National Aeronautics and Space Administration

EXPLORE SCIENCE

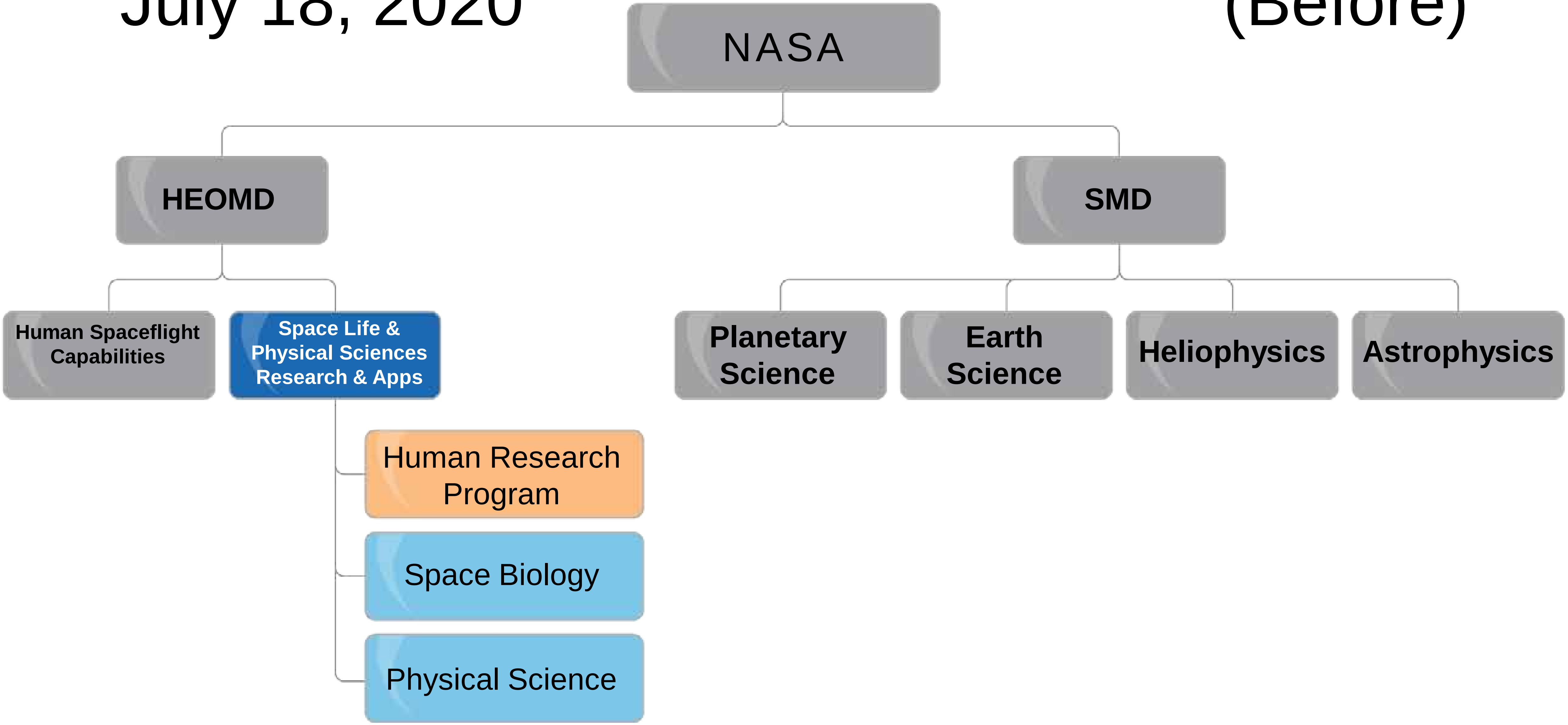
Biological and Physical Sciences Overview and Status

