Outline

• Mission Overview
• Discovery & New Frontiers Programs
• Planetary Cubesats
• Research and Analysis update
• Planetary Defense Coordination Office
• NAS studies and schedule
Planetary Science Missions Events

2014
July – Mars 2020 Rover instrument selection announcement
August 6 – 2nd Year Anniversary of Curiosity Landing on Mars
September 21 – MAVEN inserted in Mars orbit
October 19 – Comet Siding Spring encountered Mars
September – Curiosity arrives at Mt. Sharp
November 12 – ESA’s Rosetta mission lands on Comet Churyumov–Gerasimenko
December 2/3 – Launch of Hayabusa-2 to asteroid 1999 JU3

* Completed

2015
March 6 – Dawn inserted into orbit around dwarf planet Ceres
April 30 – MESSENGER spacecraft impacted Mercury
May 26 – Europa instrument Step 1 selection
July 14 – New Horizons flies through the Pluto system
September – Discovery 2014 Step 1 selection
December 6 – Akatsuki inserted into orbit around Venus

2016
March – Launch of ESA’s ExoMars Trace Gas Orbiter
July 4 – Juno inserted in Jupiter orbit
July 20 – 40th Anniversary of the Viking missions
September 8 – Launch of Asteroid mission OSIRIS – REx to asteroid Bennu
September 30 – Landing Rosetta on comet CG
Late 2016 – Discovery 2014 Step 2 selection
Discovery Program
Discovery Program

**Completed**

- Main-belt asteroids: Dawn (2007-TBD)
- Lunar surface: LRO (2009-TBD)
- ESA/Mercury Surface: Strofio (2017-TBD)
- Mars Interior: InSight (2018)

*Lost Aug 15, 2002*
Psyche: Journey to a Metal World
PI: Linda Elkins-Tanton, ASU
Deep-Space Optical Comm (DSOC)

VERITAS: Venus Emissivity, Radio Science, InSAR, Topography, And Spectroscopy
PI: Suzanne Smrekar, JPL
Deep-Space Optical Comm (DSOC)

NEOCam: Near-Earth Object Camera
PI: Amy Mainzer, JPL
Deep-Space Optical Comm (DSOC)

Lucy: Surveying the Diversity of Trojan Asteroids
PI: Harold Levison, Southwest Research Institute (SwRI)

DAVINCI: Deep Atmosphere Venus Investigations of Noble gases, Chemistry, and Imaging
PI: Lori Glaze, GSFC
New Frontiers Program
New Frontiers Program

1\textsuperscript{st} NF mission
New Horizons:
Pluto-Kuiper Belt

2\textsuperscript{nd} NF mission
Juno:
Jupiter Polar Orbiter

3\textsuperscript{rd} NF mission
OSIRIS-REx:
Asteroid Sample Return

Launched January 2006
Flyby July 14, 2015
PI: Alan Stern (SwRI-CO)

Launched August 2011
Arrived July 4, 2016
PI: Scott Bolton (SwRI-TX)

Launched Sept. 8, 2016
PI: Dante Lauretta (UA)
Juno: Mission to the Planet Jupiter

Science Objectives:
• Origin
• Interior Structure
• Atmosphere Composition & Dynamics
• Polar Magnetosphere
The Juno spacecraft launched on Aug. 5, 2011.

Spacecraft dimensions:
- Diameter: 20 meters (66 feet)
- Height: 4.5 meters (15 feet)

Instrument Subsystems:
- GS: Gravity Science subsystem (JPL/ASI)
- MAG: Magnetometer (GSFC):
  - Fluxgate Magnetometer (GSFC)
  - Advanced Stellar Camera (DTU)
- MWR: Microwave Radiometer (JPL)
- JEDI: Juno Energetic Particle Detector (APL)
- JADE: Jovian Auroral Distributions Experiment (SwRI)
- WAVES: Radio & Plasma Wave Detector (U of Iowa)
- UVS: Ultraviolet Spectrometer (SwRI)
- JIRAM: Jovian Infrared Auroral Mapper
  (Italian Space Agency)
- JunoCam: Visible Camera for E/PO
  (Malin Space Science Systems)

