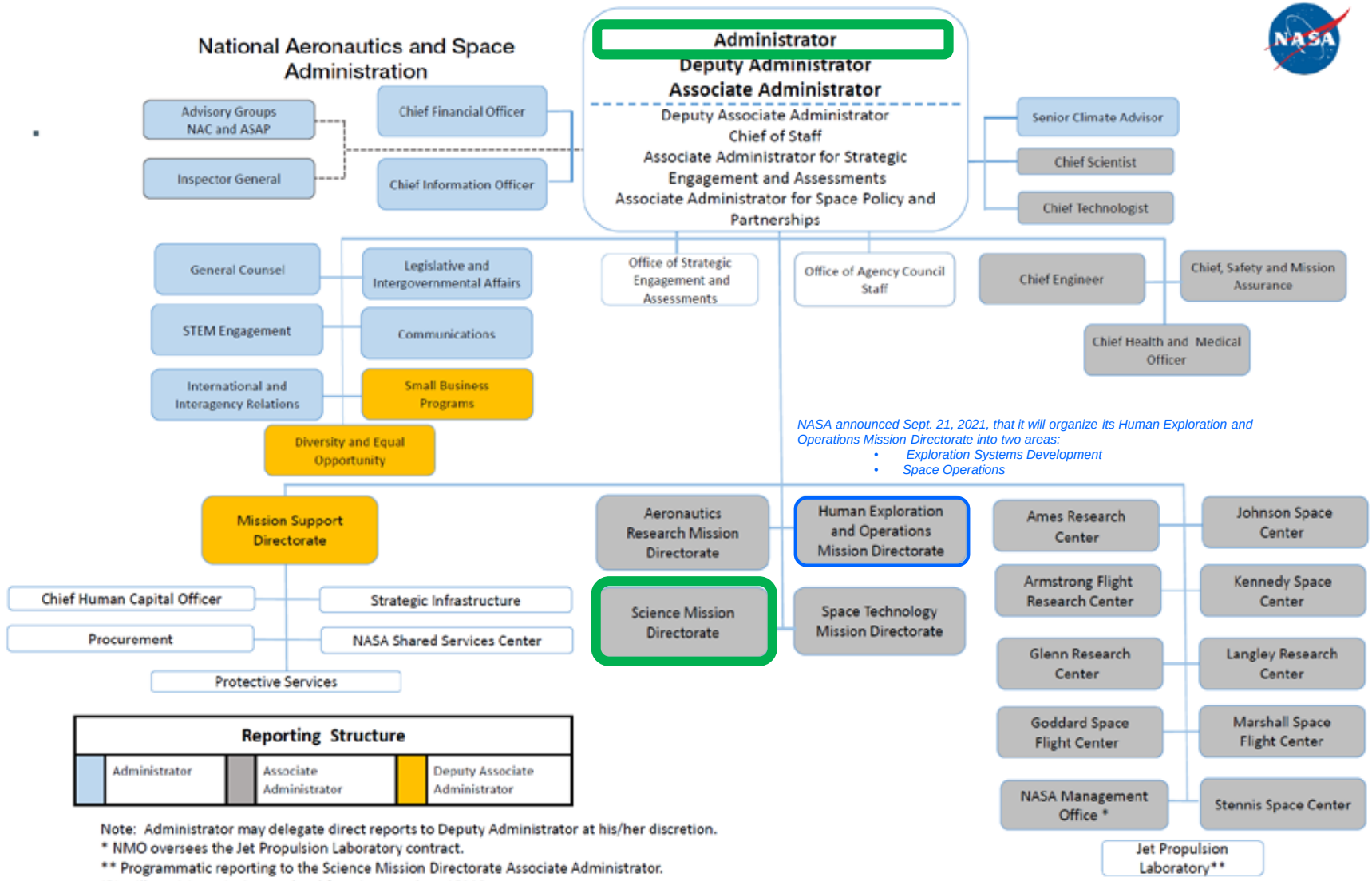
National Aeronautics and Space Administration

Biological and Physical Sciences (BPS) Program Overview

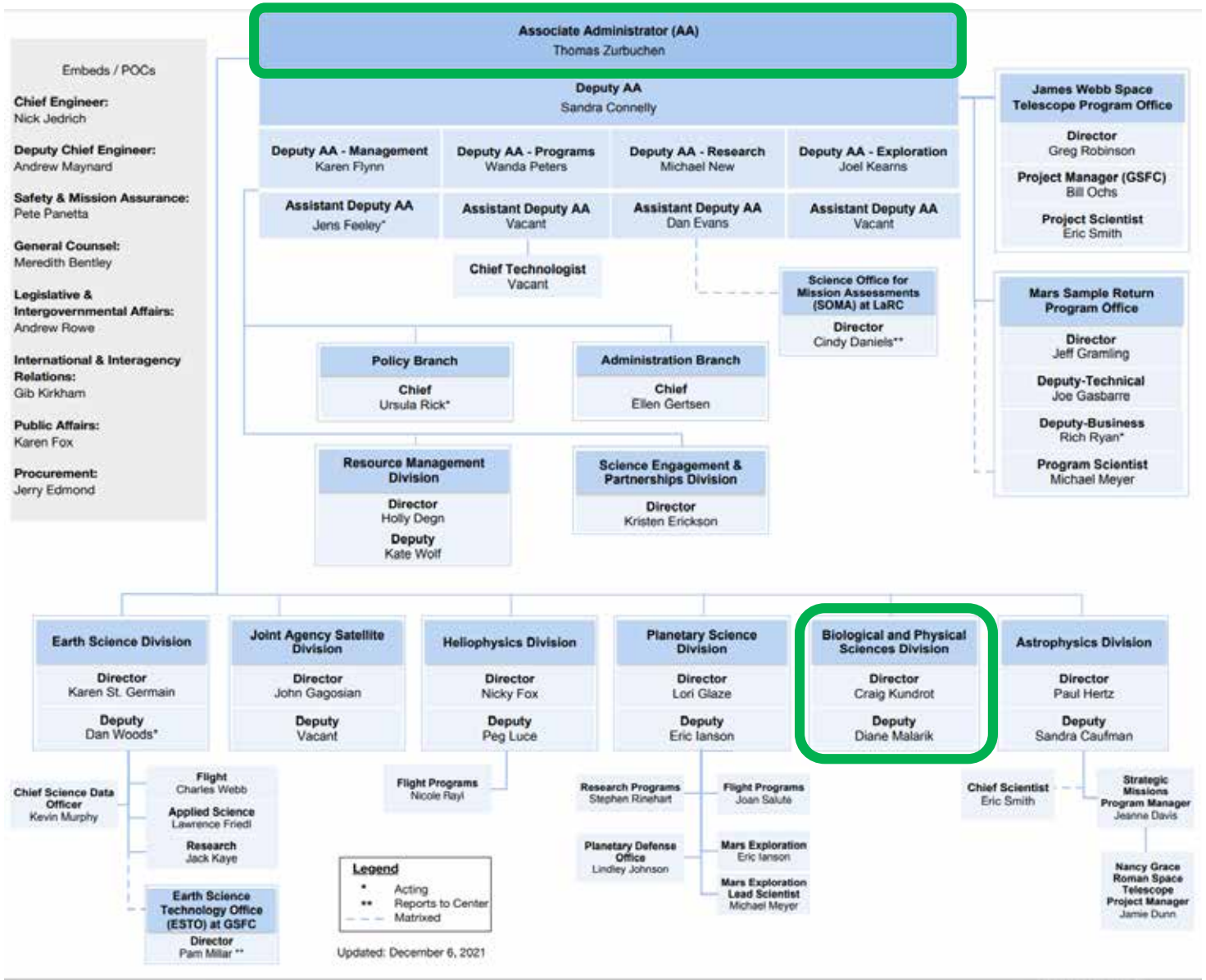
Craig Kundrot
Director
Biological and Physical Sciences Division