Craig Kundrot

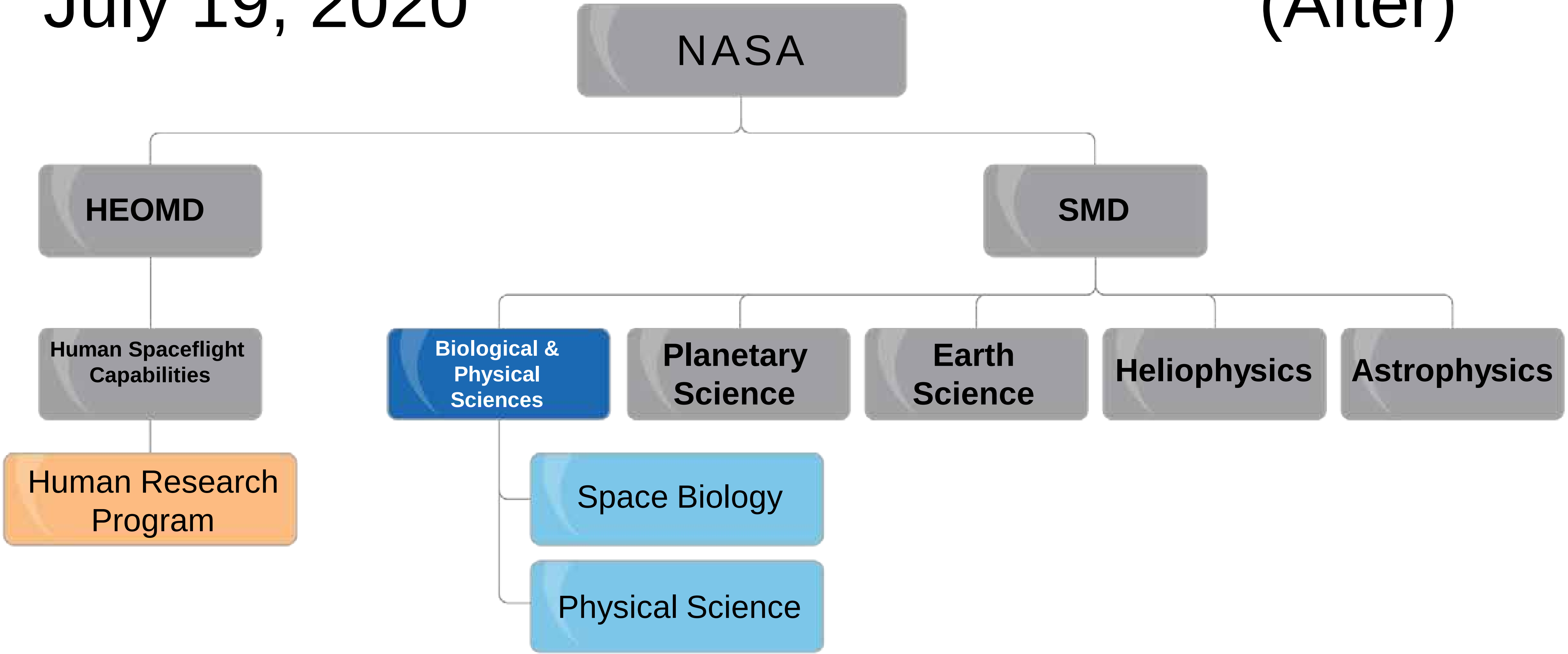
October 27, 2020

July 18, 2020

(Before)

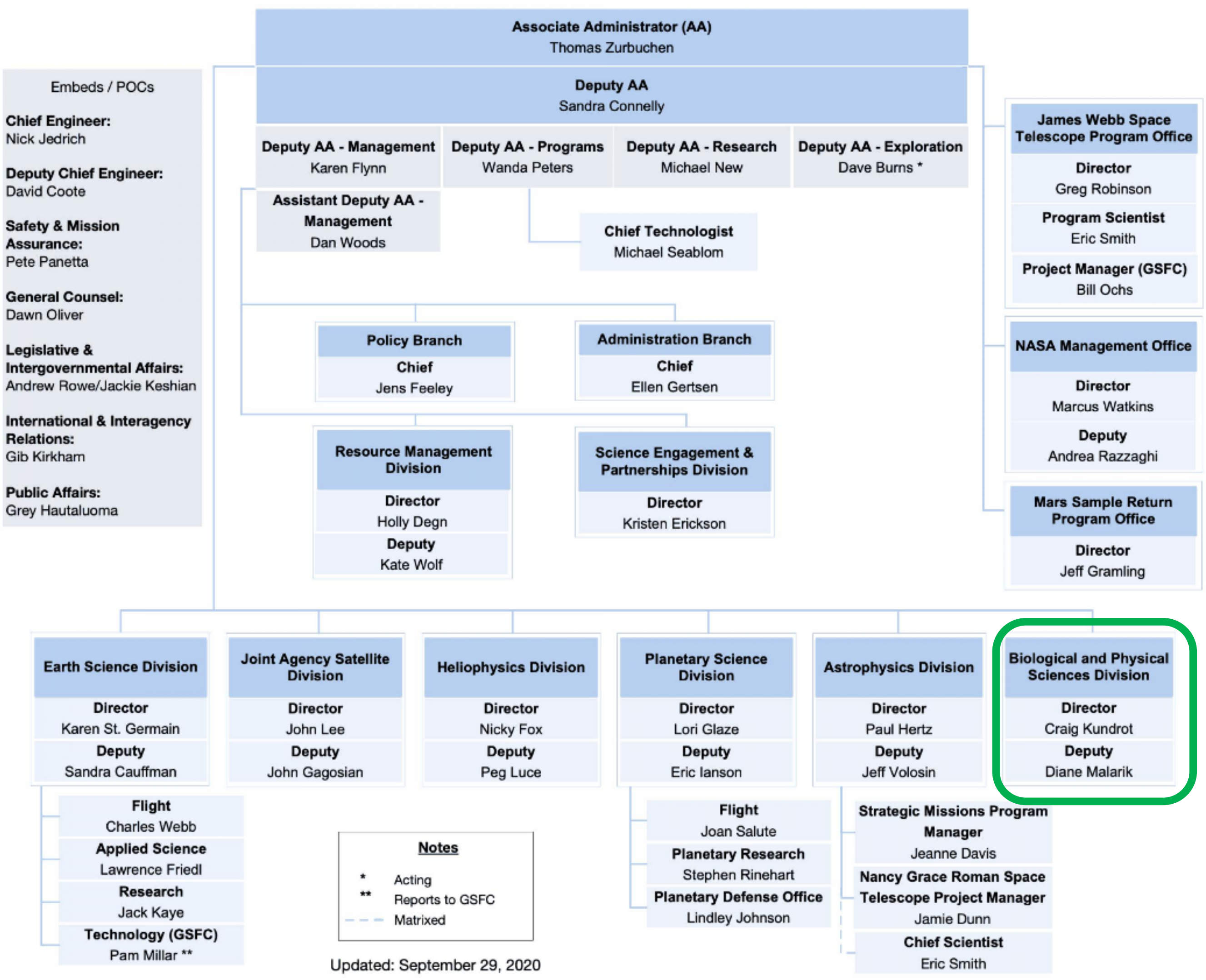


July 19, 2020 (After)



