Update on SLPSRA Program Activities

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Washington, DC

1 April 2020

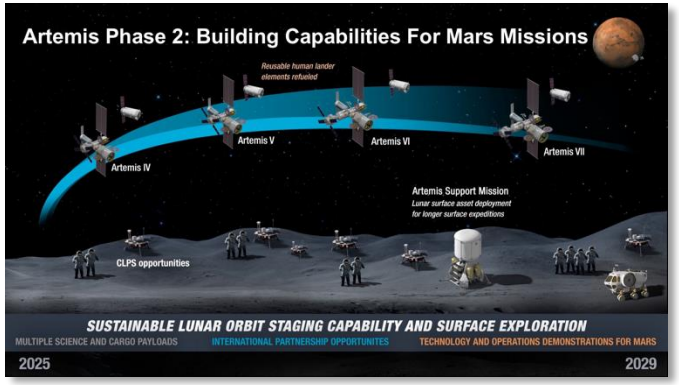
SLPSRA Strategic Framework

Vision

We lead the space life and physical sciences research community to enable space exploration and benefit life on Earth

Mission

1. Enable exploration (EE)
2. Pioneer scientific discovery (PSD)

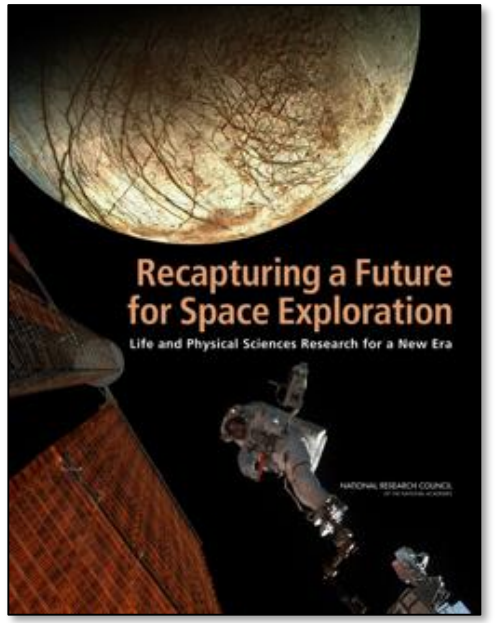


Goals

1. EE in response to pull
2. EE by providing push
3. PSD with unique science in space
4. PSD by helping others utilize space
5. Maintain key capabilities

Implementation Principles

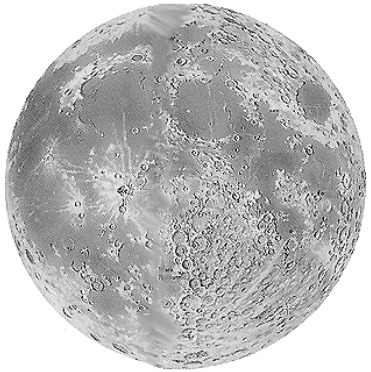
1. Ensure Scientific Integrity
2. Maximize Open Science
3. Cultivate Partnerships
4. Use Stepping Stones
5. Be an Early Adopter
6. Share Methods and Results



The Planets are Aligning

- **Opportunities for NASA and the scientific community to shape our future**
  1. Artemis-driven and -enabled science
  2. CASIS changes
  3. Move to SMD
  4. Decadal Survey

- **Biological and Physical Sciences is well prepared to capitalize on these emerging opportunities to**
  - Enable exploration
  - Pioneer scientific discovery



