National Aeronautics and
Space Administration

Science Committee Report

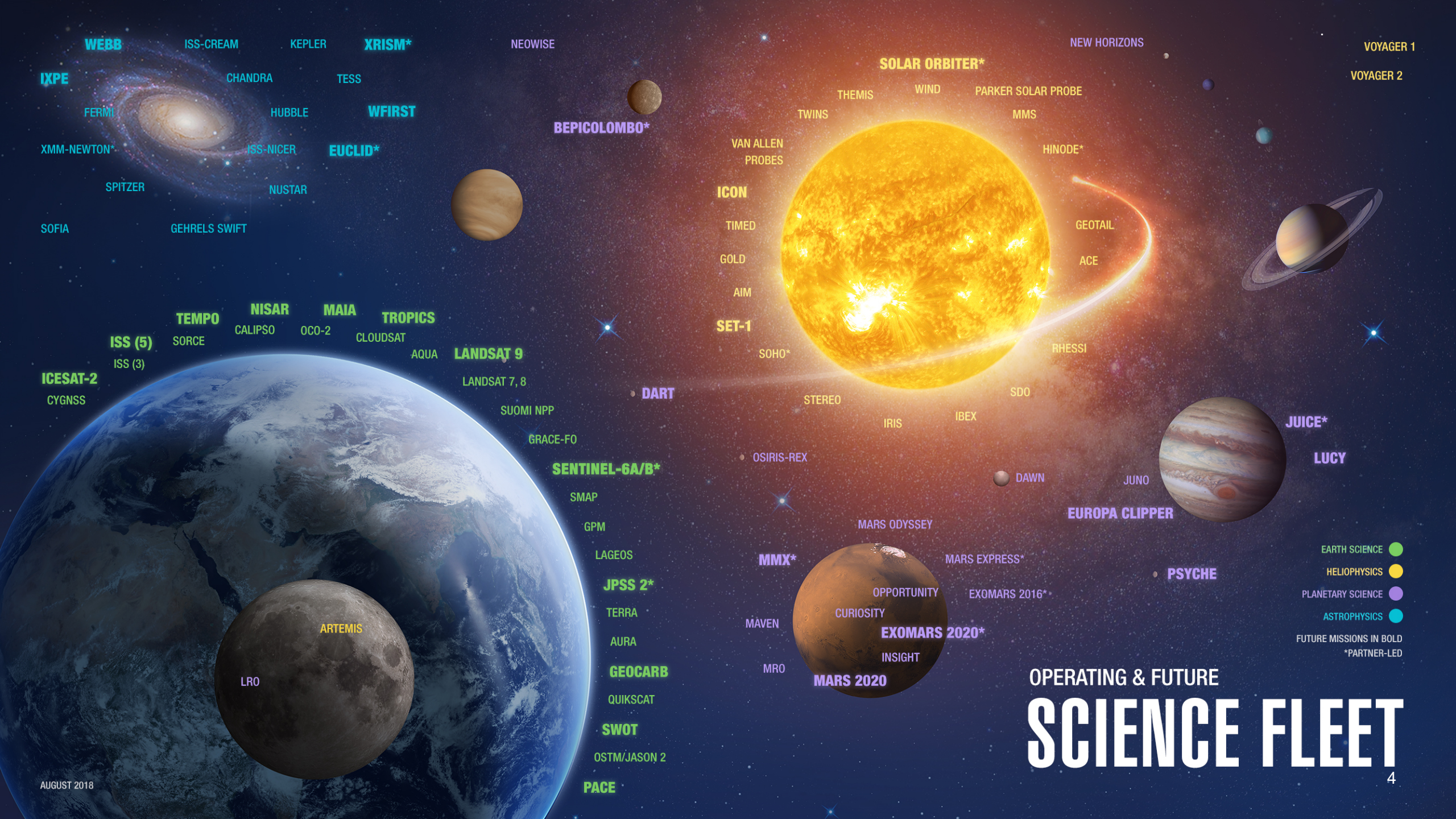
Dr. Meenakshi Wadhwa
Interim Chair, Science Committee

Science Committee Members

Dr. Meenakshi Wadhwa, Interim 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
Dr. Walter Secada, University of Miami
Mr. Marc Weiser, RPM Ventures