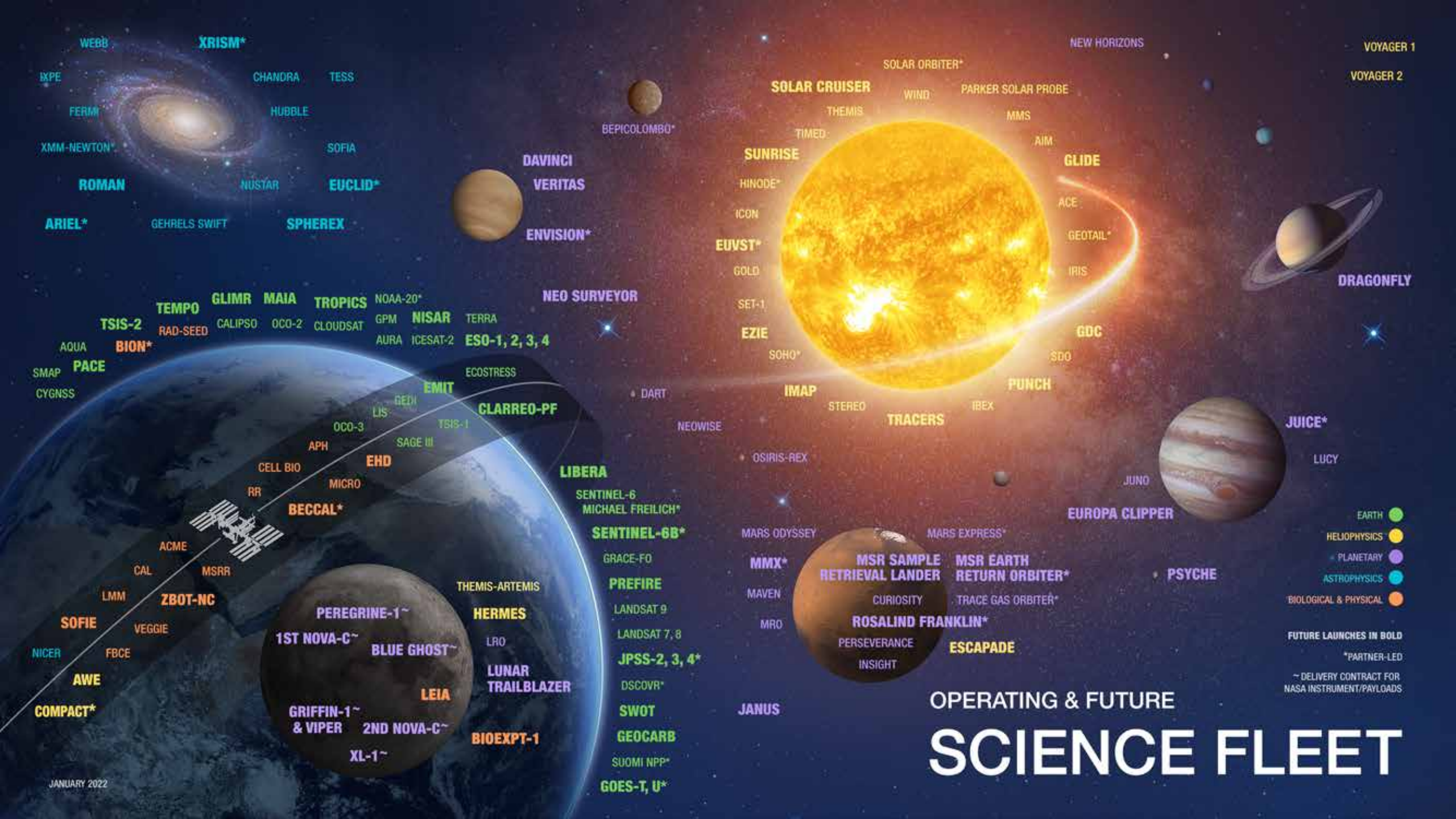
Organizational Context

NASA Organization



Science Mission Directorate Organization



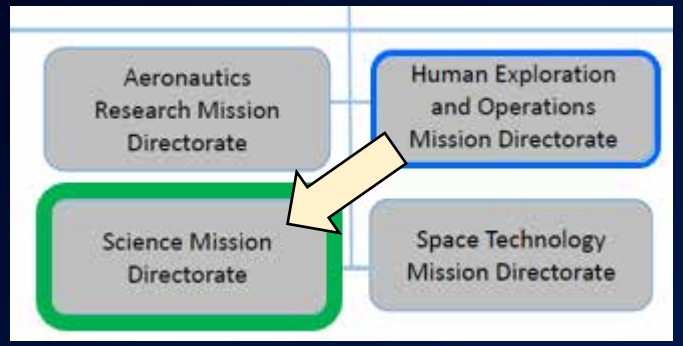


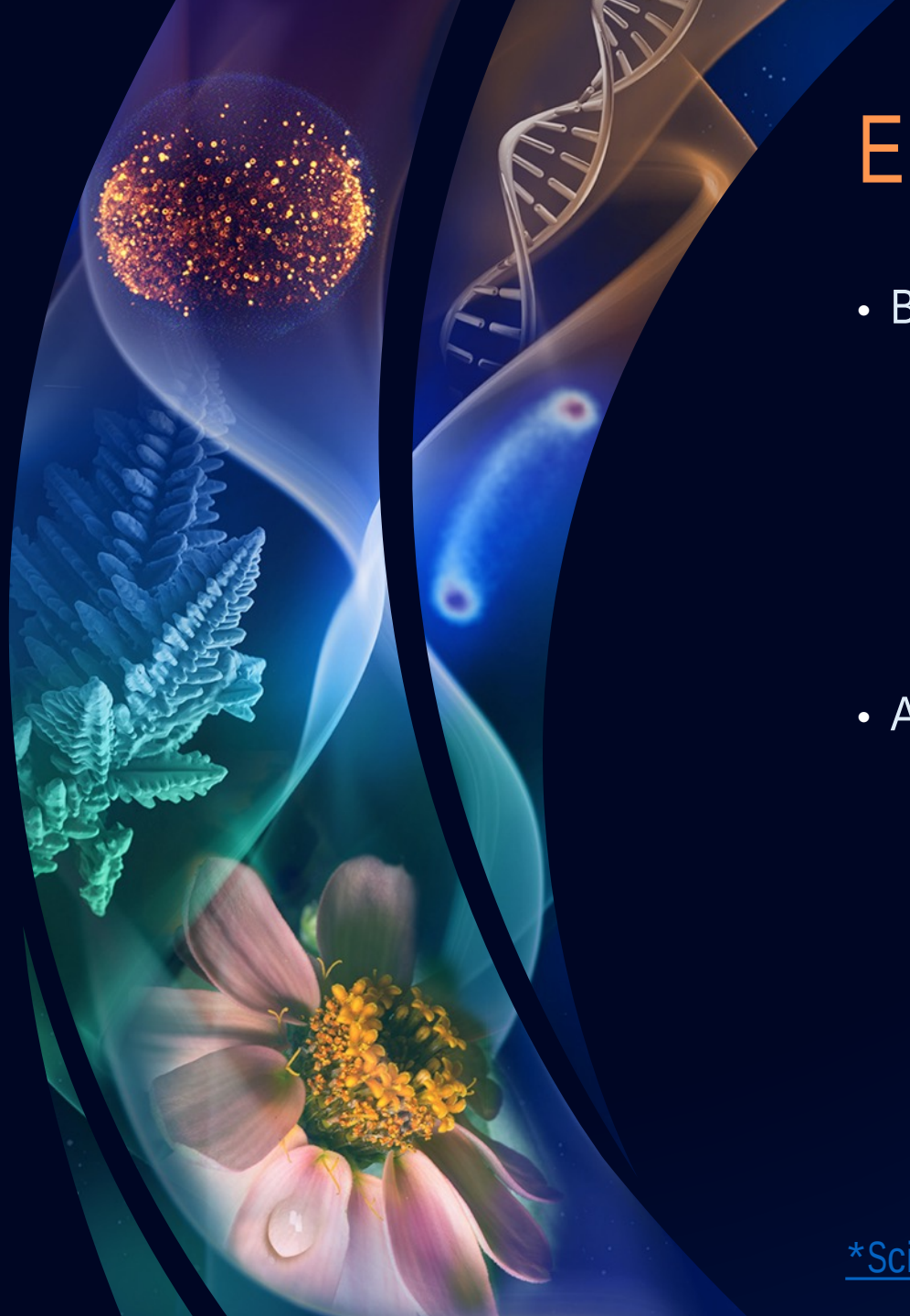
OPERATING & FUTURE

SCIENCE FLEET

The Creation of BPS

- The Biological and Physical Sciences moved in July 2020
- FROM
  - Human Exploration and Operations Mission Directorate
  - Space Life and Physical Science Research and Applications (SLPSRA) Division
- TO
  - Science Mission Directorate
  - Biological and Physical Sciences (BPS) Division



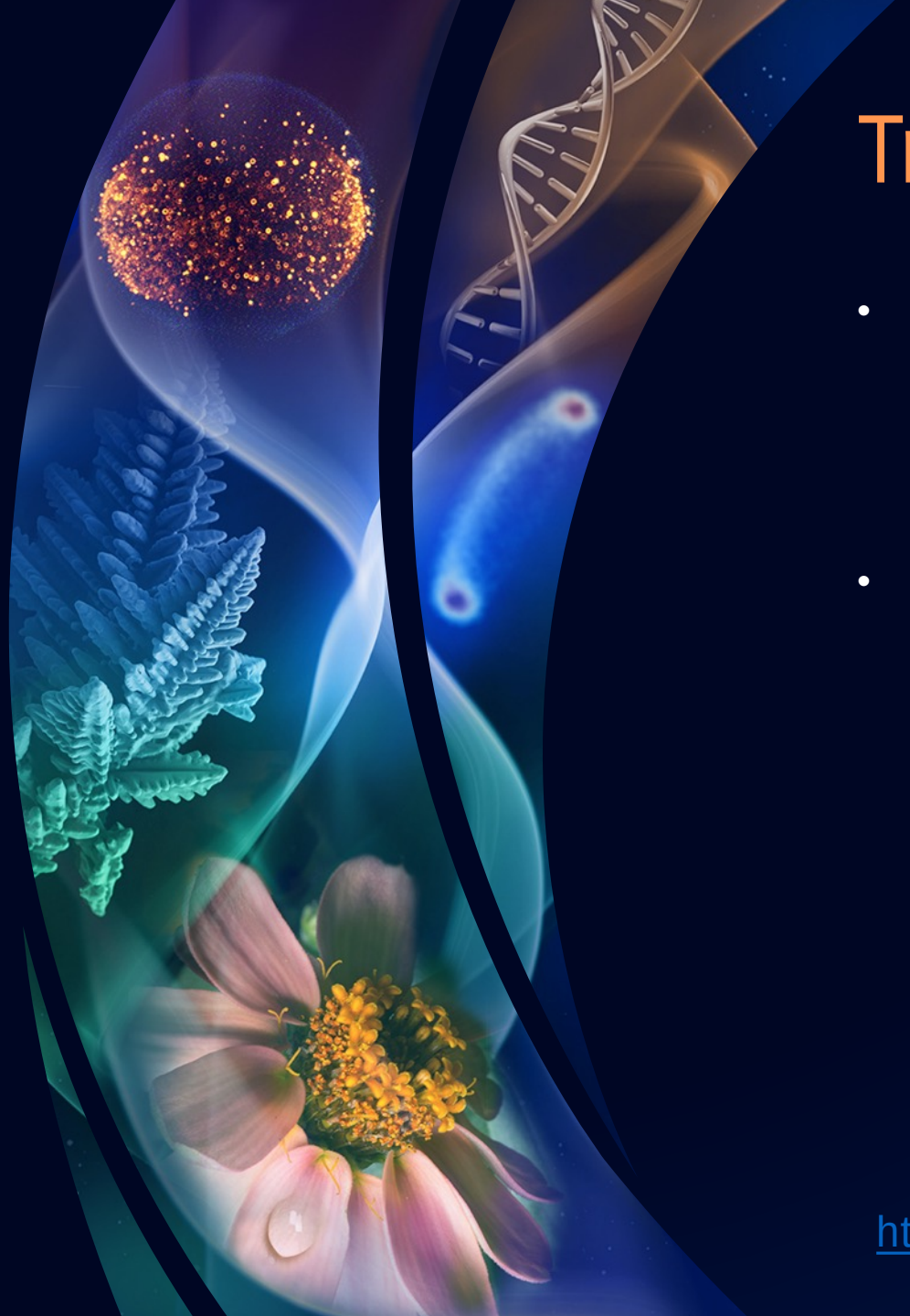


Emphases for BPS in SMD

- BPS very well aligned with SMD Science Plan*
  - Priority 1: Exploration and Scientific Discovery
  - Priority 2: Innovation
  - Priority 3: Interconnectivity and Partnerships
  - Priority 4: Inspiration

- Areas of increased emphasis for BPS in SMD
  - Broad communication
  - Inclusion, Diversity, Equity, Accessibility (IDEA)
  - Commercial spaceflight
  - Transformative science

*Science 2020-2024: A Vision for Scientific Excellence



Transformative Research

- Transformative research challenges current understanding or provides pathways to new frontiers
  - (Pioneer Scientific Discovery)
  - (Enable Sustainable Exploration)
- Transformative research involves
  - ideas, discoveries, or tools that
  - radically change
    - our understanding of an important existing scientific or engineering concept or
    - educational practice or
    - leads to the creation of a
      - new paradigm or
      - field of science, engineering, or education.

