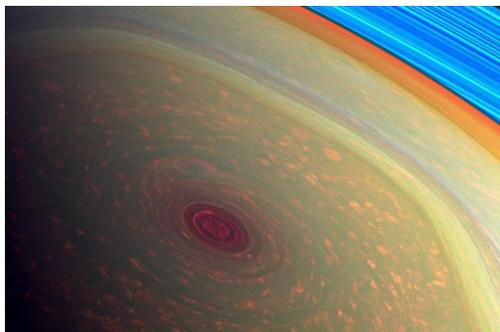


SCIENCE

National Aeronautics and
Space Administration



Planetary Science Advisory Committee (PAC)

PLANETARY SCIENCE DIVISION

Lori S. Glaze

Planetary Science Division Director
Science Mission Directorate, NASA

July 02, 2018

Planetary Science Missions: Events

2017

*Completed

January 4 – Discovery Mission selection announced

February 9-20 – OSIRIS-REx conducted Earth-Trojan search

April 22 – Cassini began plane change maneuver for the “Grand Finale”

August 21 – Solar Eclipse across America

September 15 – Cassini end of mission at Saturn

September 22 – OSIRIS-REx Earth flyby

October 28 – International Observe the Moon night (1st quarter)

2018

May 5 – Launch of InSight mission to Mars

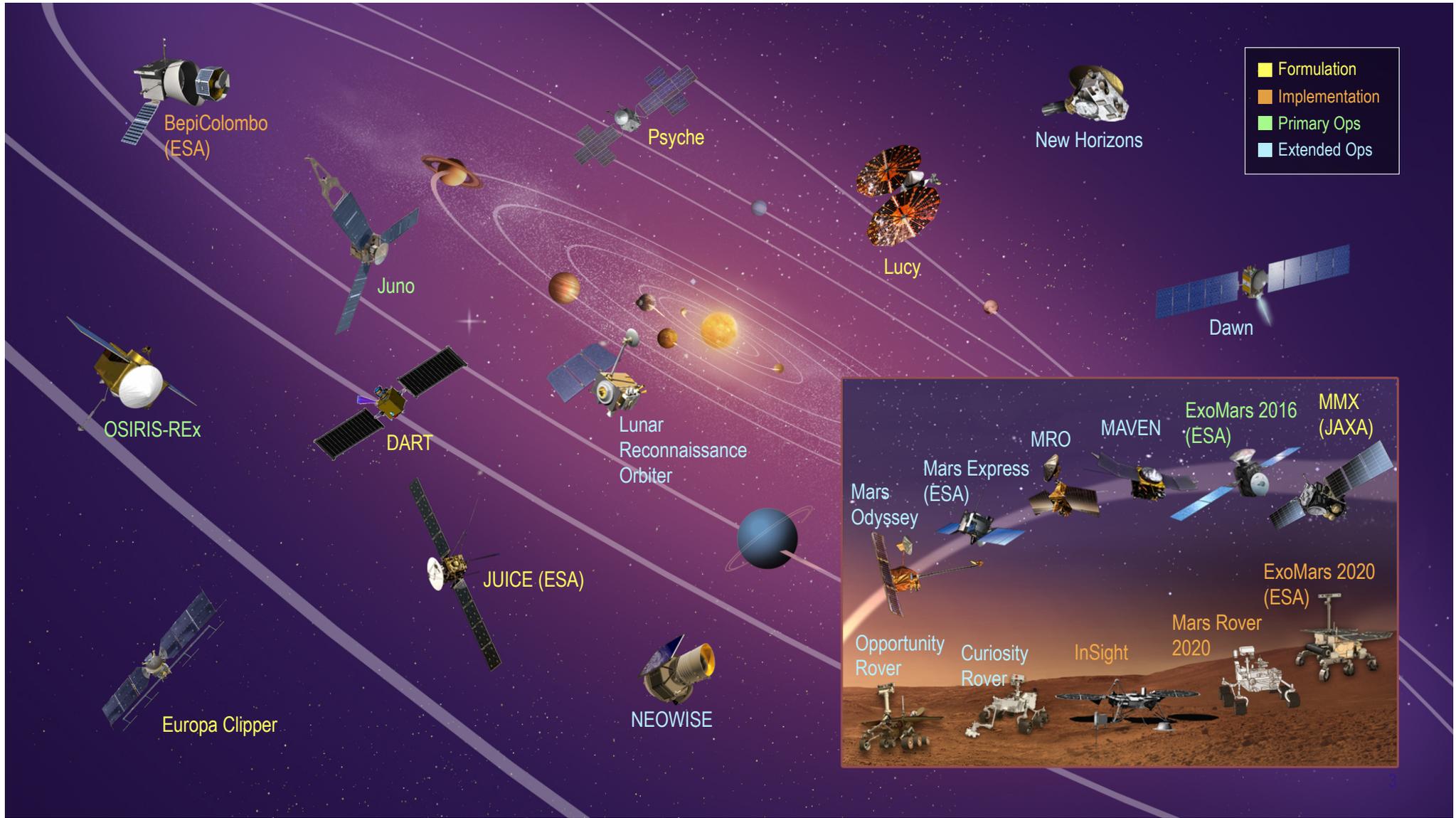
August – OSIRIS-REx begins observing Bennu

