National Aeronautics and
Space Administration

Science Committee Report

Dr. Meenakshi Wadhwa
Chair, Science Committee

Science Committee Members

Dr. Meenakshi Wadhwa, Chair, Arizona State University
Dr. Michael Liemohn, Chair, Heliophysics Advisory Cmte (HPAC)
Dr. Feryal Ozel, Chair, Astrophysics Advisory Cmte (APAC)
Dr. J. Marshall Shepherd*, Chair, Earth Science Advisory Cmte (ESAC)
Dr. Anne Verbiscer, Chair, Planetary Science Advisory Cmte (PAC)
Dr. Susan Avery, Woods Hole Oceanographic Institute
Dr. Vinton Cerf, Google
Dr. Mihir Desai*, Southwest Research Institute
Dr. Kathryn Flanagan*, Space Telescope Science Institute
Dr. Jeffrey A. Hoffman, Massachusetts Institute of Technology
Dr. Tamara Jernigan*, Lawrence Livermore National Laboratory
Dr. Michelle Larson, Adler Planetarium
Dr. Pat Patterson, Space Dynamics Laboratory
Mr. Marc Weiser, RPM Ventures

***Term ends within next 2 months.**

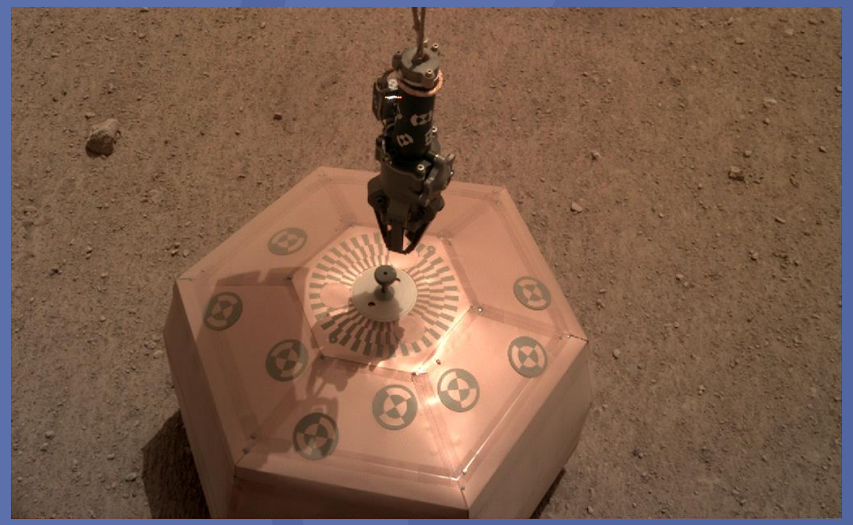
Outline

- **Science Highlights**
- Programmatic Status