https://www.nsf.gov/about/transformative_research/definition.jsp

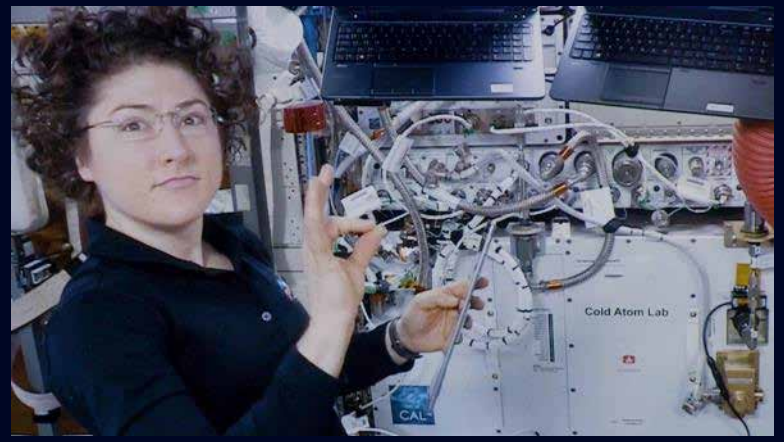
The Next Decadal Survey for BPS (2023-2032)

- 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
- Recommendations organized into broad cost categories
  - Example: New Worlds, New Horizons in Astronomy and Astrophysics (2010)
    - Table ES.4 “$100M to $200M”, “$60M to $200M”

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

BPS Today

BPS Vision



Example of Physical Sciences research: Studying quantum gasses

Example of Space Biology research: Growing plants in space

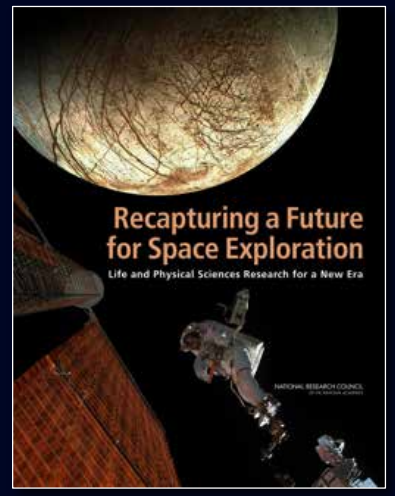
We use spaceflight environments to study biological and physical systems.

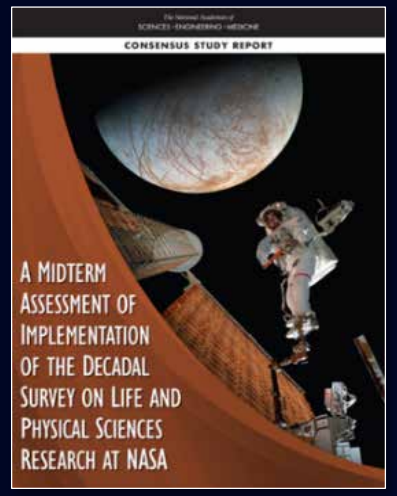
Examining phenomena under extreme conditions can help us better understand how they function.

This can contribute to significant scientific and technological advancements that

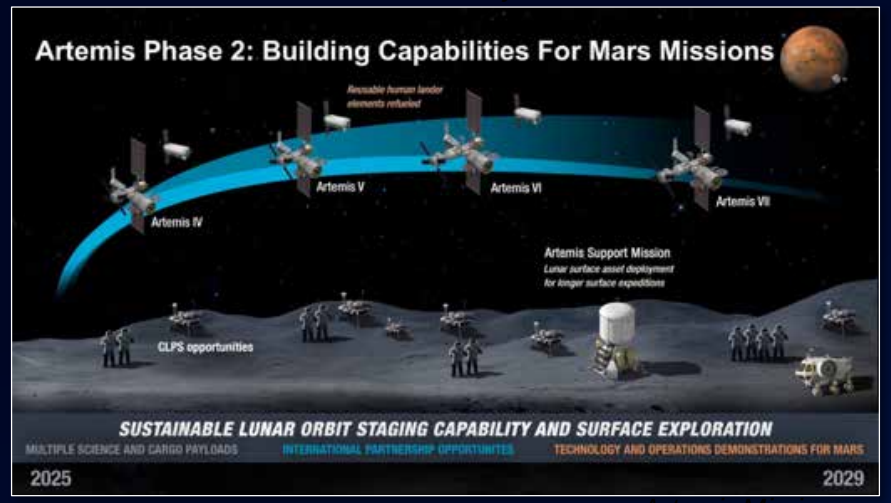
- make fundamental advances in science,
- enable space exploration, and
- benefit life on Earth.

BPS Mission





Decadal Survey



Artemis Missions

Pioneer Scientific Discovery

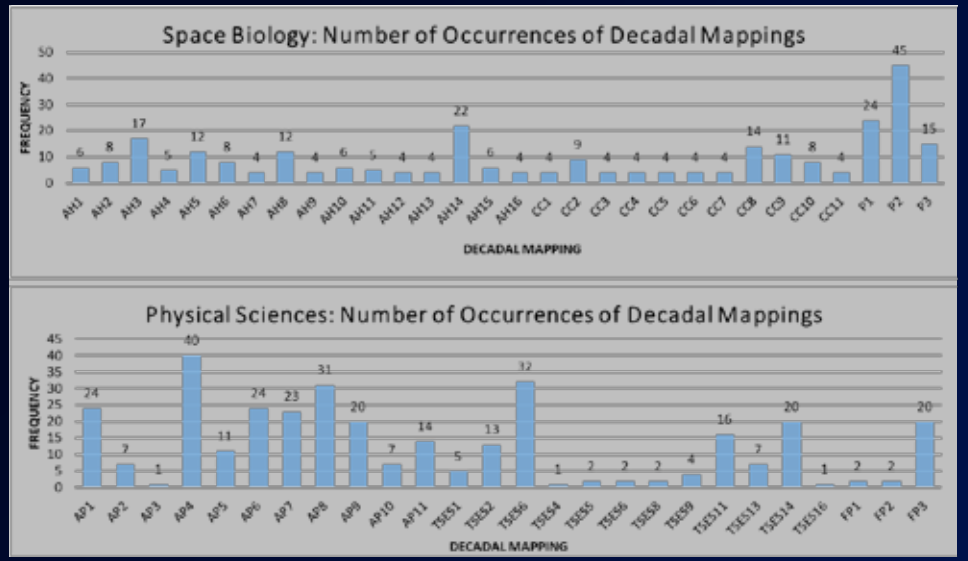
- Proactively seek out new ways to expand fundamental scientific knowledge
- Provide expertise and support to others seeking to utilize space

Enable Sustainable Exploration

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

Historical BPS Strategy

- Execute broad range of Decadal Survey (2011) highest priority recommendations
  - Decadal Survey has 65 high priority recommendations
  - SLPSRA/BPS funding has been spread among 56

