Planetary Science Division And Mission Extensions

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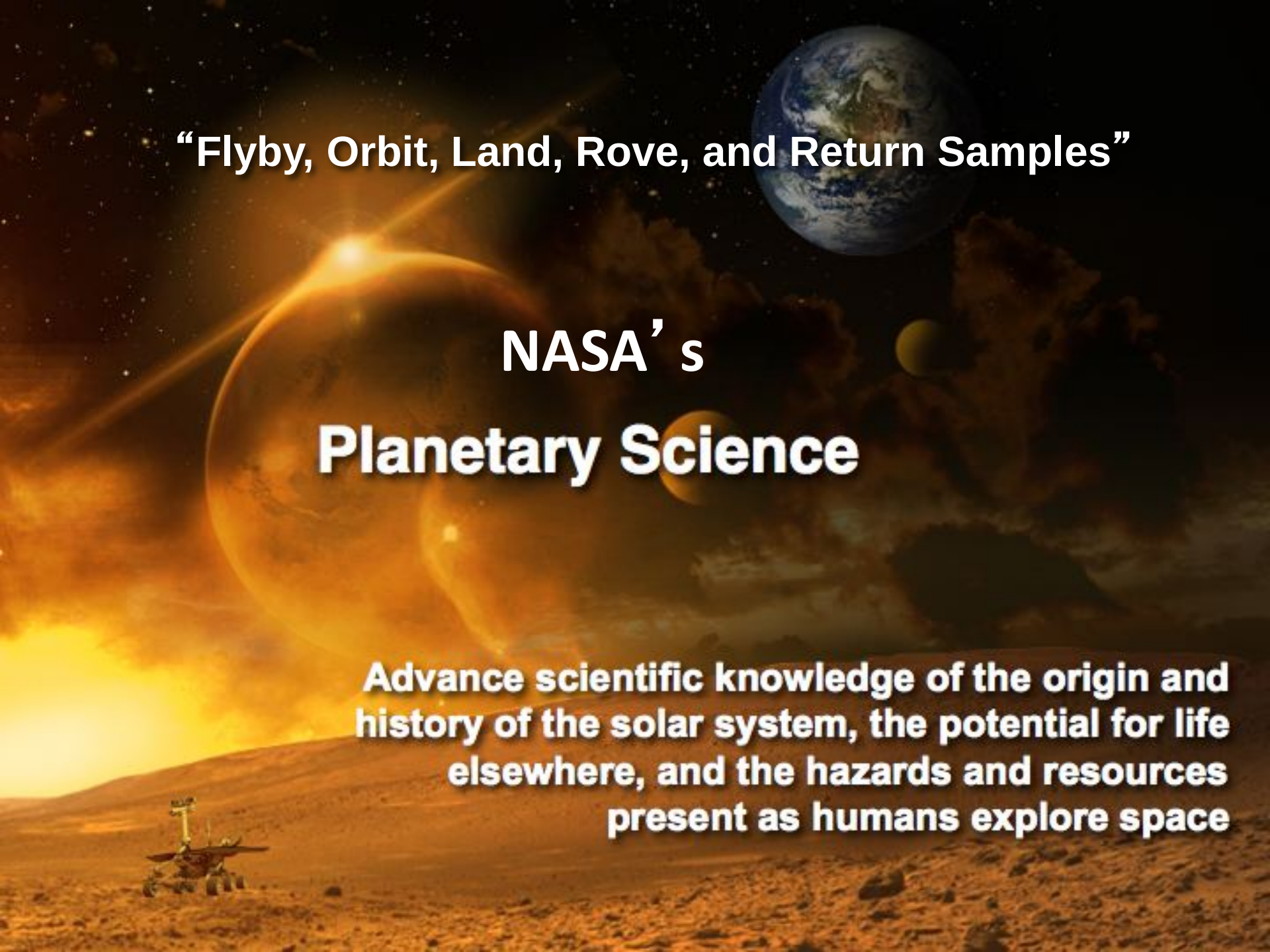
NASA, Planetary Science Division
February 1, 2016