Who

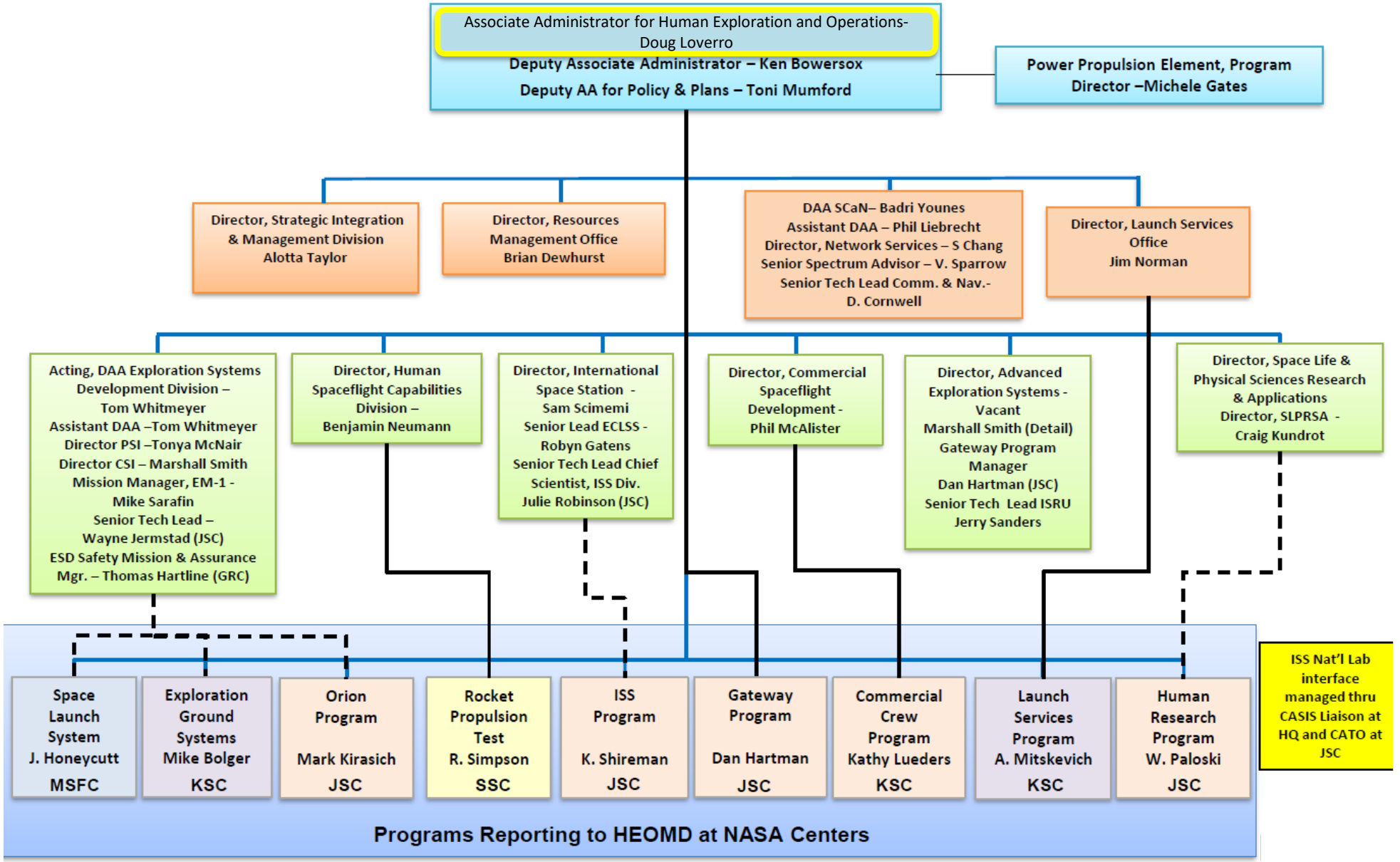
New NASA Leadership

HEOMD

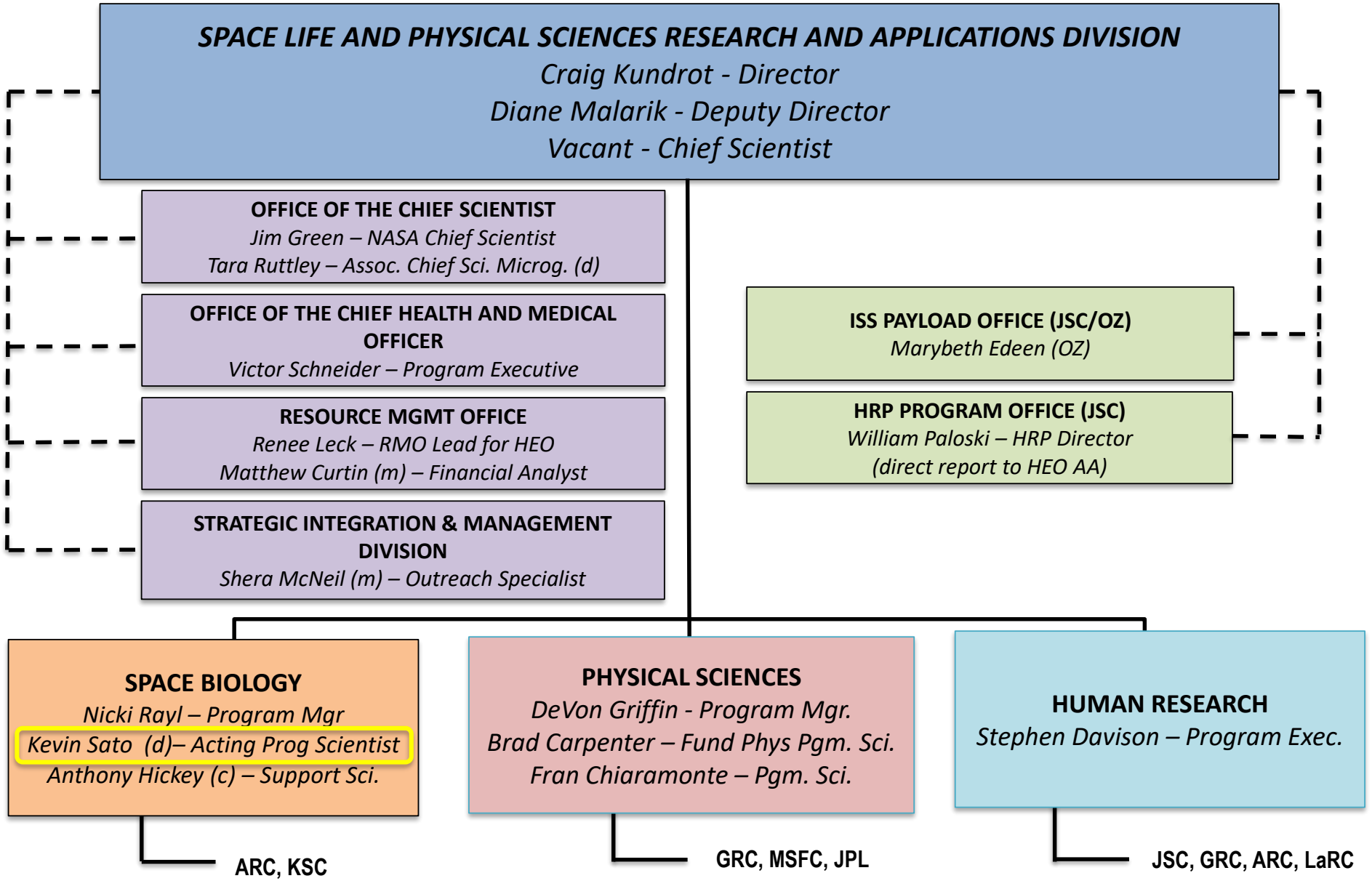
Associate Administrator

Doug Loverro

Human Exploration and Operations Mission Directorate



Space Life and Physical Sciences Research and Applications (SLPSRA) Division Organization Chart



What

Recent

Plant Habitat Lighting May Counter Changes Due to Low Gravity

John Kiss, Ph.D. - University of North Carolina, Greensboro
Javier Medina, Ph.D. - Centro de Investigaciones Biológicas (CSIC), Madrid, Spain)

- International Life Science Research Announcement (2009) grants
- Specimen: *Arabidopsis thaliana*
- *Frontiers in Plant Science. 2019 Nov; 128: 115043. doi: 10.3389/fpls.2019.01529*

Dr. John. Z. Kiss (NASA) Dr. F. Javier Medina (ESA)

NASA/ESA : EMCS Seedling Growth (SG)-1, 2, & 3

Objectives

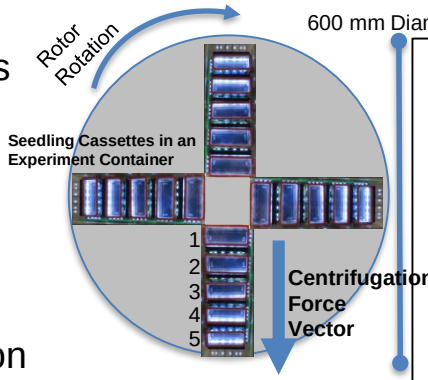
- Define the genetic interplay between gravitropism and phototropism on plant seedling development and stress responses to microgravity and partial gravity, including Moon and Mars
- Characterize the combined effects of different gravity levels and lighting wavelengths on gene expression
- Build models that describe how plants respond and acclimate to different gravity levels and lighting

Key Results to Date

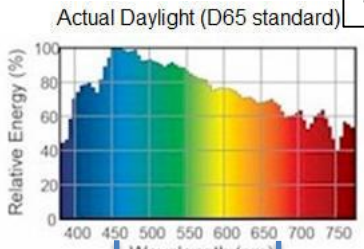
- Discovered that different gravity levels impact functions in early plant development– microgravity: light & photosynthesis genes; ug to 0.1xg: stress response genes; Moon gravity: cell wall/membrane structure/function
- Discovered that blue light photo-stimulation eliminated the changes in gene expression suggesting that blue light may be enough to reduce biological changes and stress responses due to reduction in gravity
- Data indicated that normal *Arabidopsis* development was restored at a Mars gravity-level

Relevance/Impact

- The new knowledge of the genetic interplay between lighting/phototropism and gravitropism provides foundational information that may be translated to growth of plants used for food and bioregenerative systems
- Plant habitat lighting may serve as an effective, simple method to counter changes in gravity to maintain healthy plants during early development and growth for long duration spaceflight and lunar habitation
- Discovery that simulated Mars gravity restores normal *Arabidopsis* development is the first quantitative evidence for a gravity level threshold – suggests that countermeasures are only needed for plants at < Mars gravity levels

