SBAG Meeting
PLANETARY SCIENCE DIVISION

Jonathan A. R. Rall
Planetary Research Director
Planetary Science Division
Science Mission Directorate, NASA

June 13, 2018
Planetary Science Budget
### Planetary Science Program Content

<table>
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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
Enhanced Planetary Defense

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

**NOTIONAL LAUNCHES**

**EARLY SCIENCE & TECHNOLOGY INITIATIVE**
- SMD—Pristine Apollo Sample, Virtual Institute
- HEO/SMD—Lunar CubeSats
- SMD/HEO—Science & Technology Payloads

Timelines are tentative and will be developed further in FY 2019

MAY 2018
NASA Exploration Campaign

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SMALL COMMERCIAL LANDER INITIATIVE
- HEO—Lunar Catalyst & Tipping Point
- SMD/HEO—Small Commercial Landers/Payloads

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**MID TO LARGE LANDER INITIATIVE TOWARD HUMAN-RATED LANDER**
- HEO/SMD–Mid-sized Landers (~500kg–1000kg)
- HEO/SMD–Human Descent Module Lander (5-6000kg)
- SMD/HEO–Payloads & Technology/Mobility & Sample Return
- SMD–Mars Robotics

**Timeline:**
- 2018
- 2019
- 2020
- 2021
- 2022
- 2023
- 2024
- 2025
- 2026
- 2027
- 2028
- 2029
- 2030

Timelines are tentative and will be developed further in FY 2019
NASA Exploration Campaign

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**LUNAR ORBITAL PLATFORM—GATEWAY**
- HEO—Orion/SLS (Habitation Elements/Systems)
- HEO/SMD—Gateway Elements (PPE, Commercial Logistics)/Crew Support of Lunar Missions
- HEO/SMD—Lunar Sample Return Support

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<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
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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]

PLANETARY DEFENSE

PLAN & COORDINATE
[SMPAG, PIERWG, DAMIEN IWG]
Double Asteroid Redirection Test (DART)
Mission Concept (with Proposed ASI CubeSat)

Didymos-A
S-Type Apollo
780 meter size

Didymos-B
~160 meter size
PSD R&A Update
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General R&A Updates

• ROSES 2018 released on Feb 14, 2018!!

• Facilities Update – New CAN for Facilities on hold:
  • NASA has requested a National Academies study; ad hoc committee is working: Sample Analysis Future Investment Strategy

• National Academies Study on R&A Restructuring

• Archiving manuscripts – new policy for all NASA funded work to be put into PubSpace (part of PubMed)
  https://www.nasa.gov/open/researchaccess/pubspace
Small Innovative Missions For Planetary Exploration (SIMPLEx)
• SIMPLEx is soliciting small complete science missions based on small spacecraft (SmallSats) flying as secondary payloads
  • ESPA-class (180 kg) or smaller
    • Allowable configurations include CubeSats up to 12U, and ESPA-class
    • ESPA-Grande sized spacecraft allowed for some opportunities (still limited to 180 kg)
  • Total mission cost capped at $15M - $55M
  • NASA expects awards to span the full range cost cap range

• Proposed missions are limited to the launch opportunities listed in Appendix A of the PEA. Currently listed are:
  • SMD missions (Lucy, Psyche, and IMAP),
  • Commercial Lunar opportunities,
  • LEO/GTO opportunities, and
  • Exploration Mission “x” (EM-2 or beyond)
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 second 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
Discovery Program
Discovery Program

- NEO characteristics
  - NEAR (1996-1999)
- Mars evolution
  - Mars Pathfinder (1996-1997)
- Lunar formation
- Nature of dust/coma
  - Stardust (1999-2011)
- Solar wind sampling
  - Genesis (2001-2004)

- Comet Diversity
  - CONTOUR (2002)
- Mercury Environment
- Comet Internal Structure
- Lunar Internal Structure
  - GRAL (2011-2012)
- Main-belt Asteroids
  - Dawn (2007-TBD)
- Exoplanets
  - Kepler (2009-TBD)

- Lunar Surface
  - LRO (2009-TBD)
- ESA/Mercury Surface
  - Strofio (2018)
- Mars Interior
  - InSight (2018)
- Trojan Asteroids
  - Lucy (2021)
- Metal Asteroid
  - Psyche (2022)
- Martian Moons
  - MMX/MEGANE (2024)
Psyche

Journey to a Metal World
Deep-Space Optical Comm (DSOC)

To Be Launched in 2022
Lucy

Surveying the Trojan Asteroids

To Be Launched in 2021
JAXA Martian Moons eXploration (MMX) Mission

Neutron & Gamma-Ray Spectrograph
- Solicited by NASA through the SALMON-3 AO
- Selection Announced Nov 16, 2017
  - MEGANE ("eyeglasses")
  - David Lawrence (JHU APL), PI

- Cryocooled high-purity Germanium $\gamma$-ray detector (MESSENGER GRS heritage)
- $^3$He proportional counter neutron detector (Lunar Prospector heritage)

To Be Launched in 2024
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
Reconsideration In the Use of RPS for Discovery

After analysis and consultation with the Department of Energy, NASA’s Planetary Science Division is pleased to announce that the ban on the use of Radio-isotope Power Systems (RPS’s) by proposers responding to the upcoming Discovery 2018 AO has been removed.