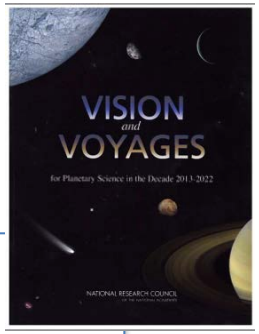
NRC Extended Mission Review

Outline

- Planetary Science Division Programs & Missions
- Purpose of a Senior Review and Budget
- Conducting Past Senior Reviews & Results
- Senior Review 2016
- Planetary Science Perspective: Lessons Learned


"Flyby, Orbit, Land, Rove, and Return Samples"
NASA's
Planetary Science
Advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space

Planetary Program Architecture
Recommended by the Planetary Decadal Survey



Large Missions ("Flagship"-scale) - Strategic

"Recommended Program" (budget increase for JEO new start)	*"Cost Constrained Program"* (based on FY11 Request)	*"Less favorable" budget picture than assumed* (e.g., outyears in FY12 request)
1) Mars Astrobiology Explorer-Cacher – descoped	1) Mars Astrobiology Explorer-Cacher – descoped	**Descope or delay Flagship mission**
2) Jupiter Europa Orbiter (JEO) – descoped	2) Uranus Orbiter & Probe (UOP)	
3) Uranus Orbiter & Probe (UOP)		
4/5) Enceladus Orbiter & Venus Climate Mission		

Discovery - PI

$500M (FY15) cap per mission (exclusive of launch vehicle) and 24 month cadence for selection