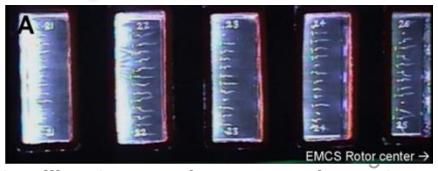


European Cultivation Module System (EMCS)
- Centrifugation rate is user defined
- Gravity gradient from Seed Cassettes 1 to 5 – enables studying Earth, Moon and Mars gravities simultaneously
- Stationary rotor for microgravity
- On-orbit 1xg control



Blue LED (450 nm) Red LED (660 nm) **EMCS Lighting**

High g ← → Low g



Rotor Center

Seedling Cassette in one Experiment Container with growing seedlings (Seedling Growth)

Developing More Effective Anti-Malarial Drugs: Antagonistic Cooperativity between Crystal Growth Modifiers

PI: Peter Vekilov, Ph.D, University of Houston

- 2013 Complex Fluids & Macromolecular Biophysics NRA grant
- System: Hematin crystallization in presence of two inhibitors
- *Nature 577, 497–501 (2020). https://doi.org/10.1038/s41586-019-1918-4*

Dr. Peter Vekilov, University of Houston, Professor of Chemical and Biomolecular Engineering & Chemistry

Objective

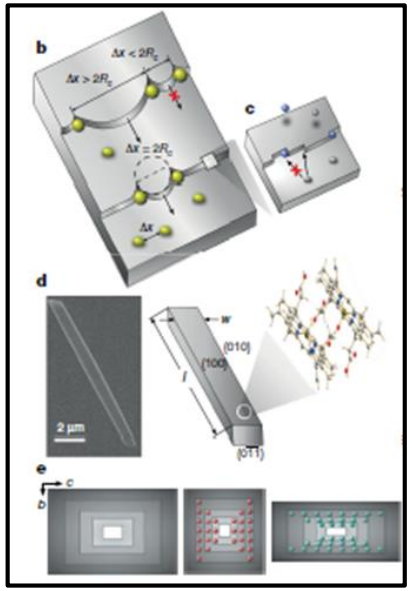
- Study detailed mechanism of crystal formation and degradation and characterize how drugs for malaria interact with each other at the molecular level.
- The molecular mechanisms employed by pairs of inhibitors in blocking the crystallization of hematin, which is a model organic compound with relevance to the physiology of malaria parasites, were investigated.
- Malaria causes around 500,000 human deaths worldwide every year.
- The current drugs are becoming ineffective because the parasite is adapting to them

Key Results to Date

- The right drug combinations interrupted the crystal growth at two separate points instead of one, inhibiting crystal growth more effectively and challenging the parasite with two effects to adapt instead of one.
- The proposed mechanisms indicate strategies to understand and control crystallization in both natural and engineered systems.

Relevance/Impact

- Discovered new ways to combine malaria drugs that may be more effective.
- The mechanism discovered may provide guidance in the search for suitable inhibitor combinations to control crystallization of pathological, biomimetic, and synthetic materials.



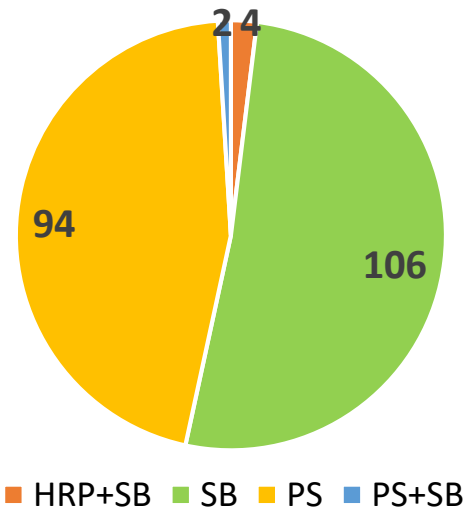
b, Schematic of step pinning. c, Schematic of inhibitors (blue). d, SEM micrograph and schematic illustrating the B-haematin crystal shape. e, Preservation of the crystal shape during growth in pure solutions and inhibitor-induced suppression of crystal length or width.

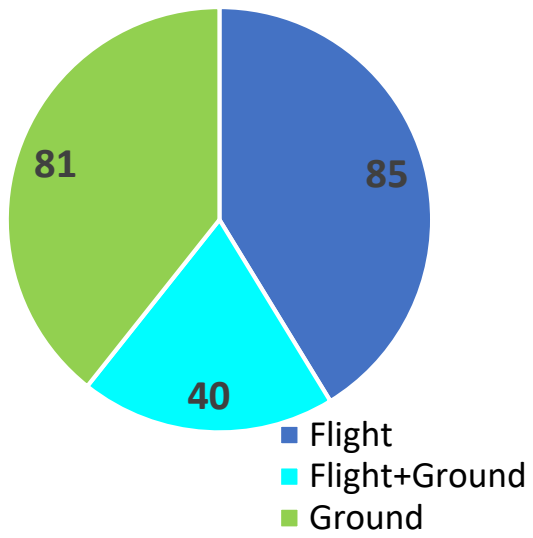
What

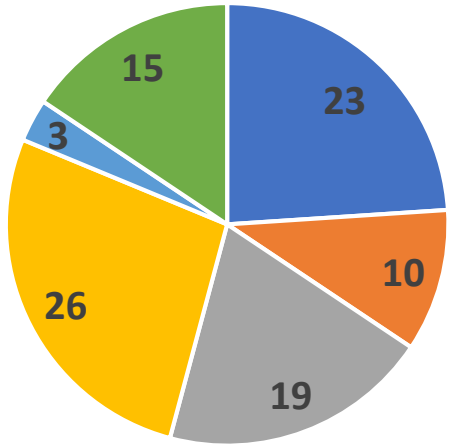
Present

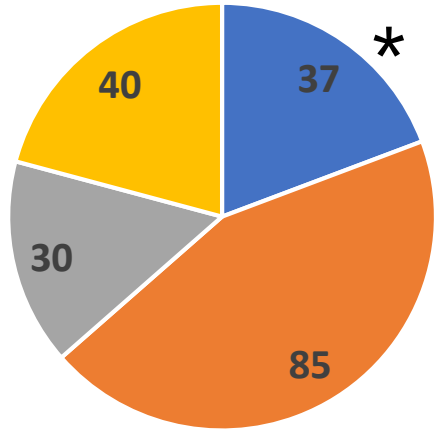
SLPRSA BPS Tasks and Research Community

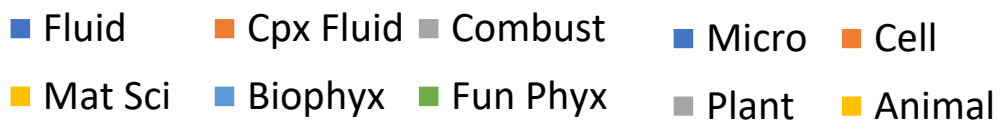
Program	Tasks	PIs	Co-Is	Post Docs	PhD students	Masters students	Bachelor students
Space Biology	112	86	201	67	52	22	146
Physical Sciences	96	88	117	53	125	26	73
Total	208	174	318	120	177	48	219
							1,264











