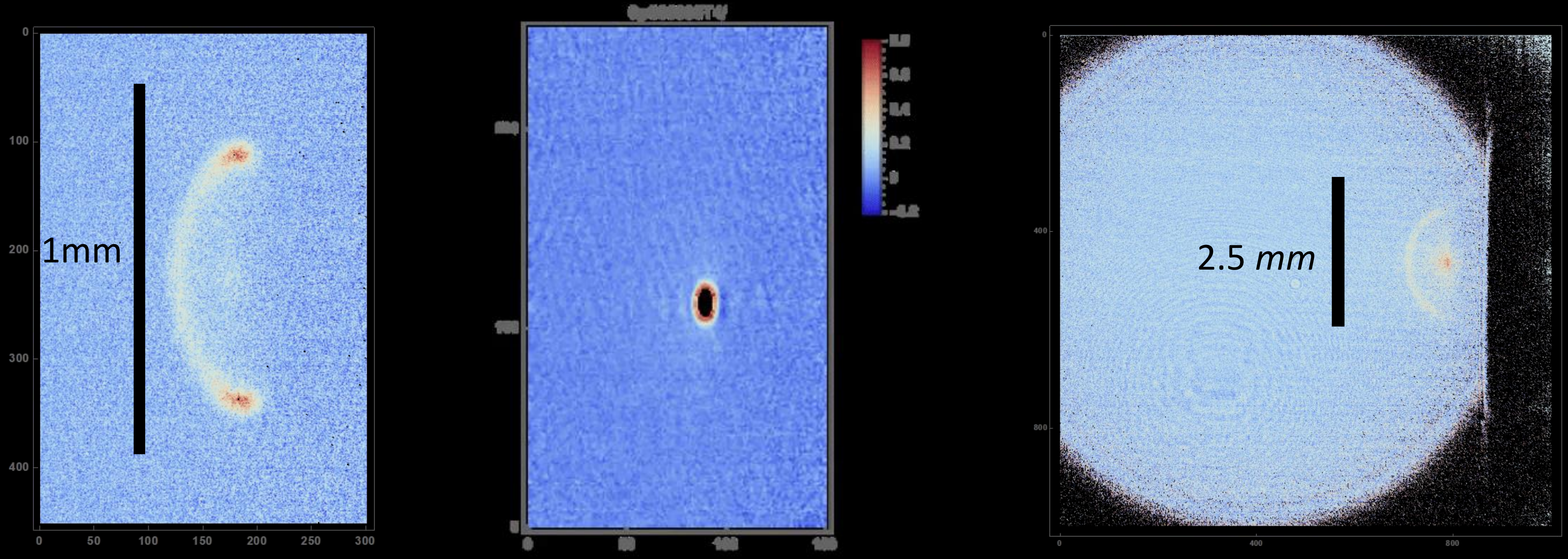
Examples of BPS Research

Soft Matter

- Colloidal interaction potentials
- Consumer product shelf life

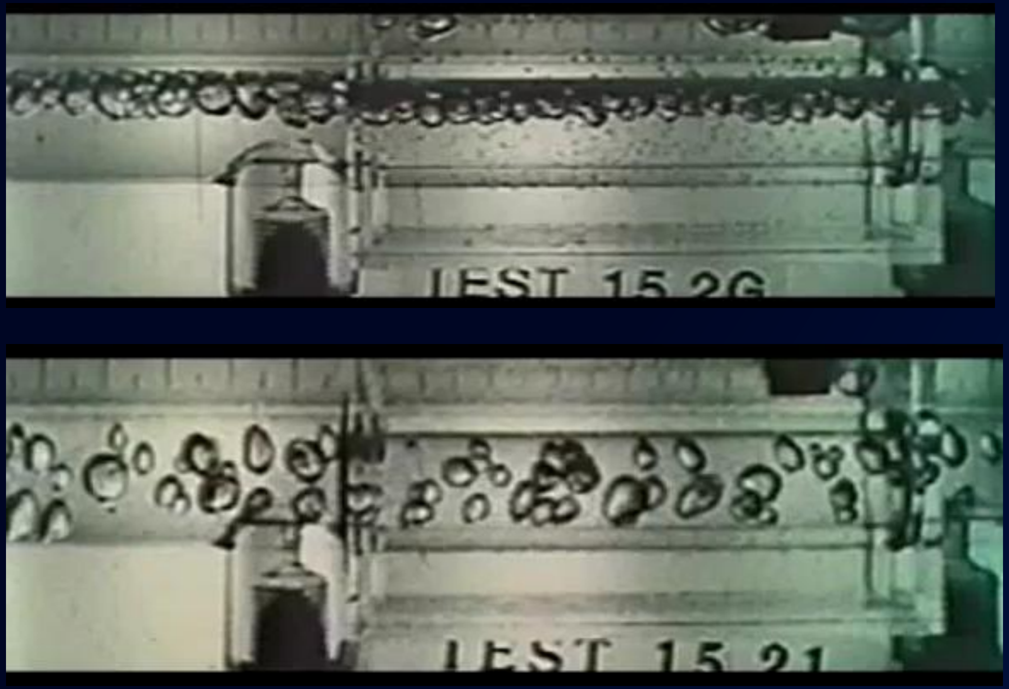


Bose-Einstein Condensates

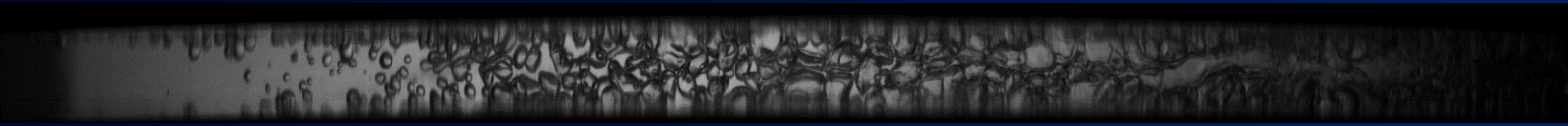