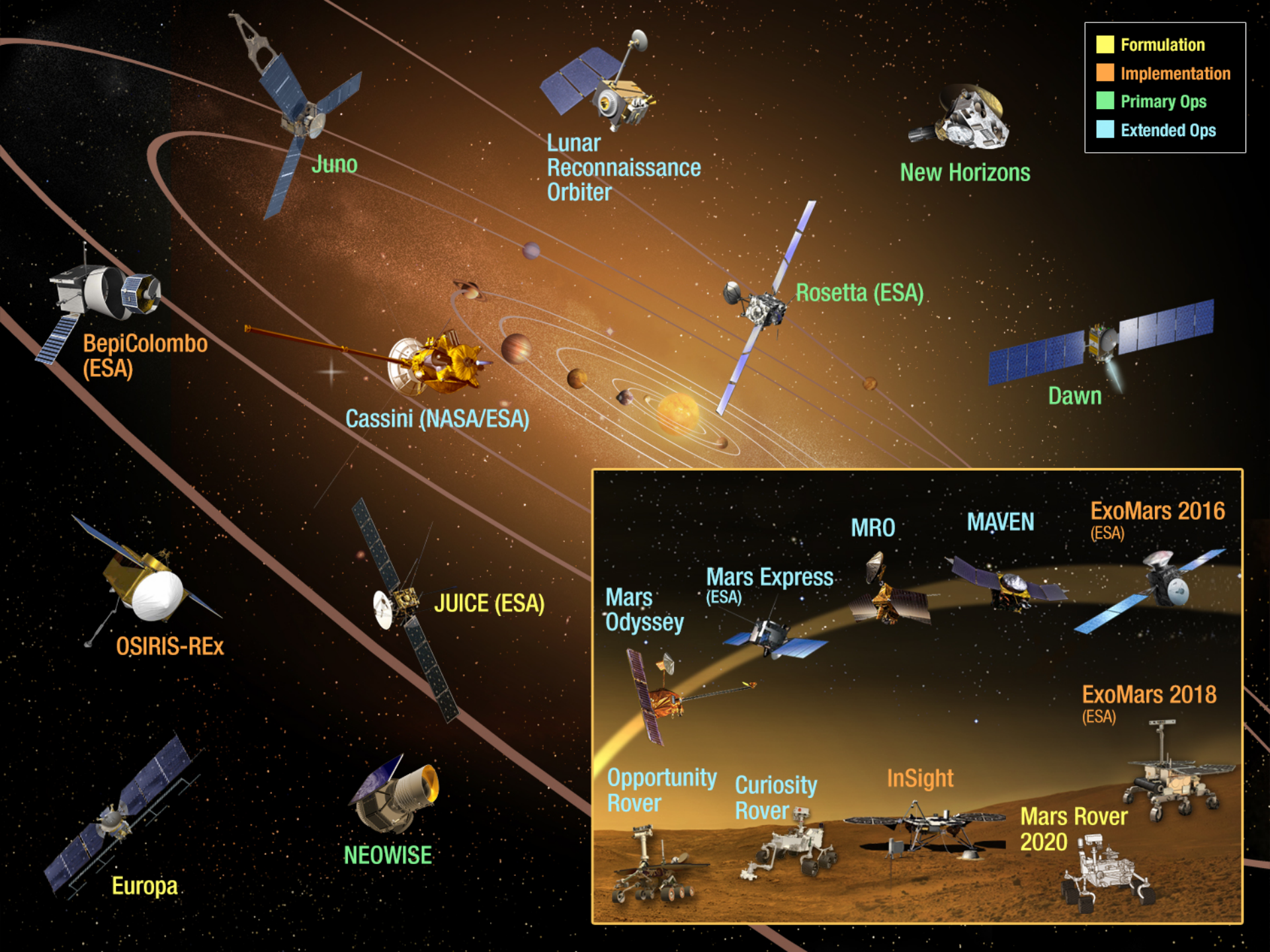
New Frontiers - PI

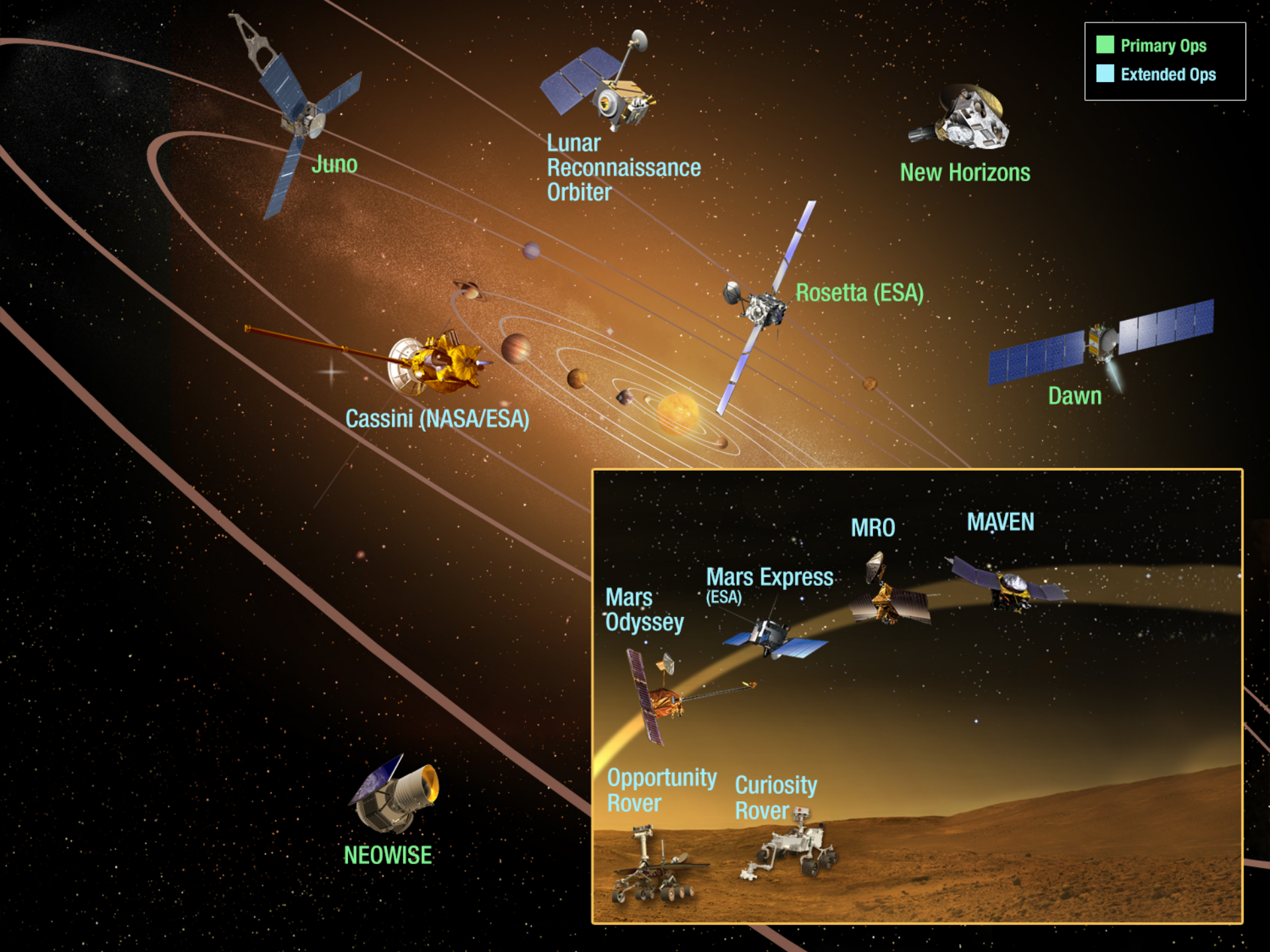
$1B (FY15) cap per mission (exclusive of launch vehicle) with two selections during 2013-22