October – Launch of ESA’s BepiColombo to Mercury

November 26 – InSight landing on Mars

2019

January 1 – New Horizons flyby of Kuiper Belt object Ultima Thule



Planetary Science Budget

Planetary Science Program Content

| | Actual | Enacted | Request | Notional | | | |
|---------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | FY 17 | FY 18 | FY 19 | FY 20 | FY 21 | FY 22 | FY 23 |
| Science | | | | | | | |
| Planetary Science | 1,827.5 | 2,227.9 | 2,234.7 | 2,199.6 | 2,180.8 | 2,162.1 | 2,143.3 |
| Planetary Science Research | 230.1 | 239.6 | 258.0 | 247.6 | 247.6 | 247.6 | 247.6 |
| Planetary Defense | 60.0 | 76.0 | 150.0 | 150.0 | 150.0 | 150.0 | 150.0 |
| Lunar Discovery and Exploration | 19.0 | 20.0 | 218.0 | 218.0 | 218.0 | 218.0 | 218.0 |
| Discovery | 194.6 | 260.3 | 381.2 | 476.6 | 375.0 | 355.6 | 348.5 |
| New Frontiers | 134.0 | 88.1 | 130.2 | 163.7 | 245.0 | 327.6 | 388.4 |
| Mars Exploration | 647.0 | 688.0 | 601.5 | 529.7 | 371.9 | 290.8 | 215.3 |
| Outer Planets and Ocean Worlds | 359.5 | 641.2 | 285.6 | 213.8 | 373.3 | 372.5 | 375.5 |
| Technology | 183.3 | 214.7 | 210.2 | 200.2 | 200.0 | 200.0 | 200.0 |

Planetary Science Budget Features

What's Changed

- New Lunar Discovery and Exploration Program supports public-private partnerships and innovative approaches to achieving science and human exploration goals
- New Planetary Defense Program for near-Earth object detection and mitigation includes development of DART and studies a low-cost, space-based near-Earth object detection mission
- Supports trade studies and technology development for returning Mars samples cached by Mars 2020 rover
- Europa Clipper as early as FY25; proposes to fly Clipper on a commercial launch vehicle given cost savings