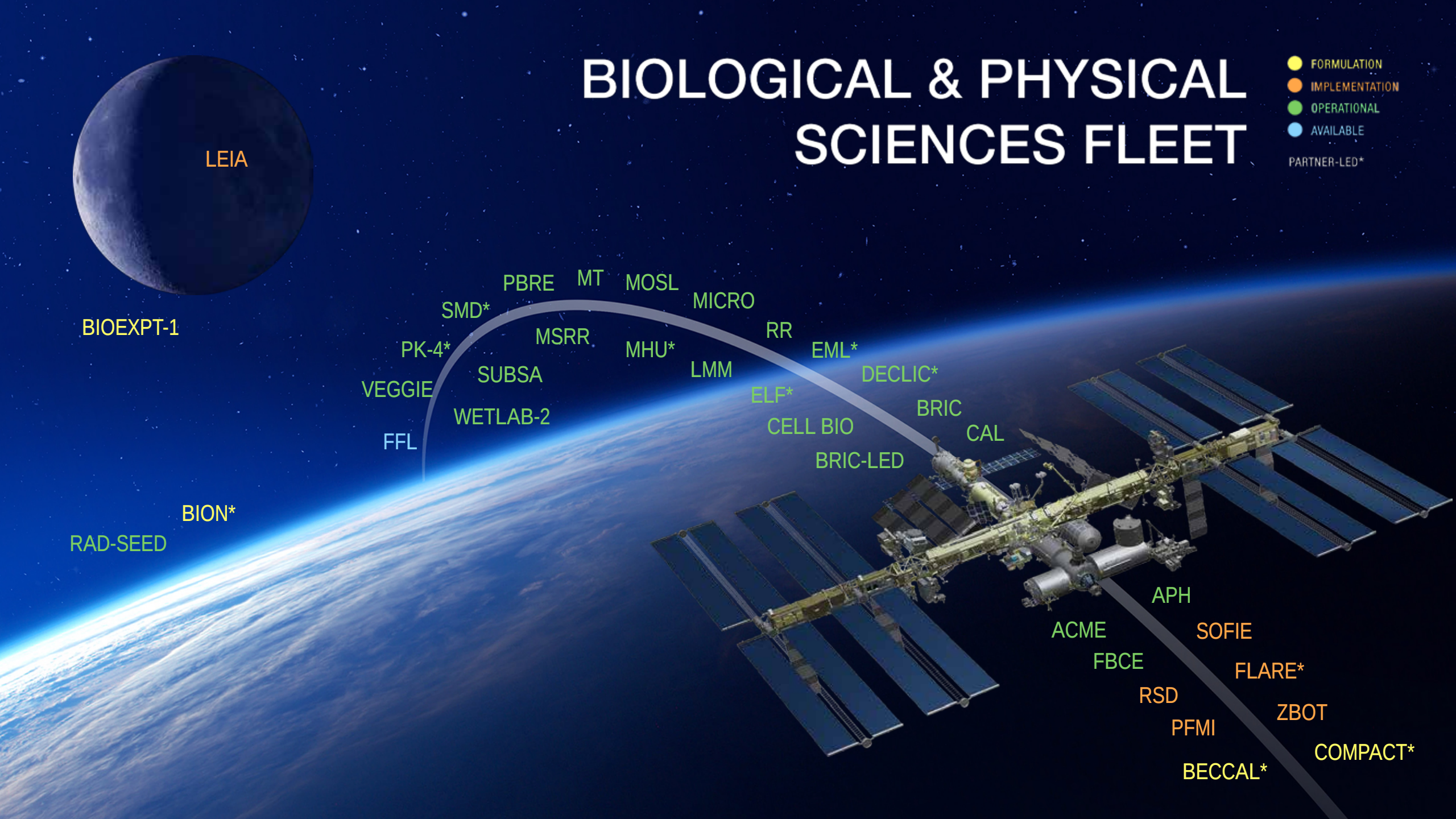


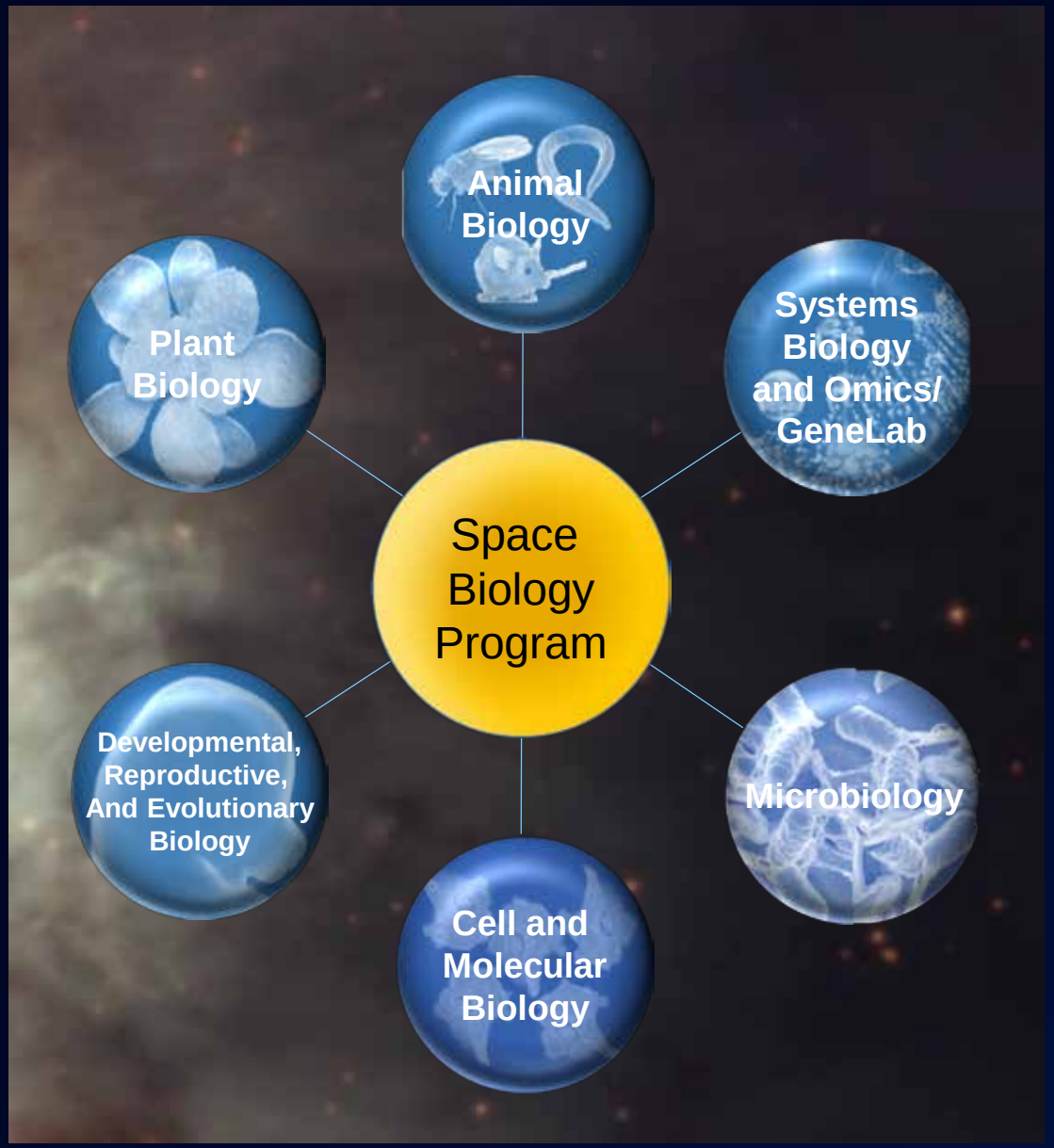
Investigations may be mapped to more than one topic

BIOLOGICAL & PHYSICAL SCIENCES FLEET

- FORMULATION
- IMPLEMENTATION
- OPERATIONAL
- AVAILABLE

PARTNER-LED*

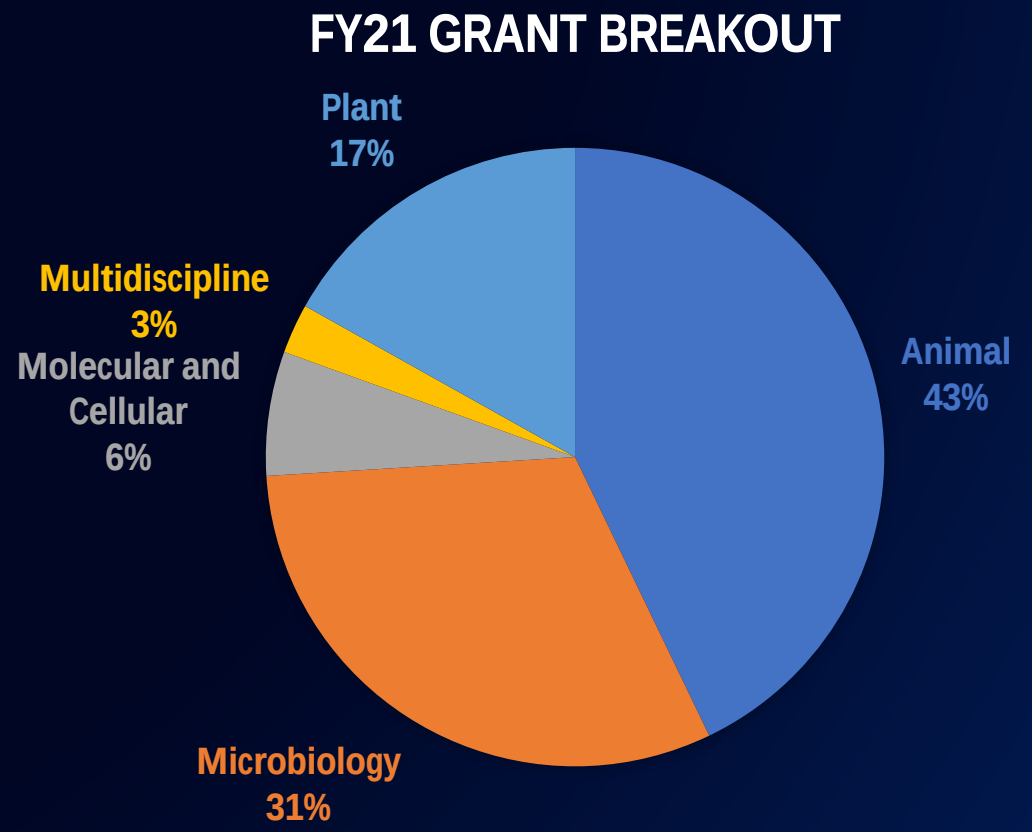




Objectives

- **Discover how biological systems respond to the space environment**
- **Identify the underlying mechanisms and develop models for biological systems in space**
- **Provide mechanistic understanding to support human health in space**
- **Promote open science through the GeneLab Data System and Life Sciences Data Archive**
- **Develop technologies to enable spaceflight research**
- **Transfer the knowledge and technology of space-based research to benefit life on Earth**