- Recommendation/Findings

InSight

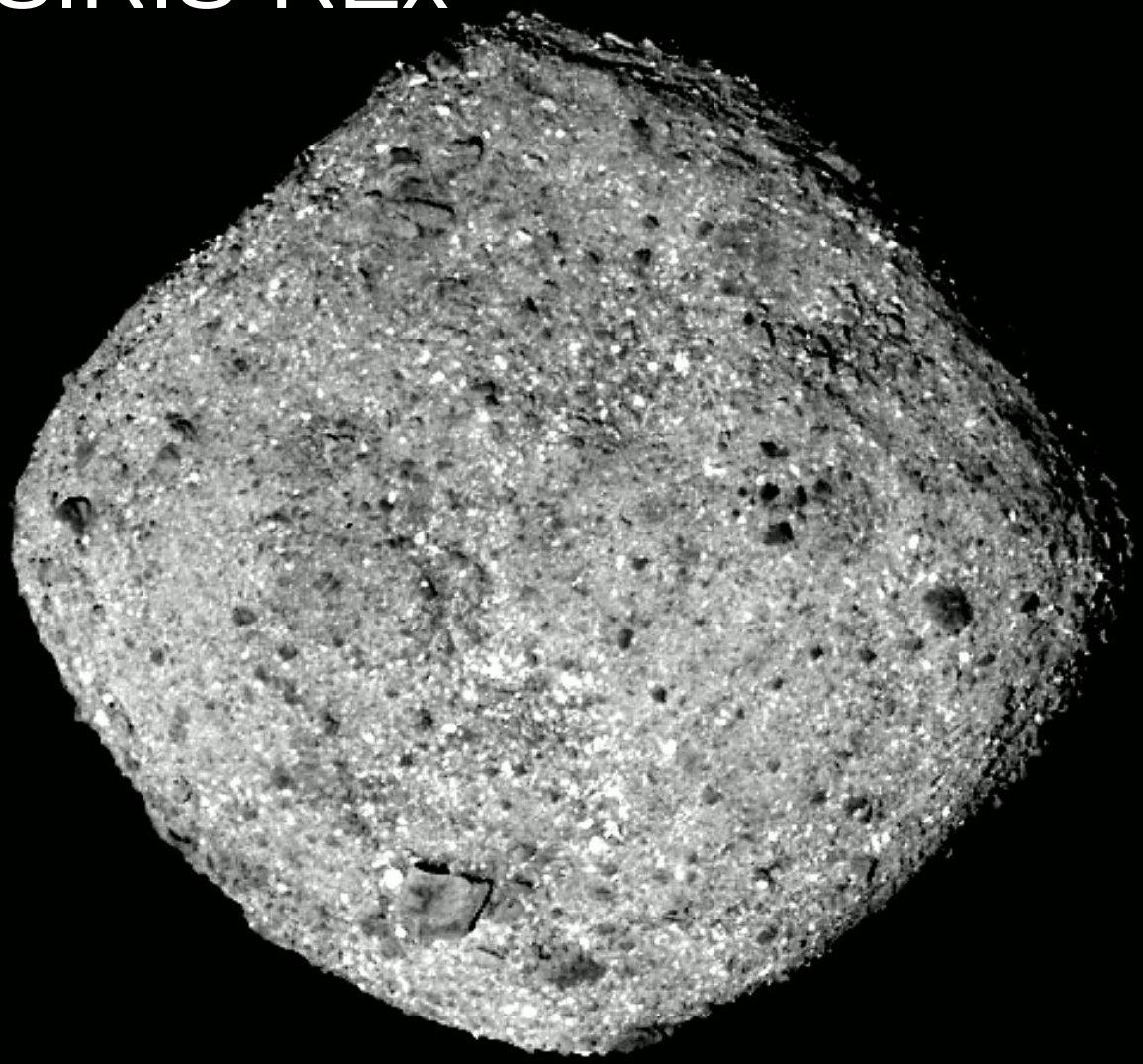
Taking the ‘Vital Signs’ of Mars

SCIENCE HIGHLIGHT

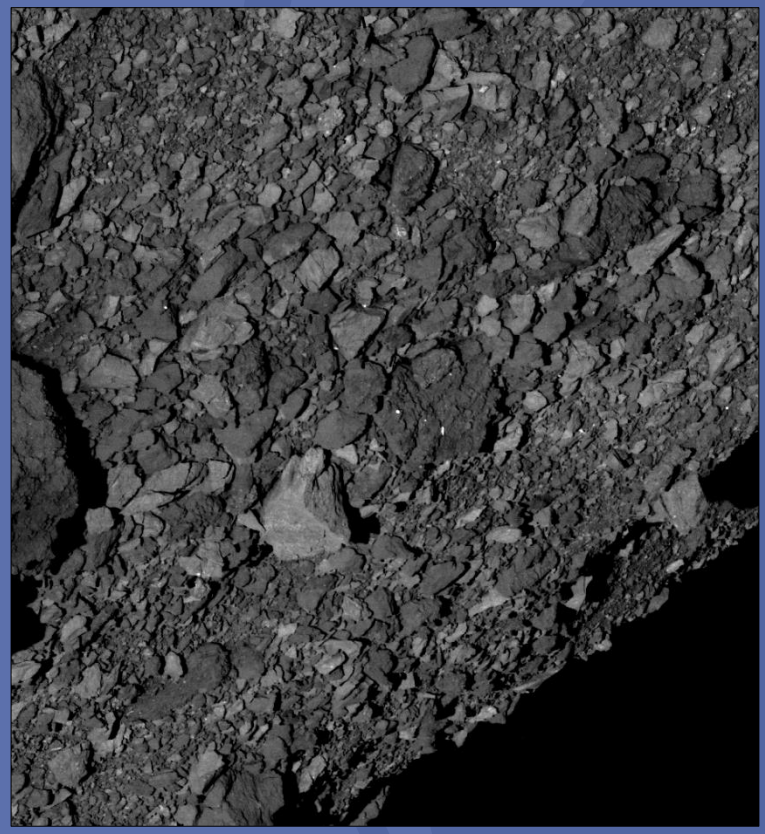


April 6, 2019 – InSight seismometer SEIS detects ground vibrations; three distinct events: Martian wind, the seismic event, and the robotic arm

OSIRIS-REx



SCIENCE HIGHLIGHT



Mar. 7, 2019 – OSIRIS-REx image shows a view across Bennu's southern hemisphere; demonstrates the number and distribution of boulders

New Horizons

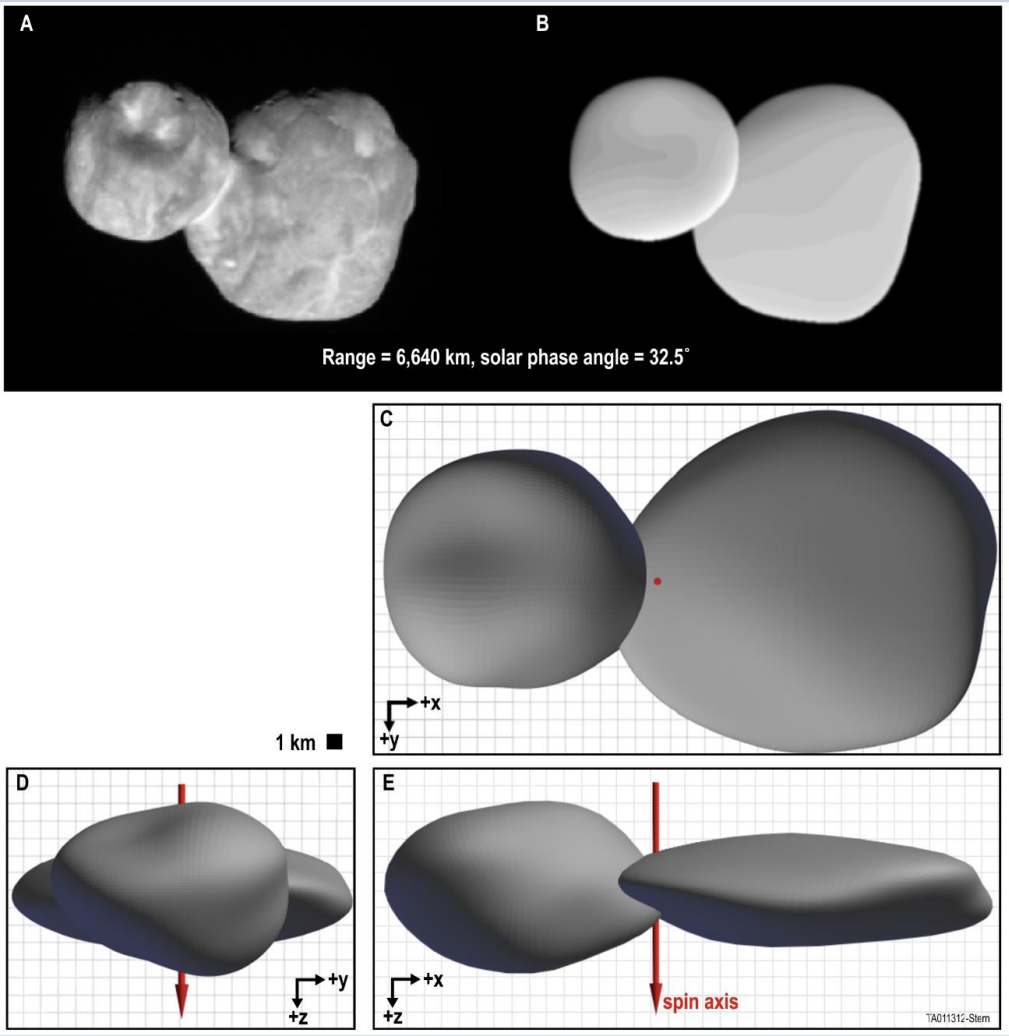
Arrival at Ultima Thule

SCIENCE HIGHLIGHT

Jan. 1, 2019 – New Horizons captures image Kuiper Belt object 2014 MU_{69} nicknamed Ultima Thule seven minutes before closest approach

New Horizons Explores a Cold Classical Kuiper Belt Object

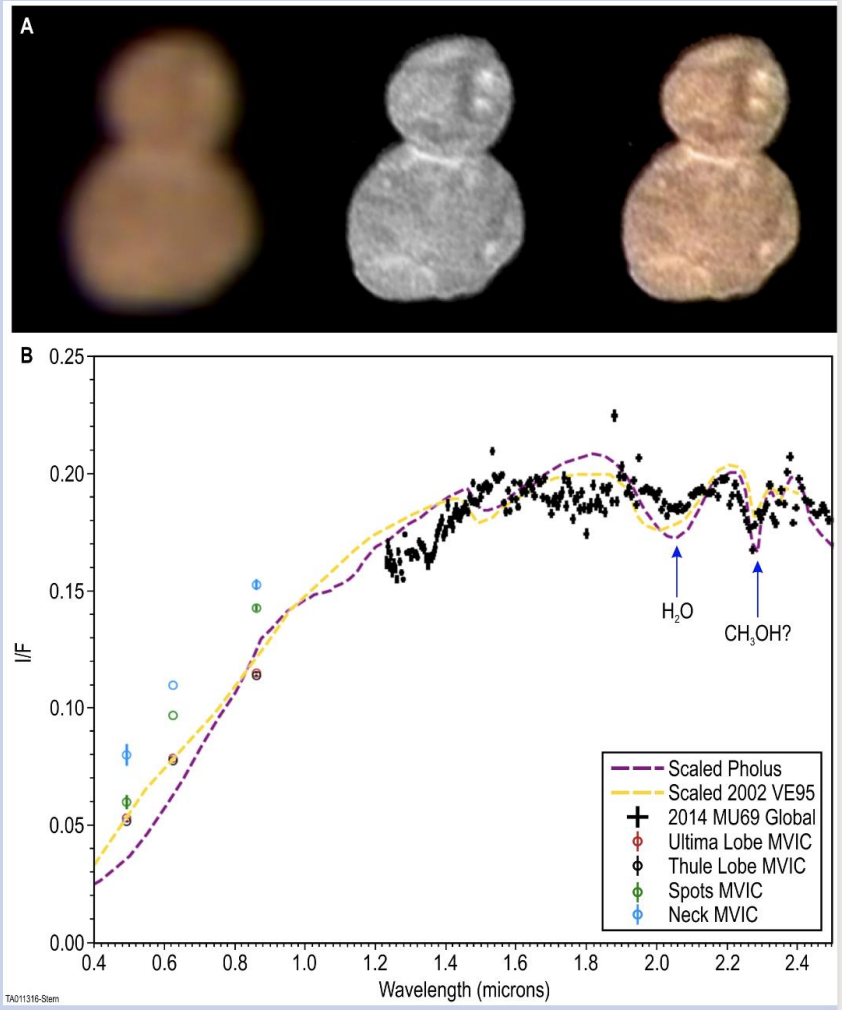
- Stern et al. (2019) provide the first summary of results from the 1 January 2019 flyby of 2014 MU_{69}, a bilobate relic from the early days of Solar System.