Research & Analysis (5% above final FY11 amount then ~1.5%/yr)

Technology Development (6-8%)

Current Commitments (ie: Operating and Extended Missions)


Formulation
Implementation
Primary Ops
Extended Ops
Juno
Lunar Reconnaissance Orbiter
New Horizons
BepiColombo (ESA)
Cassini (NASA/ESA)
Rosetta (ESA)
Dawn
OSIRIS-REx
JUICE (ESA)
Europa
NEOWISE
MRO
MAVEN
ExoMars 2016 (ESA)
Mars Express (ESA)
Mars Odyssey
ExoMars 2018 (ESA)
Opportunity Rover
Curiosity Rover
InSight
Mars Rover 2020


Primary Ops
Extended Ops
Juno
Lunar Reconnaissance Orbiter
New Horizons
Rosetta (ESA)
Dawn
Cassini (NASA/ESA)
NEOWISE
MRO
MAVEN
Mars Express (ESA)
Mars Odyssey
Opportunity Rover
Curiosity Rover

Discovery and New Frontiers

- Address high-priority science objectives in solar system exploration
- Opportunities for the science community to propose full investigations
- Fixed-price cost cap full and open competition missions
- Principal Investigator-led project

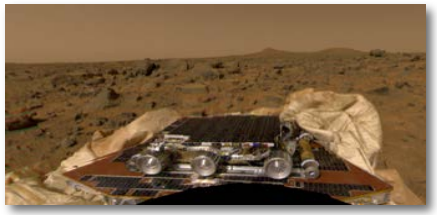
- Established in 1992
- **$450M cap** per mission excluding launch vehicle and operations phase (FY15$)
- Open science competition for all solar system objects, except for the Earth and Sun

- Established in 2003
- **$850M** cap per mission excluding launch vehicle and operations phase
- Addresses high-priority investigations identified by the National Academy of Sciences

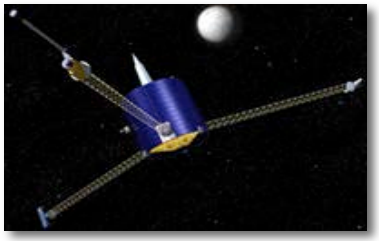
Discovery Program

Completed

Mars evolution:
Mars Pathfinder (1996-1997)