- Fundamental properties of quantum matter

Two-Phase Flow

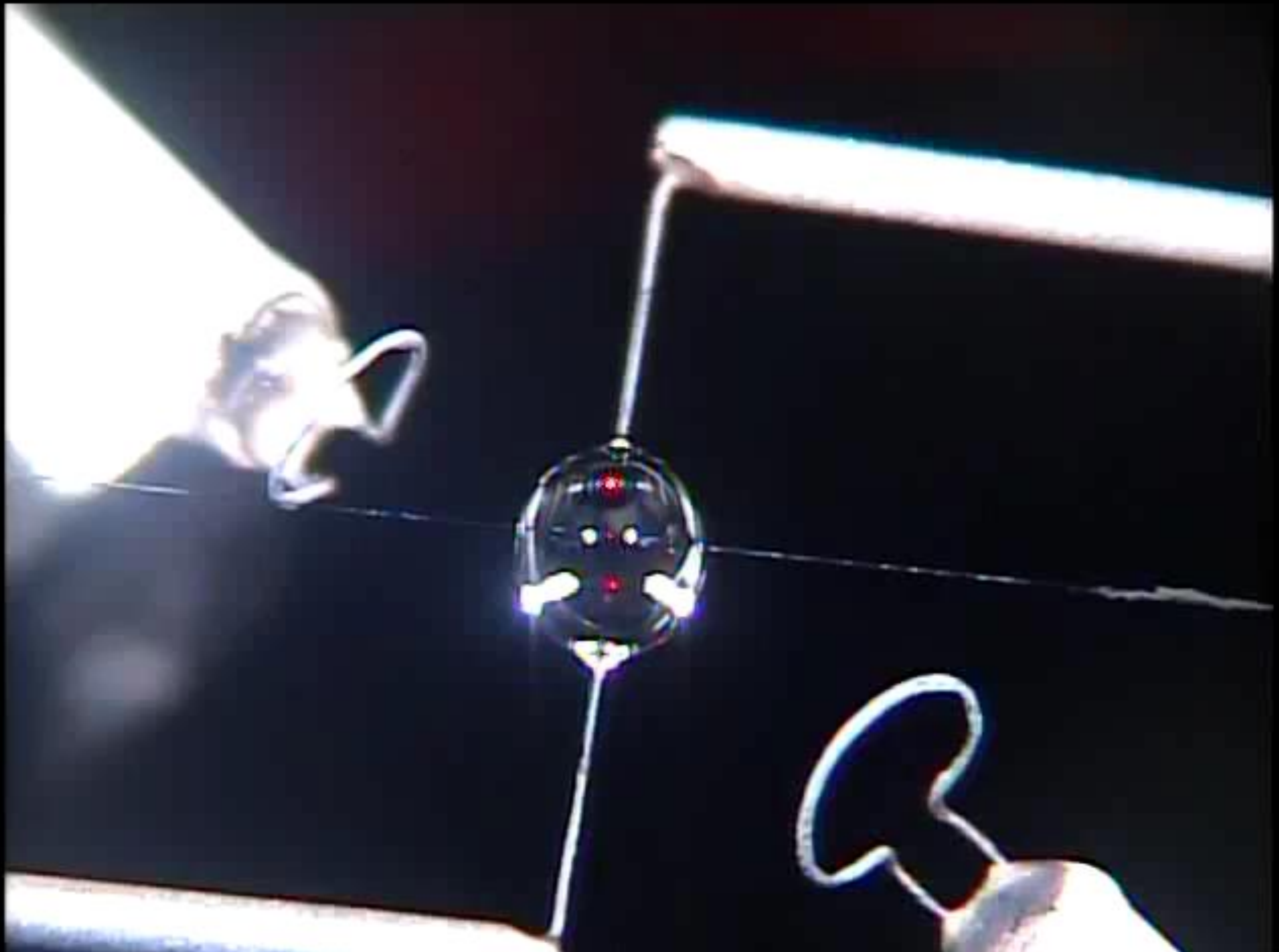


- Thermal management
- Cryogenic fuel refueling
- Power systems



Cool Flames

- Fire safety in exploration
- Terrestrial combustion models



Thriving in Deep Space (TIDES)