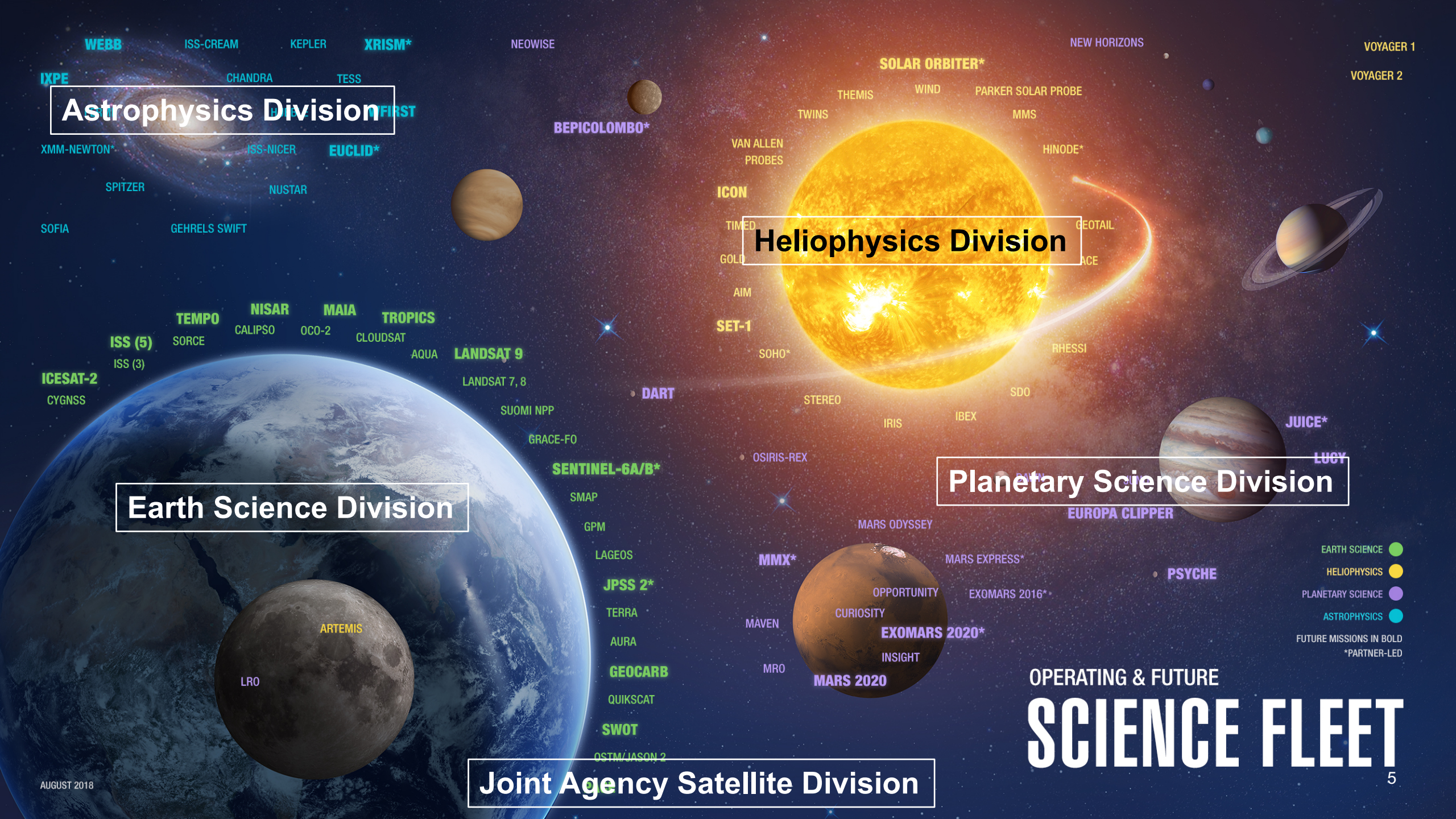
Outline

- **Science: Results and Opportunities**
- Programmatic Status
- Findings



OPERATING & FUTURE

SCIENCE FLEET


WEBB
ISS-CREAM
KEPLER
XRISM*
NEOWISE
IXPE
CHANDRA
TESS
Astrophysics Division
XMM-NEWTON*
ISS-NICER
EUCLID*
SPITZER
NUSTAR
SOFIA
GEHRELS SWIFT
BEPICOLOMBO*
NEW HORIZONS
VOYAGER 1
VOYAGER 2
SOLAR ORBITER*
THEMIS
WIND
PARKER SOLAR PROBE
TWINS
MMS
VAN ALLEN PROBES
HINODE*
ICON
TIMED
GEOTAIL
Heliophysics Division
GOLD
ACE
AIM
SET-1
SOHO*
RHESSI
TEMPO
NISAR
MAIA
TROPICS
CALIPSO
OCO-2
CLOUDSAT
ISS (5)
SORCE
AQUA
LANDSAT 9
ISS (3)
ICESAT-2
LANDSAT 7, 8
CYGNSS
DART
STEREO
SDO
SUOMI NPP
IRIS
IBEX
JUICE*
GRACE-FO
OSIRIS-REX
LUCY
SENTINEL-6A/B*
Planetary Science Division
SMAP
EUROPA CLIPPER
GPM
MARS ODYSSEY
LAGEOS
MMX*
MARS EXPRESS*
JPSS 2*
PSYCHE
TERRA
OPPORTUNITY
EXOMARS 2016*
CURIOSITY
AURA
MAVEN
EXOMARS 2020*
GEOCARB
INSIGHT
MRO
QUIKSCAT
MARS 2020
SWOT
OSTM/JASON 2
Earth Science Division
ARTEMIS
LRO
Joint Agency Satellite Division
EARTH SCIENCE
HELIOPHYSICS
PLANETARY SCIENCE
ASTROPHYSICS
FUTURE MISSIONS IN BOLD
*PARTNER-LED
OPERATING & FUTURE
SCIENCE FLEET
AUGUST 2018

Science by the NUMBERS

TECHNOLOGY INNOVATION

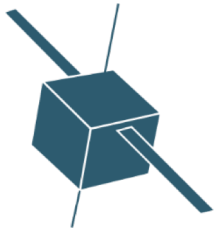
~$400M Invested Annually

RESEARCH

~10,000 U.S. Scientists Funded
~3,000 Competitively Selected Awards
~$600M Awarded Annually

SPACECRAFT

105 Missions
85 Spacecraft



SMALLSATS/CUBESATS

30 Science Missions
23 Technology Demos

SOUNDING ROCKETS

16 Science Missions
3 Tech/Student Missions

EARTH-BASED INVESTIGATIONS

25 Major Airborne Missions
8 Global Networks

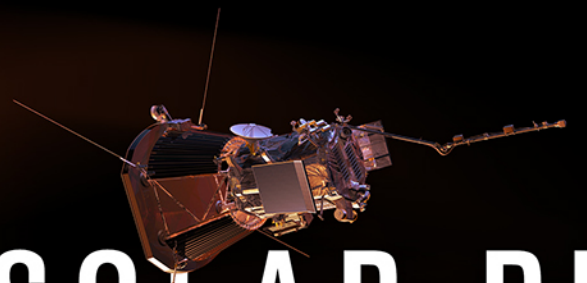
BALLOONS

13 Science Payloads
1 HASP with up to
12 student experiments

Current as of August 22, 2018

Discover the Secrets of the Universe

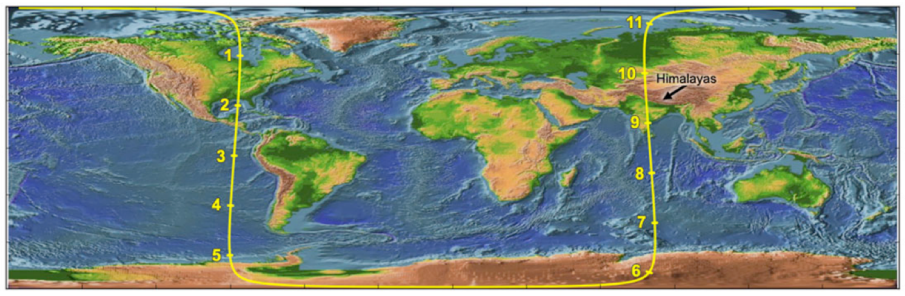
August 12, 2018 – Dr. Eugene Parker watches as his namesake launches from Cape Canaveral AFS, Florida