Proposer’s will be able to include the use of up to two (2) Multi-mission Radio-Isotope Thermal Generators (MMRTG’s) to enable or significantly enhance their mission concept.

Costs to be borne by proposers for the MMRTG’s, the related environmental impact assessments, and the required Nuclear Launch Approval process will be announced once determined.
New Frontiers Program
New Frontiers Program

1st NF mission
New Horizons
- Pluto-Kuiper Belt
- Launched January 2006
- Flyby July 14, 2015
- PI: Alan Stern (SwRI-CO)

2nd NF mission
Juno
- Jupiter Polar Orbiter
- Launched August 2011
- Arrived July 4, 2016
- PI: Scott Bolton (SwRI-TX)

3rd NF mission
OSIRIS-REx
- Asteroid Sample Return
- Launched September 2016
- PI: Dante Lauretta (UA)
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 (target).................... 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 will 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.
Planetary Defense Coordination Office
Planetary Defense Coordination Office Status

• Over 18,000 near-Earth objects (NEOs) discovered and confirmed to date
  • 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 to be released late June 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. Space-based assets will be needed to complete the catalog.
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 ~June 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
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<td>Mars sample-return next-step missions</td>
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<td>Mars medium-class missions</td>
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<td>Dwarf planet missions</td>
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<td>Io science (NEW FRONTIERS FIVE)</td>
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<td>Saturn system missions</td>
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<td>Dedicated space telescope for solar system science</td>
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Ceres Pre-Decadal Study

• CAPS highlighted Ceres for pre-decadal study
• Dawn revealed Ceres to be an active dwarf planet; It is a solid body, but is it a relic ocean world?
• JPL to lead the Ceres study; Michael Kelley is the PSD POC
• Goals are to assess science priorities and examine trade space of mission concepts
  • Spectrum of alternatives, including New Frontiers and Large Strategic missions
  • Orbiting, landing, roving, sample return?
  • Launch dates between 2024 – 2037
  • PP to be noted, uncover technologies to be addressed
• Key dates:
  • SDT call for applications issued – team is being selected
  • Design study February – Late FY18
  • Engagement with AGs and workshops/conferences
QUESTIONS ?
NASA Exploration Campaign – BackUp
Benefits of Near-Term Lunar Missions

- **Return Science**
  - Reduce costs and risk for high priority science (Decadal Survey, SCEM, etc.) through regular mission cadence
  - Ensure the strength of the lunar science community
- **Benefit Exploration**
  - Volatiles may be key to future exploration architectures; characterizing volatiles entrainment in regolith is the first step
- **Encourage Industry Participation**
  - Expand the economic sphere to cis-lunar space
  - Foster initial R&D for resource acquisition and processing
  - Leverage investments in commercial landers
- **Demonstrate Technologies**
  - Precision Landing/Hazard Avoidance and Ascent
  - Improvements in power generation and storage
  - Extreme environment instruments/systems for day/night survival/operations - relevant to Icy Moons
- **Advance planning for Mars and other destinations**
  - Enables deep-space architectures
  - Reduces logistics chain from Earth
  - Flight qualifies critical technologies such as precision landing and ascent vehicles
Commercial Lunar Payload Services (CLPS)

- Draft RFP (SMD/HEOMD/STMD developed) for CLPS posted April 27
- Competition open to U.S. commercial providers of space transportation services, consistent with National Space Transportation Policy and Commercial Space Act
- Multi-vendor catalog, 10-year IDIQ contract, managed through task order competition for specific payload missions
- First vendor selection by Dec 31; future on-ramps as more capabilities are developed
- Structured for NASA as the marginal buyer of a commercial service
- Statement of work permits addition of more complex services as vendor capabilities grow such as providing surface mobility or sample return
- Based upon prior HEOMD investments through the Lunar CATALYST public-private partnerships with industry, we expect multiple vendors to bid
Payload Development

• Current Activities to develop payloads
  • CubeSats – SIMPLEX-2 SALMON-3 PEA AO
  • Instrument Development call – DALI
  • STMD technology interests

• What payloads are available now?
  • SALMON-3 PEA AO for payloads that are ready, or nearly ready, to fly
  • GSFC retroreflectors - quick and easy
  • Resource Prospector instruments
Small Innovative Missions for Planetary Exploration (SIMPLEEx)