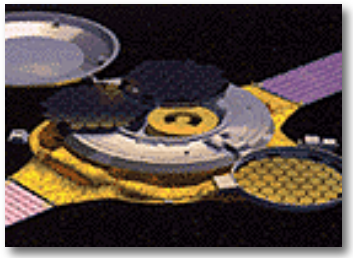


Lunar formation:
Lunar Prospector (1998-1999)



NEO characteristics:
NEAR (1996-1999)

Solar wind sampling:
Genesis (2001-2004)

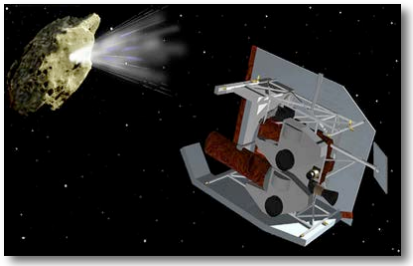


Completed

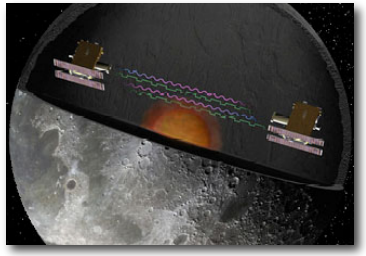
Comet diversity:
CONTOUR (2002)

Nature of dust/coma:
Stardust (1999-2011)

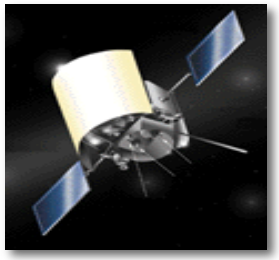
Comet internal structure:
Deep Impact (2005-2012)



Lunar Internal Structure
GRAIL (2011-2012)



Mercury environment:
MESSENGER (2004-*2015*)

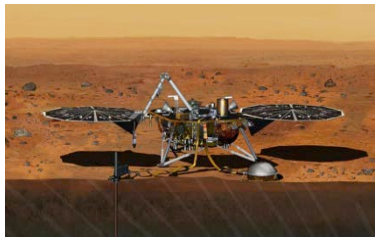


Main-belt asteroids:
Dawn (2007-*2016*)

Lunar surface:
LRO (2009-*TBD*)

ESA/Mercury Surface:
Strofio (*2017-TBD*)

Mars Interior:
InSight (*TBD*)



Status of Discovery Program

Discovery 2014 – Selections announced September 30

- About 3-year mission cadence for future opportunities

Missions in Development

- *InSight*: missed March 2016 launch window
- Strofio: Delivered to SERENA Suite (ASI) for BepiColombo

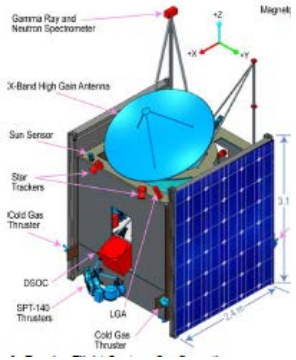
Missions in Operation

- *Dawn*: Science observations now in LAMO

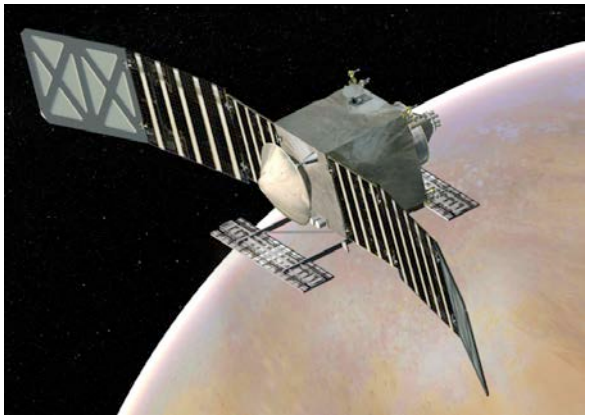
Missions in Extended Operations

- *MESSENGER*: Completed low altitude science operations before impact with Mercury
- *LRO*: In stable elliptical orbit, passing low over the lunar south pole