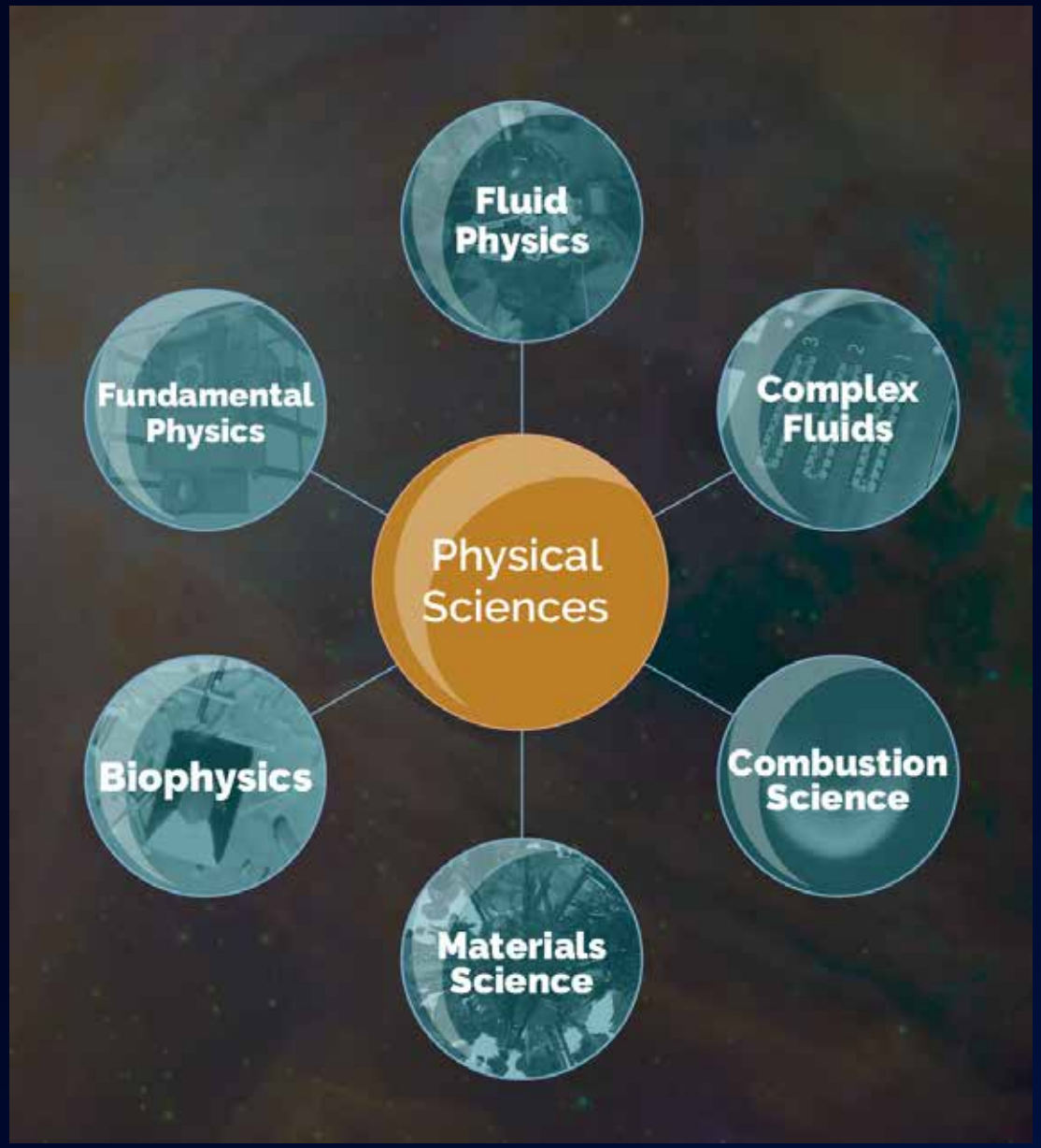
Space Biology Content



Total SB FY21 Grants	135
Flight	74
Ground	61

Number Directed vs Competed	
Directed	4
Competed	131

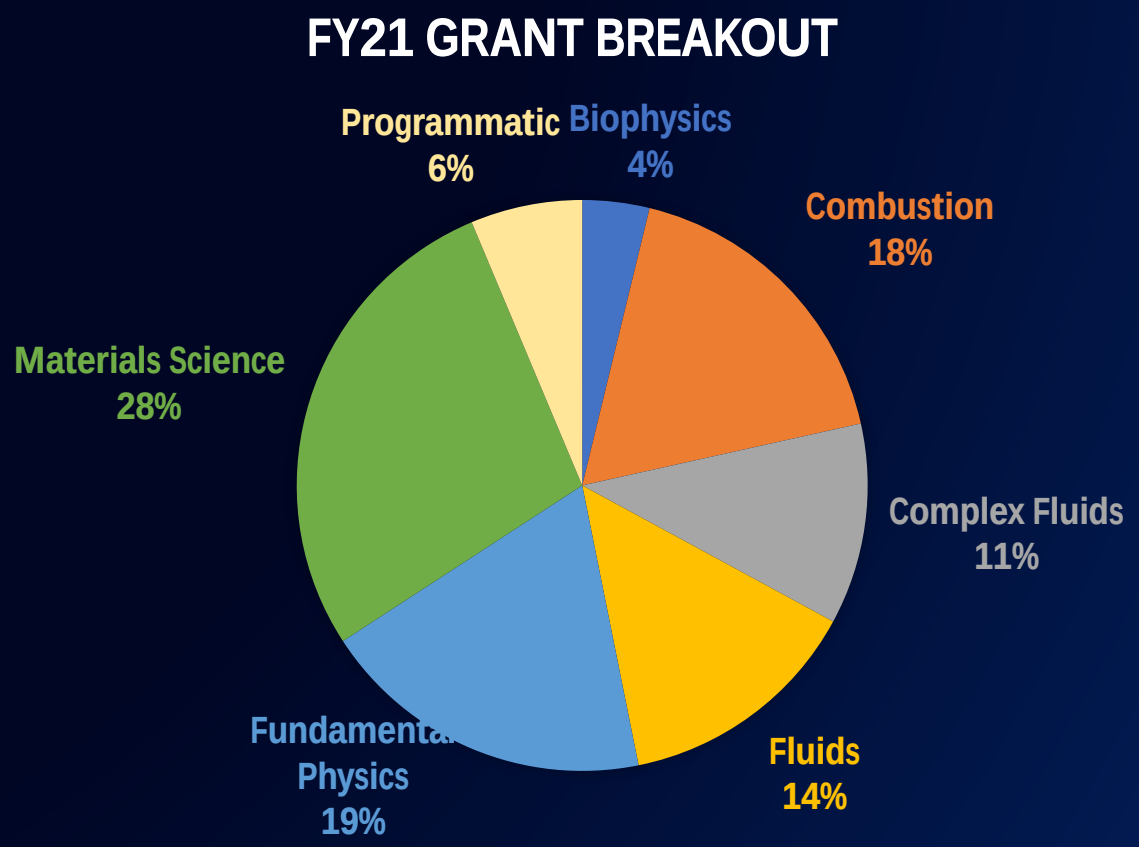
taskbook.nasaprs.com



Objectives

- Investigate **fundamental laws** of physics and **physical processes** using the space environment
- Identify the underlying **processes** and develop models for physical systems in space
- Develop **technologies** to enable spaceflight research
- Promote **open science** through Physical Science Informatics
- Transfer the knowledge and technology of space-based research to **benefit life on Earth**

Physical Sciences Content



Total PS FY21 Grants	99
Flight	66
Ground	33

Number Directed vs Competed	
Directed	2
Competed	97

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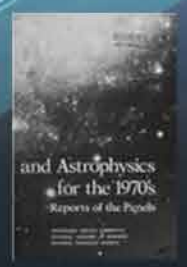
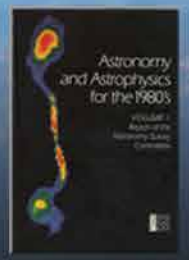
BPS Evolution

Astrophysics

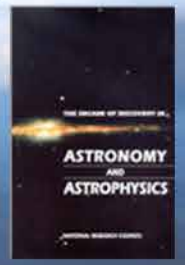
Decadal Survey Missions



1972
Decadal Survey
Hubble



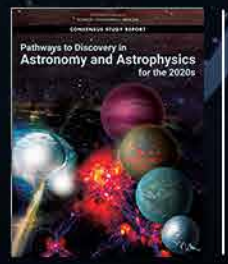
1982
Decadal Survey
Chandra



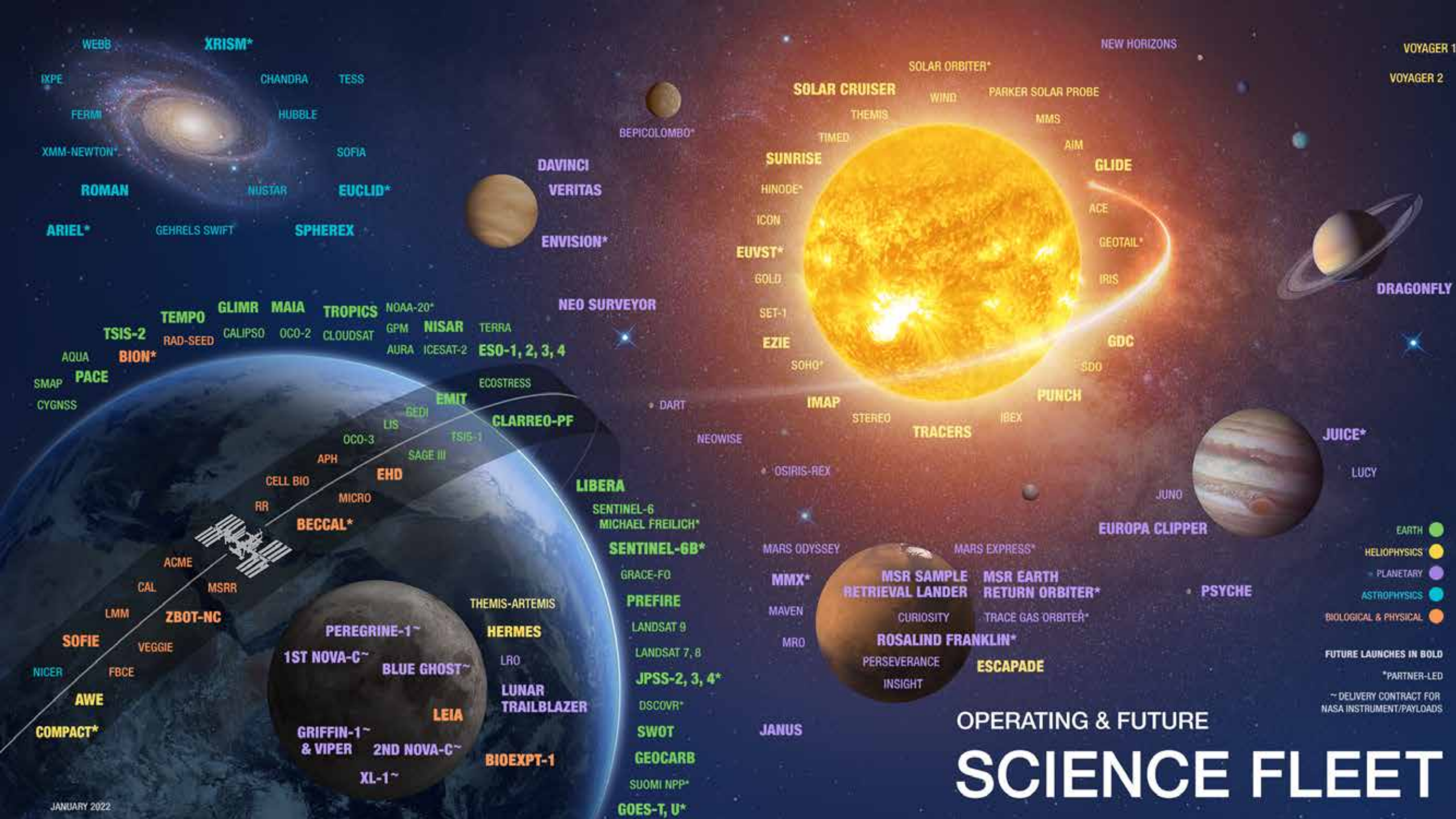
1991
Decadal Survey
Spitzer

2001
Decadal Survey
Webb

2010
Decadal Survey
Roman



2021
Decadal Survey


WEBB
XRISM*
IXPE
CHANDRA
TESS
FERMI
HUBBLE
XMM-NEWTON*
SOFIA
ROMAN
NUSTAR
EUCLID*
ARIEL*
GEHRELS SWIFT
SPHEREX
BEPICOLOMBO*
DAVINCI
VERITAS
ENVISION*
NEO SURVEYOR
NEW HORIZONS
VOYAGER 1
VOYAGER 2
SOLAR ORBITER*
SOLAR CRUISER
WIND
PARKER SOLAR PROBE
THEMIS
MMS
TIMED
AIM
SUNRISE
GLIDE
HINODE*
ACE
ICON
GEOTAIL*
EUVST*
IRIS
GOLD
SET-1
EZIE
GDC
SOHO*
SDO
IMAP
PUNCH
DART
STEREO
IBEX
TRACERS
NEOWISE
OSIRIS-REX
DRAGONFLY
JUICE*
LUCY
JUNO
EUROPA CLIPPER
PSYCHE
MARS ODYSSEY
MARS EXPRESS*
MMX*
MSR SAMPLE RETRIEVAL LANDER
MSR EARTH RETURN ORBITER*
MAVEN
CURIOSITY
TRACE GAS ORBITER*
MRO
ROSALIND FRANKLIN*
PERSEVERANCE
ESCAPADE
INSIGHT
JANUS
TSIS-2
TEMPO
GLIMR
MAIA
TROPICS
NOAA-20*
RAD-SEED
CALIPSO
OCO-2
CLOUDSAT
GPM
NISAR
TERRA
AURA
ICESAT-2
ESO-1, 2, 3, 4
AQUA
BION*
SMAP
PACE
CYGNSS
ECOSTRESS
EMIT
GEDI
CLARREO-PF
LIS
OCO-3
TSIS-1
APH
SAGE III
EHD
CELL BIO
MICRO
RR
BECCAL*
LIBERA
SENTINEL-6 MICHAEL FREILICH*
SENTINEL-6B*
GRACE-FO
PREFIRE
LANDSAT 9
LANDSAT 7, 8
JPSS-2, 3, 4*
DSCOVR*
SWOT
GEOCARB
SUOMI NPP*
GOES-T, U*
ACME
CAL
MSRR
LMM
ZBOT-NC
SOFIE
VEGGIE
NICER
FBCE
AWE
COMPACT*
THEMIS-ARTEMIS
PEREGRINE-1~
HERMES
1ST NOVA-C~
LRO
BLUE GHOST~
LUNAR TRAILBLAZER
LEIA
GRIFFIN-1~ & VIPER
2ND NOVA-C~
BIOEXPT-1
XL-1~
EARTH
HELIOPHYSICS
PLANETARY
ASTROPHYSICS
BIOLOGICAL & PHYSICAL
FUTURE LAUNCHES IN BOLD
*PARTNER-LED
~ DELIVERY CONTRACT FOR NASA INSTRUMENT/PAYLOADS
OPERATING & FUTURE
SCIENCE FLEET
JANUARY 2022