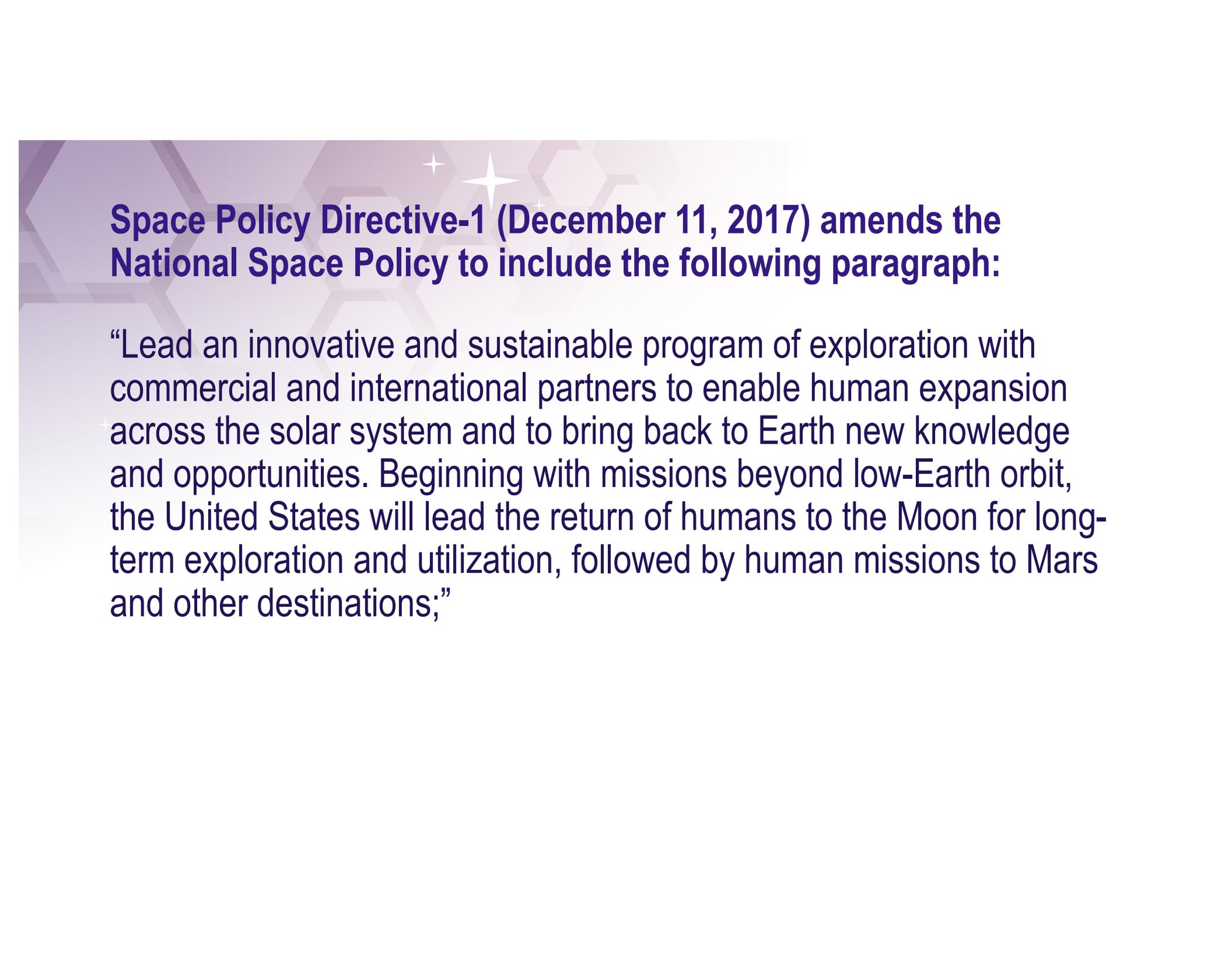
What's the Same

- Supports InSight, Psyche, Lucy, and next New Frontiers selection in FY19
- Funds all operating missions, and completes development of Mars 2020
- DoE production of radioisotope power generators and Pu-238 to fuel missions
- Healthy research program and SmallSat/CubeSat investments



NASA Exploration Campaign

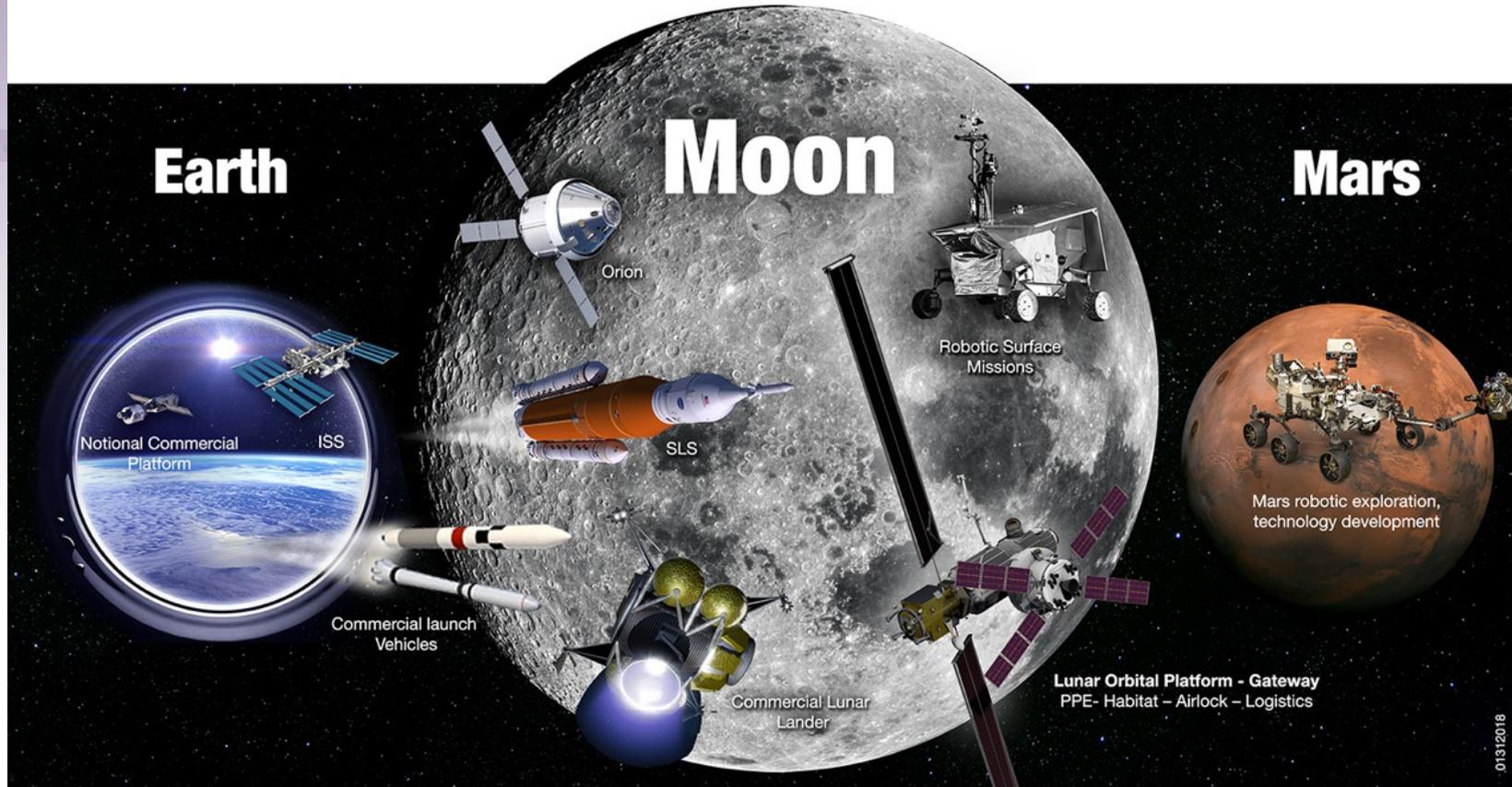
Steven Clarke – Sarah Noble



Space Policy Directive-1 (December 11, 2017) amends the National Space Policy to include the following paragraph:

“Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations;”

NASA Exploration Campaign

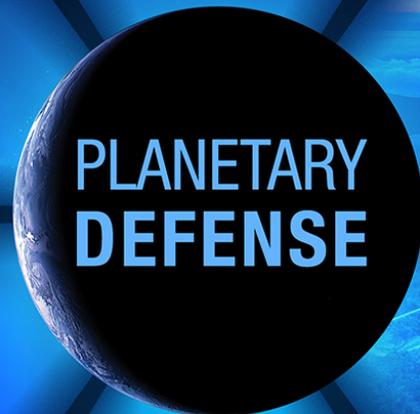


In LEO
Commercial & International
partnerships

In Cislunar Space
A return to the moon for
long-term exploration

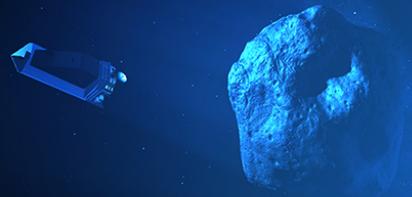
On Mars
Research to inform future
crewed missions

Planetary Defense



ASSESS

[CENTER FOR NEAR EARTH OBJECT STUDIES]



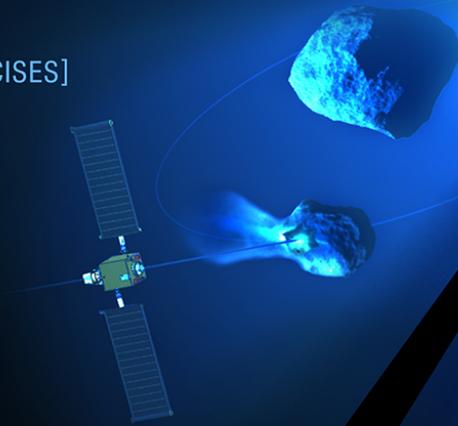
SEARCH, DETECT & TRACK

[GROUND-BASED & SPACE-BASED OBSERVATIONS, IAWN]



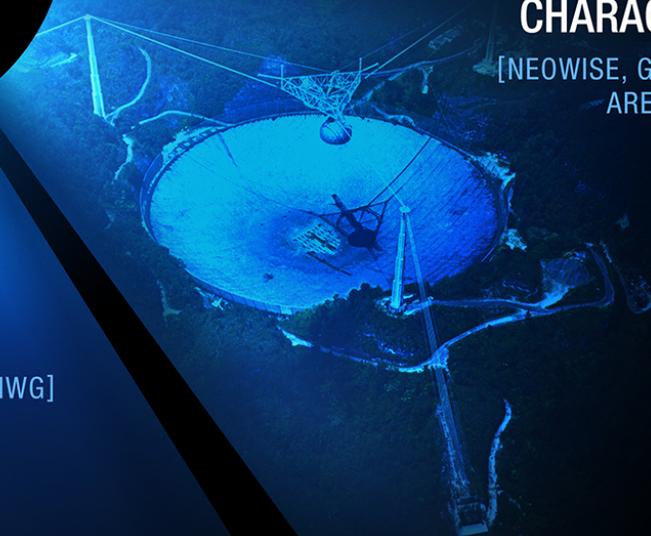
MITIGATE

[DART, FEMA EXERCISES]



CHARACTERIZE

[NEOWISE, GOLDSTONE, ARECIBO, IRTF]



PLAN & COORDINATE

[SMPAG, PIERWG, DAMIEN IWG]

Enhanced Planetary Defense

- FY19 budget request proposes an enhanced Planetary Defense program for near-Earth object detection, characterization and mitigation
- This is a significant ramping up of our NEO-related activities!
- DART, is an innovative way to test deflection capability
 - Joint study with ASI for potential CubeSat addition
- Currently studying cost-effective space-based near-Earth object detection mission

Planetary Defense Coordination Office Status

- **18,441** near-Earth objects (NEOs) discovered and confirmed to date (**versus 17,741 as of February 1, 2018**)
 - Over 8,000 NEOs greater than 140 meters in size
 - Over 1,900 NEOs are Potentially Hazardous Asteroids

- White House National Near-Earth Object Preparedness Action Plan **WAS** released on June 20, 2018, by the Detecting and Mitigating the Impact of Earth-Bound Near-Earth Objects (DAMIEN) Interagency Working Group



- 2017 NEO Science Definition Team reassessed NEO search and characterization given current technology and understanding of the NEO population. Of the estimated 25,000 NEOs 140 meters or larger in size (that can cause regional damage), 1/3 have been found. Study determined that a space-based asset will be needed to complete the 140 meter survey in less than several decades.