Biological and Physical Sciences (BPS) Division

Created July 19, 2020



Biological and Physical Sciences Organizational Chart

(c) contractor
(d) detailee
(m) matrixed
* Acting
+ Part-time support

Biological and Physical Sciences (BPS)
- Craig Kundrot – Director
- Diane Malarik – Deputy Director
- Vacant – Chief Scientist

Office of the Chief Scientist:
- Jim Green – NASA Chief Scientist
- Tara Ruttley – Assoc. Chief Sci. Microgravity

ISS Research Integration Office (JSC/OZ):
- Marybeth Edeen (OZ)

Office of the Chief Health and Medical Officer:
- Victor Schneider – Program Executive

Resources Management Division:
- Erik Edwardson (m) – Financial Analyst

SMD BPS Policy Branch
- Laura Delgado Lopez (m) - Program Planning Specialist
- Jason Callahan (m) - Program Planning Specialist

Exploration & Partnerships:
- Kevin Sato (d) – Program Scientist for Exploration
- Lisa Carnell – Senior Scientist for Partnership Development
- Doug Gruendel – Partnership Coordinator

Program Support Team:
- Joseph Burg (c) – Sharepoint Development Lead
- Jason Levine (c) – Schedule, Risk & Data Mgmt.
- Haley Fauntleroy (c) – Documentation Team Lead
- Kaley Williams+ (c) – Program Support
- Monica Washington (c) – Program Support
- William Parker+ (c) - Program Support

Communications Team:
- Gamble Gilbertson+ (c) – Communications Lead
- Julie Lele+ (c) – Communications Specialist
- Mike Brody+ (c) – Communications Specialist
- Bart Woodward+ (c) – Science Writer

Space Biology:
- Nicki Rayl – Program Manager
- Sharmila Bhattacharya – Program Scientist
- Anthony Hickey (c) – Support Scientist

Physical Sciences:
- DeVon Griffin – Program Manager
- Fran Chiaramonte – Physical Sciences Program Scientist
- Brad Carpenter – Fundamental Physics Program Scientist

Leadership

Dr. Craig Kundrot
Division Director

Diane Malarik
Deputy Director

Space Biology

Nicki Rayl
Program Manager

Sharmila Bhattacharya
Program Scientist

NEW!

Anthony Hickey
Support Scientist

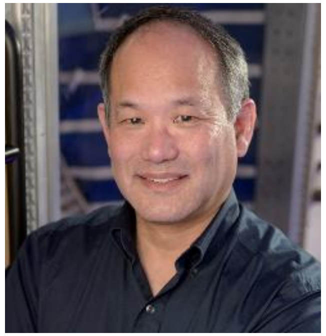
Physical Sciences

DeVon Griffin
Program Manager

Bradley Carpenter
Fundamental Physics Program Scientist

Fran Chiaramonte
Fundamental Physical Sciences Program Scientist

Exploration & Partnerships



Kevin Sato
Program Scientist for Exploration

NEW!

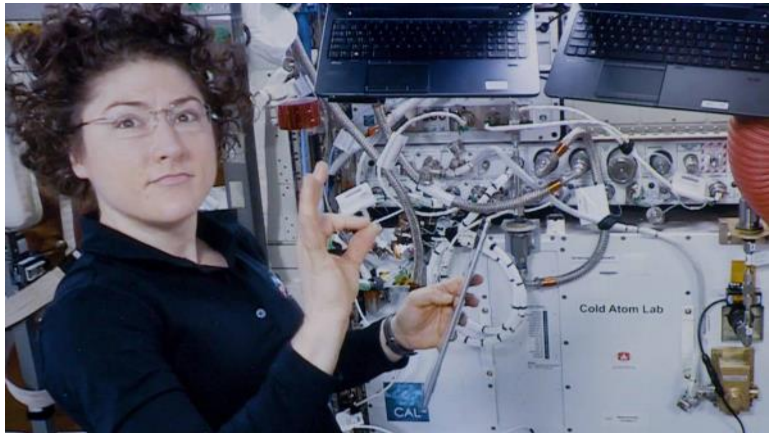
Lisa Carnell
Senior Scientist for Partnership Development