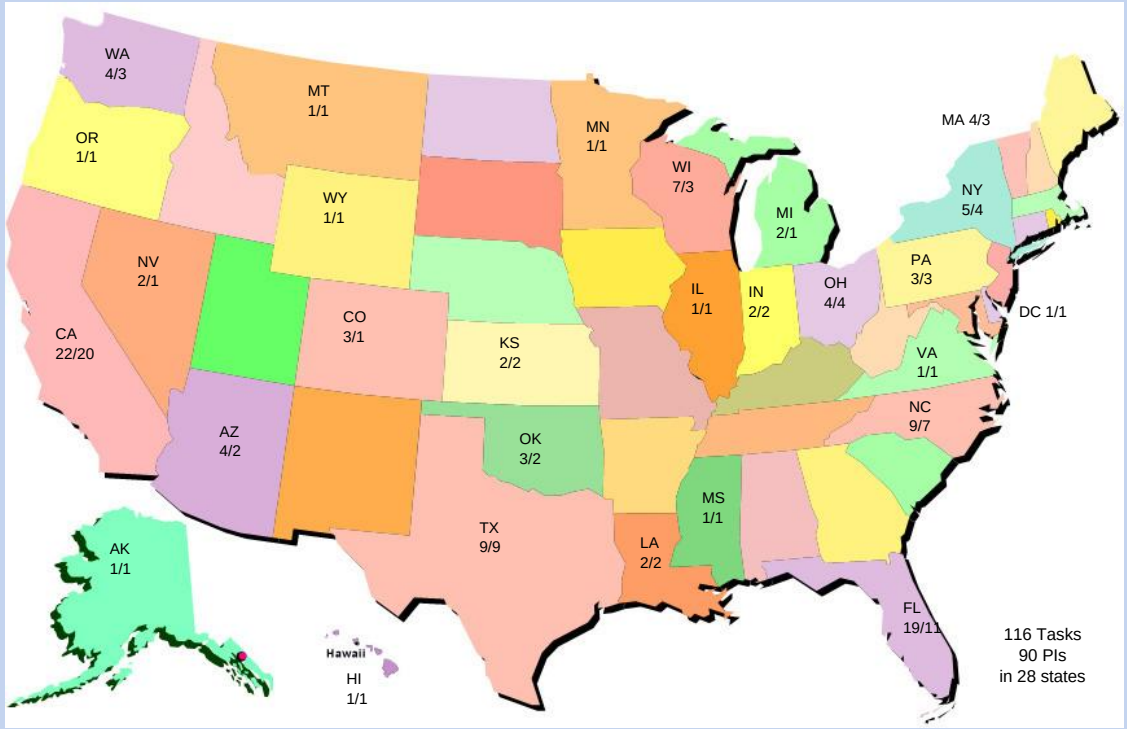
https://taskbook.nasaprs.com/Publication/index.cfm

*Some tasks assigned to more than one discipline

Tasks and Principal Investigators by State

Space Biology Program FY 2020

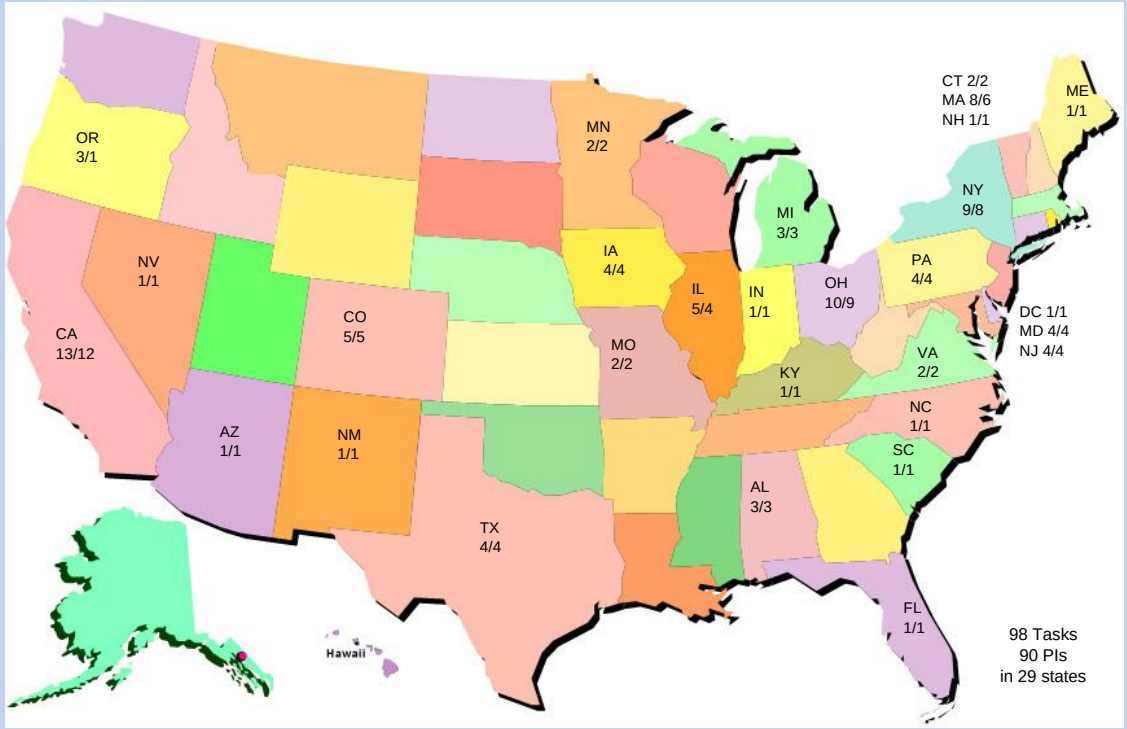
Tasks/Principal Investigators by State



Source for data, as of 03/30/2020 NASA Task Book

Physical Sciences Program FY 2020

Tasks/Principal Investigators by State



Source for data, as of 03/30/2020 NASA Task Book

Does not include distribution of students, post-docs, co-Is
Does not include EPSCoR grants

SLPSRA Partnerships Summary

- **Agreements Executed**
  - USDA: Two annexes signed for research in Biotechnology Lab @ EPCOT & microgreen research
  - International Agreement signed Chungnam National University of S. Korea: Advanced Colloids Research

- **Agreements in Formulation**
  - Trans-agency Solicitation on 3D Tissues and Microphysiological Systems in Development
    - NASA HRP and TRISH; NIH/NCATS; BARDA