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

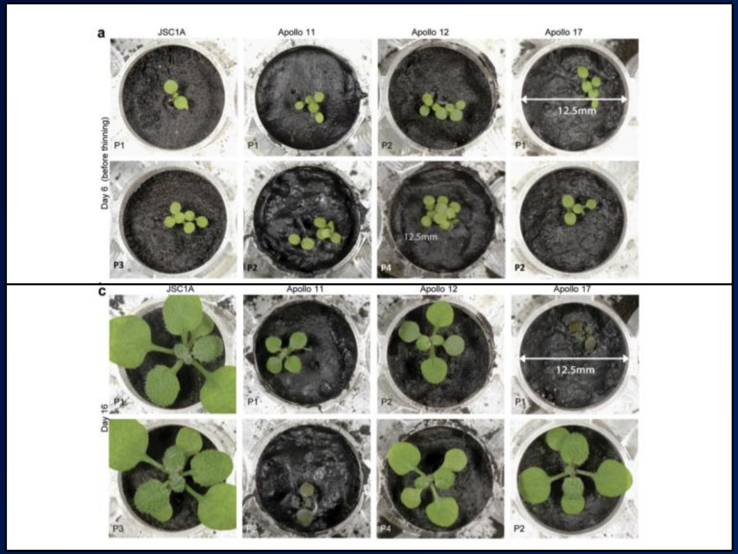
Plant Signaling

- Preparation for flight
- Ca^{2+} signaling on Earth

Plant Growth

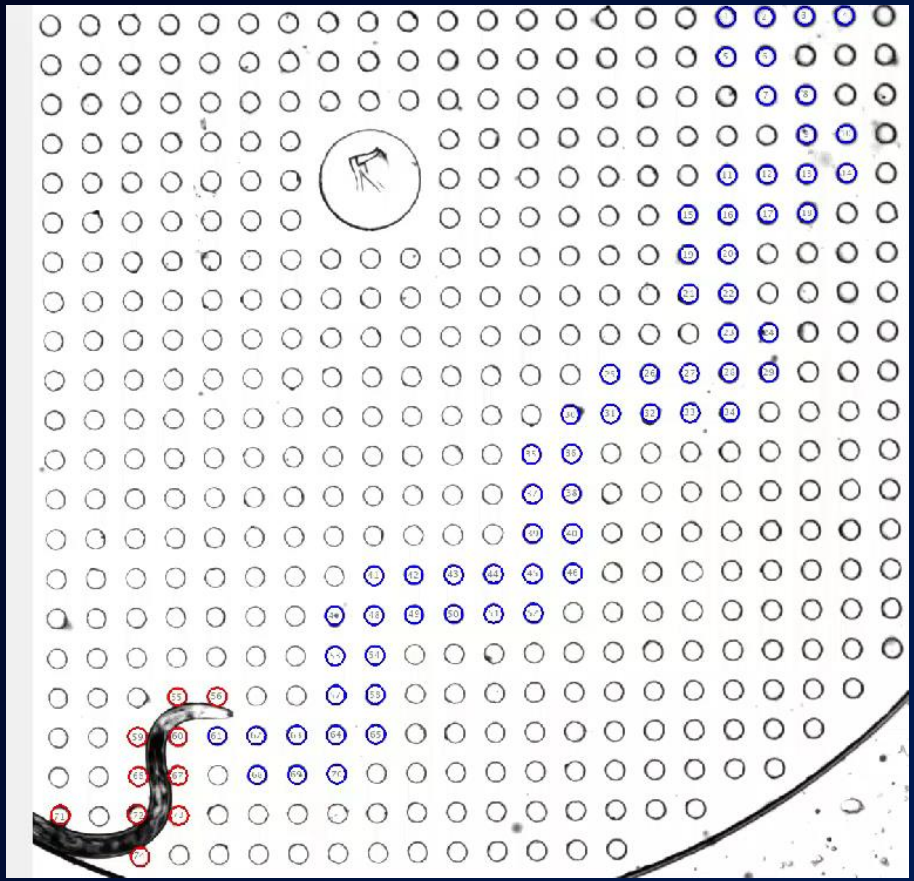
- Crop plants grown on ISS

- Plants grown in lunar regolith collected during the Apollo 11, 12 and 17 missions