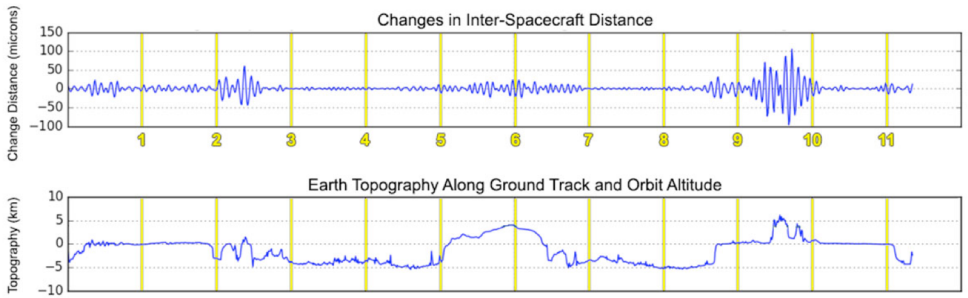


PARKER SOLAR PROBE

A Mission to Touch the Sun

GRACE Follow-On

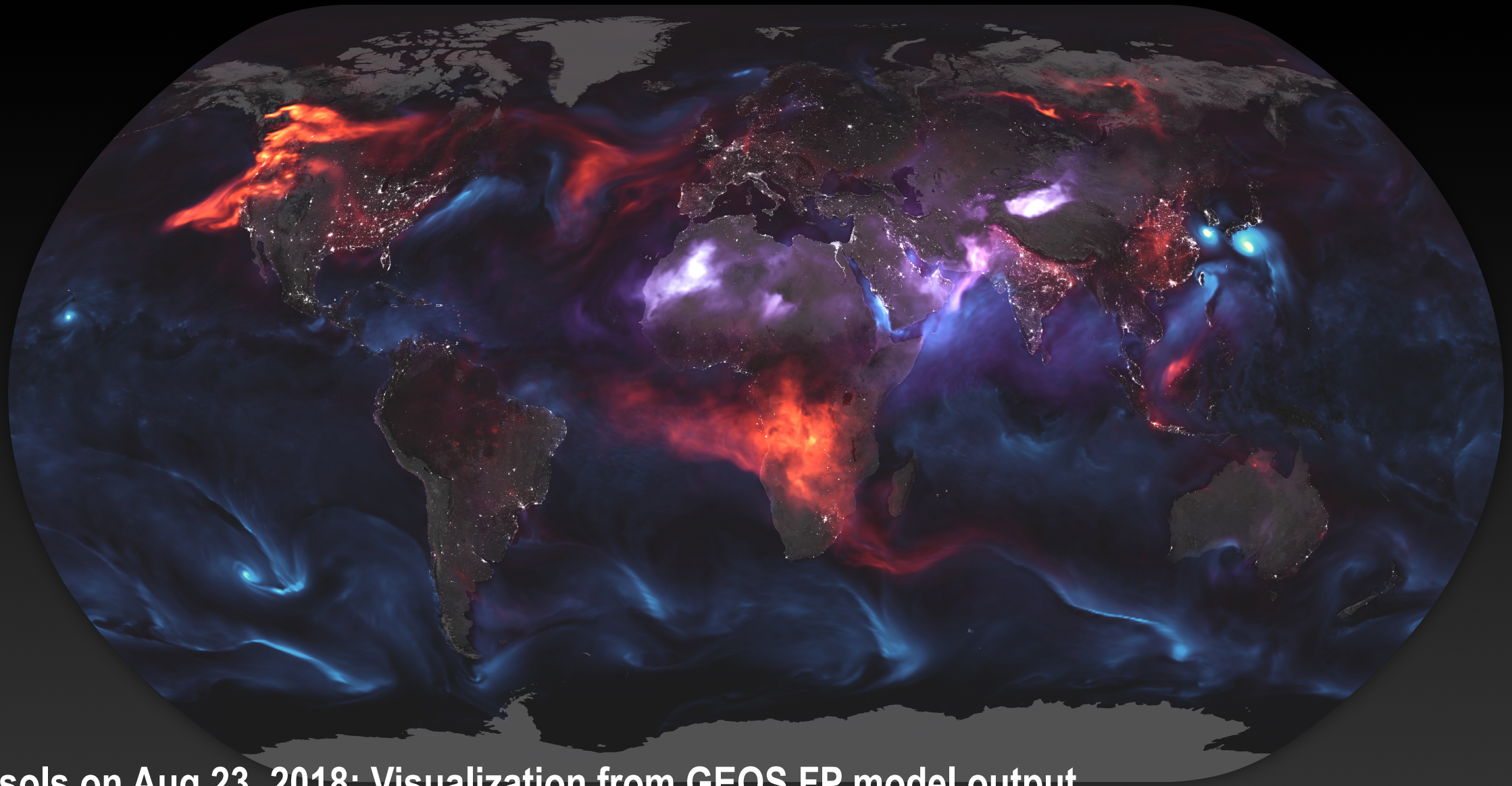




May 29, 2018 – GRACE Follow-On First Light: "Himalaya Plot"

Protect & Improve Life on Earth

Another Day on Aerosol Earth



Aerosols on Aug 23, 2018: Visualization from GEOS FP model output

OSIRIS-REx

August 17, 2018 - OSIRIS-REx spacecraft obtained the first images of its target asteroid Bennu from a distance of 1.4 million miles

Protect & Improve Life on Earth

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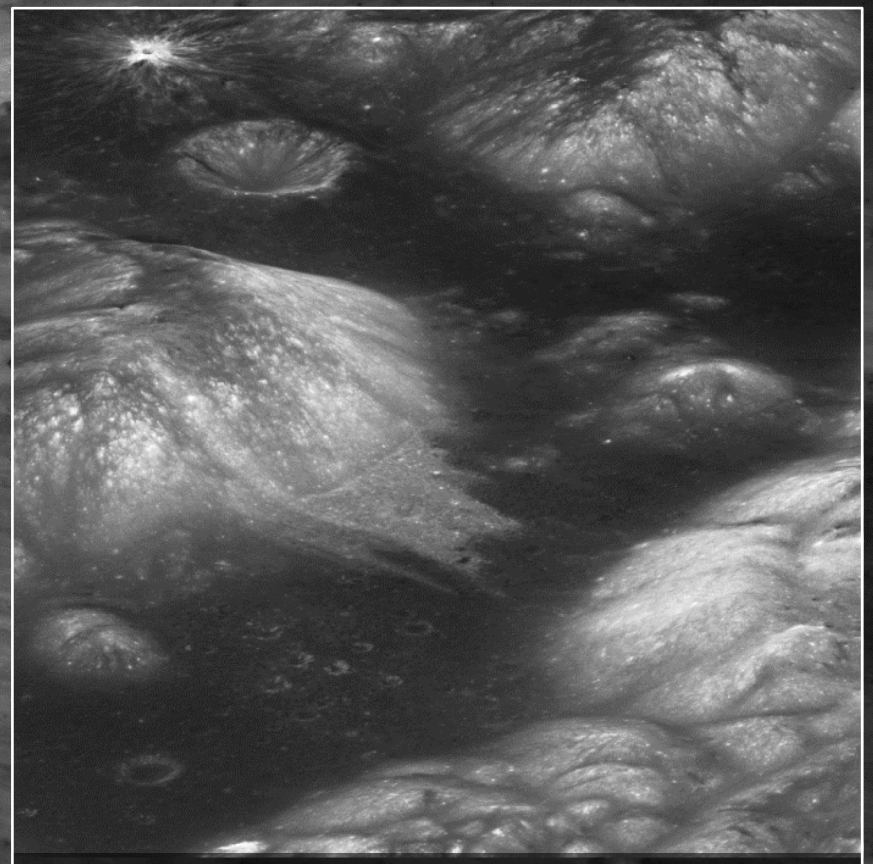
Discover the Secrets of the Universe