Jupiter Orbit Insertion July 4
Orbital Trajectory

Sun-to-Jupiter View (Jupiter North Pole Up), 1-day Tick Marks for Capture Orbits and Pre-JOI Mission Phases: JOI, Capture Orbits, PRM, Orbits 2-3, Science Orbits, Deorbit

JOI burn was July 4, 8:18 – 8:53 PM PDT

Perijove: Aug 27
First 14 day orbit: Begins Nov 16

53.5-day Capture Orbits
Orbits 4-19
Orbits 20-35
14-day Science Orbits
Extra Orbit 36
Increasing Orbit #
Jupiter North Pole View, Sun Direction Fixed (yellow dashed line)
Juno’s Orbit

Baseline mission:
- 32 polar orbits
- Perijove ~5000 km
- 14 day orbit period
- 30 sec. spin period
NASA's Juno Spacecraft Closing in on Jupiter

JunoCam, imaged Jupiter on June 21, 2016, at a distance of 6.8 million miles (10.9 million kilometers) from the gas giant.
First Image Released After JOI

7/20/2016
First Orbit: Sample of the Juno Data
OSIRIS-REx

- Return and analyze a sample of Bennu’s surface
- Map the asteroid & document the sample site
- Measure the Yarkovsky effect

September 8, 2016
OSIRIS-REx Arrives at KSC
NASA's OSIRIS-REx spacecraft is revealed after its protective cover is removed inside the Payload Hazardous Servicing Facility at Kennedy Space Center in Florida, on May 21, 2016. The spacecraft traveled from Lockheed Martin's facility near Denver, Colorado to Kennedy to begin processing for its upcoming launch, targeted for Sept. 8 aboard a United Launch Alliance Atlas V rocket. After launch, OSIRIS-REx—which stands for Origins, Spectral Interpretation, Resource Identification, Security–Regolith Explorer—has an approximately two-year cruise to reach the asteroid Bennu in 2018. Upon arrival, OSIRIS-REx will spend a year flying in close proximity to Bennu, its five instruments imaging the asteroid, documenting its lumpy shape, and surveying its chemical and physical properties. In 2020, OSIRIS-REx will collect a pristine sample of at least two ounces of the asteroid's surface material that will be returned back to Earth in 2023 for analysis. Bennu is part of the debris left over from the formation of the solar system. It is pristine enough to hold clues to the solar system's origin and the source of water and organic molecules found on Earth.
Bennu as a Potentially Hazardous Object

- In 2135 Bennu will pass between the Earth and the Moon
- During that encounter it may go through a very small “keyhole” in which the Earth’s gravity will tweak Bennu’s orbit and potentially put it into an orbit hazardous to the Earth
- This potential hazard would then be in the period 2175 and 2199
- The currently calculated cumulative chance of Bennu impacting Earth in that time period is 1 in 2,700
- Investigations by the OISIRS-Rex project will increase our understanding of the orbit perturbations on Bennu
Evolution in Bennu’s Orbit

- Orbital motion
- Spin direction
- Solar radiation pressure
  - Thermal reradiation
  - YARKOVSKY EFFECT: When sunlight warms one face of a small, spinning asteroid more than the other, the reradiated heat from the warmer side creates a thrust that alters the asteroid’s trajectory, as well as a torque that changes the asteroid’s spin.
Next New Frontiers Program AO

- New Frontiers Program Community Announcements issued January 2016 and April 24, 2016
- Investigations are focused on the following mission themes (listed without priority):
  - Comet Surface Sample Return
  - Enceladus
  - Lunar South Pole-Aitken Basin Sample Return
  - Saturn Probe
  - Titan
  - Trojan Tour and Rendezvous
  - Venus In Situ Explorer
- Draft AO released August 8, 2016
Next New Frontiers AO Time Frame

Notional Schedule:

– Release of final AO.......................... January 2017 (target)
– Preproposal conference...................... ~3 weeks after final AO release
– Proposals due .................................. ~90 days after AO release
– Selection for competitive Phase A .... November 2017 (target)
– Concept study reports due............... October 2018 (target)
– Down-selection .................................. May 2019 (target)
– KDP B ............................................... August 2019 (target)
– Launch readiness date ....................... 2024
SIMPLEx Cubesats Selections
Full missions (2) and
Approved for 1 year Tech Development (3)
Small Innovative Missions for Planetary Exploration (SIMPLEEx-2014) – New Awards in FY15