The Next Decadal Survey for BPS (2023-2032)

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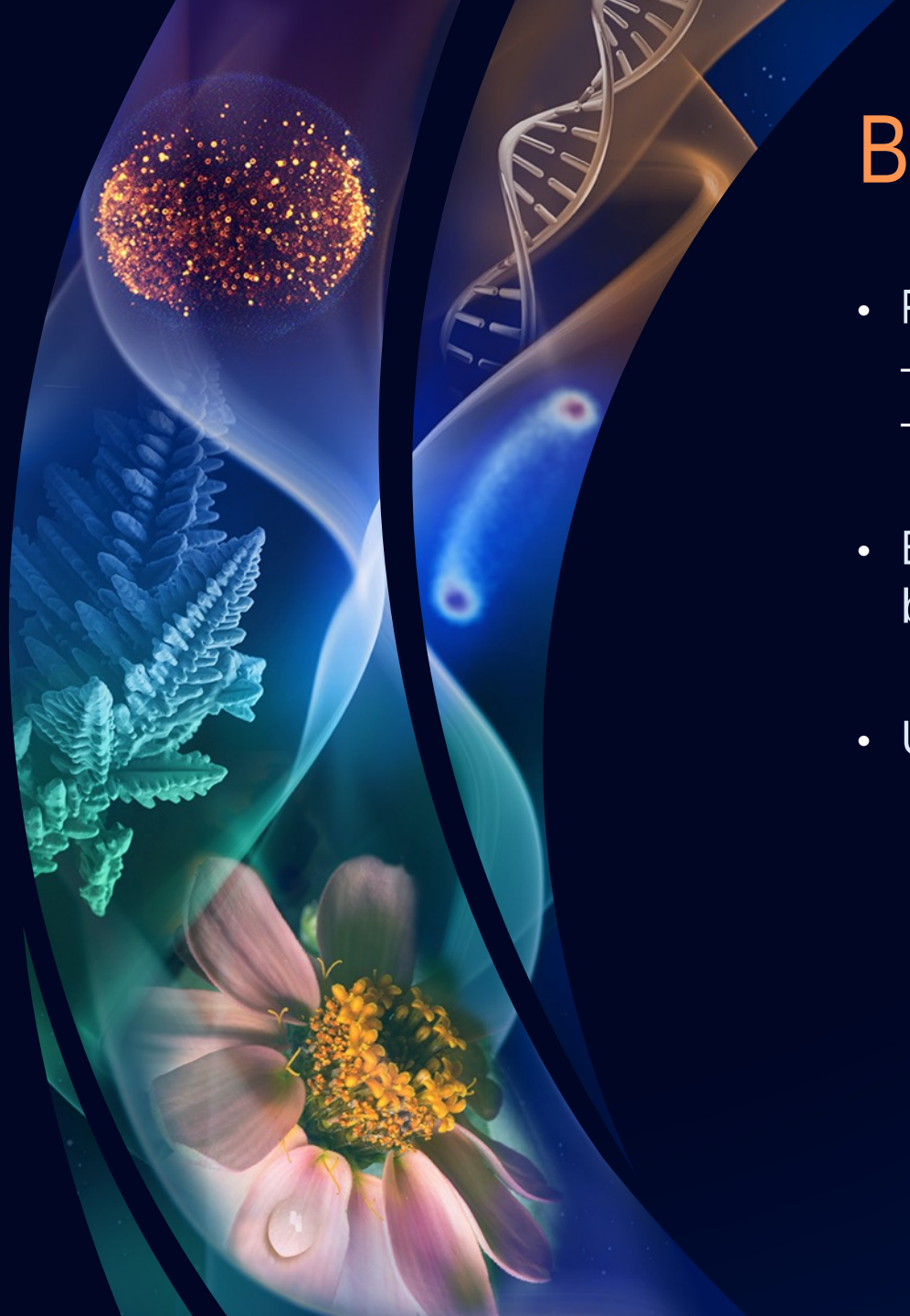
The transformative science conducted through Keystone Capabilities and Research Campaigns will be the building blocks of BPS’s scientific program for the next decade

BPS over the Next 10 Years

- Pioneer transformative science at the frontiers of biology and physical sciences in space
  - Frontiers: Conceptual and Physical
    - Areas where BPS can uniquely
      - Advance scientific knowledge
      - Meet the needs of exploration missions
      - Provide terrestrial benefits
    - Locations include
      - Commercial and governmental ground-based; commercial sub-orbital
      - Commercial Low Earth Orbit
      - Lunar orbit (Gateway)
      - Lunar surface (Commercial Lunar Payload Services, Human Landing System)
      - Mars transit vehicle
  - Pioneer
    - BPS first or among first at a frontier
    - Expect other organizations (government, commercial, academic, international) may follow
    - BPS collaborates in all phases
      - First tests of feasibility and value assessment
      - Refining methods and re-assessing value
      - Sustained research and returning value



BPS Strategy Before Decadal

- Focus on transformative research
  - Recommended by the 2011 Decadal Survey
  - Likely to be recommended by the 2023 Decadal Survey
- Balance flight-based research program with strong ground-based research program
- Use NASA and non-NASA capabilities, especially commercial
  - Partner with other government agencies, international partners, industry and academia