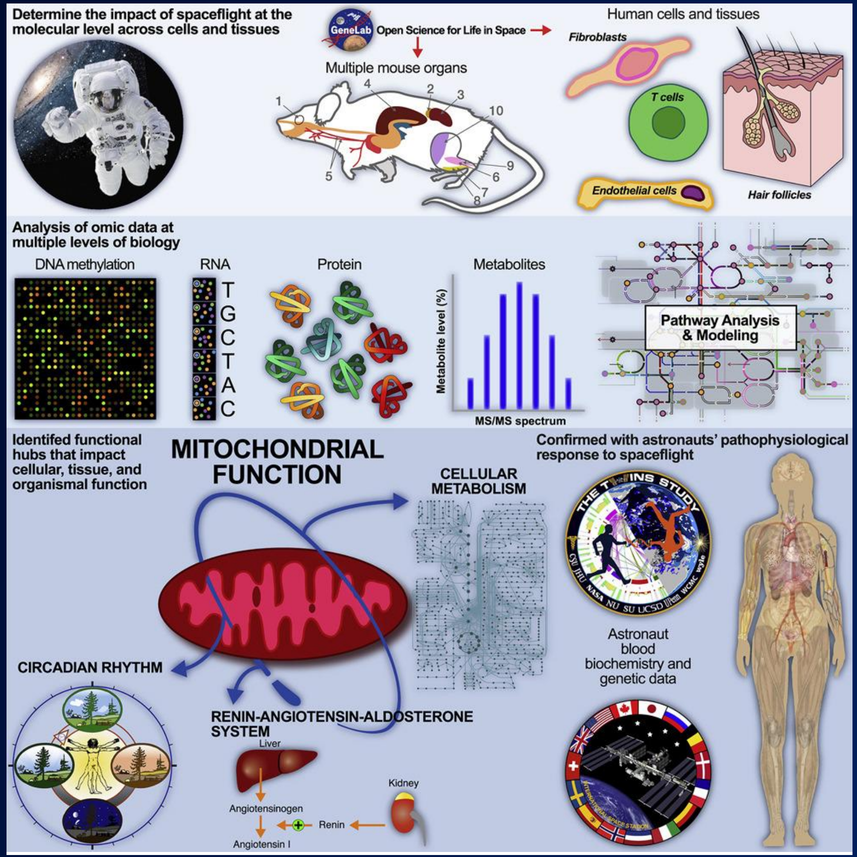
Muscle Atrophy

- Nematodes pushing pillars in orbit

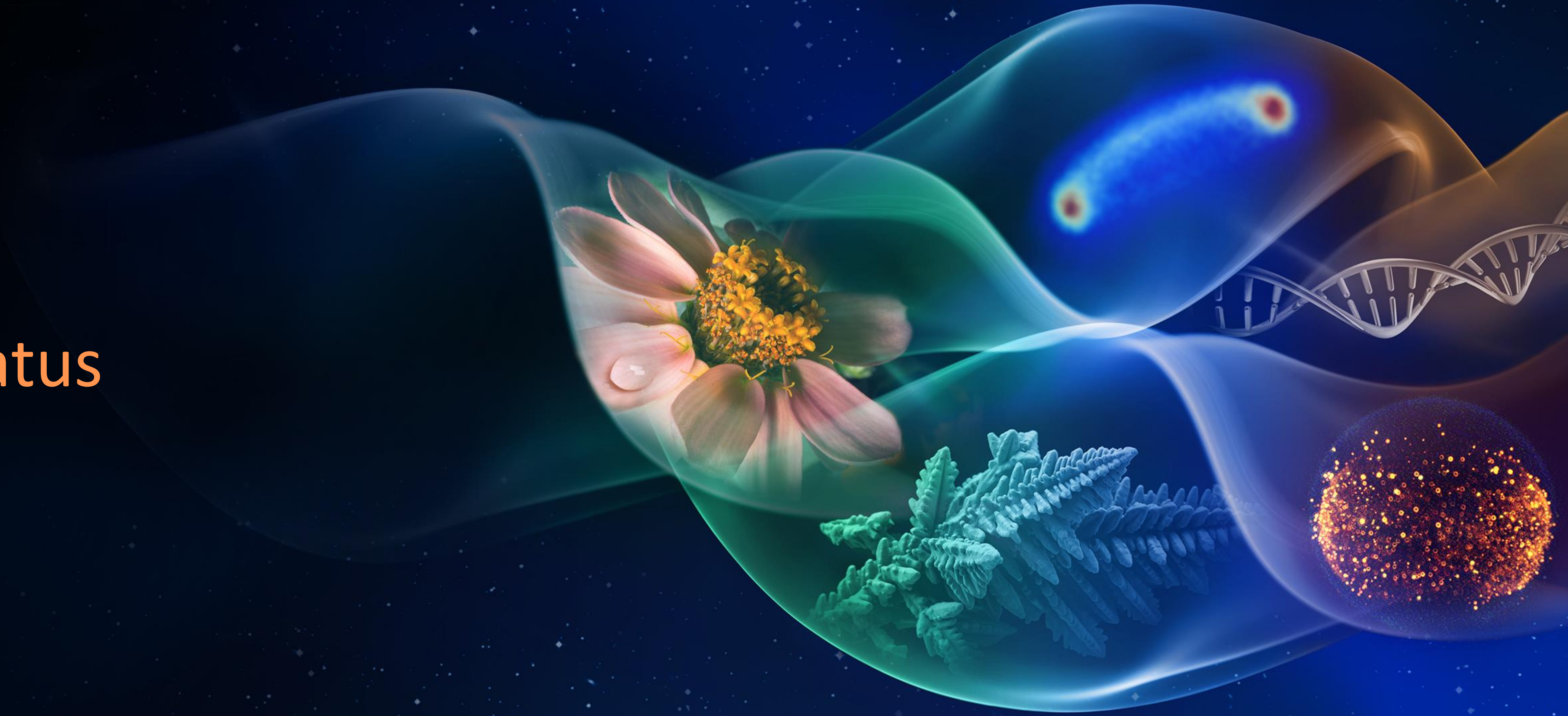


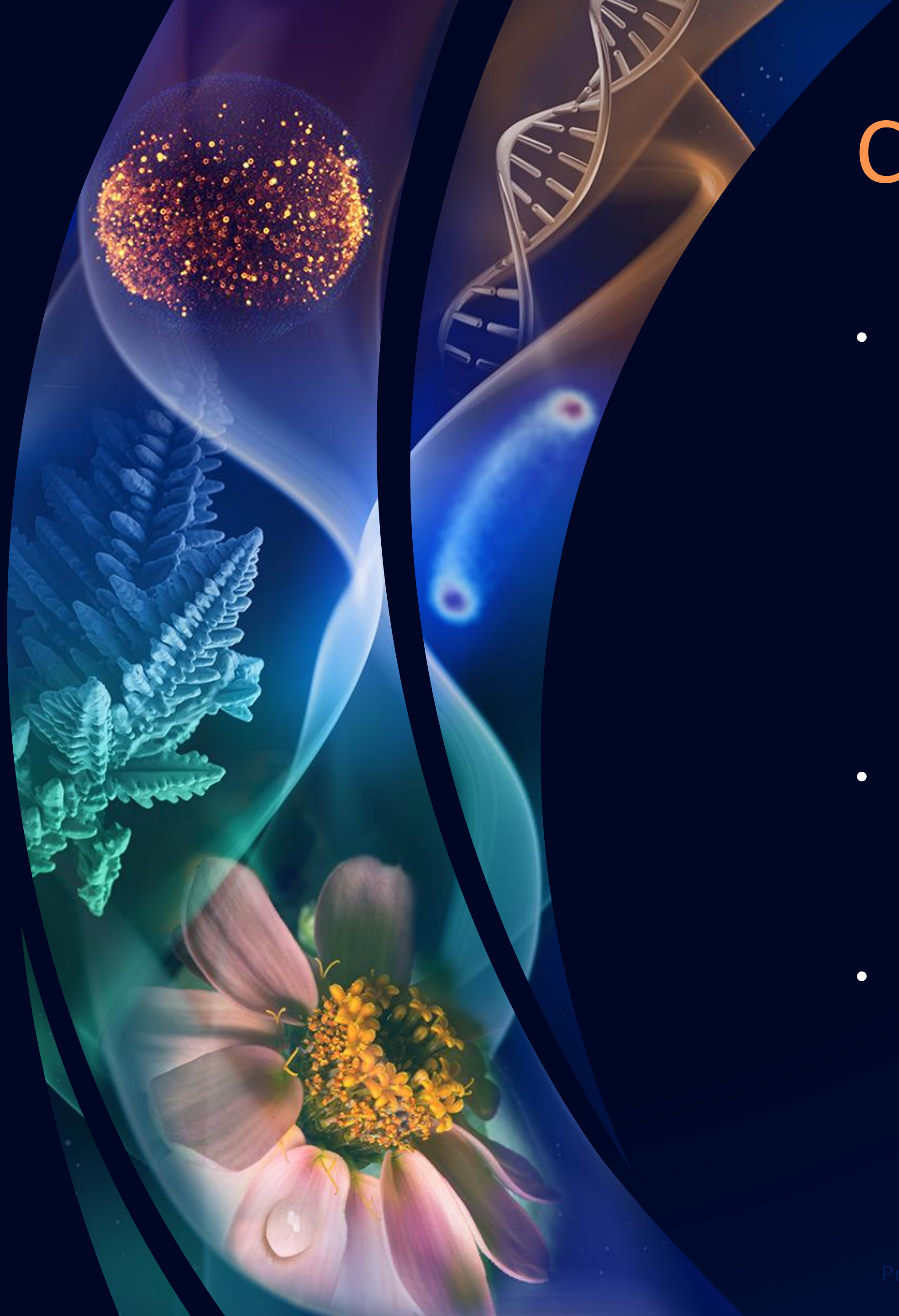
Omics

- Cell culture, mice, astronauts
- Mitochondrial dysfunction is a central hub for spaceflight response



Status





Current Status

- Continue “base” program