Doug Gruendel
Partnership Coordinator

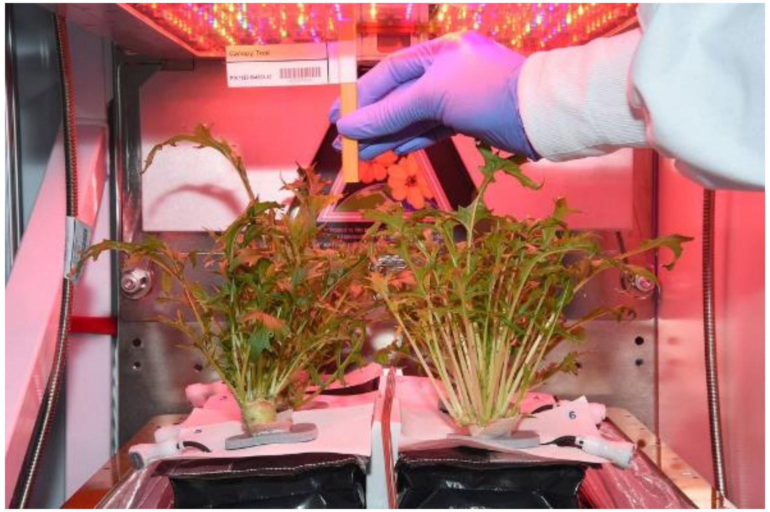
The Move to SMD

- SMD has been very welcoming
- Space Biology and Physical Sciences moved *en masse*
  - All personnel
  - All programs, projects
  - Organizational structure at HQ and relationship to field centers
- Human Research Program moved to HEOMD Human Spaceflight Capabilities Division under Benjy Neumann
- BPS maintains close working relationships with its partners
  - HRP, ISS, CASIS/ISSNL, AES, STMD
  - Other government agencies; e.g., NIH, NSF, USDA, BARDA, FDA, DoD
  - International partners
- Gradual transition
  - Year 1 is primarily for BPS and the rest of SMD to get to know one another
  - BPS beginning use of Research Opportunities in Space and Earth Science (ROSES) for solicitations

What We Do



Example of Physical Sciences research: Studying quantum gasses



Example of Space Biology research: Growing plants in space

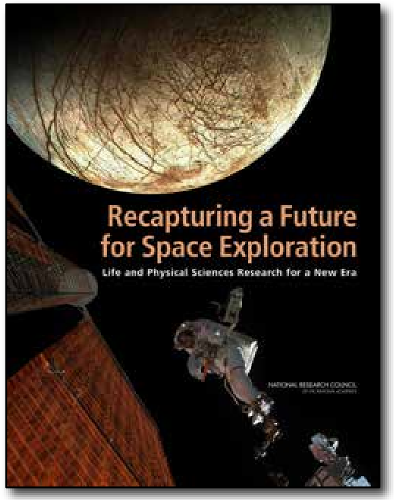
We use spaceflight environments to **study biological and physical systems**.

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

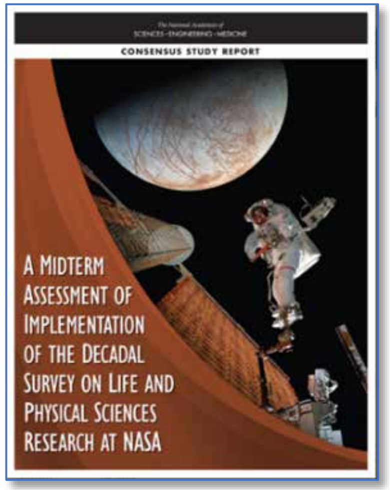
This can contribute to significant scientific and technological advancements that **enable space exploration and benefit life on Earth.**

9

BPS Mission & Goals



Decadal Survey



Midterm Assessment

Pioneer Scientific Discovery

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

Artemis Missions

Enable Exploration

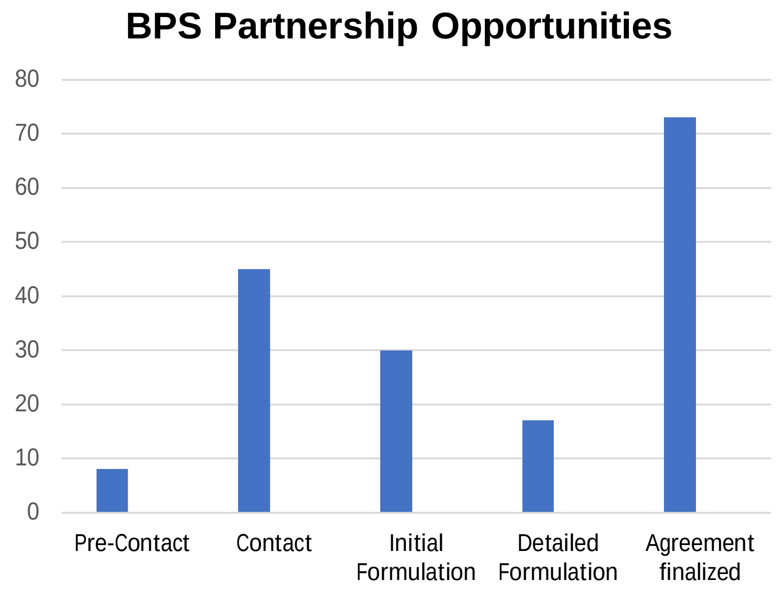
- Anticipate and investigate critical areas for scientific knowledge and technology development
- Deliver results for cryogenic fuel management, fire safety, food production, crew health, etc.

10

BPS Strategy

- Execute broad range of Decadal Survey highest priority recommendations
  - Prioritize research that both pioneers scientific discovery and enables exploration
  - Re-use flight hardware and solicit annually in Space Biology
  - Develop new flight hardware and solicit less frequently in Physical Sciences
  - Solicit for as many highest priority recommendations as feasible by limiting award amounts and number of awards for each recommendation to what is required for viability
- Leverage resources through partnerships within and external to NASA
- Use a broad range of platforms with emphasis on ISS utilization
- Augment planning and capability development for post-ISS and beyond LEO
- Inspire and train new space science researchers
- Support next Decadal Survey to identify future work

BPS Partnerships Summary



Agreements Executed

- USDA
  - *Microgreen Research MOU*
  - *Research at USDA Biotechnology Laboratory at EPCOT MOU*
- NIH/NCATS Trans-agency Solicitation MOU
- BPS, HRP, ISS NL and ISS Program MOU
- International Agreement with Chungnam National University (CNU) of South Korea
  - *Collaboration for Advanced Colloids Experiment (ACE-T1 reflight)*