December 2017 - Reinvestigation of the Apollo 17 landing site in Taurus-Littrow Valley with LRO data and other remote observations led to new understanding of geological evolution

LRO

Lunar Reconnaissance Orbiter

Discovery of the First Interstellar Object

- 1I/2017 U1 (‘Oumuamua) – first object observed that originated outside our solar system
- Discovered on October, 19 2017 by the University of Hawaii-operated Pan-STARRS1 telescope during survey operations as part of the Near-Earth Object Observations Program in NASA’s Planetary Defense Coordination Office
- Confirmed by numerous follow-up observations and by the trajectory analysis performed by the Center for Near-Earth Object Studies at JPL

Artist concept credits: European Southern Observatory/ M. Kornmesser

- Object is asteroidal in nature (no coma observed)
- Object is highly elongated, with an axis ratio of ~10:1 (Meech *et al.* 2017, *Nature*)
- Observations suggest a surface reddened due to irradiation by cosmic rays over its history

TESS

Transiting Exoplanet Survey Satellite

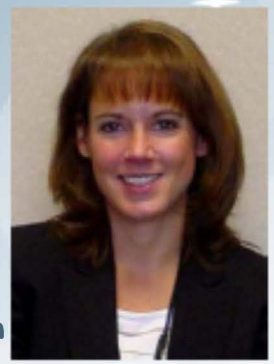
May 17, 2018 - Test image from one of the four cameras aboard TESS captures a swath of the southern sky along the plane of our galaxy after completing Lunar fly-by

Search for
Life Elsewhere

Outline

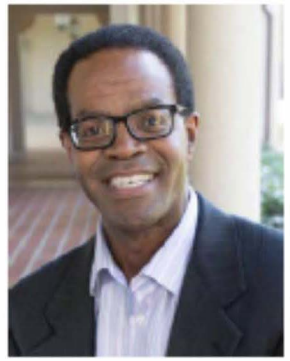
- Science: Results and Opportunities
- **Programmatic Status**
- Findings

Dr. Michael New
Deputy Associate Administrator for Research



Ms. Sandra Connelly
Deputy Associate Administrator for Programs

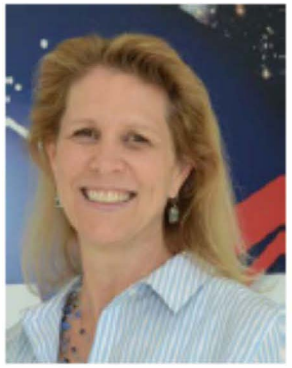
Mr. Steven Clarke
Deputy Associate Administrator for Exploration



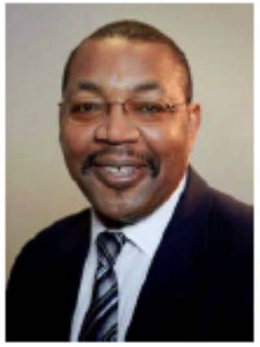
Dr. Charles Norton
Assistant Deputy AA for Programs, SmallSat Missions

Dr. Nicola Fox
Heliophysics Division Director
(starting Sept. 4, 2018)