Shape model of MU_{69} (left) shows two discrete lobes of unequal sizes, but similar albedo, composition, and color. Shape is surprisingly flat; though the z-axis was in darkness and thus is least constrained.

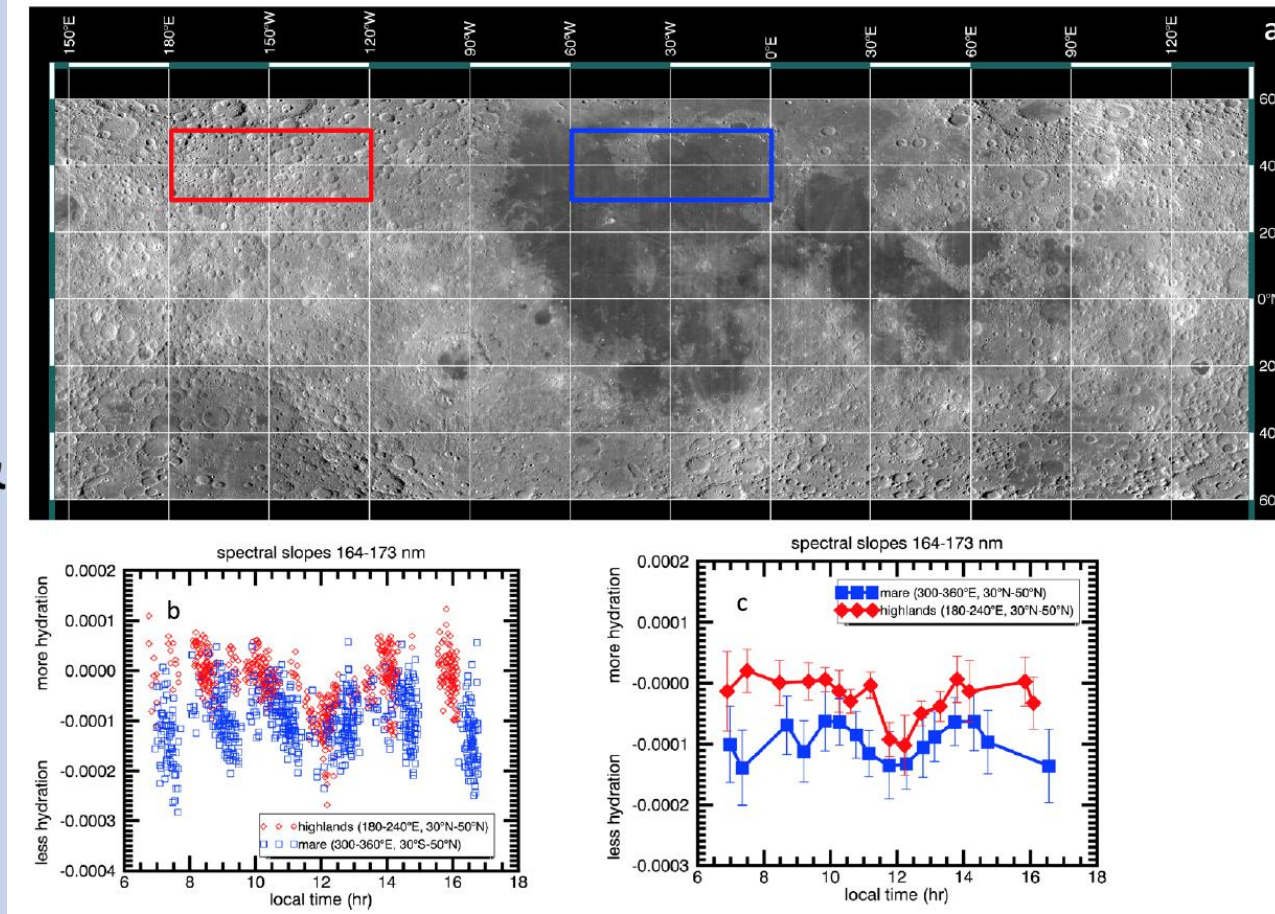
MU_{69} is the result of a gentle collision between two independently-formed bodies.

Near-infrared spectra show the presence of methanol and water ice.



Water on the Moon - LRO

- Hendrix et al. (2019) found that surface water on the Moon varies in abundance with both terrain type (highlands and maria) and local time & temperature.
- Data from the Lyman Alpha Mapping Project and Diviner (LAMP) on the Lunar Reconnaissance Orbiter (LRO).
- First detection of water from UV observations of a rocky, airless body.
- Published in *Geophysical Research Letters (GRL)* April 2019.



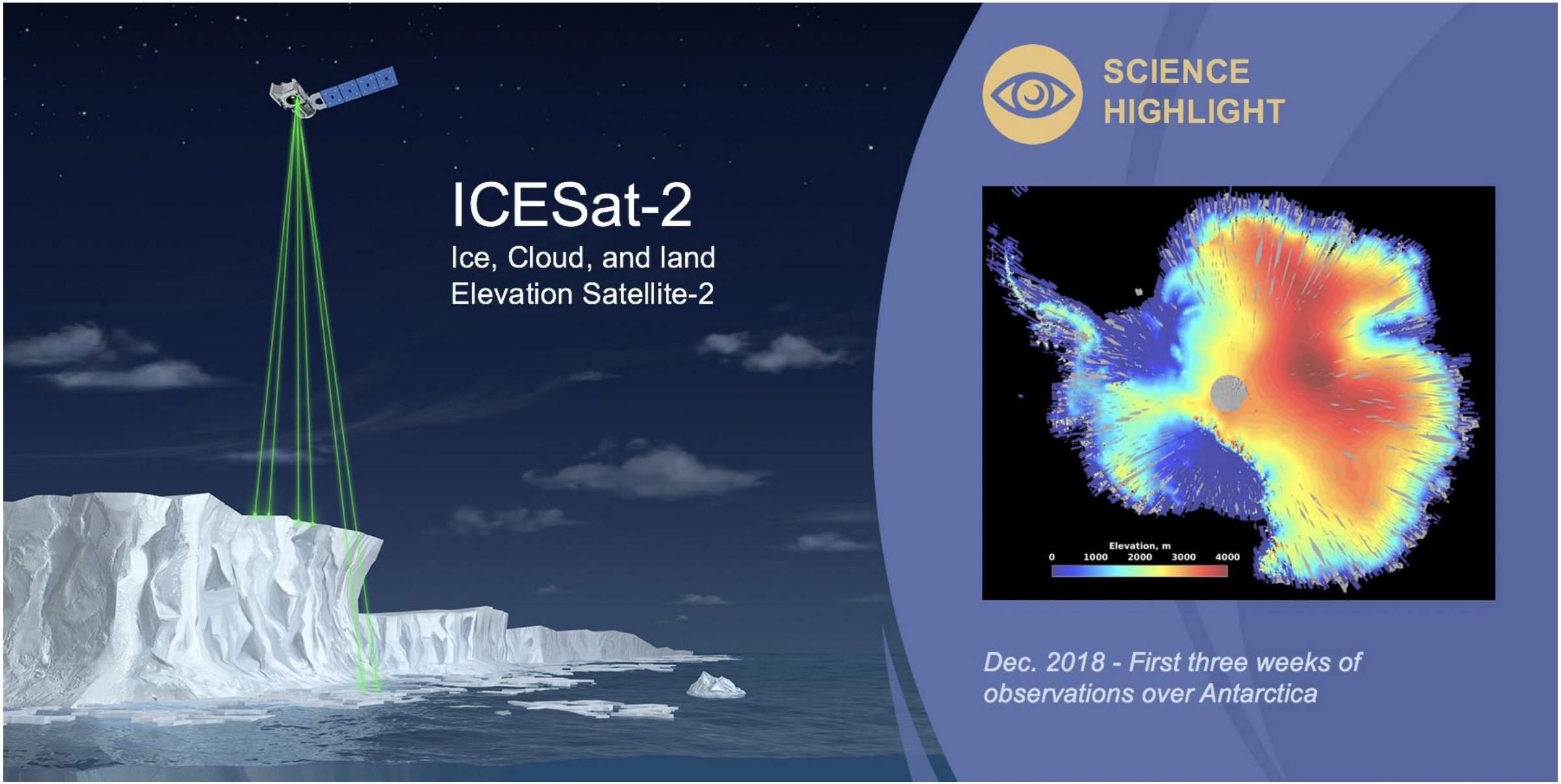
LRO Wide Angle Camera image of the Moon (top) shows regions of study (red = highlands; blue = mare).
Far UV spectral slopes corresponding to each region relative to local time for (b) all points and (c) averages show diurnal variation and loss of hydration around noon.