Lunar Polar Hydrogen Mapper (LunaH-Map)
PI: Craig Hardgrove
ASU School of Earth and Space Exploration

CubeSat Particle Aggregation and Collision Experiment (Q-PACE)
PI: Josh Colwel
University of Central Florida
Simplex Cubesats

Approved for Tech Development (1 year) Study ONLY

Mars Micro Orbiter
PI: Michael Malin
Malin Space Science Systems

Diminutive Asteroid Visitor using Ion Drive (DAVID)
PI: Geoffrey Landis
NASA Glenn Research Center

Hydrogen Albedo Lunar Orbiter (HALO)
A Lunar Cubesat Mission For EM-1 - SIMPLEx 2014

Hydrogen Albedo Lunar Orbiter (HALO)
PI: Michael Collier,
NASA GSFC
NAS Report: Achieving Science Goals with CubeSats: Thinking Inside the Box

**Recommendation to PSD:** NASA should develop and maintain a variety of CubeSat programs with cost and risk postures appropriate for each science goal and relevant science division and justified by the anticipated science return. ... also important to allow CubeSats to be used for rapid responses to newly recognized needs and to realize the potential from recently developed technology.

**PSD Response:** 1) New R&A element supports the study of spaceflight mission concepts that can be accomplished using small spacecraft, including CubeSats. NASA’s Planetary Science Program is considering including small secondary payloads on every future planetary science launch. As such, studies performed under this program element will provide valuable information to assist future AO planning and NASA’s development of small spacecraft technologies relevant to deep space science investigations... 2) SIMPLEX-2 to be released soon.
Gondola for High Altitude Planetary Science (GHAPS)

A re-useable balloon platform to meet Planetary Science Decadal Survey and mission support goals – in development

- Designed for a minimum of 5 flights and mission durations up to 100 days
- Low cost refurbishment between flights
- First performance/science demo flight planned for Fort Sumner, NM - Fall 2019
- A competitive process will be used to select guest investigators for the first flight and Principal Investigators for subsequent flights

GHAPS Status – September 2016

- GHAPS Preliminary Design Review (PDR) planned for December 2016
- Optical Telescope Assembly PDR - Oct 31, 2016
- Science Instrument Definition Team report complete and in preparation for release
- Instrument Announcement of Opportunity being developed for release
• AIDA is a mission concept to test asteroid impact mitigation with a kinetic impact technique demonstration
• AIDA would be a joint US and European mission:
  – European asteroid rendezvous spacecraft, the Asteroid Impact Mission (AIM)
  – US kinetic impactor, the Double Asteroid Redirection Test (DART) mission
• NASA has agreed with ESA to enter parallel mission formulation concept studies
• DART is currently in Phase A
• The DART mission is planned to intercept the moonlet of the binary near-Earth asteroid 65803 Didymos in October, 2022

AIDA = AIM + DART
Research and Analysis Program
<table>
<thead>
<tr>
<th>Program Name</th>
<th>Step-1 Due Date</th>
<th>Step-2 Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exoplanets (XRP)</td>
<td>03/29/2016</td>
<td>05/26/2016</td>
</tr>
<tr>
<td>Emerging Worlds (EW)</td>
<td>03/31/2016</td>
<td>06/03/2016</td>
</tr>
<tr>
<td>Cassini Data Analysis (CDAPS)</td>
<td>04/06/2016</td>
<td>06/16/2016</td>
</tr>
<tr>
<td>Solar System Obs. (SSO)</td>
<td>04/08/2016</td>
<td>06/10/2016</td>
</tr>
<tr>
<td>MatISSE</td>
<td>04/21/2016</td>
<td>06/21/2016</td>
</tr>
<tr>
<td>Laboratory Analysis of Returned Sample (LARS)</td>
<td>04/22/2016</td>
<td>06/24/2016</td>
</tr>
<tr>
<td>Planetary Data Archiving, Resto, Tools (PDART)</td>
<td>05/13/2016</td>
<td>07/15/2016</td>
</tr>
<tr>
<td>Exobiology (EXOB)</td>
<td>05/20/2016</td>
<td>07/22/2016</td>
</tr>
<tr>
<td>Concepts for Ocean Worlds Life Detection Tech (COLDTech)</td>
<td>06/17/2016</td>
<td>08/12/2016</td>
</tr>
<tr>
<td>Planetary Protection Research (PPR)</td>
<td>06/24/2016</td>
<td>09/02/2016</td>
</tr>
<tr>
<td>Mars Data Analysis (MDAP)</td>
<td>08/26/2016</td>
<td>09/30/2016</td>
</tr>
<tr>
<td>Lunar Data Analysis (LDAP)</td>
<td>09/30/2016</td>
<td>10/28/2016</td>
</tr>
<tr>
<td>PICASSO</td>
<td>09/14/2016</td>
<td>11/14/2016</td>
</tr>
<tr>
<td>Discovery Data Analysis (DDAP)</td>
<td>09/08/2016</td>
<td>11/17/2016</td>
</tr>
<tr>
<td>Habitable Worlds (HW)</td>
<td>11/18/2016</td>
<td>01/20/2017</td>
</tr>
<tr>
<td>Solar System Workings (SSW)</td>
<td>11/17/2016</td>
<td>02/23/2017</td>
</tr>
</tbody>
</table>
A Selection Metric