Mr. John Lee
Joint Agency Satellite Division
Acting Division Director



Dr. Lori Glaze
Planetary Science
Acting Division Director



Mr. Gregory Robinson
Webb Program Director

Dr. Eric Smith
Webb Program Scientist and Astrophysics Senior Scientist

Dr. Jim Green
NASA Chief Scientist

Upcoming announcement on Planetary Division Director position

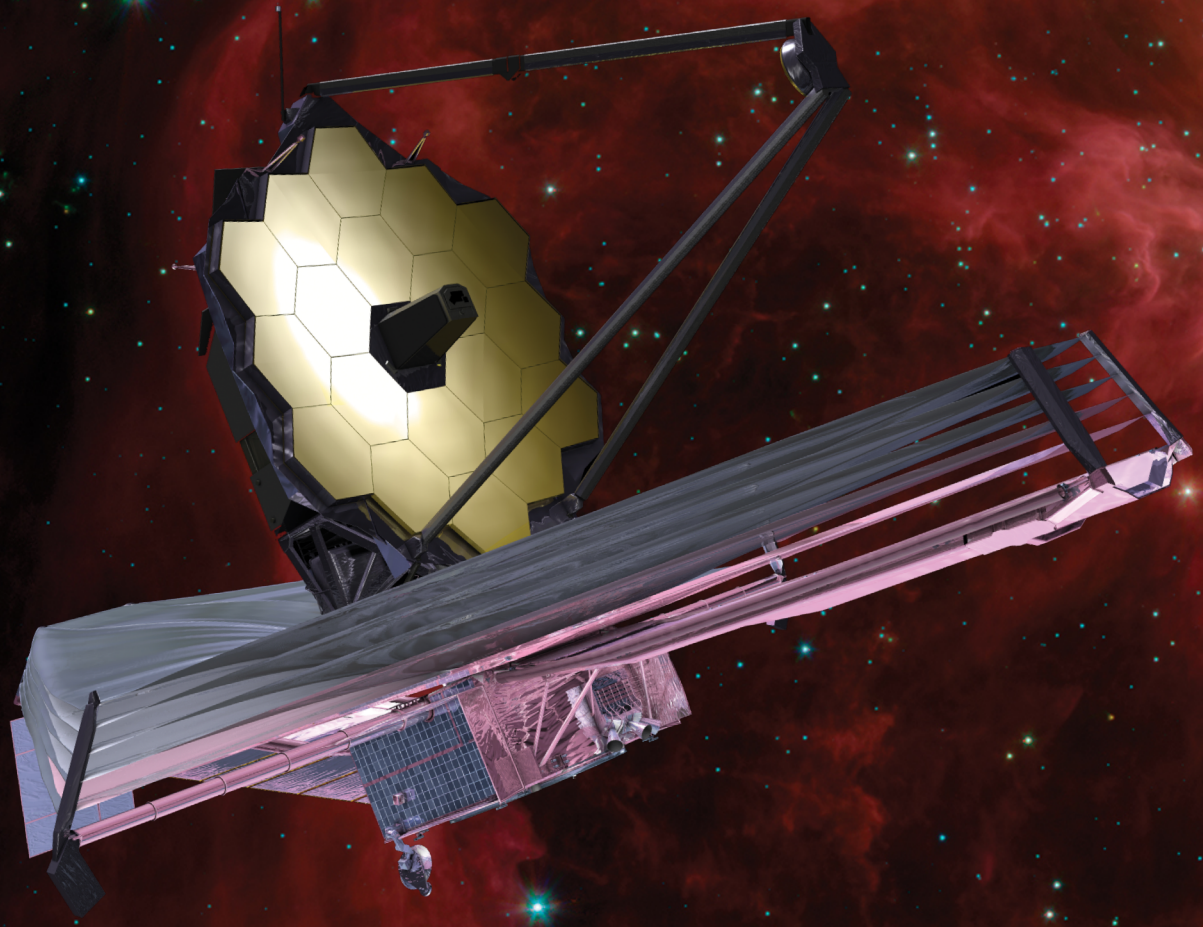
Mars 2020

Search for
Life Elsewhere

Mar 13, 2018 - A technician works on the descent stage for NASA's Mars 2020 mission inside JPL's Spacecraft Assembly Facility

Webb

The James Webb Space Telescope



Discover the Secrets of the Universe

July 25, 2018 - NASA Administrator Jim Bridenstine, left, testifies before the House Committee on Science, Space, and Technology

Key Priorities

Advance National Science and Exploration Goals

- Execute a new **Lunar Discovery and Exploration** program to leverage commercial partnerships and innovative approaches to achieve human and science exploration goals
- Build on extensive past **Lunar** exploration and science experience
- Plan a potential **Mars Sample Return** mission, a decadal survey priority, leveraging international and commercial partnerships

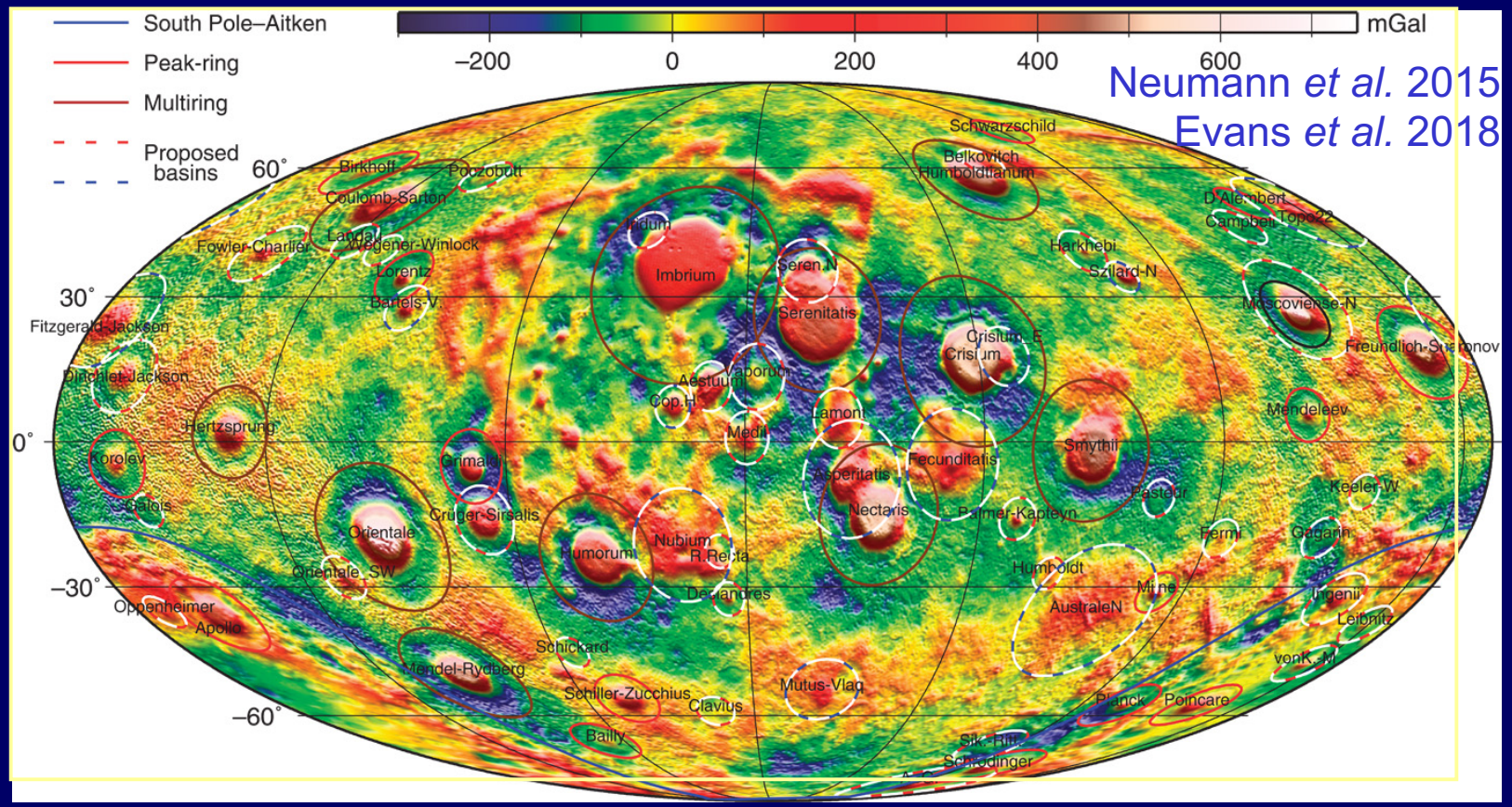
Apollo Next Generation Sample Analysis (ANGSA)