- **Other Contacts**
  - TIM on biomedical monitoring of suborbital spaceflight participants
  - Site visit to FDA planned; Presentation to FDA Emerging Science Working Group

- **Activities/Outreach**
  - Participated in an Interagency special issue of the International Journal of Radiation Biology sequestered by BARDA
  - Pre-ASGSR Workshop on “3D Tissues and Microphysiological Systems” co-organized with NIH/NCATS November 2019
  - Continuation of webinar series with NIH begins April
  - Spaceflight Research 101: STAR Summer School at ARC August 10-14, 2020

Note: Numbers above reflect progress on partnerships and increased capture of previous partnership activity

Co-Organized Workshops

- SLPRSA held Interagency Plenary Session at the NASA HRP IWS January 29, 2020
- RRS/NCI/NASA Workshop planned May 27-29, 2020: Particle Radiobiology for Spaceflight and Oncology https://www.eiseverywhere.com/website/8881/
- NASA-NIH SPACE Day TBD
- NYAS “Bioengineering in Space” Symposium, December 9-10, 2020

ISS Issues and Status of Transition Planning

- **Unstable allocation of resources**
  - Procurement of Soyuz seats
  - Start of commercial crew and establishing a rhythm
  - New CASIS / ISSNL investigations
  - Institutional Animal Care and Use Committee requirements for rodent research
- **LEO commercialization strategy evolving**
- **Crew time and cold stowage are frequent limiting factors**
- **Feast or famine: resources available to SLPSRA vary greatly between increment pairs**

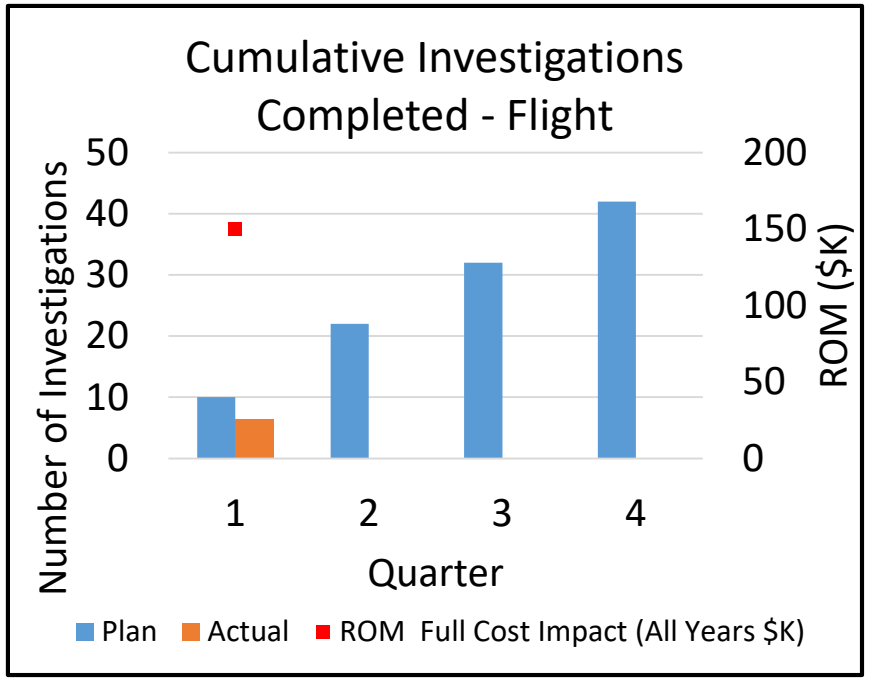
Increment Pair	55/56	57/58	59/60	61/62	63/64
Crew Hours	502	120	289	9*	0*

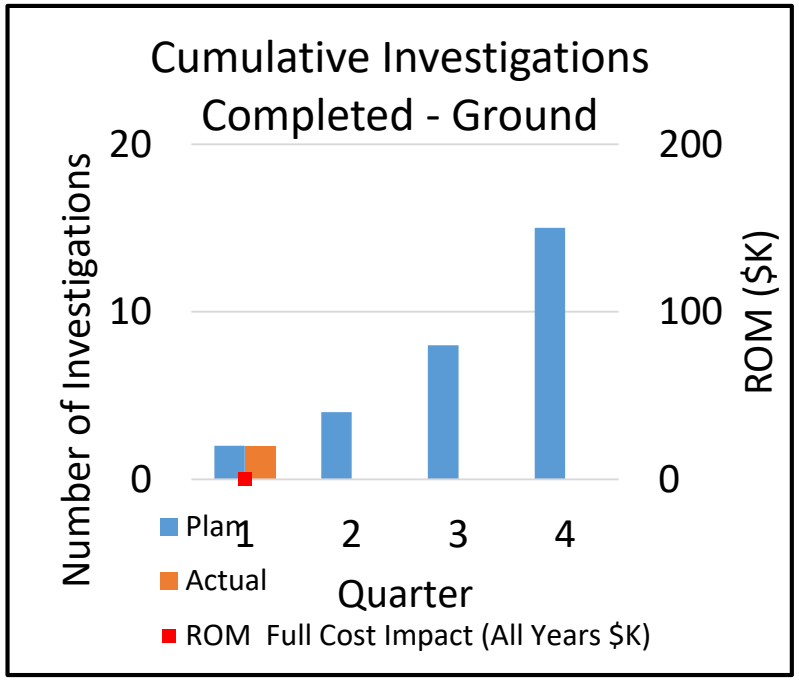
- **ISS resources distributed to all NASA investigations in a high priority category before considering any investigations in next highest priority category**
  - Categories such as non-exploration Decadal Survey research do not have minimum allocation
  - Exception: 5% of resources allocated to commercialization

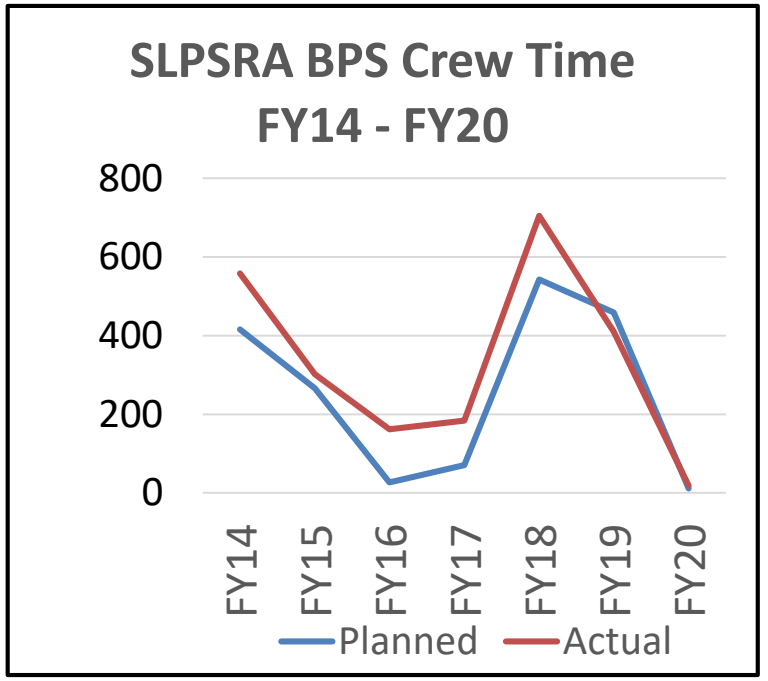
- **Funded extensions to grants delay solicitations for new grants**

*Planned

SLPSRA BPS FY20 Investigation Completion Status







- **Concern: Lack of crew time on ISS is negatively impacting the ability of SLPSRA BPS to complete science as planned.**
  - SLPSRA and ISS reviewing options to enable improved planning and scheduling to minimize cost overruns and volatility of SLPSRA ISS resources.