Orbiting Carbon Observatory 3 (OCO-3)

Launched May 4, 2019

SCIENCE HIGHLIGHT

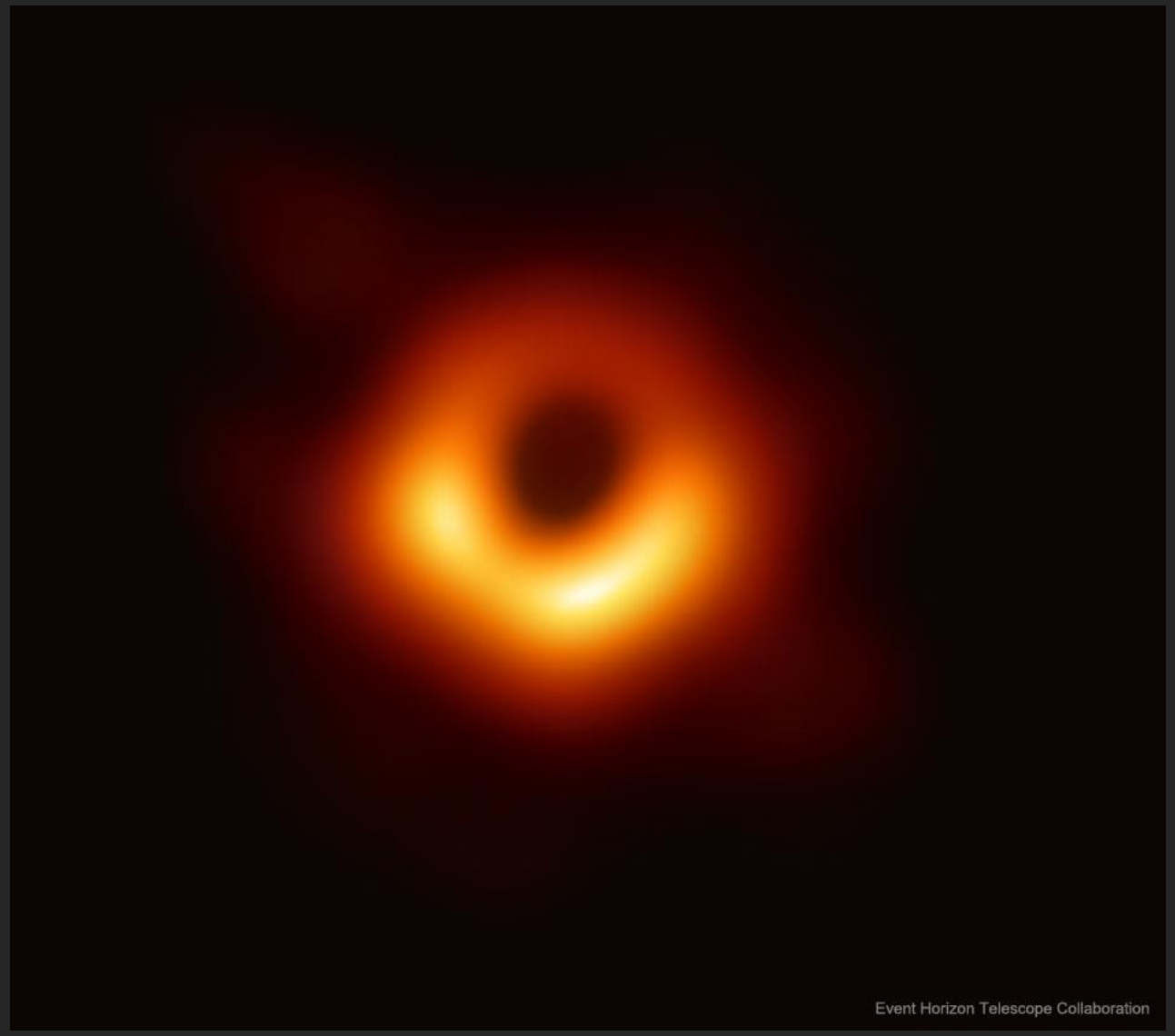
OCO-3's new feature called "snapshot mode" scanning technique swivels and points rapidly, producing a tightly woven blanket of measurements over an area of about 50 by 50 miles (80 by 80 kilometers)


ICESat-2
Ice, Cloud, and land
Elevation Satellite-2
SCIENCE
HIGHLIGHT
Elevation, m
0
1000
2000
3000
4000
Dec. 2018 - First three weeks of
observations over Antarctica

ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)

Urban areas can be up to 8 degrees warmer than surrounding suburban or natural landscapes, as seen here in a true-color image of the Atlanta area, top, and temperature data, bottom.

Dr. Feryal Ozel - SC Member Research Presentation
Detecting the Shadow of the Black Hole in M87