  - Maintain focus on and solicit new research in two areas
    - Quantum science
    - TIDES (Thriving in Deep Space)
  - Fulfill 2011 Decadal commitments in other disciplines
  - Expand Open Science and IDEA activities

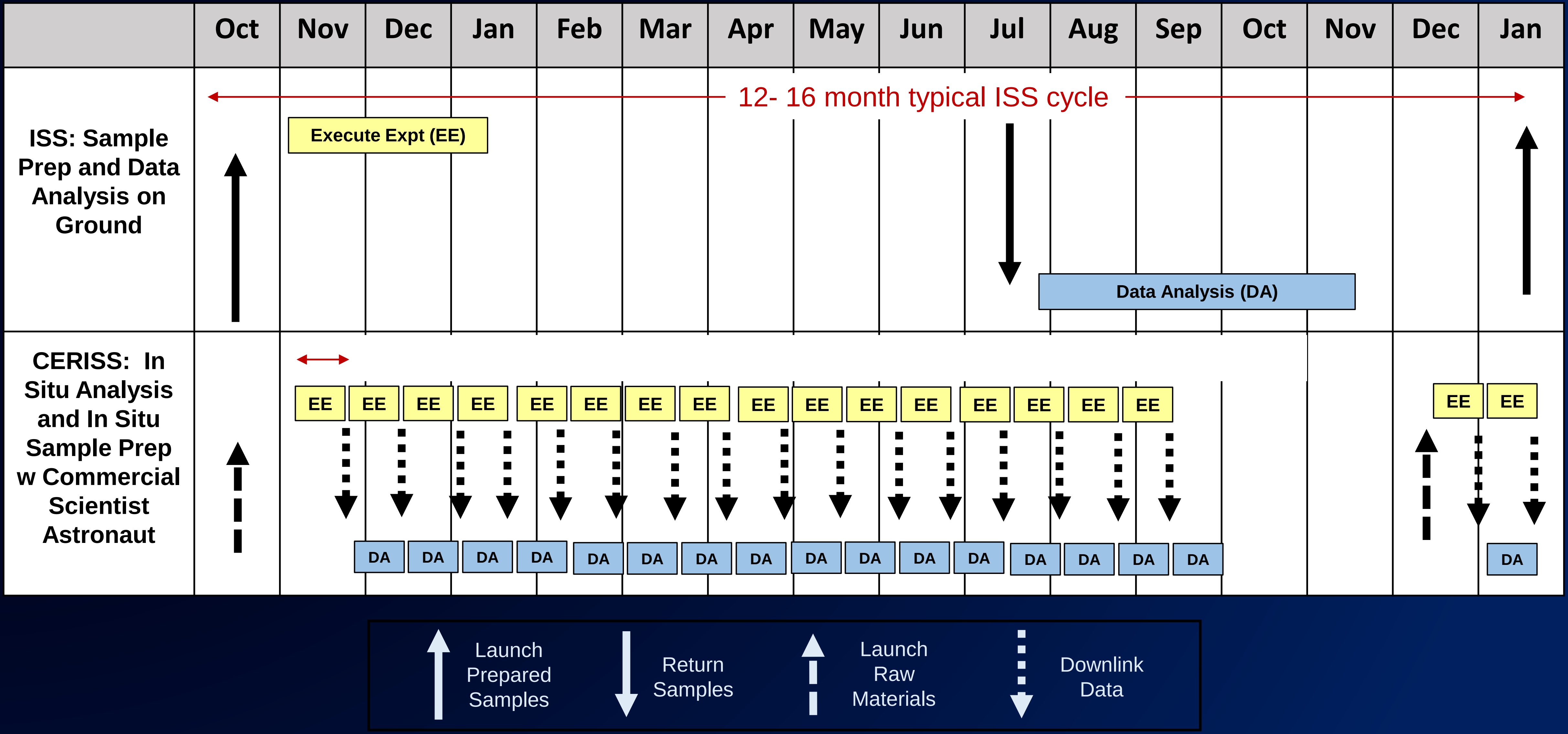
- Launch commercial initiative (CERISS) to increase research productivity and research demand in low Earth orbit