What

Future

NASA Research Announcements

- **Space Biology**
  - (15 awards) ROSBio-2018 Appendix B: Solicitation of Proposals for Flight and Ground Space Biology Research
    - 4 Microbiology Studies
    - 4 Animal Biology Studies
    - 7 Plant Biology Studies
  - (5 awards) ROSBio-2018 Appendix C: Development of Microgravity Food Production: Plant Watering, Volume Management, and Novel Plant Research on the International Space Station
    - Collaboration between SLPSRA Space Biology and AES
    - Plant spacing system, Porous Tube Nutrient Delivery System (PTNDS), Aeroponics, Electrospray, Hydrogel.
  - (In progress) ROSBio-2018 Appendix D: Solicitation of Proposals for Flight and Ground Space Biology Research
    - Proposals under review
  - (Future) Ground and Flight NRAs 10/20; 10/21; 10/22

- **Physical Sciences**
  - (In progress) NRA: Use of the NASA Physical Sciences Informatics System – Appendix F
    - Proposals under review
  - (Future) Fluids (FBCE) 5/20; PSI 9/20; Materials 10/20; Fluids 11/20; PSI 9/21; Complex Fluids & Combustion 11/21; Fundamental Physics 5/22

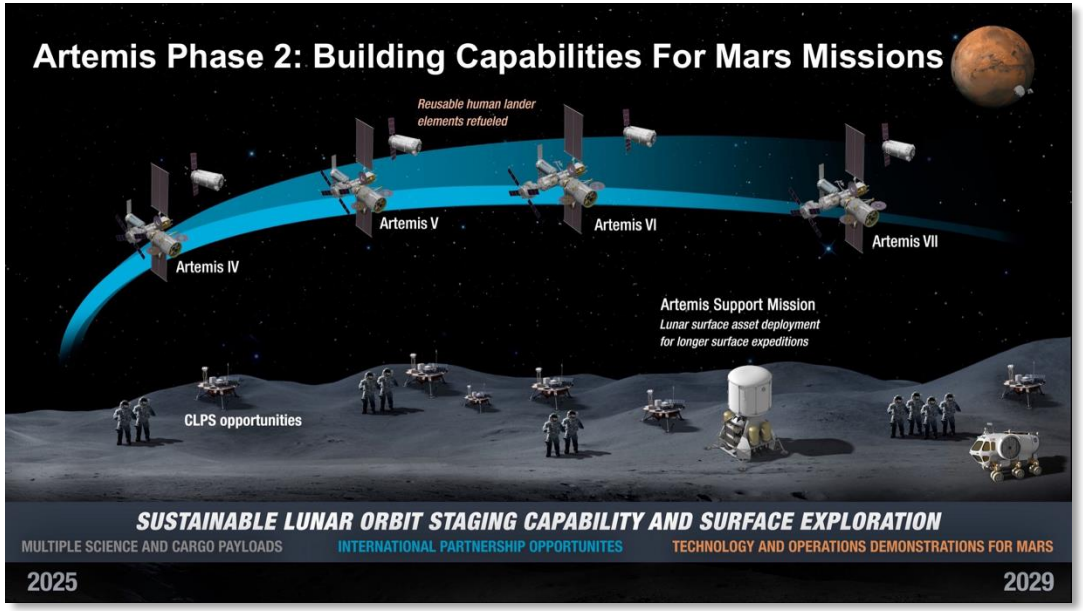
Opportunity 1

Artemis

The New Era of Lunar Exploration Requires Sustainability

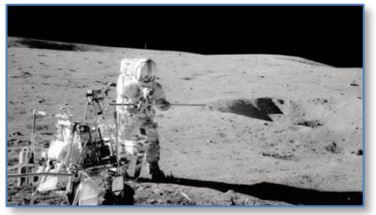
- **Project Artemis**
  - Land the first woman and the next man on the Moon by 2024
  - Establish a sustainable lunar program by 2028
- **Commercial Lander Payload Services**
  - Fourteen companies eligible to compete for missions
- **Gateway**
  - Procurements
    - Power and Propulsion Element
    - Habitation and Logistics Outpost
    - Gateway Logistics Services
- **Human Landing System**
  - Proposals under review

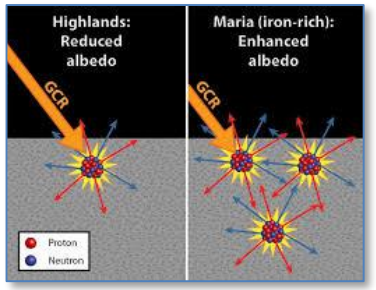
- **SLPSRA Contributions**
  - Artemis Phase 2: **Sustainable** lunar exploration
  - **Sustainable** Mars exploration

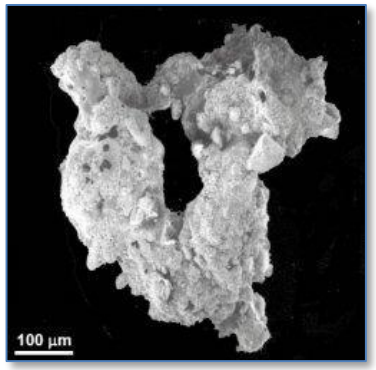


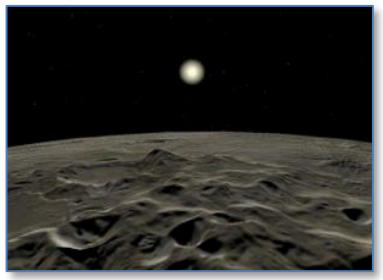
Lunar Features Enable Unique Research

- **Lunar orbit**
  - Deep space radiation
    - Radiation effects on microbes, plants, crew
  - Closed habitat (pCO_2, pH_2O, T; infrequent influx of crew and materials, dormancy)
    - Microbiome of humans, plants, vehicle; biofilm production, biocorrosion
  - Distance from Earth
    - Long range fundamental physics
- **Lunar surface**
  - Reduced gravity (1/6-*g*)
    - Flammability, fire safety
    - Two phase flow (pool and flow boiling, packed bed reactors, cryogenic fuel management)
    - Soldering, brazing, welding; additive manufacturing
    - Food crop production
  - Deep space radiation & albedo radiation (see above)
  - Lunar regolith and dust
    - Granular materials processing, in-situ surface construction, cement/concrete production
    - Metal and/or O_2 extraction from regolith
    - Dust mitigation
  - Unattenuated solar spectrum and plant growth
  - Closed habitat (see above)