Activities in Work

- Trans-agency Solicitation on 3D Tissues and Microphysiological Systems
  - *NIH/NCATS, NIH/NIAID, BARDA, FDA, Space Biology, Human Research Program*
- Spaceflight Technologies, Application and Research "STAR" Course
- RFI released on "*Commercially Available Vehicles and/or Launch Capabilities to Support Free-Flyer Research Missions within Low Earth Orbit and Beyond Low Earth Orbit*" – evaluating responses

Workshops Co-Organized

- Fluid Physics Workshop Oct 16-17, 2019
- NCATS-NASA Pre-ASGSR Workshop on "3D Tissues and Microphysiological Systems" Nov 19, 2019
- NYAS "Bioengineering in Space" Symposium, December 9-10, 2020
- RRS/NCI/NASA Workshop: "Particle Radiobiology for Spaceflight and Oncology" June 21-23, 2021 https://na.eventscloud.com/website/8881/

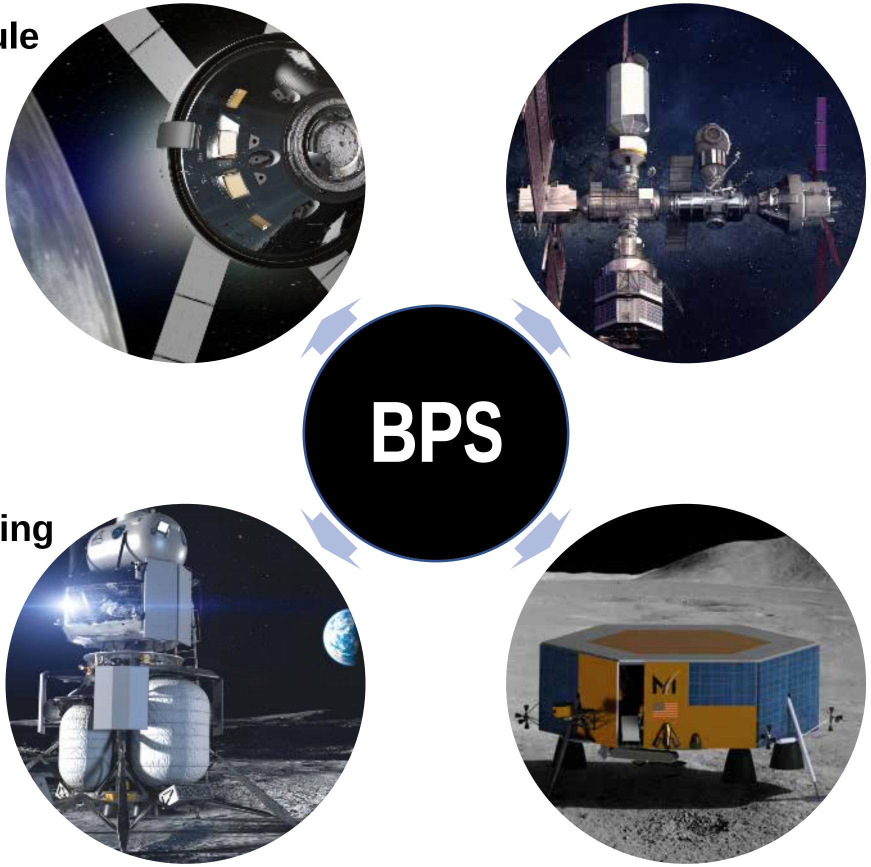
CASIS/ISSNL

- Interaction between BPS and CASIS/ISSNL remains excellent
- Responses to the IRT report continue to be implemented
  - New Board of Directors
  - Roadmap Working Group established
    - Roadmaps support near- and long-term coordination and collaboration
    - Initial membership: CASIS, BPS, HRP, Advanced Exploration Systems (AES), Space Technology Mission Directorate (STMD)
  - User Advisory Committee should be named within the next month

Multiple ways to conduct science in the lunar environment, but only one way to bring it back to Earth

Orion Capsule

Gateway
- Priority on multi-national science payloads



Human Landing System

Commercial Lunar Payload Services Lander
- Payload housed on lander
- Placed directly on the lunar surface by a lander capability
- Pre-positioning on the moon for astronaut access

- Ø Currently, only Orion Capsule can return science specimens
- Ø Each Platform has its own processes and teams for science integration

BPS science are being integrated into all efforts for NASA activities for science beyond LEO

- Gateway
  - Phase 1 science in review
  - 15-year science strategy and objectives roadmap – including capabilities/resources
  - Space Biology DWG; Astrophysics DWG
  - Integrated work with international human health DWG and JSC Crew Health and Performance
- BPS Lunar surface science workshops
- Artemis Science Definition Team – science objectives; Artemis III science
- CLPS Lunar surface science
  - PRISM solicitation
- ISS4Mars – ISS Analog working group meetings
- Planetary Protection Roadmap
- Integrated human health roadmap