- Maximize science derived from samples returned by Apollo Program in preparation for future lunar missions
- ANGSA solicits research on specially curated materials from Apollo 15, 16, and 17 sample collections
- New research opportunities with current analysis tools
- Research awards in early 2019

Rethinking Solar System Bombardment: New Views on the Timing and Delivery of Lunar Impactors

Dr. Nicolle Zellner - Albion College (MI) Physics Department

What's New? GRAIL Data

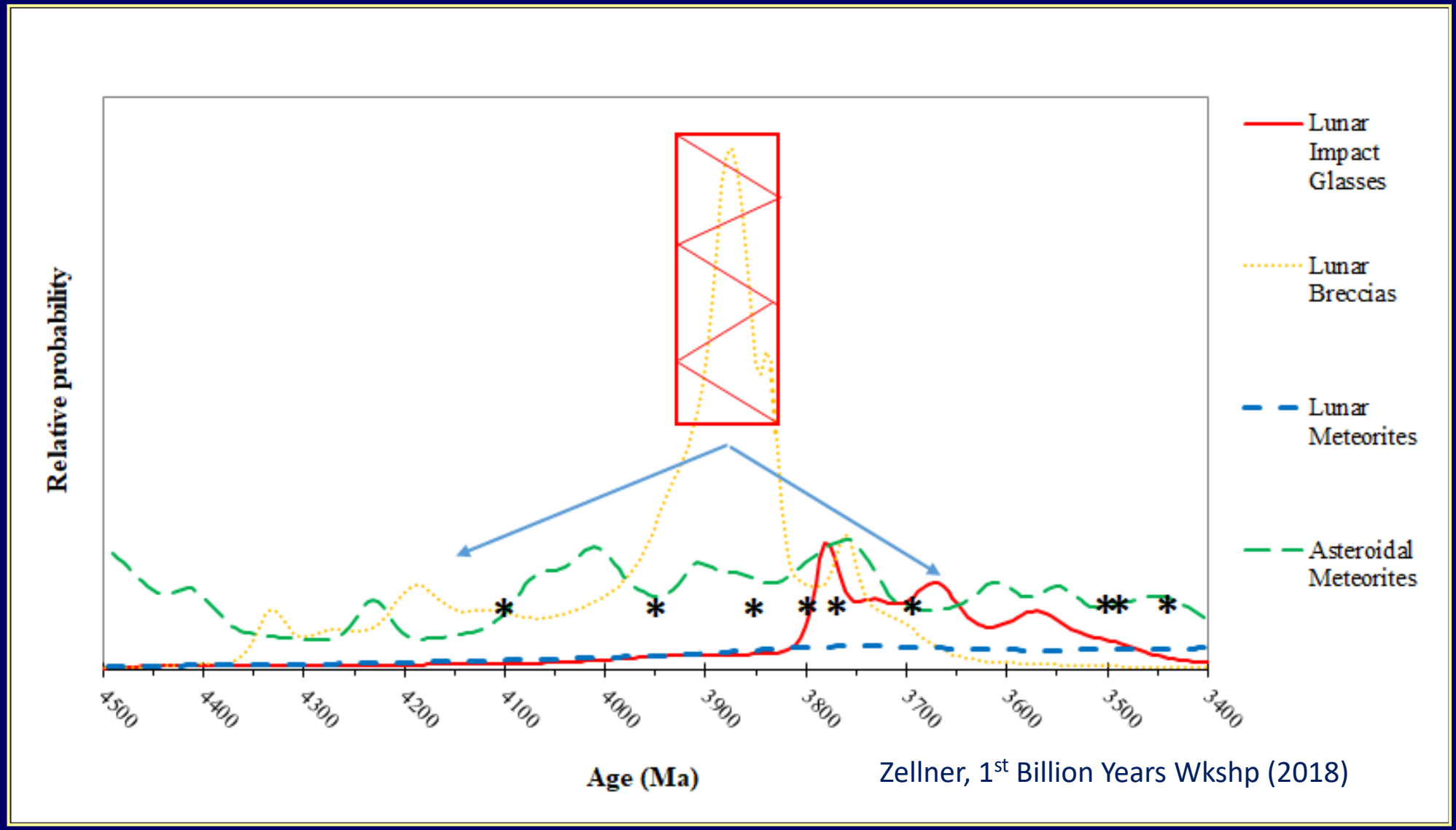


Multiple new basins w/ >300 km diameters

6 known basins with D >200 km larger than previously measured

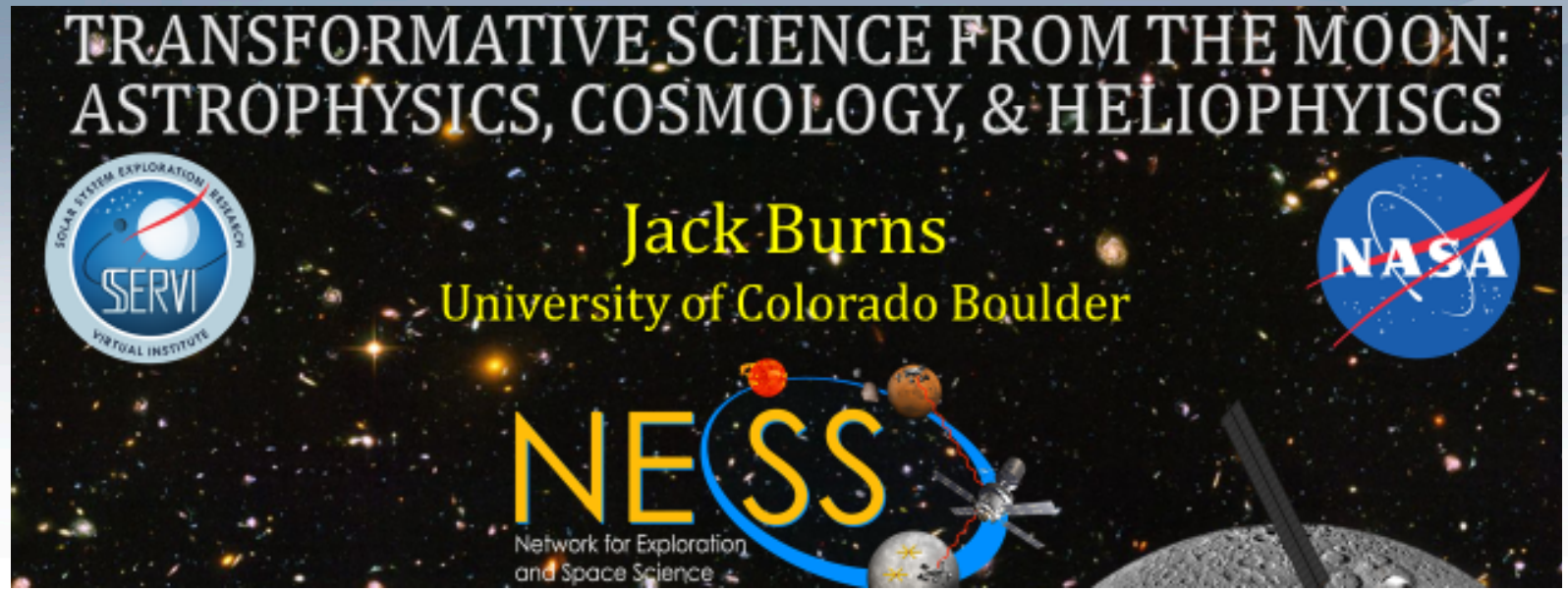
Impact flux needs to be recalibrated!