SCIENCE HIGHLIGHT

TESS TRANSITING EXOPLANET SURVEY SATELLITE

Discovers Its First Earth-sized Planet

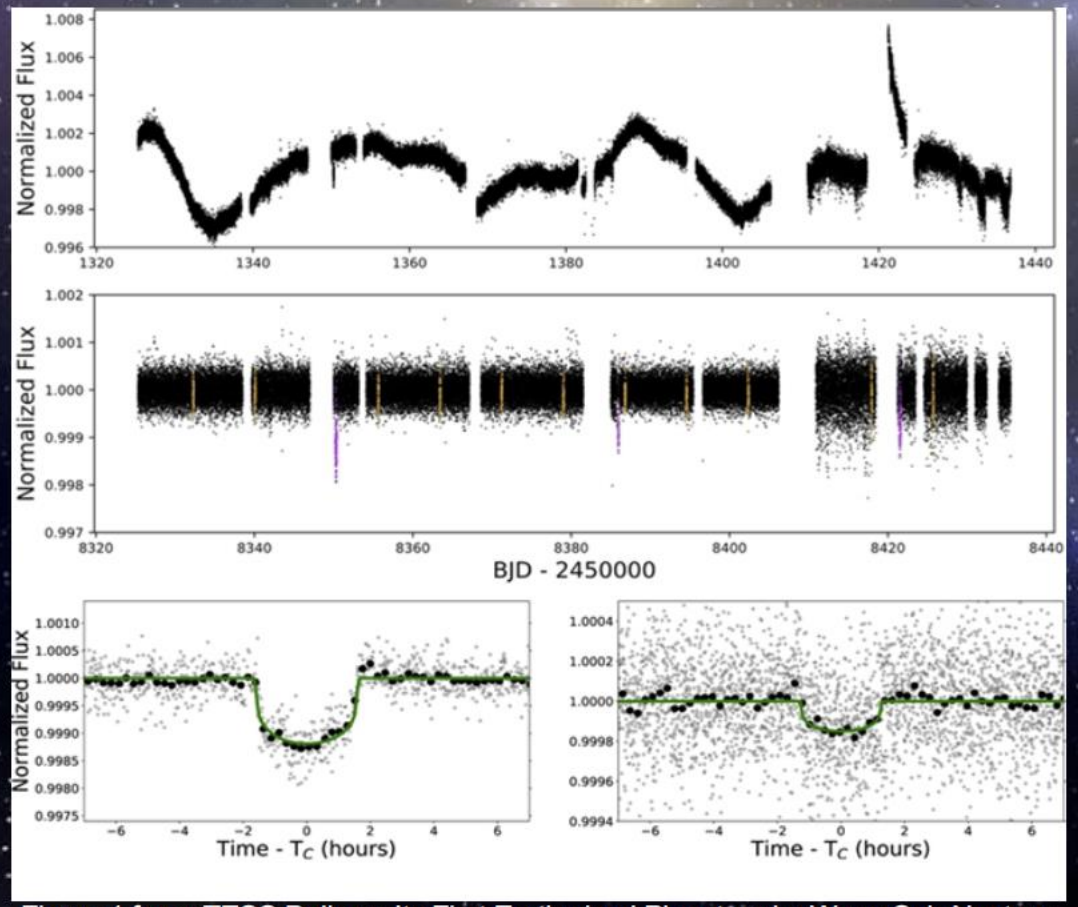


Figure 1 from TESS Delivers Its First Earth-sized Planet and a Warm Sub-Neptune
Diana Dragomir et al. 2019 ApJL 875 L7 doi:10.3847/2041-8213/ab12ed

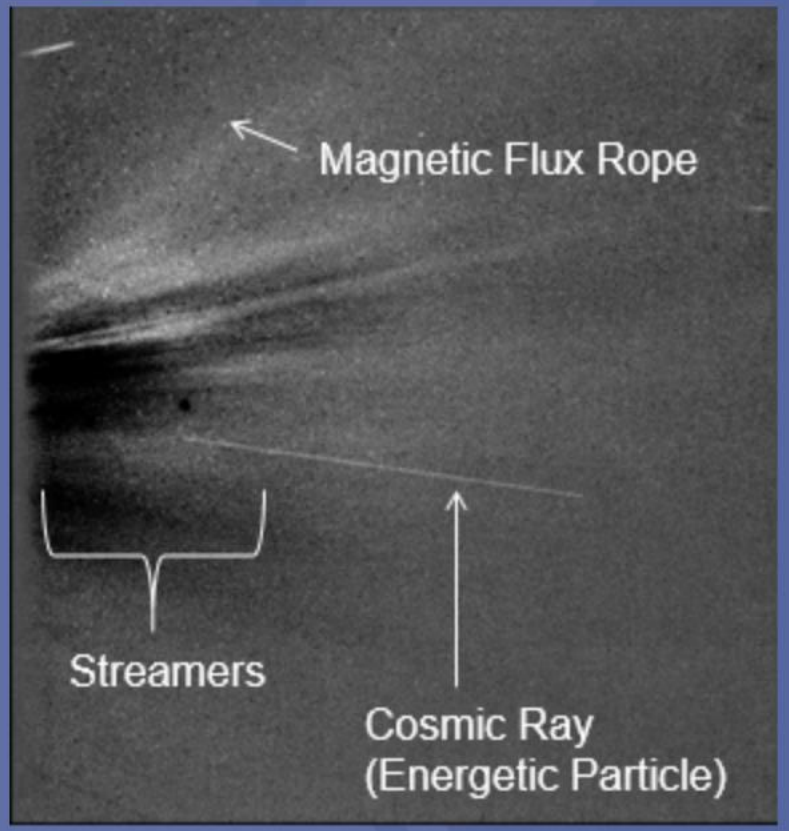
HD 21749c
R = 0.89 RE
P = 7.8 days

HD 21749
K star
V = 8.1
D = 16 pc

Parker Solar Probe

A Mission to Touch the Sun

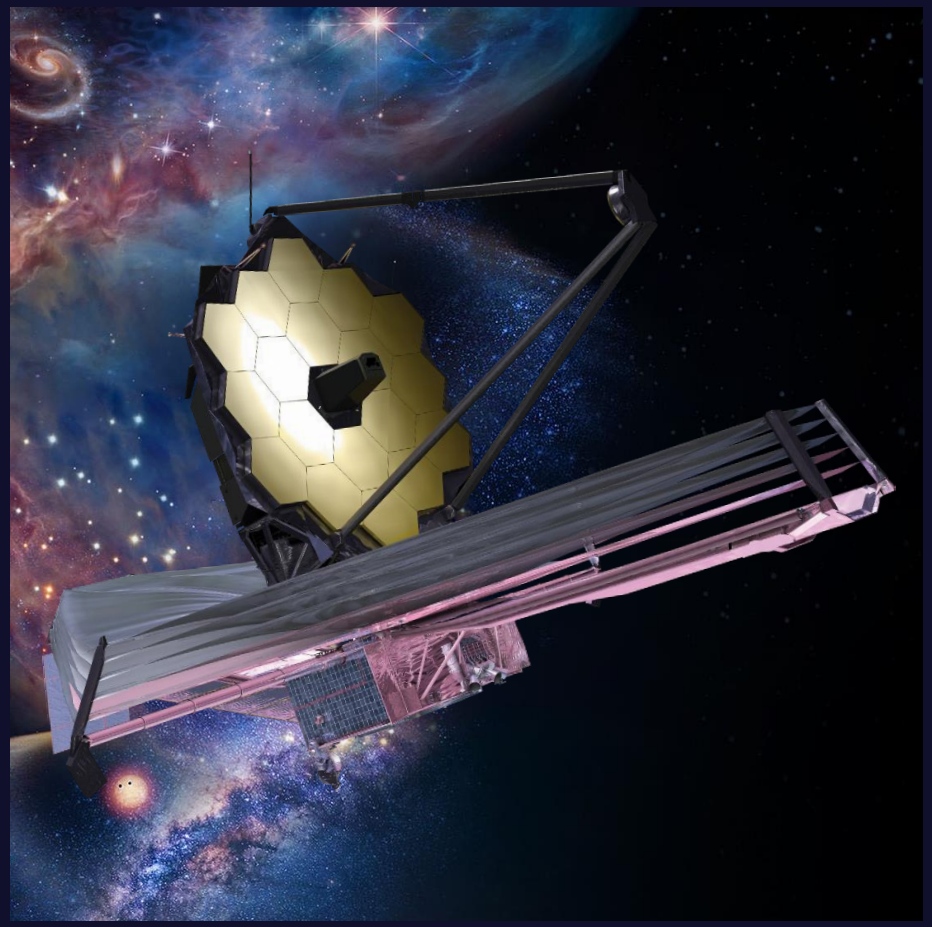
SCIENCE HIGHLIGHT



Nov. 6, 2018, 18:16 UT – Data from WISPR instrument on Parker Solar Probe during first perihelion