Shown are proposals submitted to ROSES-2014, including all core programs (EW, SSW, HW, SSO, EXO) and all DAPs (MDAP, DDAP, LDAP, CDAPS).

Percentage of proposals with this score selected for funding.

Overall rate = 21%

Data assembled by Doris Daou.
The speed of money

Data and analysis provided by Jared Leisner.
Keyword Analysis

• Analysis of keyword distribution, 2011-2015 for categories:
  – Type of Task (keyword category 1)
  – Object(s) of Study (keyword category 2)
  – Science Discipline (keyword category 3)

• Analysis includes:
  – R&A awards, including NAI CAN awards
  – Data Analysis Programs
  – Participating Scientist and Guest Investigator Programs

• Analysis excludes:
  – Support activities
  – Facilities (e.g. RPIFs, AVGR, GEER, PAL, RELAB, ...)

• Caveats
  – If more than one keyword was used within any category, approved amount was equally divided between keywords
  – Return rate varied from year to year, portfolio to portfolio, and keyword category to keyword category
  – Keywords might have been used inconsistently between program officers
The chart illustrates the budget allocation for different types of tasks from FY2011 to FY2015. The categories include:

- Keywords not populated
- Theoretical/computational
- Support
- Sample analysis
- Purchase of Major Equipment
- None specified
- New observations
- Mission data analysis
- Instrument/Tech Development
- Field-based
- Experimental
- E/PO
- Archiving/Data Restoration

The chart shows the budget distribution for each fiscal year (FY) for these categories.
KEYWORD 2 - OUTER PLANETS BREAKOUT

- **FY2011**
  - Non-specific Rings: $9.8M
  - Non-specific Outer Planets: $12.6M
  - Non-specific Icy Bodies: $3.5M
- **FY2012**
  - Non-specific Rings: $20.5M
  - Non-specific Outer Planets: $15.2M
  - Non-specific Icy Bodies: $12.3M
- **FY2013**
  - Non-specific Rings: $12.0M
  - Non-specific Outer Planets: $25.4M
  - Non-specific Icy Bodies: $7.8M
- **FY2014**
  - Non-specific Rings: $13.4M
  - Non-specific Outer Planets: $14.6M
  - Non-specific Icy Bodies: $1.2M
- **FY2015**
  - Non-specific Rings: $15.9M
  - Non-specific Outer Planets: $15.9M
  - Non-specific Icy Bodies: $515K

- **Uranian System**
- **Neptunian System**
- **Saturnian System**
- **Jovian System**
KEYWORD 2 - SMALL BODIES BREAKOUT