- Prepare to respond to the 2023 Decadal Survey

Commercially-Enabled RapId Space Science (CERISS)

- Objective
  - 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 can take years to plan, develop, launch, operate, return samples and begin the cycle again
- 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

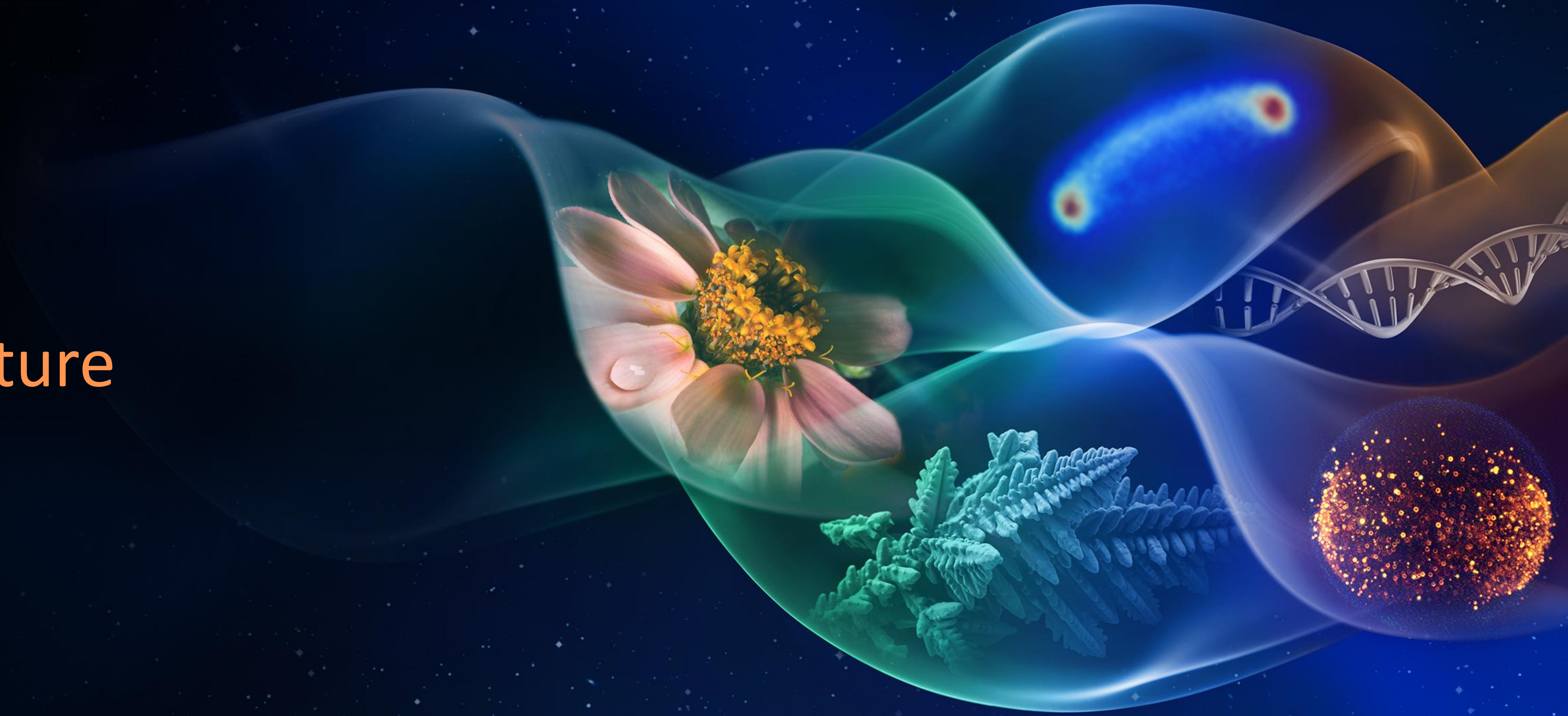


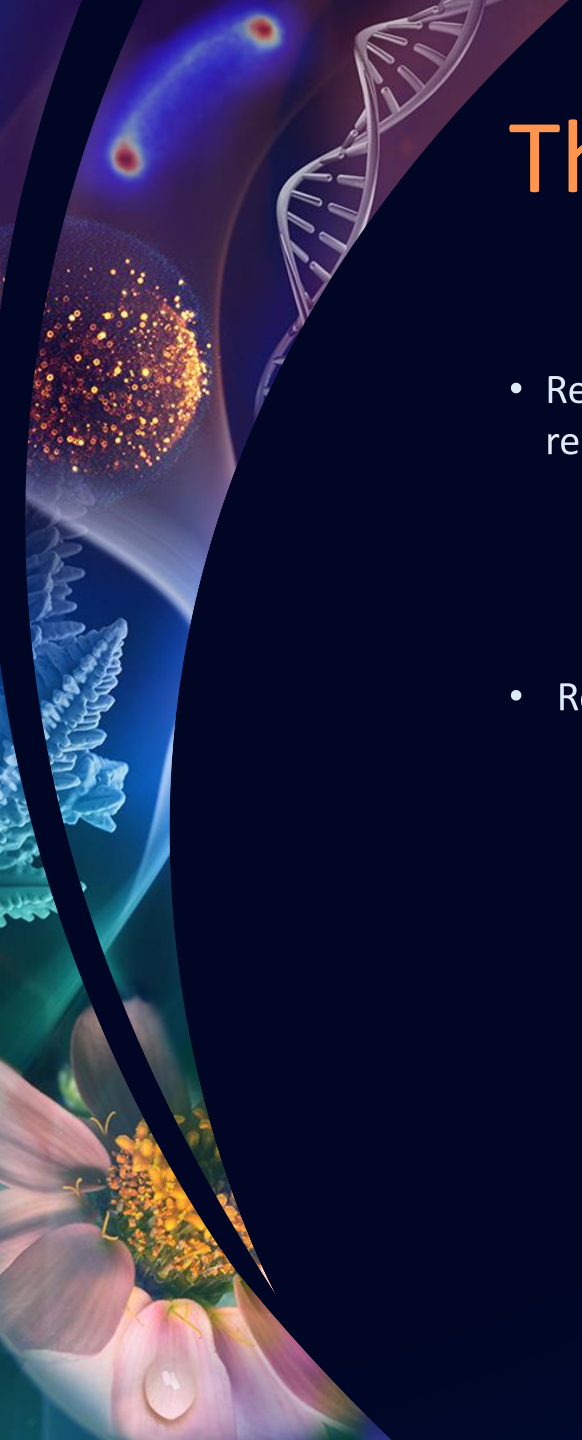
CERISS Approach

- Develop and deploy in situ analysis and in situ preparation capabilities in low Earth orbit for use by all astronaut types (NASA, PAM, SAM)
  - Issue RFIs and conduct gap analysis with Space Operations Mission Directorate
    - RFI 1: Existing state-of-the-art capabilities, capabilities in development
    - RFI 2: Decadal Survey priorities that benefit 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

Future





The Next Decadal Survey for BPS (2023-2032)

- Recommendations for a decade of transformative science at the frontiers of biological and physical sciences research in space
  - Uniquely advance scientific knowledge,