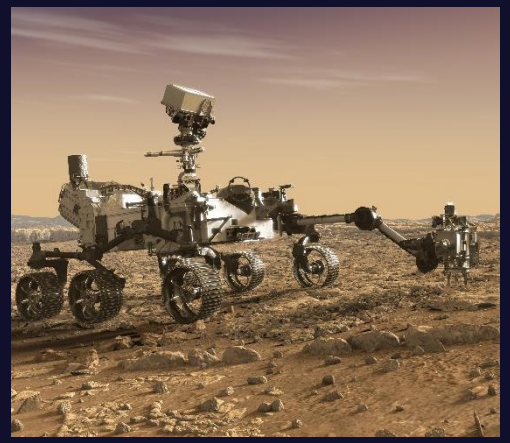
Outline

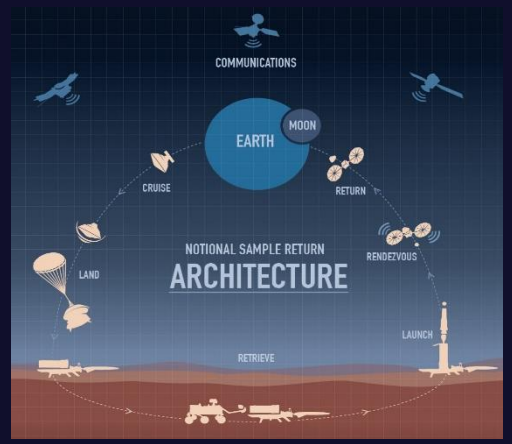
- Science Highlights
- **Programmatic Status**
- Recommendation/Findings

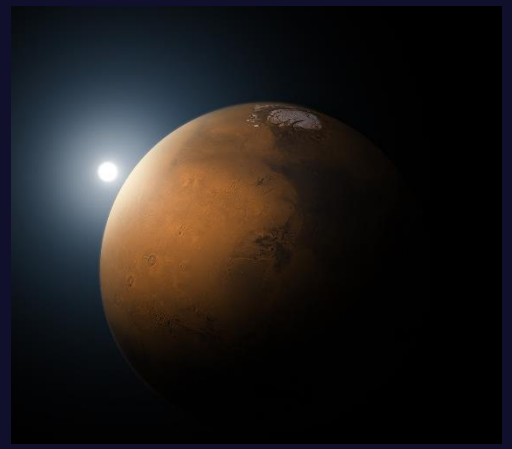


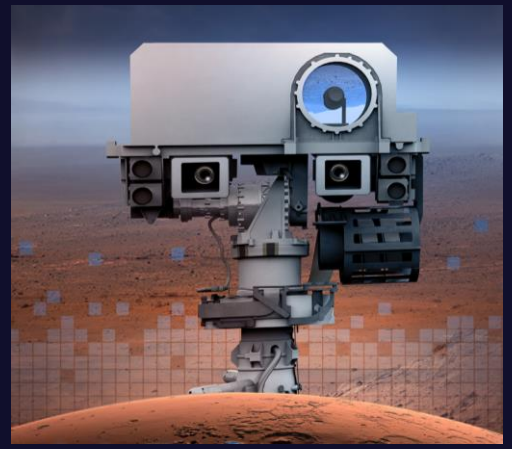
Webb Update

- Astrophysics portfolio fully funds Webb for launch in March 2021
- Key Progress/Milestones
  - Spacecraft element has completed thermal vacuum testing (Spring 2019)
  - Telescope element and spacecraft element integration planned for late Summer 2019
  - Current execution plan and schedule margin supports a March 2021 LRD
- Webb overrun covered using offsets from Astrophysics Probes









Mars 2020 on Track for 2020 Launch

- RIMFAX, MOXIE, MEDA delivered to assembly, test and launch operations (ATLO)
- SHERLOC concluded risk review
  - Flight unit to be delivered end of June
  - Flight laser power supply replaces engineering model by end of 2019
- All other systems and instruments to be delivered over next several months

FORWARD TO THE MOON:

NASA's Strategic Plan for Lunar Exploration

Lunar Science by 2024

Polar Landers and Rovers

- First direct measurement of polar volatiles, improving our understanding of their lateral and vertical distribution, as well as their physical state and chemical composition
- Information on the geology of the South-Pole Aitken basin, the largest impact in the solar system

Non-Polar Landers and Rovers

- Ability to explore scientifically valuable terrains not explored by Apollo.
  Examples include:
  - Land at a lunar swirl and make the first surface magnetic measurement
  - Visit young volcanic features such as Ina to understand volcanic evolution
- PI-led instruments - Discovery-class science such as geophysical network and visiting lunar volcanic region

Artemis 1 – Cube Satellite Program

- Over a dozen satellites will be launch as part of Artemis 1

Orbital Data

- Cubesats delivered by CLPS providers, or comm/relay spacecraft could acquire new scientifically valuable datasets
- Global mineral mapping (including resource identification), global elemental maps, improved volatile mapping

In-Situ Resource Initial Research

- What is the composition and ability to use lunar ice for sustainment and fuel

Lunar Science After 2024

Human and Robotic Missions Provide Unique Science Opportunities

On Gateway

- Deep space testing of Mars-forward systems
- Hosts groundbreaking science for space weather forecasting, full-disc Earth observation, astrophysics, heliophysics, and lunar and planetary science

Surface Exploration

- Understanding of how to use in-situ resources for fuel and life
- Sampling of material, and geophysical measurements will provide new insight into the Moon's geologic evolution
- Collection, and return to Earth, of carefully selected samples of rock types will revolutionize our understanding of the origin and evolution of the Moon
- Samples from different geologic areas will provide important information about the inner solar system
- In-situ study of lunar impact craters will help us understand the physics of impact cratering, the most prevalent geologic process in the solar system
- Humans have the ability to set up complex surface instrumentation; these instruments will cover astrophysics, heliophysics and Earth observation

Surface Telerobotics to Provide Constant Science

- Sending rovers into areas that are too difficult for the crew to explore; rovers can be teleoperated from Earth to maximize the scientific return

Lunar Discovery and Exploration Program (LDEP)

LDEP is a key component of the National Exploration Campaign, including

- Commercial Lunar Payload Services (CLPS)
- Instrument Development
  - To fly on CLPS landers
  - Development and Advancement of Lunar Instrumentation (DALI)
- Lunar Reconnaissance Orbiter (LRO) Mission Operations
- Lunar SmallSats through Small Innovative Missions for Planetary Exploration (SIMPLEX)
- Future mobility and orbital capabilities
- Communications/data relay assets

Science Strategy of the Moon

Science Goals

- Science goals are driven by community-produced documents, including
  - National Academies of Sciences 2013 Decadal Survey: Vision and Voyages for Planetary Sciences in the Decade 2013-2022, the National Research Council 2007 Report: The Scientific Context for the Exploration of the Moon, the LEAG Advancing Science of the Moon report and the NASA Strategic Knowledge Gaps
    1. Explore the history of the Solar System using the Moon
    2. Explore processes that shape planetary bodies
    3. Use the Moon as a platform for novel and unique measurements
    4. Study of lunar volatiles and explore the utility of lunar resources for exploration and beyond