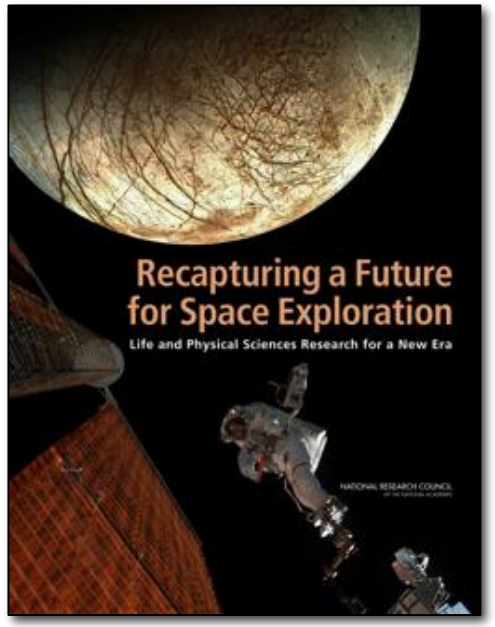






Examples of Lunar Science in the 2011 Decadal Survey

- AP1: Reduced-gravity multiphase flows, cryogenics and heat transfer database and modeling, including phase separation and distribution (i.e., flow regimes), phase-change heat transfer, pressure drop, and multiphase system stability.
- AP3: Dynamic granular material behavior and subsurface geotechnics to improve predictions and site-specific models of lunar and martian soil behavior.
- AP6: Fire safety research to improve methods for screening materials for flammability and fire suppression in space environments.
- AP9: Reduced-gravity research on materials synthesis and processing and control of microstructure and properties, to improve the properties of existing and new materials on the ground.
- AP10: Development of new and advanced materials that enable operations in harsh space environments and reduce the cost of human space exploration.
- AP11: Fundamental and applied research to develop technologies that facilitate extraction, synthesis, and processing of minerals, metals, and other materials available on extraterrestrial surfaces.



AP: Applied Physical Sciences in Space

Cross-platform Strategy for Exploration-related Physical Sciences

EARTH

ISS

GATEWAY

LUNAR SURFACE

MARS DRM

Dust Mitigation

Earth simulant tests → Microgravity deposition studies for intra-vehicle, habitat, & ECLSS mitigation → Lunar dust mitigation technology demonstrations → Mars dust mitigation plans and technologies

Cryogenic Storage, Chill-down & Tank Transfer

Cryogenic fluid physics one-G, drop tower, aircraft, suborbital, testing. → Fluid Physics µG data & model development → µG Chill-down & Tank Transfer (for Gateway propellant depot technology) → 1/6 G Storage, Chill-down and Tank Transfer → 3/8 G Tank Transfers

Flam-ability, fire safety

One-G testing, drop towers for micro & partial G, modeling → µG combustion testing for analysis, modeling, and one-g fire safety test comparison → 1/6 G Combustion Tests of planetary habitat materials → 3/8 G Combustion Models

Regolith Extraction & Solidification

One-G testing and analysis, simulation of materials processes and modeling → Cement formation, metal, & water ice extraction testing in µG and partial G via centrifuge (lunar & mars regolith simulant materials) → 1/6 G Extraction & solidification demonstration → 3/8 G Construction Techniques

Cross-platform Strategy for Exploration-related Biological Sciences


EARTH


ISS


GATEWAY


LUNAR SURFACE


MARS DRM

Crop Production

Research and develop crop system → Research and develop technology for microgravity crop production and reliability for mars transit → Validate mars transit crop system (Deep space seed viability) → > 1 Year, Dormancy robotic crop system → Transit and Surface robotic cropping system

Microbiome

Microbiome of the Built Environment (MoBE) under continuous occupancy/turnover → MoBE deep space radiation and intermittent occupancy

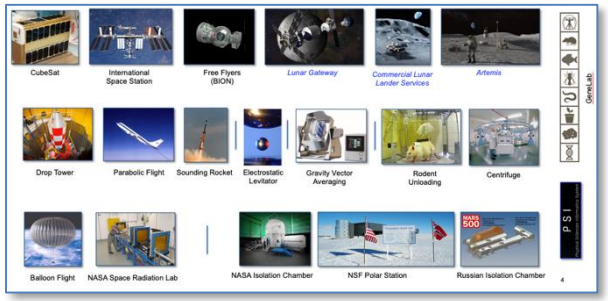
In-situ monitoring technology → MoBE deep space radiation and intermittent occupancy

MoBE deep space radiation and intermittent occupancy → Lunar surface MoBE → MoBE under long duration occupancy without turnover

MoBE deep space radiation and intermittent occupancy → Planetary spread of Earth-origin microbes → Planetary Protection applications and surveillance

Moving Forward with HEOMD and SMD

- **Coordination with HEOMD**
  - Roadmaps for enabling exploration to the Moon and Mars
  - Gateway science requirements



- **Coordination with SMD**
  - Use of / participation in Commercial Lunar Payload Services
  - Likely move of Space Biology and Physical Sciences to SMD in 2020
    - Increase linkage to Commercial Lunar Payload Services
    - Increase coordination with Astrobiology and Planetary Protection research
    - Provide more opportunity for program growth

Opportunity 2

CASIS / ISS National Laboratory

Relationship to CASIS / ISS National Laboratory

- **CASIS proposed changes to ISS NL**
  - Mission (March) and Budget (July)
- **NASA called for Independent Review Team to examine CASIS mission and resources**
  - Commissioned (August) and Completed (February)

- **NASA issued response (March?)**
  - Top impacts from SLPSRA perspective
    - TBD

- **Conclusion of IRT activity will enable resumption of move of Biological and Physical Sciences to the Science Mission Directorate**

Resonance with SLPSRA Strategic Framework

Vision

We lead the space life and physical sciences research community to enable space exploration and **benefit life on Earth**

Mission

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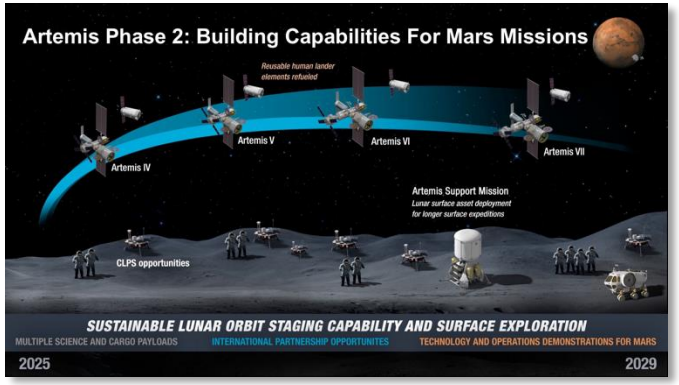
2. **Pioneer scientific discovery (PSD)**