Examples of BPS 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

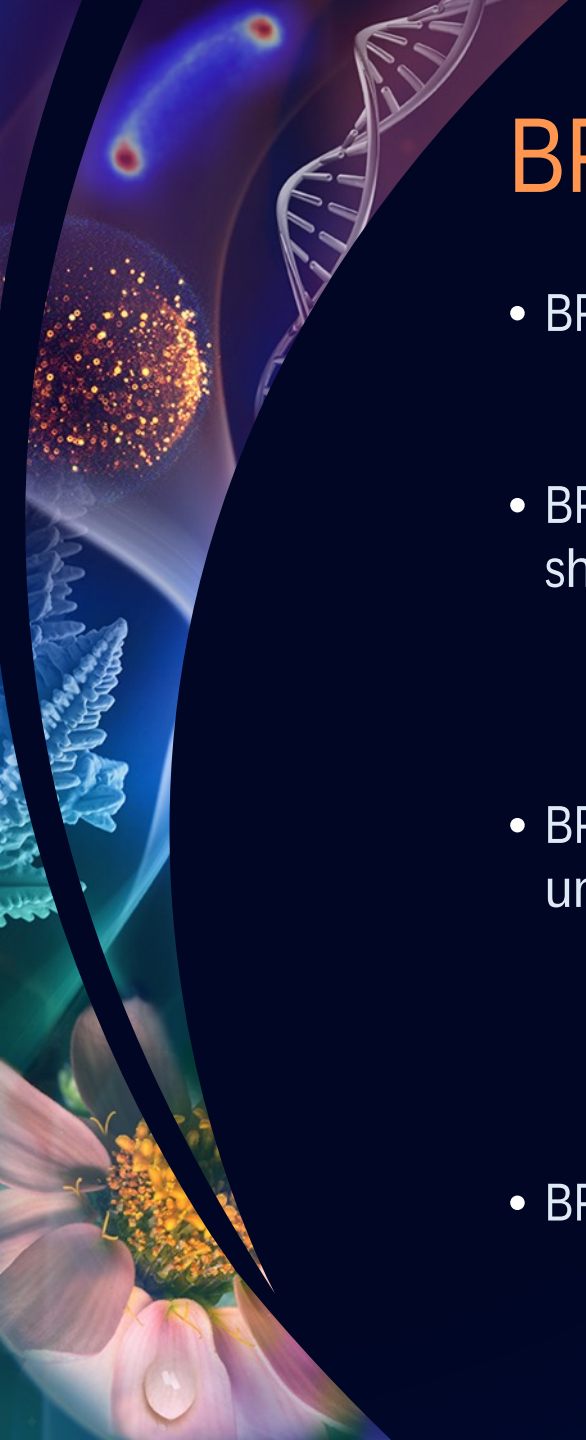
Physical Sciences
Informatics

GeneLab

BPS Expects to Use Multiple Spaceflight Platforms

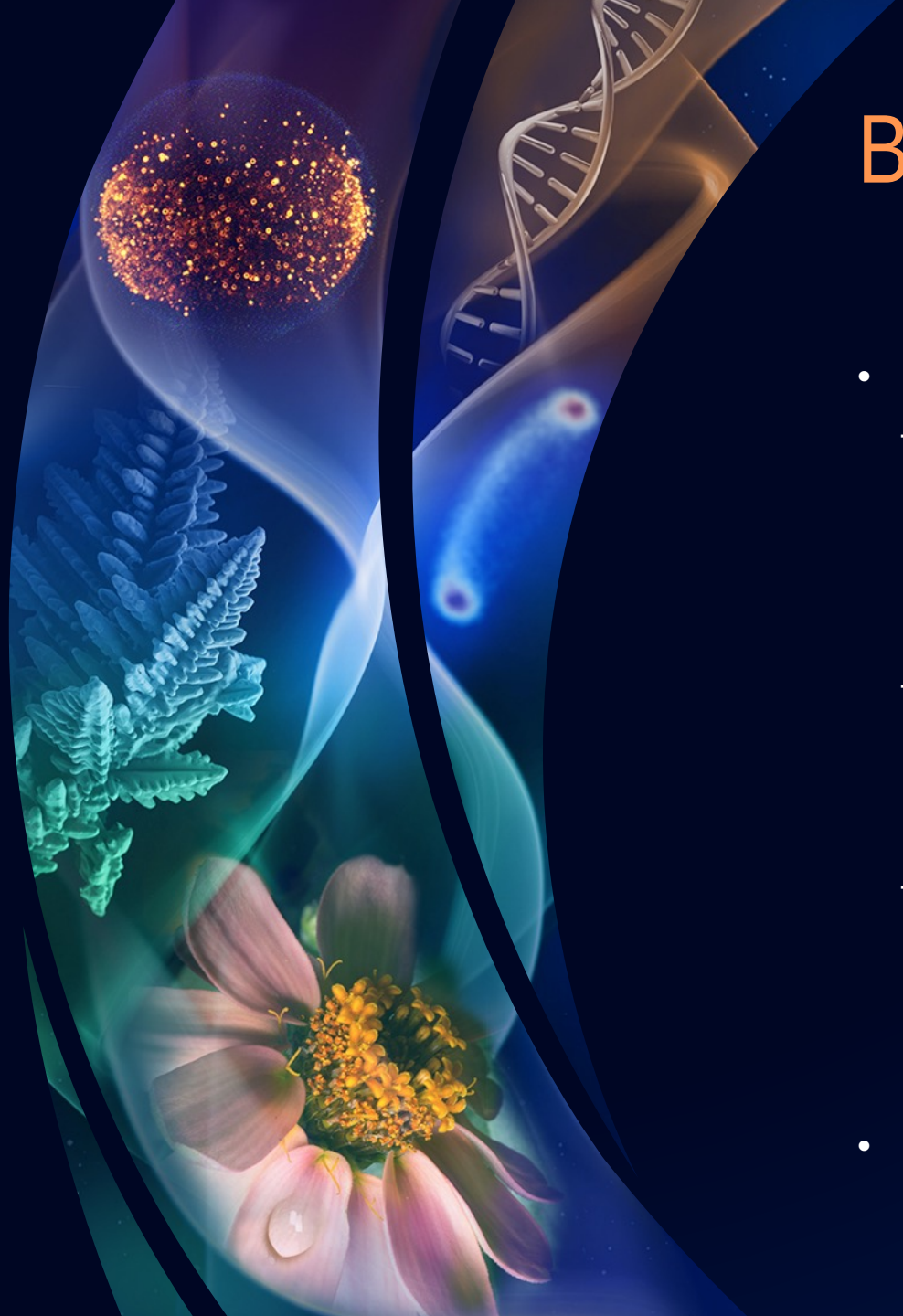
- The Decadal Survey priorities and resulting science requirements will dictate the choice of platform and environment
- Experiments may be conducted or applications developed in several spaceflight environments
  - Ground-based, sub-orbital, low Earth orbit (LEO), deep space, lunar orbit, lunar surface, Martian orbit, Martian surface
  - Commercial, US government, international partner
- A series of environments or platforms may be employed as steppingstones
  - Example: Development of a lunar surface experiment focused on effects of 1/6-g
  - Steppingstones could include:
    - NASA drop tower
    - Commercial parabolic flight
    - Commercial sub-orbital flight
    - International Space Station
    - Commercial Lunar Payload Services delivery of NASA payload to lunar surface

BPS Expects to Continue Robust Partnerships



BPS Relationship to Partners

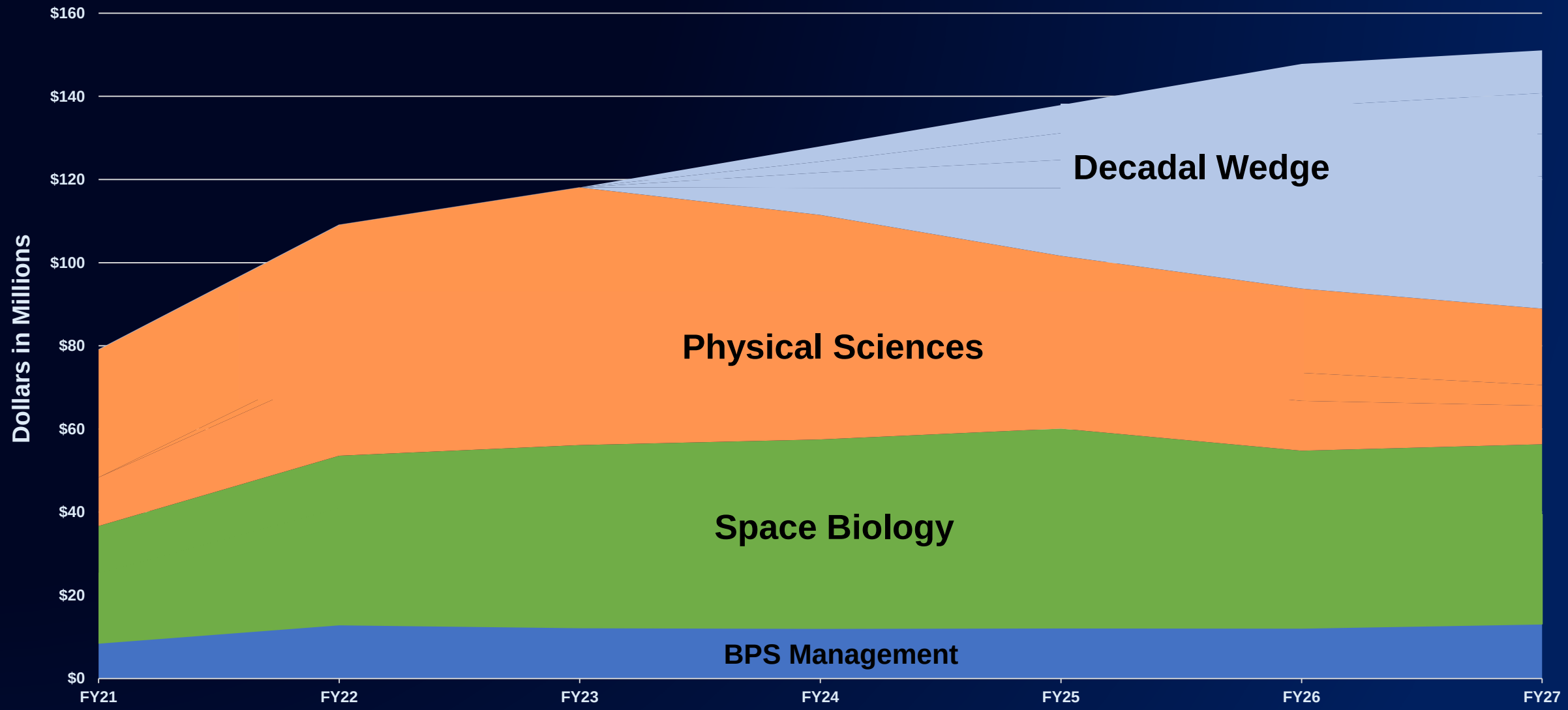
- BPS partnerships help Pioneer Scientific Discovery and Enable Sustainable Exploration
  - Leverage BPS resources
  - Maximize impact of research results
- BPS collaborates with other government agencies (OGAs) and international partners on shared
  - Research questions
  - Technology needs
  - Infrastructure needs
- BPS collaborates with other NASA organizations to provide the fundamental/mechanistic understanding and solutions based thereon
  - Space Technology Mission Directorate
  - Exploration Systems Development Mission Directorate
  - Space Operations Mission Directorate
    - Human Research Program
- BPS collaborates with the ISS National Laboratory (ISSNL) on shared
  - Research interests
  - Resources on ISS



BPS Budget Strategy

- Near-term: Focus on transformative areas
  - Bolster three areas likely to be recommended by the 2023 Decadal Survey
    1. Quantum Science (Cold matter)
    2. Thriving in Deep Space (TIDES) (Animal/Human, Plant)
    3. Soft Matter (Far-from-equilibrium processes; unique assemblies)
  - Prepare for large research activities to be recommended by the 2023 Decadal Survey
    - Keystone Capabilities/Missions
    - Research Campaigns
  - Pause other areas until 2023 Decadal Survey received
    - Complete funding of existing grants
    - Defer or descope future solicitations
    - Pause early-stage flight projects
- Long-term: Implement 2023 Decadal Survey priorities

BPS Budget Plan Based on President's Budget Request FY22



Summary

- BPS research has made advances in a broad range of disciplines over several decades

- BPS now seeks to tackle the most transformative research questions
  - Driven by
    - Advancing science,
    - Enabling exploration, and/or
    - Benefiting life on Earth
  - Using capabilities in and beyond current and planned NASA programs
    - Commercial and governmental platforms
    - Ground-based, low Earth orbit, Gateway, lunar surface

- 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

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
- The Decadal Survey will enable Biological and Physical Sciences to tackle the most transformative research questions
  - Ø To pioneer scientific discovery,
  - Ø Enable sustainable exploration,
  - Ø Benefit life on Earth

Thank you!