PSD R&A Update

Jonathan Rall

Missions Participating Scientist Programs

- The InSight PSP program is about to complete its review and is very close to making final decisions with regard to selecting Participating Scientists
- Korean Pathfinder Lunar Orbiter (KPLLO) PSP Call will be released soon
- BepiColombo will also have an opportunity for scientists to participate, most likely via a Guest Investigator Program or an InterDisciplinary Scientist program

ISFM – Goddard Space Flight Center

- There are 5 GSFC work packages:
 - ✓ Goddard Instrument Field Team (GIFT)
 - ✓ Exosphere-Ionosphere-Magnetosphere Modeling (EIMM)
 - ✓ Fundamental Laboratory Research (FLARE)
 - ✓ Planetary Geodesy Capabilities
 - ✓ Sellers Exoplanet Environments Collaboration (SEEC)
- Each package has already received some money in FY18.
- The total amount of support received, to date, is approximately \$7.5M

*GIFT is a cross-center program that includes a small component at ARC

ISFM – Ames Research Center

➤ There are 6 ARC work packages:

- ✓ Center for Life Detection
- ✓ Origins of Life
- ✓ Microbial Innovation and Ecosystem Research
- ✓ Planetary Formation and Exoplanets Theory
- ✓ Habitable Environments and Biosignatures
- ✓ Mars Climate Modeling Center

➤ Each package has already received some money in FY18

➤ The total amount of support, to date, is approximately \$4.6M

ISFM – Johnson Space Center

➤ There are 5 JSC work packages:

✓ Coordinate Analysis

✓ Geocosmochemistry

✓ Mission Enabling Research

✓ Organic Geocosmochemistry

✓ Process Simulation

➤ Each package has already received some money in FY18

➤ The total amount of support, to date, is approximately \$6.6M

ISFM – Langley Research Center and Marshall Space Flight Center

- There is one combined work package between LaRC and MSFC:
 - ✓ Global Reference Atmospheric Model (GRAM)
- Both centers have received money this year to support the work package
- The total amount of support, to date, is approximately \$.5M



Small Innovative Missions For Planetary Exploration (SIMPLEx)

SIMPLEx Selection Schedule

- July 24, 2018
 - Proposal due date for first round of evaluation/selections
 - Final Proposal due date for Lucy and Psyche
 - **NON-CONFLICTED VOLUNTEERS for Science Review Doris.Daou@nasa.gov**
- Proposal due date for CYCLE-2 round of evaluations/selections will be announced well in advance of that deadline. This due date is likely to be no earlier than July, 2019.
- September 2018
 - Science Review Panels
- October 2018 – January 2019
 - Technical Management Cost Review Panels
 - Only a subset of the proposals, based on their science review scores
- ~February 2019 – Selection Announcements
- ~May – ~August 2019 – Contract Awards
 - Contract award time based on dollar value of contract



Mars Exploration Program

Jim Watzin

Discovery Program

Discovery Long-Range Planning

- Cost Cap \$495M Phase A-D (FY19) excluding LV
- ~~May not propose the use of radio-isotope power systems (RPS)~~ – **UPDATED**
- May include radioisotope heater units (RHUs)

| | |
|---|---------------------------------|
| Release of draft AO | September 2018 (target) |
| Release of final AO | February 2019 (target) |
| Pre-proposal conference | ~3 weeks after final AO release |
| Proposals due | 90 days after AO release |
| Selection for competitive Phase A studies | December 2019 (target) |
| Concept study reports due | November 2020 (target) |
| Down-selection | June 2021 (target) |
| Launch readiness date | NLT December 31, 2026 |



New Frontiers Program

New Frontiers 4 AO

Investigations (listed without priority)

- Comet Surface Sample Return
- Lunar South Pole-Aitken Basin Sample Return
- Ocean Worlds (Titan, Enceladus)
- Saturn Probe
- Trojan Tour and Rendezvous
- Venus In Situ Explorer

12 Proposals received on April 28, 2017

Step-1 Selections Announced December 2017

Phase A Concept Study Reports due..... December 2018

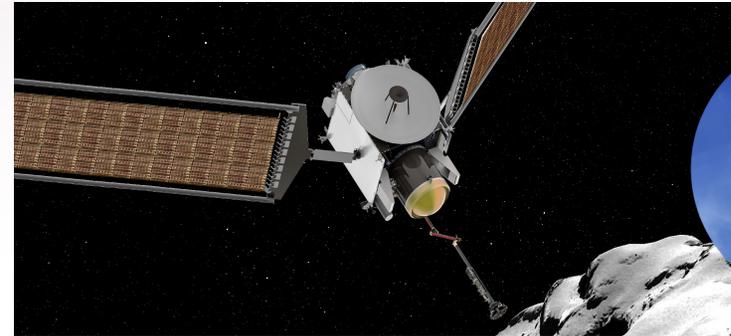
Down selection for Flight (target)..... July 2019

Launch Readiness Date..... NLT December 31, 2025

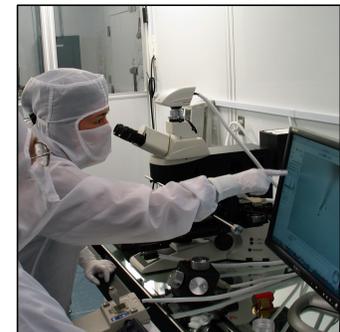


Comet Astrobiology Exploration Sample Return

- Comets record presolar history, the initial stages of planet formation, and the sources of prebiotic organics and volatiles available for the origin of life.
- Target comet is 67P/Churyumov-Gerasimenko.
- Mission and Sample Acquisition System (SAS) have been designed for the known properties of 67P.
- SAS collects at least 80 g of comet nucleus sample.
- As volatiles evolve from the sample they are transferred to a separate reservoir, preventing sample alteration. Both non-volatile and volatile materials are returned to Earth for analysis.
- Sample stored at -80° to -40° C through return cruise, and below 0° C through entry, descent, landing, and recovery.