FY2011: $6.4M
FY2012: $7.8M
FY2013: $7.3M
FY2014: $7.5M
FY2015: $8.5M

- Small Bodies
- KBOs/TNOs
- Meteorites
- Comets
- Asteroids
- Plutonian System
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Wind</td>
<td>$265K</td>
<td>$224K</td>
<td>$1.3M</td>
<td>$1.4M</td>
<td>$1.6M</td>
</tr>
<tr>
<td>Near Earth Objects</td>
<td>$13.1M</td>
<td>$11.3M</td>
<td>$8.5M</td>
<td>$6.7M</td>
<td>$14.3M</td>
</tr>
<tr>
<td>Protoplanetary Disks</td>
<td>$2.4M</td>
<td>$6.5M</td>
<td>$8.1M</td>
<td>$9.9M</td>
<td>$12.4M</td>
</tr>
<tr>
<td>Presolar Nebula</td>
<td>$355K</td>
<td>$3.1M</td>
<td>$2.2M</td>
<td>$7.9M</td>
<td>$14.3M</td>
</tr>
<tr>
<td>Potentially Hazardous Objs</td>
<td>$3.4M</td>
<td>$2.2M</td>
<td>$1.3M</td>
<td>$1.4M</td>
<td>$2.3M</td>
</tr>
<tr>
<td>Non-specific Planets</td>
<td>$2.4M</td>
<td>$8.1M</td>
<td>$9.9M</td>
<td>$12.4M</td>
<td>$18.3M</td>
</tr>
<tr>
<td>None specified</td>
<td>$1.3M</td>
<td>$1.3M</td>
<td>$1.3M</td>
<td>$1.4M</td>
<td>$1.6M</td>
</tr>
<tr>
<td>Interstellar Grains</td>
<td>$1.3M</td>
<td>$1.3M</td>
<td>$1.3M</td>
<td>$1.4M</td>
<td>$1.6M</td>
</tr>
<tr>
<td>Hypervelocity Impacts</td>
<td>$2.4M</td>
<td>$6.5M</td>
<td>$8.1M</td>
<td>$9.9M</td>
<td>$12.4M</td>
</tr>
<tr>
<td>Dust</td>
<td>$2.4M</td>
<td>$6.5M</td>
<td>$8.1M</td>
<td>$9.9M</td>
<td>$12.4M</td>
</tr>
</tbody>
</table>
NAS Studies for Planetary Science
Timeline of NAS Studies

- 1\textsuperscript{st} Planetary decadal: 2002-2012
- 2\textsuperscript{nd} Planetary decadal: 2013-2022
- Cubesat Review: Completed June 2016
- Extended Missions Review: Completed Sept 2016
- R&A Restructuring Review:
  - Tasked August 13, 2015
  - Report due to NASA December 2016
- Large Strategic NASA Science Missions
  - Tasked December 23, 2015
  - Report due to NASA August 2017
- Midterm evaluation:
  - Tasked August 26, 2016
  - Cubesats, EX Missions, R&A Restructuring & Large Strategic Missions will be input
  - Expect report due December 2017
- New Study: Sample Analysis Future Investment Strategy (to be submitted)
- 3\textsuperscript{rd} Planetary Decadal: 2023-2032
  - To be tasked \textit{before} October 2019
  - Expect report to NASA due 1\textsuperscript{st} quarter 2022
**Brief Sample Management Background**

- PSD has been investing in laboratory analysis instruments and techniques for several decades at a variety of institutions.
- Current sample curation and archive resides at JSC contains all extraterrestrial samples for the science community:
  - CAPTEM: Peer Review of sample requests for analysis.
- International science community with significant sample analysis capability includes:
  - Japan, Germany, and England.
- Entering an era of significant sample return missions:
  - Mars: Martian Moons eXplorer, Mars Sample Return.
  - Asteroids: Hayabusa 1&2, OSIRIS-REx.
  - Others to follow.
- Request NAS to provide recommendations for the analysis of current and future extraterrestrial samples that PSD can use to develop an investment strategy to take advantage of future sample acquisition opportunities & maximize science.
Sample Analysis Instrumentation Evolution
Statement of Task

The Committee will assess:

• What laboratory analytical capabilities are required to support PSD (and partner) analysis and curation of existing and future extraterrestrial samples?
  – Which of these capabilities currently exist, and where are they located (including international partner facilities)?
  – What existing capabilities are not currently accessible that are/will be needed?

• Whether the current sample laboratory support infrastructure and NASA’s investment strategy meets the analytical requirements in support of current and future decadal planetary missions.

• How can NASA ensure that the science community can stay abreast of evolving techniques and to be at the forefront of extraterrestrial sample analysis.