The 1st Billion Years



Zellner, 1st Billion Years Wkshp (2018)

* = biological events on Earth, in the context of impact flux



- There is much promising, transformative science from the Moon in astrophysics and heliophysics using the anticipated infrastructure from the Lunar Gateway and the lunar surface.
- Arrays of low frequency antennas at <10 MHz, initially on the lunar nearside, will provide the location and timing of radio bursts associated with CMEs, provide location of electron acceleration and magnetic field configurations, and serve as space weather alerts.
- Sensitive low frequency radio observations from the lunar farside can characterize space weather and magnetospheres in exoplanetary systems to probe habitability.
- The Gateway has promise to facilitate construction of large aperture UV/visible telescopes to characterize habitable planets.
- Hydrogen cosmology from the Moon has unique potential to characterize the first stars and galaxies, and to investigate dark matter in the Dark Ages.
- Teleoperation of rovers on the lunar farside by astronauts aboard the Gateway can be used to assemble low frequency radio telescopes even before astronauts reach the surface.

NAC SC Initial Discussion: Public/Private Partnerships

What kind of public/private interactions should NASA SMD be doing that could lead to breakthroughs in new ways to do science? Are there certain SMD activities that lend themselves to fruitful commercial partnerships (e.g. business cases, pathways)? What are the priorities you see?

Priorities/opportunities:

- Small satellite constellations for multi-point observations
- Autonomous systems
- Machine learning
- Artificial intelligence
- Environmental sensing (e.g. urban heat islands) with DOE and the private sector
- Citizen science apps

Important to identify how;

- specific project partnerships can scale up for greater solutions
- NASA can enable new science to result from the partnerships, not just a re-allocation of science efforts and resources

Completion of NAC SC Products

Division Advisory Committees
Research and Analysis (R&A) Charge Response

Charge to the SMD Advisory Committees:
Review NASA SMD R&A Methods to Foster High-Impact and Interdisciplinary Research
July 2017

Purpose: Determine how SMD's Research and Analysis (R&A) program can foster and enable, in the best way, potentially high-impact and highly innovative endeavors, while preserving important foundational and/or more gradual research activities, and interdisciplinary research, balancing this with discipline-focused research, to the benefit of the nation and scientific community. Both content and process aspects (which are connected) will be involved.

Division Advisory Committees
Research and Analysis (R&A) Charge Response

Commonalities

-No strong satisfaction/dissatisfaction with existing processes
-Need for clear guidance to proposers and reviewers on high-impact or high-risk proposals
-Need for better tracking and evaluation by SMD
-Diverse review panels needed in order to encourage interdisciplinary research

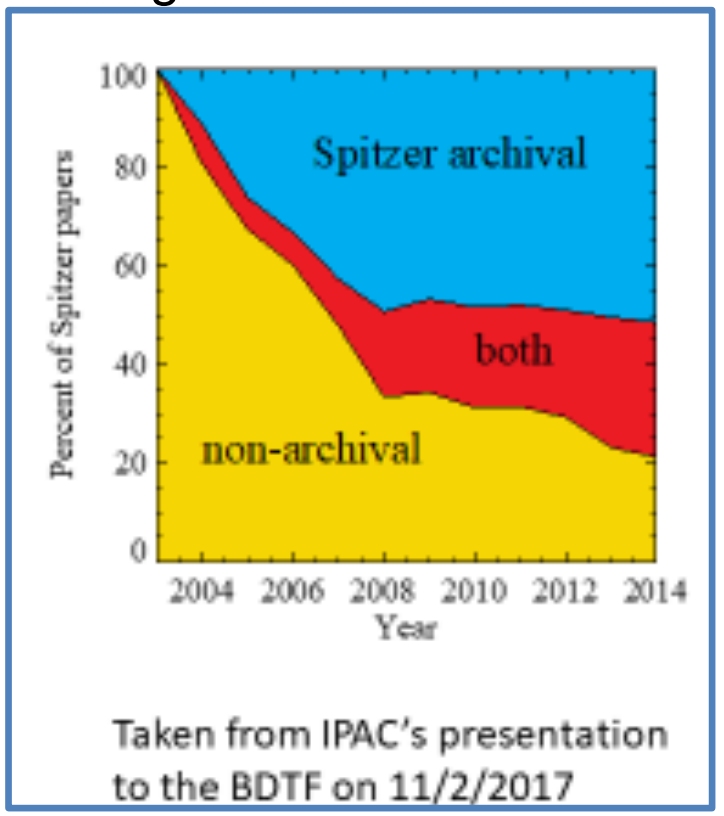
Divergences

-Whether or not to have a separate AO for high-impact/high-risk proposals
-Whether or not to have a separate funding pool for high-impact/high-risk proposals within same AO

Big Data

NAC SC Ad Hoc Task Force on Big Data, Terms of Reference *(excerpt)*: The scope of the Task Force includes all NASA Big Data programs, projects, missions, and activities. The Task Force will focus on such topics as exploring the existing and planned evolution of NASA's science data cyber-infrastructure that supports broad access to data repositories for NASA Science Mission Directorate missions; best practices within NASA, other Federal agencies, private industry and research institutions; and Federal initiatives related to big data and data access.

BDTF at JPL, Nov 3, 2017



The use of data in NASA archives has significantly increased the science resulting from the original mission. This is the trend in all of SMD's science data archives.