PI: Steve Squyres, Cornell University. CAESAR would return the first sample from the nucleus of a comet. Sample analysis in worldwide laboratories will address questions about Solar System starting materials, and how they came together to form planets and give rise to life.





A rotorcraft to explore prebiotic chemistry and habitability on the ocean world Titan

- Flight is highly efficient on Titan, enabling Dragonfly to sample materials in a variety of settings with its **science payload:**

- Mass spectrometer
- Gamma-ray and neutron spectrometer
- + ➢ Meteorology and seismic sensors
- Camera suite

Science Objectives:

- Analyze chemical components and processes at work that produce biologically relevant compounds
- Measure atmospheric conditions, identify methane reservoirs, and determine transport rates
- Constrain processes that mix organics with past surface liquid water reservoirs and subsurface ocean
- Search for chemical evidence of water-based or hydrocarbon-based life

Aerial mobility provides access to Titan's diverse materials at a wide range of geologic settings at dozens of sites, 10s to 100s of kilometers apart

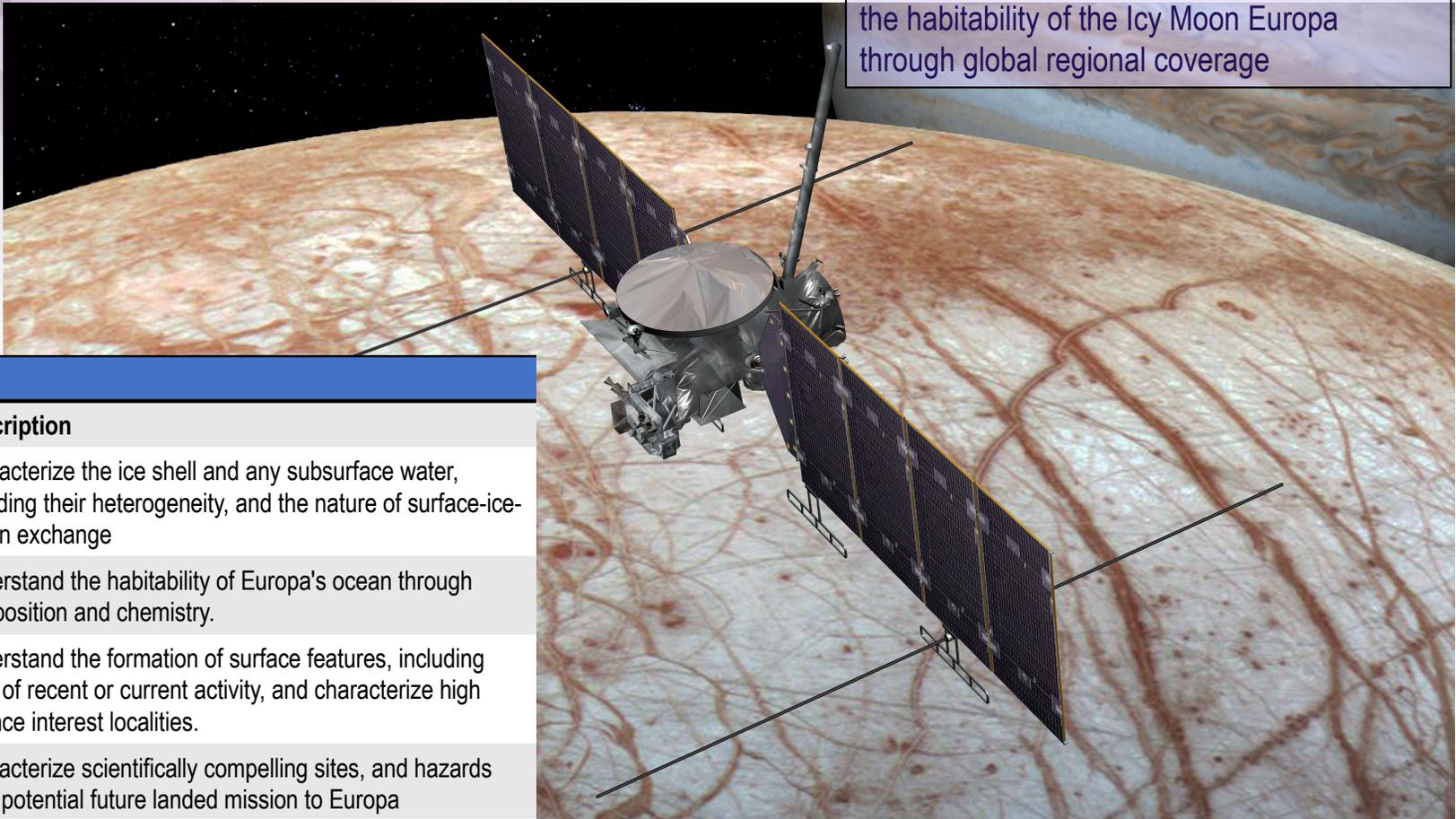


PI: Dr. Elizabeth Turtle at APL
Dragonfly would arrive at Titan in 2034 and explore for over 2 years, performing detailed chemical analyses, measuring the atmosphere and seismic activity, and imaging the surface.