  Will submit task to the NAS before October 1st
FINDINGS from PSS June Virtual Meeting
Communications about Mars Sample Return and other Developments

• The Committee was encouraged to hear positive updates regarding ongoing trade studies of Mars sample retrieval architectures that included:

(1) the use of a stationary lander with precision landing;
(2) a fetch vehicle to gather cached samples from the Mars 2020 mission;
(3) the development of a small Mars Ascent Vehicle (MAV) with modest technology readiness level (TRL) risks for placing the samples in orbit;
(4) a next orbiter than can receive the samples;
(5) a potential ESA-collaboration mission to return the samples; and
(6) ongoing considerations regarding sample reception and management (including possible use of non-NASA facilities).

The rapid development of these engineering architectures will be spurred further by upcoming industry participation.
Communications about Mars Sample Return and other Developments

• Because these activities have implications for Mars 2020 sample caching and future analyses of returned samples from Mars (and potentially other bodies), the Committee encourages the PSD to provide:
  – frequent updates regarding the progress of these activities to the PSS; and
  – opportunities for dedicated science involvement (e.g., through the use of MEPAG and CAPTEM) in studies regarding sample issues such as encapsulation and preservation, sustainability during cruise, integrity during hard-landing returns to Earth, and optimizing expeditious distribution to sample scientists.
  – We extend this request for more frequent communication to other developments, such as the Europa lander mission.

• RESPONSE:
  – PSD agrees. Ref: Presentations by Mars and Europa Leads
PI-Led Laboratories

- PSS survey on support for PI-led laboratories revealed concern about the sustainability of laboratories that do critical work in support of the PSD mission...

- PSS is concerned that these pressures will steadily erode the ability of the US-based research community to meet PSD’s science objectives, particularly given the role of sample acquisition and retrieval in formulating mission science objectives and the increasing interest in analyses of returned samples. The PSS also recognizes that many respondents perceive the recent PSD R&A reorganization as a contributing factor in shifting support for laboratory research to other areas, and that this problem is part of a larger, emerging crisis in research infrastructure support that extends beyond PSD and beyond NASA.
PI-Led Laboratories

• The PSS encourages PSD to:
  a) discuss these concerns with counterparts in other NASA divisions and other federal science agencies to ascertain their extent and the need for NASA-wide or government-wide solutions, before our next meeting;
  b) create a committee to identify the specific laboratory capabilities critical to PSD that are at risk based on the survey responses, to suggest solutions that could be implemented within PSD to address these cases as well as future needs in the context of the Decadal Survey.

• RESPONSE:
  – New NAS Study: Sample Analysis Future Investment Strategy
Chartering of SMD Division Committees

NASA Science Mission Directorate
Chartering of Division Committees

• NASA is proposing that the NAC Science Committee’s four subcommittees associated with SMD divisions become stand-alone Federal Advisory Committee Act (FACA) committees.
  – Earth Science Subcommittee
  – Planetary Science Subcommittee
  – Astrophysics Subcommittee
  – Heliophysics Subcommittee

• Committees will advise the respective Division Director within SMD
  –Advice to be delivered and acted upon at the right organizational level
  – Many community-based studies (e.g., Senior Reviews, Science and Technology Definition Teams) will now have a chartered Federal advisory committee to report to

• Committees will have
  – Charters (rather than a Terms of Reference)
  – Membership balance plans

• Next steps
  – As of Sept 1, charters and membership balance plans are in review by the General Services Administration (GSA) Secretariat
  – Federal Register 15-day publication announcing the planned establishment of the new discretionary FACA advisory committees
  – Charters signed by the NASA Administrator
  – Filing with Congress
Example:
Astrophysics Advisory Committee

- Once chartered, this Astrophysics Subcommittee (APS) will be replaced by the Astrophysics Advisory Committee (APAC)
  - Will report to the Director of the Astrophysics Division
  - APAC Chair will continue to serve as a member of the NAC Science Committee

- Once the Astrophysics Advisory Committee is chartered, the Director of the Astrophysics Division will establish subordinate groups
  - Senior Reviews
  - Science and Technology Definition Teams (STDTs)/Science Definition Teams (SDTs)
  - Other
Questions?