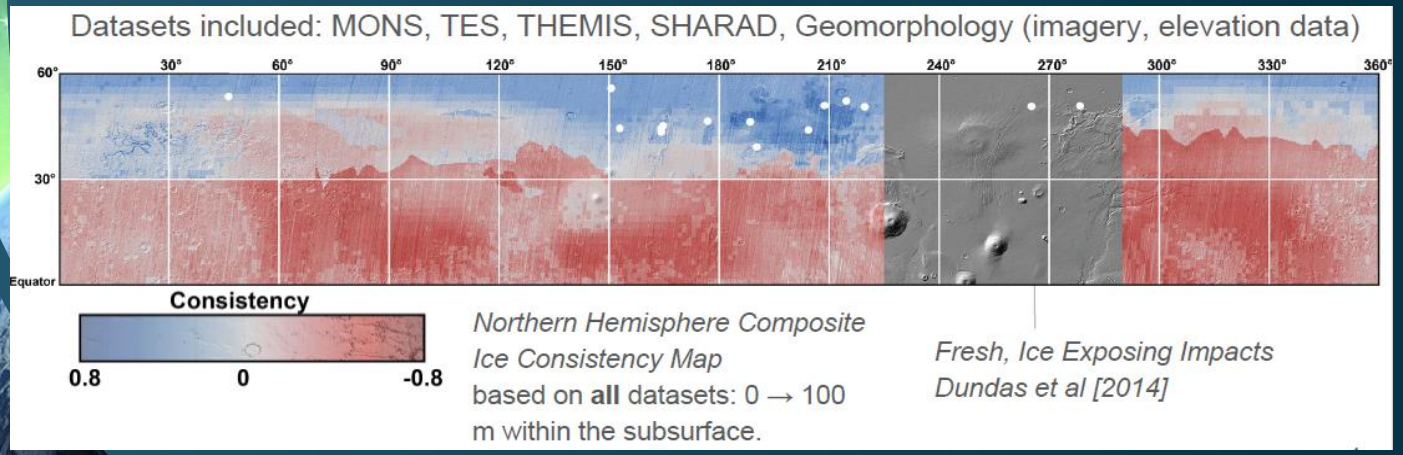
Priorities & Principles

- Achieve Decadal survey objectives for multiple disciplines
- Perform research to NASA SMD standards (competitive selections, open data policy)
- Enable human exploration, which in turn enables more science

Preparing for Human Exploration of Mars

Current Initiatives in the Mars Exploration Program

- Mars Exploration Program Goal 4:
  Prepare for Human Exploration of Mars
  - Building on decades of robotic exploration to understand fundamental elements and priorities for future human Mars exploration
- Mars Human Landing Site Study (HLS^2)
  - Identified 47 candidate landing sites
  - Helped develop key questions and generated forward work to narrow options for human landing site selection



Consistency map of subsurface ice detections across the northern hemisphere

- Water Mapping Efforts
  - Global next generation maps of both subsurface ice and hydrated minerals
  - Enabling identification of targets for a potential "special regions drill" and to support the next HLS^2 workshop
- Mars Sample Return (MSR)
  - Major decadal science priority
  - In addition, MSR is probably needed to better understand mechanical properties of the regolith/dust, to inform the design of human surface systems (e.g., suits, rovers, habitats, etc.), and potential health hazards for astronauts

NASA SCIENCE PLAN 2019 - 2024

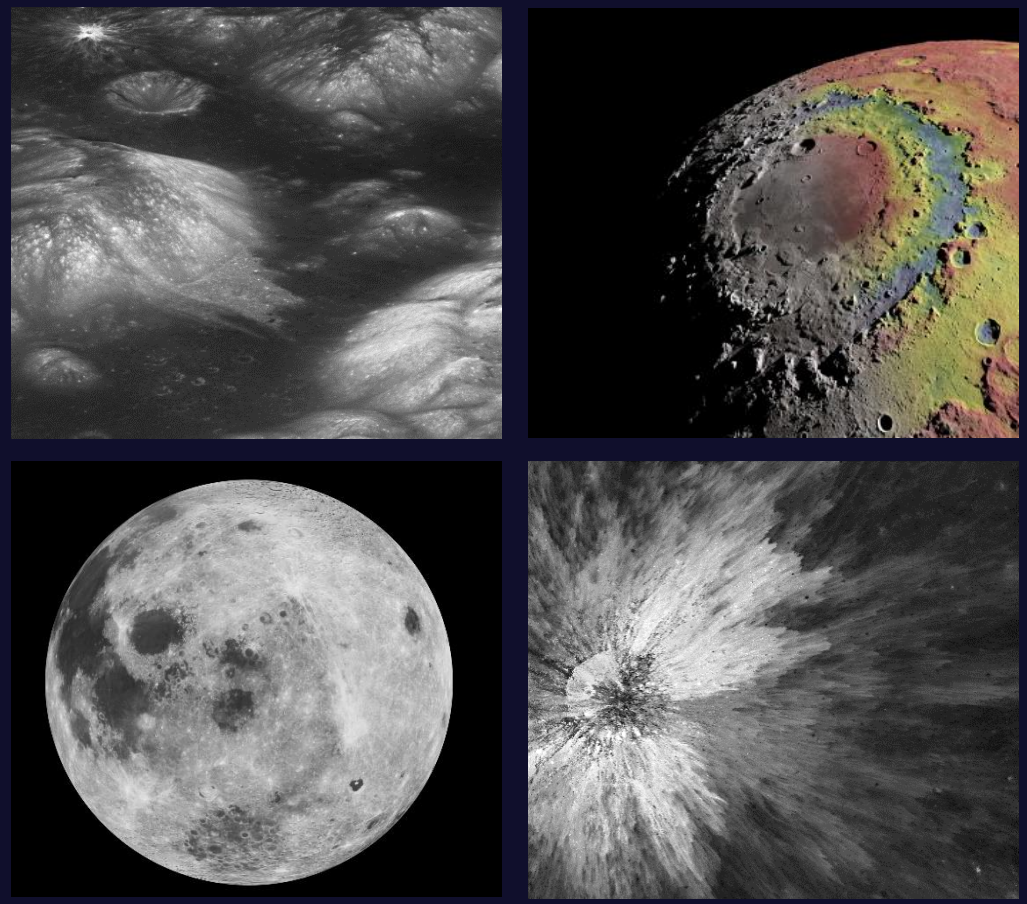
A Vision for Scientific Excellence

- Lay out ambitious program over next five years to build on current activities and drive change in high-priority areas
- Demonstrate commitment to excellence across SMD portfolio through leadership and strategic engagement with partners
- Continually assess progress for transparency and accountability

New Planetary Protection Review Board

Following NASEM and NASA Advisory Council (NAC) advice and recommendations, established independent Planetary Protection Review Board

- Assesses current planetary protection guidelines in the context of the current space exploration landscape, and formulates recommendations
- Reviews and recommends updates to biological contamination guidelines developed by Committee on Space Research (COSPAR)
- Provides direction to inform future planetary mission activities and possible future Mars sample return mission



Proposed Science of the Moon Subcommittee

- Announced by Administrator Bridenstine at the Summer NAC meeting (August 29, 2018)
- Subcommittee of NAC Science Committee (SC); Chair will be a SC member
- Will support advisory needs of NASA SMD for exploring science opportunities from, near, and of the Moon; will support other NASA directorates as needed
- Will consist of 10-20 lunar science experts drawn from industry, academia, independent researchers and government
- Extensive and diverse pool of member candidates currently in review

Diverse Teams / Safe Environments
Follow-On Report from SC Subgroup

Recommendation based on review and reports on best practices from:

Dr. Michael Liemohn, Subgroup Leader	AGU Diversity and Inclusion Strategic Plan & AGU Ethics and Equity Center
Dr. Marshall Shepherd	American Meteorological Society & University of Georgia
Dr. Kathryn Flanagan	Recruitment and hiring at Space Telescope Science Institute/AURA & peer-review panels at STScI

Outline

- Science Highlights
- Programmatic Status
- **Recommendation/Findings**
  - **1 Recommendation**
  - **12 Findings**
    - **4 on Draft Science Strategy of the Moon**
    - **7 on Draft NASA Science Plan**
    - **1 on STDTs**

SC Recommendation: Multi-Tiered Strategy to Facilitate Diverse Teams and Safe Environments
(for transmission to SMD AA)

Recommendation:

- **The Science Committee (SC) recommends that SMD develop a multi-tiered strategy to facilitate diverse teams and safe environments.**
- **To achieve these goals, the SC recommends the following actions:**
  - **We strongly encourage the development of a 5-year strategic plan for diversity, equity, and inclusion (DEI), as a first step in the process.**
  - **We strongly endorse the continuation of the "PI 101" and "PI Incubator" programs recently developed by NASA SMD.**
  - **NASA SMD should continue its DEI-enlightened proposal review processes, including diverse review panels, providing DEI training at the beginning of every proposal review, the clear explanation of evaluation criteria, and the enforcement of these policies and criteria throughout the panels.**
  - **NASA SMD Announcements of Opportunity should include a required element of how the proposed activities and proposal team aligns with NASA's DEI goals.**

SC Recommendation: Diverse Teams and Safe Environments (cont.)