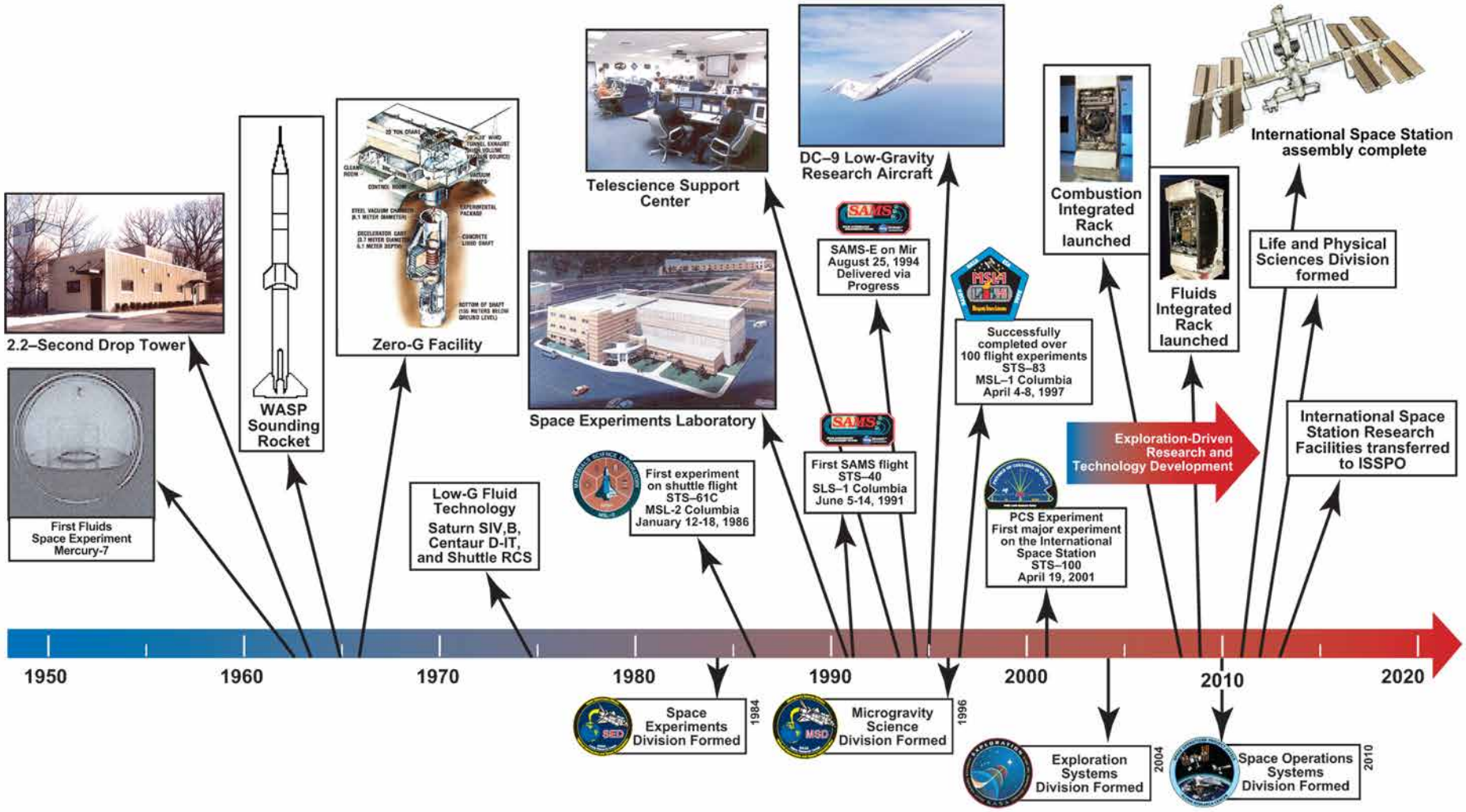
Supplemental Information

Experimental Variables in Spaceflight Environments

Experimental Variable	Types / Values	Biological Impact Examples	Physical Sciences Impact Examples
Acceleration: (Altered sedimentation, buoyancy-driven convection, hydrostatic pressure)	Microgravity Lunar surface (1/6-g) Mars surface (3/8-g) Earth (1-g) Launch & landing (3 to 9-g)	Fluid shifts, body forces, neuro-vestibular, plant growth	Flammability, two-phase flow, solidification, additive manufacturing, soft matter structure and dynamics
Ionizing Radiation	Solar Particle Events (SPE), Galactic Cosmic Rays (GCR), lunar albedo, Van Allen belts	Damage to animals, plants, microbes	Damage to materials
Atmosphere (vehicle)	pCO_2, pH_2O, pHe; volatile organics, temperature Infrequent influx of crew and materials Unoccupied periods	Microbiome of humans, plants, vehicle Biofilm production, biocorrosion	-
Atmosphere (external)	LEO (vacuum, atomic oxygen), deep space (hard vacuum)	Desiccation, radiation exposure	Damage to materials
Lunar surface composition	Regolith, dust	Dust toxicity, plant growth	Granular materials processing, in-situ surface construction, cement/concrete production Metal and/or O2 extraction from regolith Dust mitigation
Extreme thermal changes	LEO, deep space, lunar surface (-170 C to +120 C)	Challenge for life support systems	Thermal expansion/contraction
Lighting	Unattenuated solar spectrum, attenuated solar spectrum, artificial lighting	Plant growth Circadian rhythm entrainment	-
Distances	Up to Earth-Moon distance (340, 000 km)	Social isolation	Long-range fundamental physics (e.g., quantum entanglement)

BPS Programs Started in the 1960's

Example: History at Glenn Research Center



Ground-based (Sub-orbital) Platforms

- Ground-based platforms are used for
  - Rapid, low-cost tests of experiment concepts and new technology to reduce risk prior to flight
  - The experiment environment for an investigation

- To the extent required to achieve Decadal Survey priorities,
  - BPS will continue use of
    - Microgravity simulators (e.g., clinostats)
    - Drop towers
    - Parabolic flight
    - Balloons
    - Radiation facilities (e.g., NASA Space Radiation Laboratory)
  - BPS will develop use of
    - Multi-factor ground based simulators
      - E.g., low dose rate radiation + altered atmosphere + simulated microgravity
    - Sub-orbital flight
      - Autonomous payloads
      - Crew-tended payloads

Low Earth Orbit (LEO) Platforms

- Platforms in LEO have provided the spaceflight environment for the majority of BPS investigations
- BPS will use these platforms to the extent required to achieve Decadal Survey priorities

- ISS
  - Premier destination for long-duration, crew-tended microgravity research
  - Stepping stone for research beyond LEO
  - BPS assumes ISS will operate through 2030
  - BPS interested in reviving concept of Payload Specialist
    - Private Astronaut Missions (PAMs) or other mechanisms
- Commercial LEO Destinations (CLDs)
  - Available in the mid- to late 2020s
  - Individually, less capability than ISS
  - In aggregate, capability closer to ISS
- Un-crewed free-flyers
  - BPS interested in CubeSats, SmallSats, modules, and spacecraft that return to Earth

Platforms Beyond LEO

- Platforms Beyond LEO are destinations for human exploration and/or a stepping stone to Mars missions
- BPS will use these platforms to the extent required to achieve Decadal Survey priorities

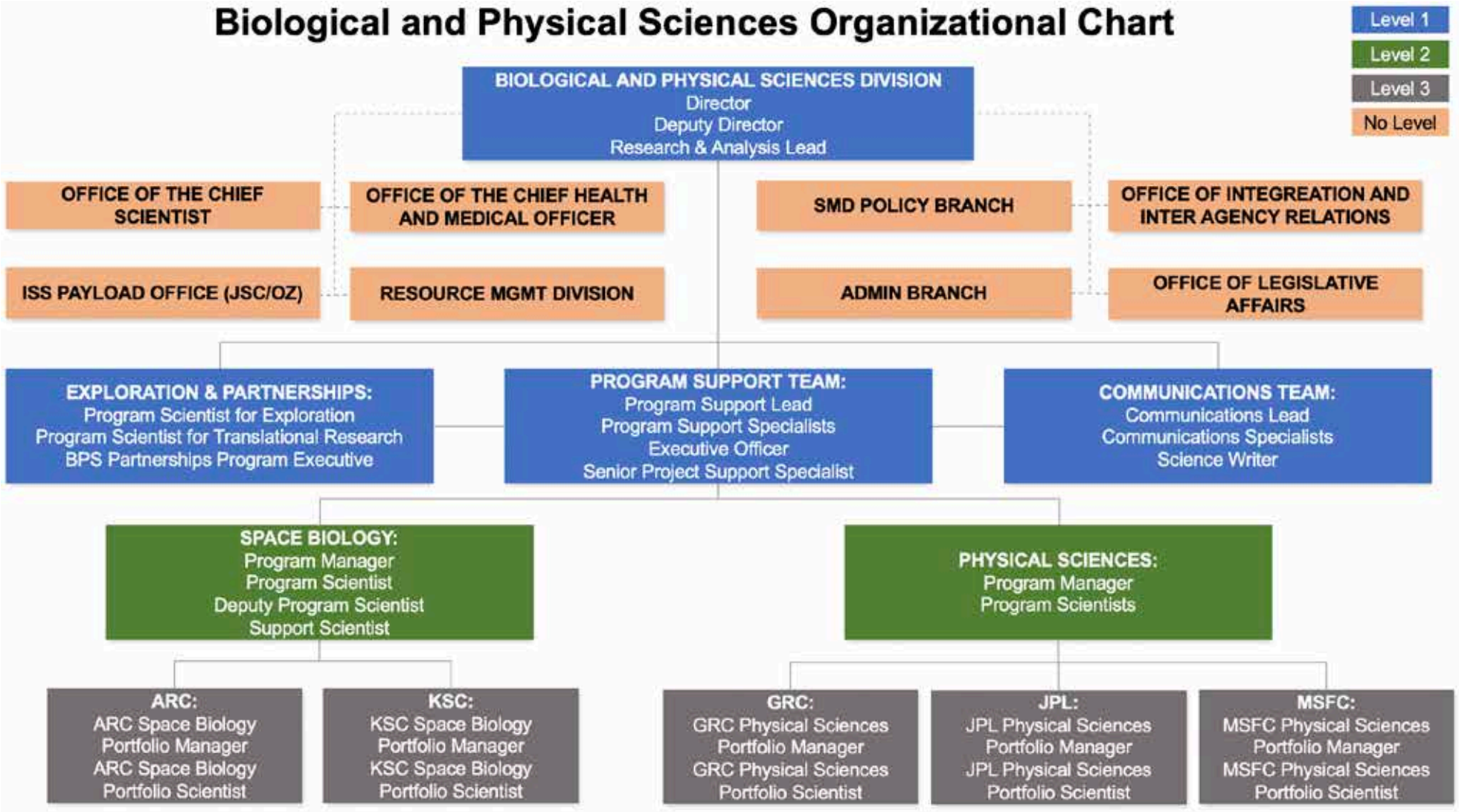
- Artemis
  - BPS pioneering use of and planning long-term use of
    - Gateway
    - Orion (e.g., Artemis I and II)
    - Commercial Lunar Payload Services (CLPS)
  - BPS plans use of integrated Artemis mission capabilities (including Human Landing System (HLS)) as they develop

- Un-crewed free-flyers
  - BPS interested in CubeSats, SmallSats, modules, and spacecraft that return to Earth

BPS Disciplines Supporting Human Exploration

BPS Program	BPS Discipline	Mission Directorate	Organization	Applications
Space Biology	Animal	SOMD	HRP	Biomarkers, countermeasures, risk assessment
	Plant	SOMD	HRP	Micronutrients, behavioral health; macronutrients, life support
	Plant	SOMD	SCLT	Crop growth systems
	Microbial	SOMD	HRP	Risk management
	Microbial	ESDMD	AES	Radiation biodosimetry
	Cell Biology	SOMD	HRP	Biomarkers, countermeasures, risk assessment
Physical Sciences	Combustion	ESDMD	AES	Fire safety
	Fluid Physics	ESDMD	AES	Water recovery systems, cryogenic fluid management
	Fluid Physics	SOMD	ISS	ISS Water recovery system
	Fluid Physics	STMD	Tech Demo	Cryogenic fluid management, thermal management
	Materials Science	STMD	Game Changing	In-space manufacturing
	Materials Science	STMD	Game Changing	Lunar ISRU - 3D Printing Construction Systems

Biological and Physical Sciences Org Chart



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Acronyms

Acronym	Term
AES	Advanced Exploration Systems (NASA)
BPS	Biological and Physical Sciences (NASA)
CAL	Cold Atom Lab
CLPS	Commercial Lunar Payload Services
ECLSS-CHP SCLT (SCLT)	Environmental Control and Life Support Systems – Crew Health and Performance Systems Capability Leadership Team
HEO /HEOMD	Human Exploration and Operations / Mission Directorate (NASA)
HLS	Human Landing System
HRP	Human Research Program (NASA)
IDEA	Inclusion, Diversity, Equity, and Accessibility
ISS	International Space Station
ISSNL	International Space Station National Lab
ISRU (Lunar ISRU)	In Situ Resource Utilization
LEO	Low Earth Orbit
MOU	Memorandum of Understanding
SLPSRA	Space Life and Physical Sciences Research and Applications (NASA)
SMD	Science Mission Directorate (NASA)
STMD	Space Technology Mission Directorate (NASA)