  - Meet the needs of human and robotic exploration missions, and/or
  - Provide terrestrial benefits
- Recommendations for implementing the transformative science goals and objectives
  - Research activities
  - Associated facilities and platforms (“Keystone Capabilities/Missions”)
  - Research Campaigns

The transformative science conducted through Keystone Capabilities and Research Campaigns will be the building blocks of BPS’s scientific program for the next decade

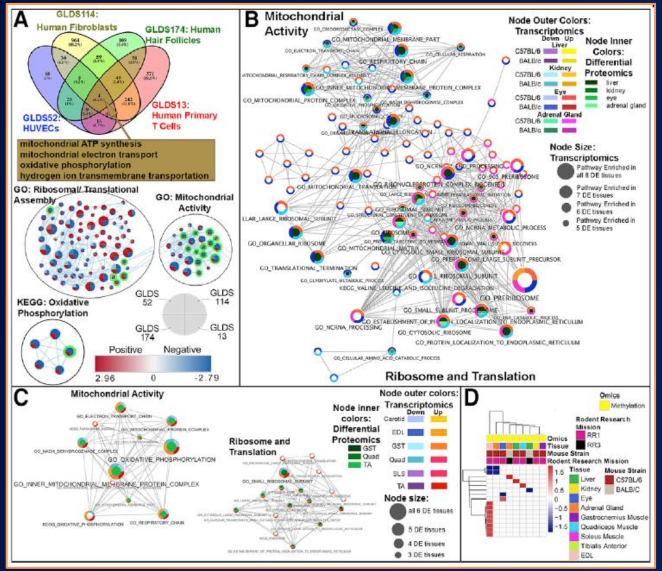
Possible Transformative Areas in Physical Sciences

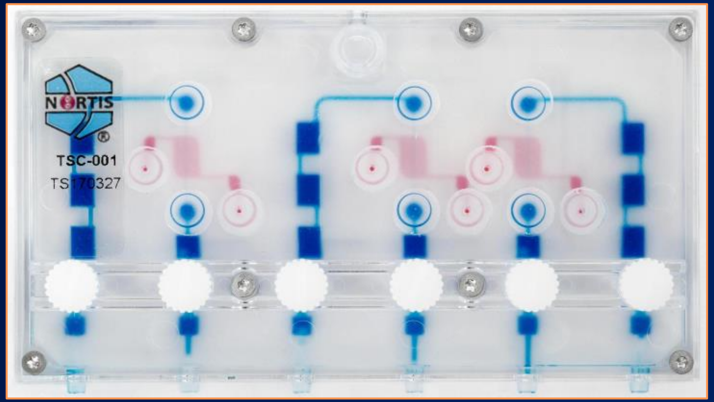
- Soft Matter: Active, non-equilibrium systems responsive to external forces controlled in space and time.
- Quantum Matter – the physics of few- to many-body quantum systems
- General Relativity (GR) – precision metrology exploring the limits of GR
- Dark Matter (DM) and Dark Energy (DE) – quantum mechanics applied to search for signatures of DM and DE
- Quantum Mechanics – entanglement in relativistic systems and over solar system-scale distances