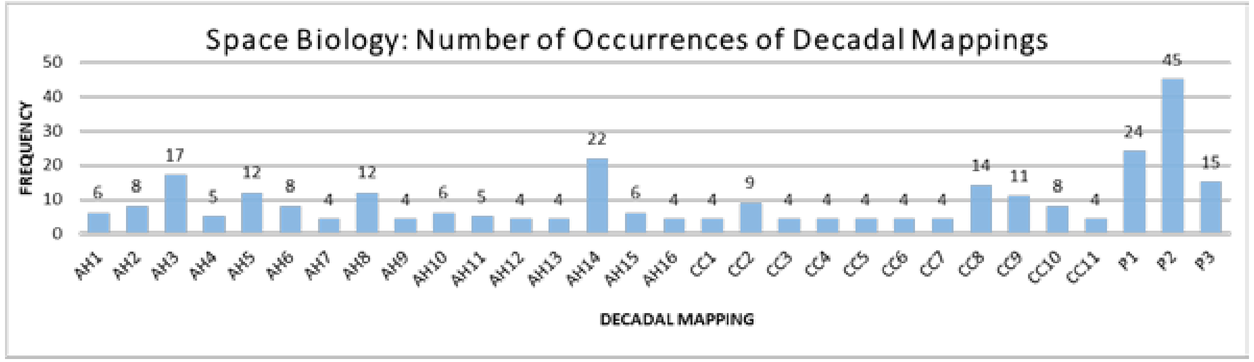
Transformative Research

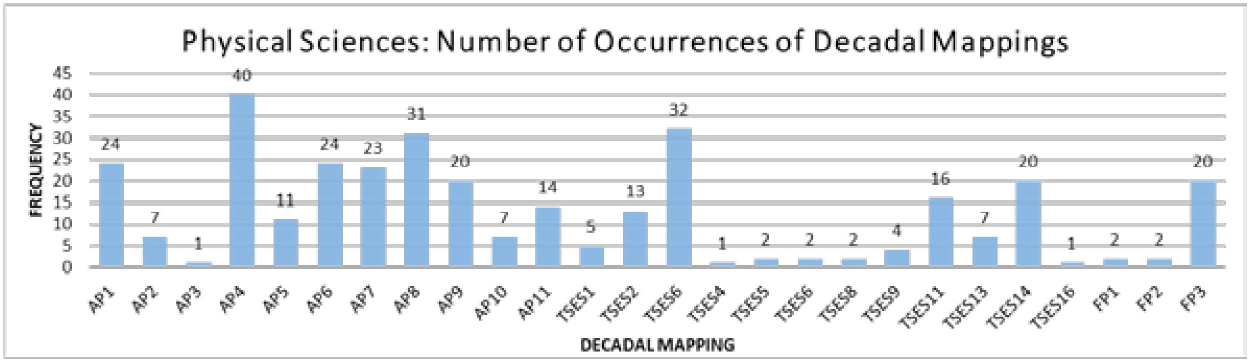
- Transformative research challenges current understanding or provides pathways to new frontiers
- Transformative research involves
  - ideas, discoveries, or tools that
  - radically change
    - our understanding of an important existing scientific or engineering concept or
    - educational practice 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

Trend: Emphasis on Transformative Research

- Previous strategy in HEOMD: Execute broad range of Decadal Survey highest priority recommendations
  - Current Decadal Survey has 65 high priority research areas
  - BPS funding is spread among 56 areas
- Emerging Strategy in SMD: Increase the amount of transformative research





Investigations may be mapped to more than one topic
Abbreviations defined on charts in backup

Decadal Survey

- Statement of Task finalized
- https://www.nationalacademies.org/our-work/decadal-survey-on-life-and-physical-sciences-research-in-space-2023-2032
- Formal start expected late 2020 or early 2021
- Key: Decadal Surveys are based on community input
  - Whitepapers submitted by the community are the most important input to the Decadal Survey process
  - **BPS funding ASGSR activity to facilitate the development of whitepapers**
    - https://asgsr.org/decadal-survey/

Elements of Decadal Survey

- Research areas as in current Decadal Survey
- “Keystone Capabilities”
  - Like Flagship missions in other SMD divisions, but much smaller
    - Hardware centric like Cold Atom Lab, Combustion Rack, Fluids Rack
    - Single environment (e.g., ground, LEO, Lunar orbit or surface)
    - Supports multiple investigations
- Research Campaigns
  - Well-defined set of investigations
    - Multiple lines of investigation
    - Not focused on hardware or single environment
  - Clear, transformative goal

Elements of Decadal Survey

- Cost estimates for Keystone Capabilities and Research Campaigns
  - Important guidance for scaling the activity appropriately
  - May need to be a range
    - There may be important flexibility in the content
    - No single database captures the wide range of costs for past BPS projects
    - The commercial payload developer market is evolving and may be hard to forecast
    - Precedent exists in other Decadal Surveys

TABLE ES.4 Space: Recommended Activities—Medium-Scale (Priority Order)

Recommendation	Science	Appraisal of Costs[a]	Cross-Reference in Chapter 7
1. New Worlds Technology Development Program	Preparation for a planet-imaging mission beyond 2020, including precursor science activities	\$100M to \$200M	Page 215
2. Inflation Probe Technology Development Program	Cosmic microwave background (CMB)/ inflation technology development and preparation for a possible mission beyond 2020	\$60M to \$200M	Page 217

[a] The survey's cost appraisals are in FY2010 dollars and are committee-generated and based on available community input.