Oceans Worlds

Europa Clipper Overview

Will conduct approximately 45 low altitude flybys (25 – 100 km altitude) to characterize the habitability of the Icy Moon Europa through global regional coverage



| Science | |
|-------------------|---|
| Objective | Description |
| Ice Shell & Ocean | Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange |
| Composition | Understand the habitability of Europa's ocean through composition and chemistry. |
| Geology | Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities. |
| Recon | Characterize scientifically compelling sites, and hazards for a potential future landed mission to Europa |



NASA Astrobiology Institute

Building a Research Collaboration Network

NASA SMD is committed to interdisciplinary and interdivisional research:

- There are numerous ways to stimulate and support this type of research
- NAI is one, another is NExSS which is based on a Research Collaboration Network (RCN) model

NAI cutting-edge nature and the collaborations it fostered play a critical role in:

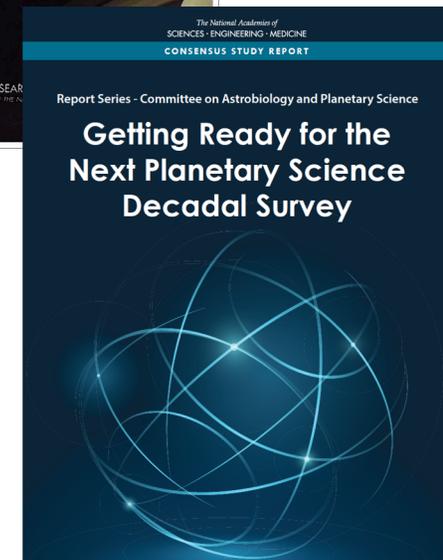
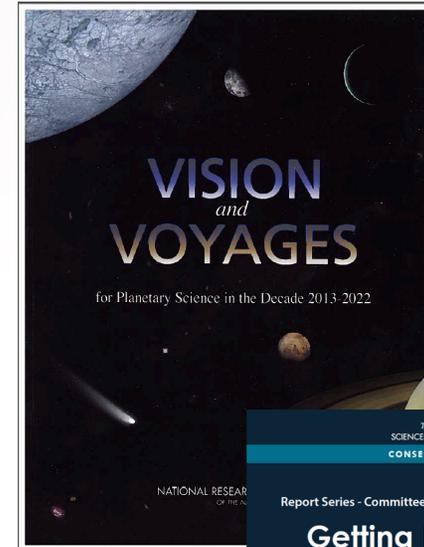
- Growing the astrobiology discipline and community
- Leading the international astrobiology community for much of its 20 years of existence

NExSS experiment has proven itself and a key reason is that it is run by the community itself

NASA Planetary Science Studies

Timeline of Studies

- 1st Planetary decadal: 2002-2012
- 2nd Planetary decadal: 2013-2022
- CubeSat Review: Completed June 2016
- Extended Missions Review: Completed Sept 2016
- R&A Restructuring Review: Completed June 2017
- Searching For Life : Completed Sept 2017
- Large Strategic Science Missions: Completed Aug 2017
- Midterm evaluation:
 - Tasked August 26, 2016
 - Above NAS studies will be input
 - Expect report to NASA due ~ Late July 2018
- Sample Analysis Investment Strategy
 - Started November 2017
- 3rd Planetary Decadal: 2023-2032
 - To be tasked *before* October 2019
 - Expect report to NASA due 1st quarter 2022
- CAPS reviewed completed studies and recommended several more to be completed



Mission Studies Completed Thus Far

- Mars orbiter
 - 2015 MEPAG's Next Orbiter Science Analysis Group
- Uranus and Neptune (Ice Giants) system missions
 - 2017 NASA science definition team report
- Europa lander
 - 2017 NASA science definition team report
- Venus orbiter and lander (Venera-D)
 - 2017 joint U.S.-Russian science definition team report
- NEO Search and Characterization
 - 2017 NEO science definition team updated report

CAPS Priority Areas Candidates for Large or Medium Class Mission Studies (Unprioritized)

| | |
|---|--|
| Venus exploration missions (assigned to gsfc but team has not formed yet) | Additional concepts beyond the Venera-D orbiter and lander |
| Lunar science missions | Understanding interior processes and polar volatiles (Volatiles SAT Team-2) |
| Mars sample-return next-step missions | Mission elements beyond Mars 2020 necessary for second and third phases of a Mars sample-return campaign |
| Mars medium-class missions | Multiple mobile explorers, polar explorers, & life-detection. Investigations responsive to new discoveries |
| Dwarf planet missions (starting to move forward JPL) | Large- & medium-class mission concepts to Ceres, Pluto, Triton |
| Io science (NEW FRONTIERS FIVE) | Reexamine mission to Io |
| Saturn system missions | Affordable, large strategic missions that visit multiple targets |
| Dedicated space telescope for solar system science | Dynamic phenomena on planetary bodies |