Major Reasons for the Recommendation

Efforts are needed to improve diversity of the NASA-SMD workforce and grant/contract awardee cohort, as well as inclusivity and equity (to make all feel welcome and to address systemic disparities).

These are needed to patch the "leaky" pipeline affecting recruitment and retention, ensure a culture that values inclusion/equity, and assure that the next generation of STEM professionals inspired by NASA is truly reflective of the entire Nation.

In addition, it is important for potential principal investigators (PIs) to be trained and be ready to serve in such roles. NASA is already making strides in this direction with the "PI 101" and "PI Incubator" programs.

Consequences of No Action on the Recommendation

Diverse teams working in equitable and inclusive environments have been shown to produce more creative solutions. Inaction would leave the NASA workforce and grant/contract awardee cohort dominated by a single demographic not reflective of the nation's demographics.

SC Finding: Why Return to the Moon (DRAFT Science Strategy of the Moon)

(for transmission to SMD AA)

The SC finds that the draft Strategy's introduction lacks a well-articulated narrative regarding the opportunity presented by returning to the Moon at this time, which could invite the perception that it is simply an "its about time" endeavor. A narrative, perhaps around the scientific and technological advancements that have occurred over these past 50 years, could highlight NASA's progress and articulate why now is a rich environment in which to return to the Moon to further our exploration capabilities and scientific understanding.

SC Finding: Science Goals (DRAFT Science Strategy of the Moon)

(for transmission to SMD AA)

Three of the four Science Goals in the draft Strategy are derived from multiple community-based documents and are well-articulated and well-justified. However, one of the goals (Science Goal #3; particularly subgoals 3A and 3C) is based primarily on outcomes from a single workshop (Deep Space Gateway Concept Science Workshop, held on February 27-March 1, 2018). The science areas in this goal were not as well-justified or as clearly stated as for the other goals. For instance, it was not clear what was meant by "identical sensors", and what the level of "high temporal frequency" would be. It was also not clear what was "novel and unique" about the science in the areas of heliophysics, astrophysics, and Earth science enabled by going to the Moon.

SC Finding: Partial Gravity
(DRAFT Science Strategy of the Moon)
(for transmission to SMD AA)

In the NASA Science Role section of the draft Strategy, there is no mention of the fact that lunar exploration will also provide the first opportunity for scientific study of the effect of partial gravity on human health and performance.

Such research is expected to fall under the purview of NASA's Human Exploration and Operations Mission Directorate (at Johnson Space Center's Human Health and Performance Directorate) and is not referenced in this document. Mention of this research in this document would be informative to readers of this important NASA scientific activity.

SC Finding: Priorities and Principles (DRAFT Science Strategy of the Moon)

(for transmission to SMD AA)

In the Priorities and Principles section of the draft Strategy, the third bullet is redundant with the second bullet.

Also, for the fourth bullet, it is unclear what is meant by "providing situational awareness." If referring to space weather, this could be clarified.

Priorities and Principles (DRAFT)

- Achieve the decadal survey objectives across the disciplines that can be addressed at the Moon or near the Moon
- Perform all research to the standards of NASA Science, including competitive selections, open data policies, etc.
- Enable competitive research through Mission of Opportunities or otherwise on or around the Moon
- Actively enable human exploration through providing situational awareness

SC Finding: Introduction and Future State (DRAFT NASA Science Plan)

(for transmission to SMD AA)

SMD is in an exciting era when there is transformational potential for a science strategy that enables excellence and innovation. We see inspirational language that speaks to this in each of the Focus Areas, and in the "2024 Future State" summary of the Science Update presentation, but find the introduction section to be merely descriptive by comparison. An introduction and conclusion that capture the visionary and ambitious plan for the future would provide much needed context for the document.

It may also be useful to identify the SMD divisions in the introduction below the description of the key science themes.

SC Finding: Rename "Protect and Improve" Theme (DRAFT NASA Science Plan)

(for transmission to SMD AA)

One of the three themes, "Protect and Improve Life on Earth" (highlighted in the Introduction and the SMD Mission Statement) does not inspire the same level of wonder and excitement as the other two themes; as written, it implies an applied science focus rather than the discovery science implied by the other two themes. This theme could be re-worded along the lines of the following:

- **"Unlocking the mysteries of our planet"**
- **"Advancing the frontiers for humanity"**

The first of these options conveys the excitement for exploring the many unknowns of our interconnected planet (Earth system). The second of these options conveys the message that NASA SMD pushes the forefront of knowledge for applications that benefit life and society.

SC Finding: Interconnectivity and Partnerships (DRAFT NASA Science Plan)

(for transmission to SMD AA)

While there is discussion of collaboration with HEOMD and STMD specifically in the context of the exploration initiative (in Strategy 1.2), the document does not sufficiently or broadly highlight the areas and mechanisms for interconnectivity and partnerships between SMD and the other mission directorates.

SC Finding: Foster Innovation (DRAFT NASA Science Plan)

(for transmission to SMD AA)

The SC finds the use of the word "create" in Strategies 2.1 and 2.2 of the draft NASA Science Plan to neglect the work that is currently being done to seed a culture that embraces innovation and collaboration. Use of words such as "foster" or "grow" would communicate the need for progress, while acknowledging that work has already begun in these areas.

STRATEGY 2.1: Create a culture that encourages innovation and entrepreneurship across all elements of the NASA Science portfolio.
STRATEGY 2.2: Create a culture that encourages collaboration in pursuit of common goals.

SC Finding: Diversity, Equity and Inclusion (DRAFT NASA Science Plan)

(for transmission to SMD AA)

While referencing the importance of diversity (e.g., in the Teamwork section and in Strategy 4.1), it was noted that there is not adequate emphasis on equity and inclusion in the document. Diversity alone is not sufficient to ensure the best outcomes in driving excellence and innovation.

SC Finding: Human Health in Space (DRAFT NASA Science Plan)

(for transmission to SMD AA)

This draft NASA Science Plan document covers the activities of NASA's Science Mission Directorate. The Space Life and Physical Sciences Research and Applications (SLPSRA) Division, part of NASA's Human Exploration and Operations Mission Directorate, supports research on the effects of spaceflight on human health and performance and on biological and physical systems. These scientific activities are discussed in SLPSRA's strategic plan and could be referenced here to increase readers' awareness of the full scope of science at NASA.

SC Finding: Portfolio Summaries (DRAFT NASA Science Plan)

(for transmission to SMD AA)

The draft NASA Science Plan portfolio summaries for the programs within each division should include all programs listed for each division in SMD's Science Budget Request Summary table. In the planetary science portfolio summary, the Outer Planets and Ocean Worlds Program was omitted.

SC Finding: Science & Technology Definition Teams
(for transmission to SMD AA)

The SC is concerned about the switch to FACA authorization for Science and Technology Definition Teams (STDTs) for upcoming mission concept development. This means that STDTs cannot recommend any implementation strategies, but instead only make recommendations on the science investigations and measurement requirements necessary to address these objectives. This has several negative ramifications.

One impact is that this slows the process of NASA science mission development. SMD must now conduct an implementation analysis after the STDT, rather than doing this as part of the STDT process.

Another impact is the potential for cost growth. The development of science objectives and measurement requirements independently from technical implementation concepts and associated cost analysis could lead to financially unfeasible missions. When these steps are integrated, cost targets can be included in the science objective formulation discussion.