- SIMPLEEx-2 AO is released; in addition to soliciting SmallSat proposals for all planetary destination, specific emphasis has been added for SmallSats to conduct lunar science or address exploration SKGs
- Available for potential delivery by commercial lander service provider
  - Ride along under CLPS; providing additional opportunities for commercial companies
- Science that would help us prepare for human exploration
DALI (Development and Advancement of Lunar Instrumentation)

- Step 1 proposals were due April 3, Step 2 were due June 5
- Lunar instruments that support NASA’s broader lunar exploration goals, including human exploration and in situ resource utilization (ISRU), as well as lunar science.
- “Particularly interested” in instruments for small stationary landers, but call is open for any lunar instrumentation, including orbiters/rovers.
- “Most interested in” technologies that will reach at least TRL 6 by end of grant, flight hardware builds for landers with flight opportunities as early as ~2021.
DALI (Development and Advancement of Lunar Instrumentation)

- Received 47 Step 2 proposals
  - UV/Vis/IR/Thermal Spectrometers, Mass Spectrometers, Raman Spectrometers, Neutron/Gamma Ray Spectrometers
  - Dust/plasma/solar wind instruments,
  - Seismic instruments, heat flow probe
  - Lunar Laser Ranging
  - Magnetometers, RADAR
  - LIDAR, LIBS, XRD/XRF
  - Volatiles detection, Radiation detection
Scope of Science and Technology Payload
SALMON PEA

- Payloads that are ready, or nearly ready, to fly
  - Engineering models
  - Student-built hardware
  - Modified off the shelf
- Cross-division/directorate call
  - Open to Planetary/Heliophysics/Astrophysics/Earth
  - HEOMD SKGs/ISRU
  - STMD goals (“technology”, not just “instruments”)
- Significant international participation will be permitted
  - but not international proposals, they will have to partner with US researchers
- 15 kg limit per instrument, but may combine multiple instruments for a single flight opportunity
2-Stage process

• Different from our usual 2-step downselects
• Phase 1 – “get your instrument ready to fly”
  • No guarantee you will fly
  • Expect to select on order of 8-12 instruments
  • Selections expected ~Summer 2019
• Phase 2 – integrate onto a specific flight opportunity
  • Additional funds for integrating, ops, and science
  • Internal process based on factors such as ease of accommodation, readiness timeline, and appropriateness for landing site for the science or technology proposed
NASA GSFC/MIT Laser Retro-reflector Arrays (LRA) for Lunar Landers

- **What they are:**
  - Custom glass cube corner arrays that retro-reflect incoming laser beams over a wide incident angle.
  - Light weight, rad-hard, and long lifetime
  - Similar LRAs are carried by Earth-orbiting satellites for precision laser tracking from ground stations

- **Science applications**
  - Lander position and movement determination (laser tracking from orbiting or descent LIDAR)
  - Permanent fiducial markers on the Moon
    - Location of science measurements by on board instrument, e.g., seismometer
    - Landmarks for precision landing of future lunar craft
  - Test of concept of LRA on Mars, asteroids, etc.

GSFC and MIT LRA team information – Contact Michael Amato, Dave Smith, Xiaoli Sun, for more information.
Resource Prospector Legacy Instruments

• NASA recently conducted an internal science and engineering assessment of RP instruments.
• Determined that all four RP instruments are at a high enough TRL and have ability to obtain useful science data on the Moon.
• As development continues, plan to integrate instruments into early CLPS missions.
Long-Lived Instruments, Landers and Small Rovers

• Initial landers delivered through the Commercial Lunar Payload Services (CLPS) are expected to last one lunar day (14 Earth days)

• NASA is planning investments to enable operations and mobility for long-lived instruments, stationary landers and small rovers
  • Power supplies, electronics, and mechanisms to survive and/or operate across the extreme temperatures of lunar day and night, despite lunar dust
  • Mobility systems or surface utility stations to enable small, long-lived rovers compatible with delivery to the lunar surface under CLPS capabilities
  • Radioisotopes for heat or power
  • An initial Long Duration Lunar Surface Operations workshop is planned for Fall 2018 co-sponsored by HEOMD, SMD, and STMD
PDCO Mission Projects

**NEOWISE**
- Continues in extended NEO survey operations

**NEOCam: Near-Earth Object Camera**
- Infrared survey telescope optimized for meeting congressional mandate to find and characterize NEOs down to 140 meters in size
- Continues in extended Phase A
- Passed SRR/MDR on February 28, 2018

**DART: Double Asteroid Redirection Test**
- Demonstration of kinetic impactor mitigation technique
- Target - Moon of 65803 Didymos
- Launch period opens June 2021, impact October 2022
- Passed mission-level PDR on April 12, 2018
- KDP-C scheduled for June 22, 2018
Mars – BackUp
Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight)

Launched May 5, 2018
Seeking Signs of Life: Mars 2020 Rover

Geologically diverse site of ancient habitability

Returnable cache of samples

Critical ISRU and technology demonstration required for future Mars exploration

Coordinated, nested context and fine-scale measurements
Oceans Worlds – BackUp
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.

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