PAC Recommendations from February 21, 2018

1. NSPIRES External Reviews

- PAC recommends that external reviewers must be notified within 48 hours that they have been officially selected as a reviewer.
- PAC recommends that NSPIRES be modified to provide automated notifications to external reviewers whenever any review is assigned.
- PAC recommends that NSPIRES be modified such that all panelists who have completed their reviews can see all external reviews as soon as they are completed.
- PAC recommends that NSPIRES be modified such that group chiefs can always see the status of all reviews for the panel (i.e., accept/decline, not logged in, in progress, completed).
- ✓ The NSPIRES proposal and review management system is administered under the NASA Research and Education Support Services (NRESS) contract. The contracting organization has begun a refresh/rebuild of the NSPIRES system, as outlined in the contract. Jonathan Rall will go over the process in his presentation.
- ✓ PSD is committed to improving reviewers experience and answering their needs. As such, we will confirm and work with NRESS updating the NSPIRES system to answer these recommendations

2. Post 2020 Mars Sample Return

- NASA's Lean Sample Return strategy does not include collecting a contingency sample, whereas returning any sample has been a mission success criterion for past sample return missions.
- PAC recommends collecting a simple, contingency grab sample with a curation plan.
- ✓ The program is exploring options for maximizing the probability of returning samples within the cost constraints of the mission, including the possibility of retaining some samples onboard M2020 that could be delivered to the lander. We plan to have a curation plan for any samples that are returned.

3. Mercury Assessment Group

- Mercury is not currently represented in any of the Analysis or Assessment Groups.
- PAC recommends that NASA starts a new assessment group for Mercury, rather than add it to an already existing Assessment/Analysis Group.
- ✓ We have identified a PSD scientist to serve as the NASA liaison with the group and we are working on bringing her on board.
- ✓ PSD is confident that the Mercury Community will soon proceed with the creation of the New Analysis Group.

4. Radioisotope Power Systems (RPS) in the Discovery Program

- PAC would like to see the Discovery Program open to all destinations and targets, regardless of power supply requirements. The Discovery Program should allow the use of RPS if the supply of Pu-238 is sufficient to support a Discovery mission that requires RPS.
- ✓ As of March 20, 2018, PSD NASA reconsidered the use of RPS in the Discovery Program. Use of RPS is now allowed.

5. Venus Opportunities in Discovery and New Frontiers Programs

- Although NASA selected Venus missions as finalists in the most recent Discovery mission opportunity and Venus missions were proposed to the New Frontiers Program, none was selected for flight.
- PAC recognizes that Venus remains an important and under-investigated target and recognizes its connections to exoplanets and habitability.
- ✓ PSD recognizes that Venus is critical in the path of understanding terrestrial planet formation, evolution, habitability and exoplanetary environments
- ✓ Next Opportunities:
 - ✓ SIMPLEx
 - ✓ Discovery in 2019
 - ✓ New Frontiers 5 in 2022
- ✓ PSD is looking forward to receiving the updated VEXAG Roadmap and formulating a responsive strategy that would include Discovery and/or NF5

6. NASA's Early Career Fellowship (ECF) Program

- PAC recommends the revision and restoration of NASA's ECF Program. PAC recommends dividing the way the ECF program is administered for tenure-track (or tenure-track equivalent) and non-tenure track researchers. For early career planetary scientists that do not yet have a tenure-track or tenure-track equivalent position, the ECF could be modeled after NASA's Postdoctoral Program awards or Hubble Fellowships. For those that already have faculty positions, the NSF's CAREER program could be the model for those that are on the tenure track or have tenure-equivalent positions.
- ✓ PSD is committed to healthy Early Career support, which ensures diversity and inclusion of underserved and underrepresented communities.
- ✓ PSD is aiming to implement an Early Career Fellowship Call to ROSES 18
- ✓ We expect the awards to be 5 years. The size and the numbers of the awards are not yet determined.
- ✓ Jonathan will have more details in his presentation.

7. Standardization of Planetary Data Formats and Definitions

- The use of standard data formats ensures data interoperability, reduces redundant efforts, and can maximize the scientific return from planetary spacecraft missions.
- PAC recommends that NASA make a concerted effort to facilitate the development of standard formats and definitions for planetary data (i.e. Geographic Information System (GIS) and spatial data).
- ✓ PSD requests from the PAC an assessment of the needs of the community regarding PDS data accessibility, ingest (types of data), standard data formats, and definitions for planetary data
- ✓ Provide a report that includes specifics on what is not working and recommendations/options for resolutions

8. Report to the PAC from the Planetary Defense Coordination Office

- Given the importance of planetary defense to NASA and the public, PAC recommends that NASA's Planetary Defense Coordination Office makes regular reports to the PAC on the progress and plans being made in regards to meeting the George E. Brown survey objective of detecting and tracking >90% of Near Earth Objects (NEOs) larger than 140m, and smaller NEOs.
- ✓ The Planetary Defense Coordination Office will continue to provide updates to the PAC during the face to face meetings
- ✓ Updated NEO statistics included in PSD Director's presentation.

QUESTIONS ?