New Worlds, New Horizons in Astronomy and Astrophysics (2010)

Opportunities and Challenges

- Opportunities
  - Focus on transformative science
  - Coordination and collaboration with other SMD programs
    - Astrobiology and Planetary Protection
    - Physics of the Universe
  - Sharing best practices
    - Heliophysics DRIVE program

- Challenges
  - Long time horizon for full response to next Decadal Survey
    - Winter 2023 delivery impacts budget planning for FY25
  - Providing COVID-19 relief funding to graduate students, post-docs, etc.
  - Divestment of some research areas to focus on transformational science
  - Generating payload developer capability in the BPS research community

Conclusion

- Space Biology and Physical Sciences moved to SMD in July
  - Programs, projects, grants, personnel moved *en masse*
  - Exploring coordination and collaboration with SMD Divisions
  - Retaining close relationships with all partners
    - Improving coordination with CASIS/ISSNL
- Mission to Pioneer Scientific Discovery and Enable Exploration is unchanged
  - Shifting to more emphasis on transformative research
- Building a foundation for research beyond Low Earth Orbit
- Decadal Survey
  - Begins late 2020 or early 2021
  - Focus on transformative science
  - Research areas, Keystone Capabilities, Research Campaigns
  - Working with ASGSR to facilitate community involvement

We are excited to take advantage of these changes and developments to push the boundaries of scientific knowledge for the benefit of exploration and life on Earth

Backup

Decadal Survey Recommendations Definitions

AP1	Reduced-gravity multiphase flows, cryogenics, and heat transfer: database and modeling
AP2	Interfacial flows and phenomena
AP3	Dynamic granular material behavior and granular subsurface geotechnics
AP4	Dust mitigation
AP5	Complex fluid physics
AP6	Fire safety
AP7	Combustion processes
AP8	Numerical simulation of combustion
AP9	Materials synthesis and processing and the control of microstructure and properties
AP10	Advanced materials
AP11	In situ resource utilization
TSES1	Conduct research to address issues for active two-phase flow relevant to thermal management
TSES2	To support zero-boiloff propellant storage and cryogenic fluid management technologies, conduct research on advanced insulation materials research, active cooling, multiphase flows, and capillary effectiveness (T2), as well as active and passive storage, fluid transfer, gauging, pressurization, pressure control, leak detection, and mixing destratification (T3).
TSES3	NASA should enhance surface mobility; relevant research includes suited astronaut computational modeling, biomechanics analysis for partial gravity, robot-human testing of advanced spacesuit joints and full body suits, and musculoskeletal modeling and suited range-of-motion studies (T4). plus studies of human-robot interaction (including teleoperations) for the construction and operation of planetary surface habitats (T26).
TSES4	NASA should develop and demonstrate technologies to mitigate the effects of dust on extravehicular activity (EVA) systems and suits, life support systems, and surface construction systems. Supporting research includes impact mechanics of particulates, design of outer-layer dust garments, advanced material and design concepts for micrometeoroid mitigation, magnetic repulsive technologies, and the quantification of plasma electrodynamic interactions with EVA systems (T5); dynamics of electrostatic field coupling with dust (T23); and regolith mechanics and gravity-dependent soil models (T27).
TSES5	NASA should define requirements for thermal control, micrometeoroid and orbital debris impact and protection, and radiation protection for EVA systems, rovers, and habitats and develop a plan for radiation shelters. (T19)
TSES6	NASA should conduct research for the development and demonstration of closed-loop life support systems and supporting technologies. Fundamental research includes heat and mass transfer in porous media under partial gravity and microgravity conditions (T6) and understanding the effect of variable gravity on multiphase flow systems. (T21, T22)
TSES7	NASA should develop and demonstrate technologies to support thermoregulation of habitats, rovers, and spacesuits on the lunar surface. (T20)

TSES8	NASA should perform critical fire safety research to develop new standards to qualify materials for flight and to improve fire and particle detectors. Supporting research is necessary in materials qualification for ignition, flame spread, and generation of toxic and/or corrosive gases (T7) and in characterizing particle sizes from smoldering and flaming fires under reduced gravity (T8).
TSES9	NASA should develop a standard methodology for qualifying fire suppression systems in relevant atmospheres and gravity levels and would benefit from strategies for safe post-fire recovery. Specific research is needed to characterize the effectiveness of fire suppression agents and systems under reduced gravity (T9) and to assess the toxicity of various fire products (T10).
TSES10	Research should be conducted to allow regenerative fuel cell technologies to be demonstrated in reduced-gravity environments. (T11)
TSES11	To support the development of new energy conversion technologies, research should be done on high-temperature energy conversion cycles, device coupling to essential working fluids, heat rejection systems, materials, etc. (T12). Research is also required on more efficient surface-base primary power and on the technologies to enable solar electric propulsion as an option to transfer large masses of propellant and cargo to distant locations (T18).
TSES12	To make fission surface power systems a viable option, research is needed on high-temperature, low-weight materials for power conversion and radiators and on other supporting technologies. (T13)
TSES13	Development and demonstration of ascent and descent system technologies are needed, including ascent/descent propulsion technologies, inflatable aerodynamic decelerators, and supersonic retro propulsion systems. The required research includes propellant ignition, flame stability, and active thermal control (T14); lightweight flexible materials (T15); and rocket plume aerothermodynamics and vehicle dynamics and control (T16).
TSES14	Research is required to support the development and demonstration of space nuclear propulsion systems, including liquid-metal cooling under reduced gravity, thawing under reduced gravity, and system dynamics. (T17)
TSES15	Research is needed to identify and adapt excavation, extraction, preparation, handling, and processing techniques for a lunar water/oxygen extraction system. (T24)
TSES16	NASA should establish plans for surface operations, particularly ISRU capability development and surface habitats. Research is needed to characterize resources available at lunar and martian surface destinations (T25) and to define surface habitability systems design requirements (T28).
FP1	Research on complex fluids and soft matter. Microgravity provides a unique opportunity to study structures and forces important to the properties of these materials without the interference caused by Earth-strength gravity.