Outline

- Science: Results and Opportunities
- Programmatic Status
- **Findings**

Finding: NASA SMD Research and Analysis
(for transmission to SMD AA)

The NAC SC finds that SMD should "stay the course" with the overall Research and Analysis (R&A) strategic objectives, incorporating attention to high-impact/high-risk research, as history has shown that such investment can be game-changing. Just because incremental progress is being made, it does not mean that tremendous impact is not occurring. In general, key to the selection of high-impact/high-risk proposals is for SMD to

1) clearly train review panels regarding high-impact/high-risk research, and encourage proposers and review panels to address and evaluate mitigation of risk in high-impact/high-risk proposals,
2) have attendant expertise on the review panels,
3) closely coordinate with each program manager on this approach, and
4) have the high-impact/high-risk solicitation remain within each SMD discipline rather than in a separate proposal call that mixes disciplines, as it could not be reviewed effectively. In each solicitation, SMD could note that high-impact/high-risk proposals are welcome. This approach results in high-impact/high-risk research embedded in each review panel for their examination, which is beneficial.

Finally, the NAC SC finds that NASA SMD effectively responds to the scientific community when an interdisciplinary research need is identified, and sets up appropriate structures to promote such collaboration. Most interdisciplinary work is being done through collaborative research mechanisms (e.g. Nexus for Exoplanet System Science (NExSS), NASA Astrobiology Institute (NAI)), and may not exist outside of these. To increase emphasis, 1) SMD could encourage the scientific community to increase communication with the NAC SC in pinpointing interdisciplinary/interdivisional opportunities, and, 2) the next SMD ROSES call could welcome proposals wherein astrophysics data will be used by planetary science investigators, and conversely, planetary science data will be used by astrophysics investigators.

For more information, reference "NAC SC Response to SMD Research and Analysis Charge" that contains SC feedback on specific questions: https://science.nasa.gov/science-committee/meetings

Finding: NASA SMD Big Data
(for transmission to SMD AA)

The NAC SC finds the enthusiasm of the Ad Hoc Task Force on Big Data (BDTF) impressive. The BDTF completed a large amount of work and provided a very thorough report. Many of the BDTF's findings and recommendations reflected the thinking of the NAC SC, with divergences often having to do with *how* ideas are implemented by SMD.

Overall, NAC SC agrees with the BDTF that SMD data archive programs and projects are performing well and are properly taking steps to modernize. However, the volume, variety and velocity of NASA science data is taxing established methods and technologies. The SC finds that SMD should

1) make investments in hardware, software, training and education to accelerate modeling workflows,
2) participate in the Department of Energy's (DOE) exascale computing program,
3) implement server-side analytics (SSA) capabilities (with caution),
4) forge a joint program with the National Science Foundation's (NSF) Big Data Innovation Regional Hubs and Spokes program, and,
5) incorporate data science and computing advisory positions in the SMD advisory committees.

In all efforts, the SC underscores that it is important that data science and computing experts work closely and collegially with domain scientists to implement effective solutions that are based on an understanding of the domain.

As to the future, the SC commends that an SMD Strategic Data Working Group has been set up that will bring forward these ideas, without interfering with how each division manages data.

For more info, reference "NAC SC Big Data Product" that contains SC feedback on each of the SC's Ad Hoc Task Force on Big Data findings/recommendations: https://science.nasa.gov/science-committee/meetings

Proposed NAC Finding

- The NAC's HEO and Science Committees met jointly on August 28th to review plans for the development of the cislunar Gateway, some results from previous lunar science missions, and potential future exploration and science operations in cislunar space and on the lunar surface.
- The committees were impressed with the level of collaboration evident between SMD and HEOMD as well as the potential for future joint efforts.
- It was clear from the presentations at the joint session that there are many opportunities for valuable exploration and science activity in cislunar space aboard the Gateway.
- It was also evident that there is great synergy between investigations that can be performed from lunar orbit and science activity on the lunar surface.
- The committees look forward to a future joint session as plans mature for science and exploration activity in lunar orbit and on the surface.

Proposed NAC Finding

The HEO and Science Committees jointly acknowledge and applaud the direction NASA has taken toward a complementary approach to exploration, that facilitates a balance between exploration and scientific discovery. The approach includes work in LEO, cislunar space (currently envisioned as the Gateway), lunar surface exploration, and deep space exploration. NASA's plans have the potential to support both HEO and Science Mission Directorate objectives and goals, while meeting the intent of Space Policy Directive-1 (SPD-1) for a return to the Moon. This concept features a role for international and commercial partners, reusability, sustainability, reconfigurable components, and builds toward the ultimate national vision for deep space exploration and science, including a crewed mission to Mars.

Proposed NAC Finding

- The Joint NASA Science and Human Exploration Operations Committees applaud NASA's inclusion of international partners in the Gateway Program. The value of international cooperation goes beyond the technical synergies realized through collaborations among traditional and emerging international partners. Perhaps more importantly, space exploration, pursued as an international community, facilitates peaceful interactions at large among all participating nations.

Proposed NAC Finding

- The HEO and the Science Committees observe that new technologies being developed for terrestrial industries may be applied to both HEO & SMD missions, like the Gateway. For example, autonomous vehicles on Earth and space may share similar instrumentation and sensing computational capability. Developing high resolution solid state LIDAR, teleoperations, and new techniques for sensor fusion will be important for any autonomous vehicle on earth or in deep space.

Proposed Recommendation for SMD AA and HEOMD AA

Title: Use of decadal surveys and exploration objectives to set priorities for the Gateway

Recommendation:

For the SMD AA: The joint committees recommend that the science initiatives implemented at the Gateway should be prioritized to align with the National Academies' decadal surveys.

For the HEOMD AA: The joint committees recommend that the objectives for exploration initiatives enabled by the Gateway approach should be clearly articulated by HEOMD to set expectations for all stakeholders.

Major reasons for proposing the recommendation: The Science and Human Exploration and Operations Committees applaud the leadership of HEOMD and SMD for fostering a balance between exploration and discovery in the Gateway concept. When communicating about the Gateway concept both science and exploration should indeed be emphasized. Clearly articulated exploration objectives for the gateway and reference to science decadal surveys will be critical as requirements for the gateway are developed in order to set expectations for all Gateway stakeholders and prioritize future Gateway science activity.

Consequences of no action on the proposed recommendation: Failure to articulate exploration objectives and science priorities for the gateway could result in confusion amongst stakeholders and unnecessarily decrease the effectiveness of a major NASA initiative.