- Combustion: High pressure transcritical combustion; low temperature chemical kinetics
- Fluid Physics: Cryogenic fuel management; thermal management systems
- Materials Science: Additive manufacturing; lunar surface construction using regolith

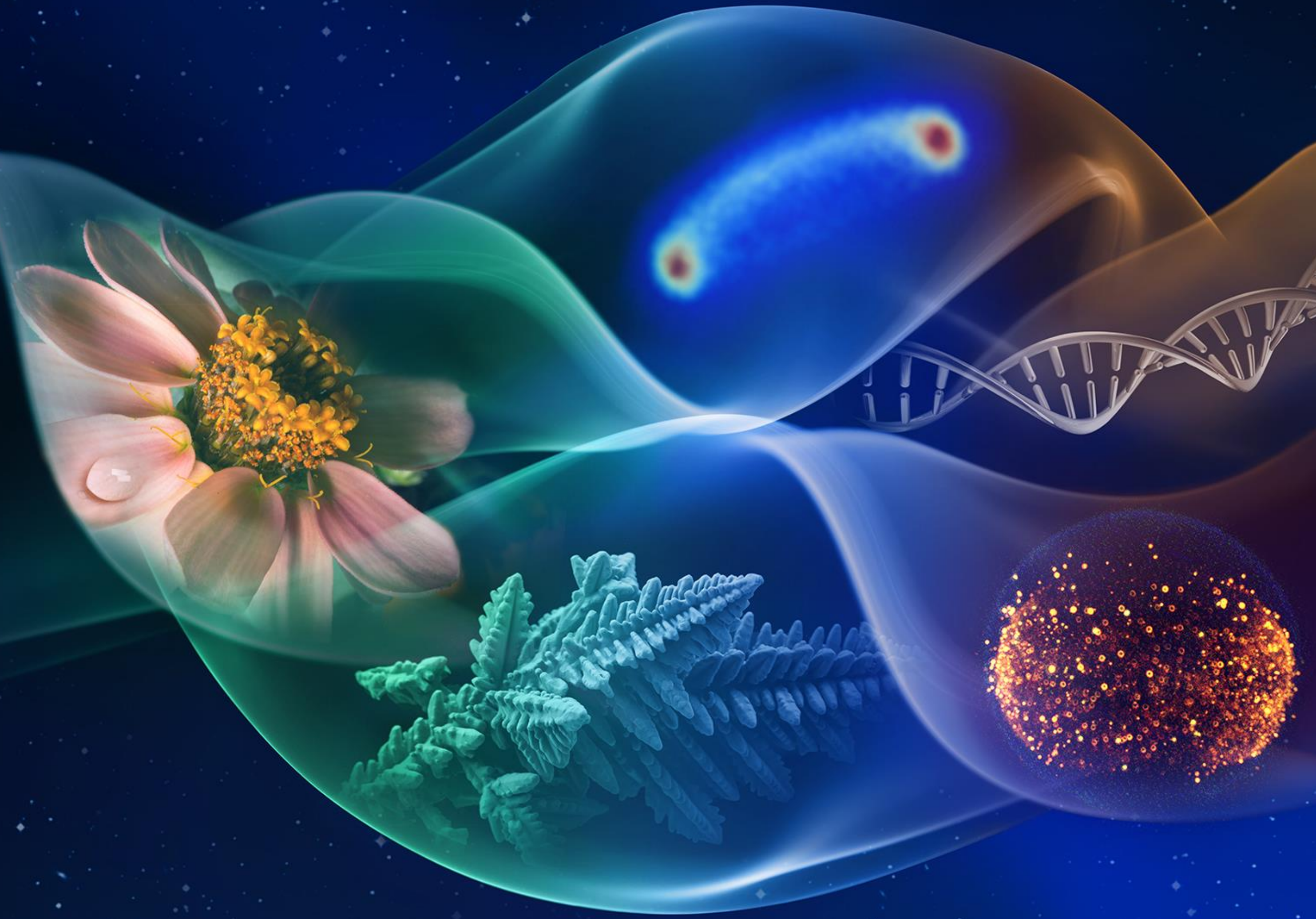
Possible Transformative Areas in Space Biology

- Systems Biology
- Quantitative Genetics
- Genetic Engineering of Plants
- 3D Tissues & Organ-on-Chip Models
- Automation, Miniaturization & Data Telemetry
- Artificial Intelligence/Machine Learning (AI/ML)





Conclusion



More about BPS

- News
  - Twitter: @NASASpaceSci
  - Website: science.nasa.gov/biological-physical
- Funding and Requests for Information
  - NASA Solicitation and Proposal Integrated Review and Evaluation System
    - nspires.nasaprs.com
    - **CERISS solicitation: NNH22ZDA014L**
  - Research Opportunities in Space and Earth Sciences (ROSES)
- Research Portfolio
  - Task Book: taskbook.nasaprs.com
- Commercial Contacts
  - Lisa Carnell, Program Scientist
    - lisa.a.scottcarnell@nasa.gov
  - DeVon Griffin, Program Manager
    - devon.w.griffin@nasa.gov

Conclusion

- As commercial spaceflight capabilities expand in sub-orbital, LEO, and lunar domains and
  - As NASA plans to
    - return to the lunar surface,
    - develop sustainable lunar habitation, and
    - prepare to explore Mars

- Biological and Physical Sciences will, guided by the 2023 Decadal Survey, tackle the most transformative research questions
  - ➢ To pioneer scientific discovery,
  - ➢ Enable sustainable exploration,
  - ➢ Benefit life on Earth



Thank you!