Decadal Survey Recommendations Definitions

FP2	Understanding of the fundamental forces and symmetries of nature. High-precision measurements in space can test relativistic gravity, fundamental high-energy physics, and related symmetries in ways that are not practical on Earth. Novel effects predicted by new theoretical approaches provide distinct signatures for precision experimental searches that are often best carried out in space.
FP3	Research related to the physics and applications of quantum gases. The space environment enables many investigations, not feasible on Earth, of the remarkably unusual properties of quantum gases and degenerate Fermi gases.
FP4	Investigations of matter near a critical phase transition. Experiments that have already been designed and brought to a level of flight readiness can elucidate how materials behave in the vicinity of thermodynamically determined critical points. These experiments, which require a microgravity environment, will provide insights into new effects observable when such systems are driven away from equilibrium conditions.
P1	Establish a microbial observatory program on the ISS to conduct long-term, multigenerational studies of microbial population dynamics.
P2	Establish a robust spaceflight program of research analyzing plant and microbial growth and physiological responses to the multiple stimuli encountered in spaceflight environments.
P3	Develop a research program aimed at demonstrating the roles of microbial-plant systems in long-term life support systems.
AH1	The efficacy of bisphosphonates should be tested in an adequate population of astronauts on the ISS during a 6-month mission.
AH2	The preservation/reversibility of bone structure/strength should be evaluated when assessing countermeasures.
AH3	Bone loss studies of genetically altered mice exposed to weightlessness are strongly recommended.
AH4	New osteoporosis drugs under clinical development should be tested in animal models of weightlessness.
AH5	Conduct studies to identify underlying mechanisms regulating net skeletal muscle protein balance and protein turnover during states of unloading and recovery.
AH6	Conduct studies to develop and test new prototype exercise devices and to optimize physical activity paradigms/prescriptions targeting multisystem countermeasures.
AH7	Determine the daily levels and pattern of recruitment of flexor and extensor muscles of the neck, trunk, arms, and legs at 1 g and after being in a novel gravitational environment for up to 6 months.
AH8	Determine the basic mechanisms, adaptations, and clinical significance of changes in regional vascular/interstitial pressures (Starling forces) during long-duration space missions.
AH9	Investigate the effects of prolonged periods of microgravity and partial gravity (3/8 or 1/6 g) on the determinants of task-specific, enabling levels of work capacity.

AH10	Determine the integrative mechanisms of orthostatic intolerance after restoration of gravitational gradients (both 1 g and 3/8 g).
AH11	Collaborative studies among flight medicine and cardiovascular epidemiologists are recommended to determine the best screening strategies to avoid flying astronauts with subclinical coronary heart disease that could become manifest during a long-duration exploration-class mission (3 years).
AH12	Determine the amount and site of the deposition of aerosols of different sizes in the lungs of humans and animals in microgravity.
AH13	Multiple parameters of T cell activation in cells should be obtained from astronauts before and after re-entry to establish which parameters are altered during flight.
AH14	Both to address the mechanism(s) of the changes in the immune system and to develop measures to limit the changes, data from multiple organ/system-based studies need to be integrated.
AH15	Perform mouse studies of immunization and challenge on the ISS, using immune samples acquired both prior to and immediately upon re-entry, to establish the biological relevance of the changes observed in the immune system. Parameters examined need to be aligned with those in humans influenced by flight.
AH16	Studies should be conducted on transmission across generations of structural and functional changes induced by exposure to space during development. Ground-based studies should be conducted to develop specialized habitats to support reproducing and developing rodents in space.
CC1	To ensure the safety of future commercial orbital and exploration crews, quantify post-landing vertigo and orthostatic intolerance in a sufficiently large sample of returning ISS crews, as part of the immediate post-flight medical exam.
CC2	Determine whether artificial gravity (AG) is needed as a multisystem countermeasure and whether continuous large-radius AG is needed or intermittent exercise within lower-body negative pressure or short-radius AG is sufficient. Human studies in ground laboratories are essential to establish dose-response relationships, and what gravity level, gradient, rotations per minute, duration, and frequency are adequate.
CC3	Conduct studies on humans to determine whether there is an effect of gravity on micronucleation and/or intrapulmonary shunting or whether the unexpectedly low prevalence of decompression sickness on the space shuttle/ISS is due to underreporting. Conduct studies to determine operationally acceptable low suit pressure and hypobaric hypoxia limits.
CC4	Determine optimal dietary strategies for crews and food preservation strategies that will maintain bioavailability for 12 or more months.
CC5	Initiate a robust food science program focused on preserving nutrient stability for 3 or more years.
CC6	Include food and energy intake as an outcome variable in dietary intervention trials in humans.

Decadal Survey Recommendations Definitions

CC7	Conduct longitudinal studies of astronauts for cataract incidence, quality, and pathology related to radiation exposures to understand both cataract risk and radiation-induced late tissue toxicities in humans.
CC8	Expand the use of animal studies to assess space radiation risks to humans from cancer, cataracts, cardiovascular disease, neurologic dysfunction, degenerative diseases, and acute toxicities such as fever, nausea, bone marrow suppression, and others.
CC9	Continue ground-based cellular studies to develop end points and markers for acute and late radiation toxicities, using radiation facilities that are able to mimic space radiation exposures.
CC10	Expand understanding of gender differences in adaptation to the spaceflight environment through flight- and ground-based research, particularly potential differences in bone, muscle, and cardiovascular function and long-term radiation risks.
CC11	Investigate the biophysical principles of thermal balance to determine whether microgravity reduces the threshold for thermal intolerance.