Goals

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2. EE by providing push
3. **PSD with unique science in space**
4. **PSD by helping others utilize space**
5. Maintain key capabilities

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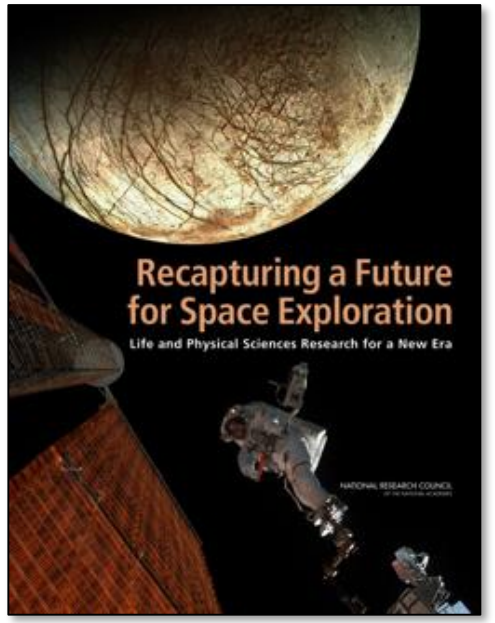


Possible Legislative Changes

- **Pre-requisite: well defined goal state for LEO commercialization and role of government agencies**

- **TBD**

Opportunity 3

Moving to SMD

Moving Biological and Physical Sciences from HEOMD to SMD

- **A return "home" of sorts**
  - 1970's to 1993 (~20 years): Office of Space Science and Applications (OSSA)
  - 1993 to 2000 (7 years): Office of Life and Microgravity Sciences and Applications (OLMSA)
  - 2000 to 2005 (5 years): Office of Biological and Physical Research (OBPR)
  - 2005 to 2020 (15 years): Part of human space flight
- **BPS would retain its relationships with ISS and HRP**
- **Better prospects for growth in SMD**

- **Many similarities between BPS and SMD**
  - Decadal Survey, advisory committees, NRAs, peer review, open science, international
- **Major differences**
  - BPS is primarily experimental science; SMD observational
  - BPS studies terrestrial systems in space; SMD studies space systems
  - BPS is a minor funder in its fields; SMD is core funder and scientific driver
- **Opportunity to explore synergies between Space Biology, Astrobiology and Planetary Protection research**

Opportunity 4

#BPSDecadalSurvey

Examples of the Influence of Decadal Survey 2011

- **Space Biology**
  - P1: Series of investigations using ISS as a Microbial Observatory show diversity of species, low virulence, plasmid DNA conferring multiple drug resistance, evolution of populations. Co-sponsor Gordon Research Conference; informed NASEM Microbes of the Built Environment.
  - P2: Wide ranging series of investigations probe mechanisms of gravitropism to suitability of plant varieties for crew consumption. Crop production now in exploration roadmaps.
  - AH3/AH5/AH15: Rodent research studies inform future crew studies by revealing physiological responses and activated pathways to variable gravity levels for bone, muscle, cardiovascular and immune systems. SANS related effects studied in detail.
- **Physical Sciences**
  - FP3: The multi-PI Cold Atom Laboratory facility was funded stating in 2012 and launched to the ISS in 2018. Seven PIs selected through an NRA; 3 Nobel Laureates involved. The first Nature article has been accepted for publication.
  - AP1: The Packed Bed Reactor Experiment improved the modeling for pressure drop and flow pattern transition for two-phase flows through porous media. Now being used to improve ISS operations and develop systems for exploration.
  - AP2: Zero Boiling Off Tank experiment improved modeling of cryogenic fluid systems; experiment series now including in STMD Cryogenic Fluid Management roadmap.

P: Plant and Microbial Biology AH: Animal and Human Biology FP: Fundamental Physical Sciences in Space

Decadal Survey 2023 (1)

- **Scope: Life and physical sciences research in space or that supports spaceflight 2023-2032**
  - Discipline areas covered in the previous decadal report and emerging areas of interest
  - Disciplines pertaining to crew health and performance will focus on fundamental or long-term research questions and emerging research issues and tools
- **Assist NASA plans to**
  - Meet the needs of exploration missions
  - Provide terrestrial benefits
  - Uniquely advance scientific knowledge
- **Tasks**
  1. Review of the current state of knowledge in the major and emerging areas of space-related biological and physical sciences research
  2. Identify the most compelling science priorities
  3. Identify facility and platform capabilities and environmental requirements for each of the areas of recommended science
  4. Recommend approaches to the development of a robust, resilient and appropriately balanced program of life and physical science space research
  5. Assemble notional proof-of-concept research campaigns that address identified science priorities and are organized into broad cost categories

Decadal Survey 2023 (2)

- **May consider NASA, commercial and international programs and plans**
  - NASA capabilities versus transition to commercial providers
  - NASA's research role in light of LEO commercial research platforms
  - Research synergies between NASA and OGAs, commercial entities and international partners
  - State of the profession nationally and globally to support U.S. progress in this survey's areas
  - Current position and expected evolution of the U.S. relative to other countries in the areas covered by the study, including the uniqueness (or lack thereof) of U.S. efforts.
- **Describe how the identified research objectives could**
  - Enable exploration activities
  - Produce knowledge
  - Provide benefits to terrestrial and other applications
- **Recommend**
  - Criteria for identifying and updating a high value research
  - A high value research portfolio based on these criteria
  - Decision rules for the recommended research priorities that can accommodate changes in urgency precipitated by major advances in a scientific field

Transition Planning Issues for Decadal Survey 2023

- **Artemis**
  - Need for **sustainable** exploration
  - NASA System Capability Leadership Teams and other groups are identifying gaps in sustainability and, in some cases, developing work breakdown structures or roadmaps

- **CASIS / ISSNL**
  - TBD

- **Development of Decadal Survey research campaigns can be informed by the above**
    - Work breakdown structures or roadmaps
      - Products needed
      - Underlying scientific questions
    - Candidate organizations to engage in broader discussions

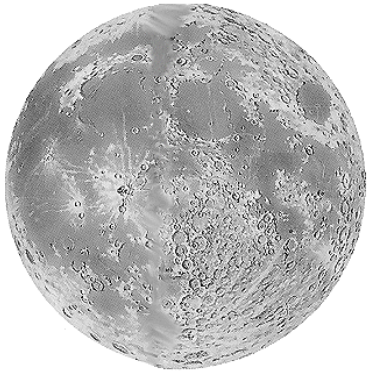
- **The Decadal Survey will inform NASA exploration and CASIS ISSNL roadmaps**

Finally…

The Planets are Aligning

- **Opportunities for NASA and the scientific community to shape our future**
  1. Artemis-driven and -enabled science
  2. CASIS changes
  3. Move to SMD
  4. Decadal Survey

- **Biological and Physical Sciences is well prepared to capitalize on these emerging opportunities to**
  - Enable exploration
  - Pioneer scientific discovery




Thank you
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