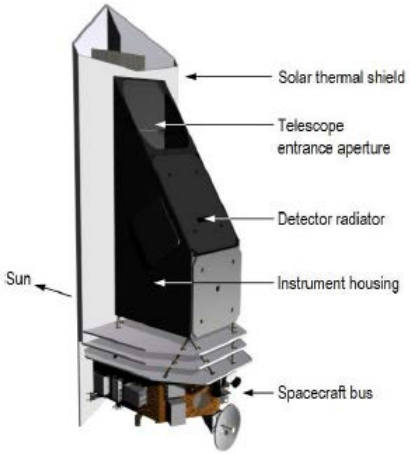
Discovery 2014 Selections



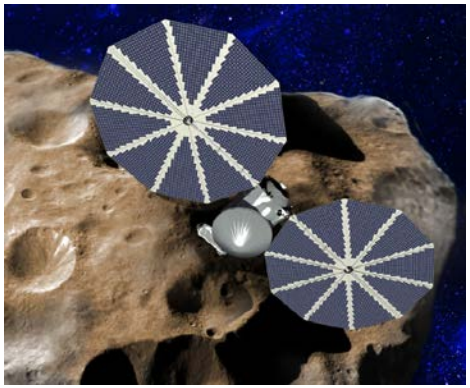
Psyche: Journey to a Metal World
PI: Linda Elkins-Tanton, ASU
Deep-Space Optical Comm (DSOC)



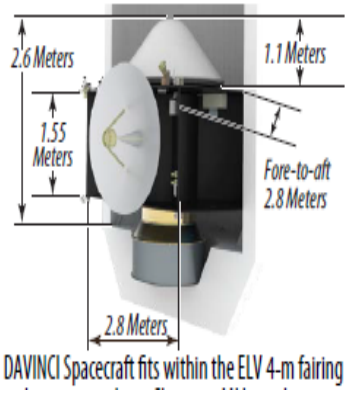
VERITAS: Venus Emissivity, Radio Science, InSAR, Topography, And Spectroscopy
PI: Suzanne Smrekar, JPL
Deep-Space Optical Comm (DSOC)



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)
Advanced Solar Arrays



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

New Frontiers Program

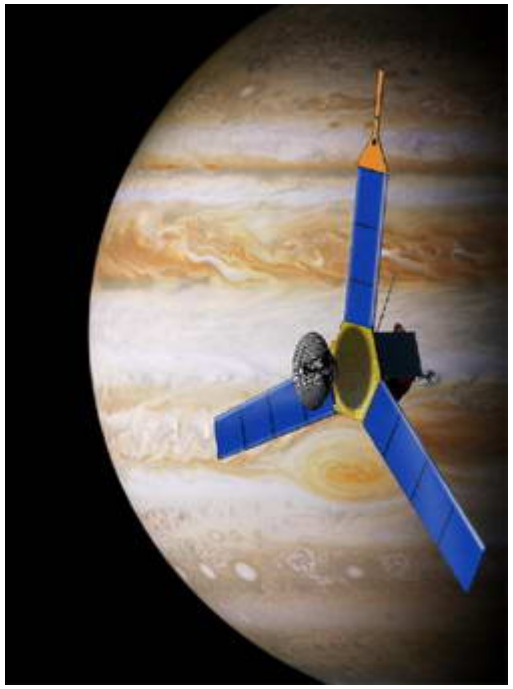
1st NF mission
New Horizons:

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
Arrives July 4, 2016
PI: Scott Bolton (SwRI-TX)

3rd NF mission
OSIRIS-REx:

Asteroid Sample Return

To be launched: Sept. 8, 2016
PI: Dante Lauretta (UA)

Status of New Frontiers Program (1/2)

Missions in Development – OSIRIS-REx

- Launch in Sept 2016 & encounter asteroid Bennu in Oct 2018.
- Operate at Bennu for over 400 days.
- Returns a sample in 2023 that scientists will study for decades with ever more capable instruments and techniques.

Missions in Operation

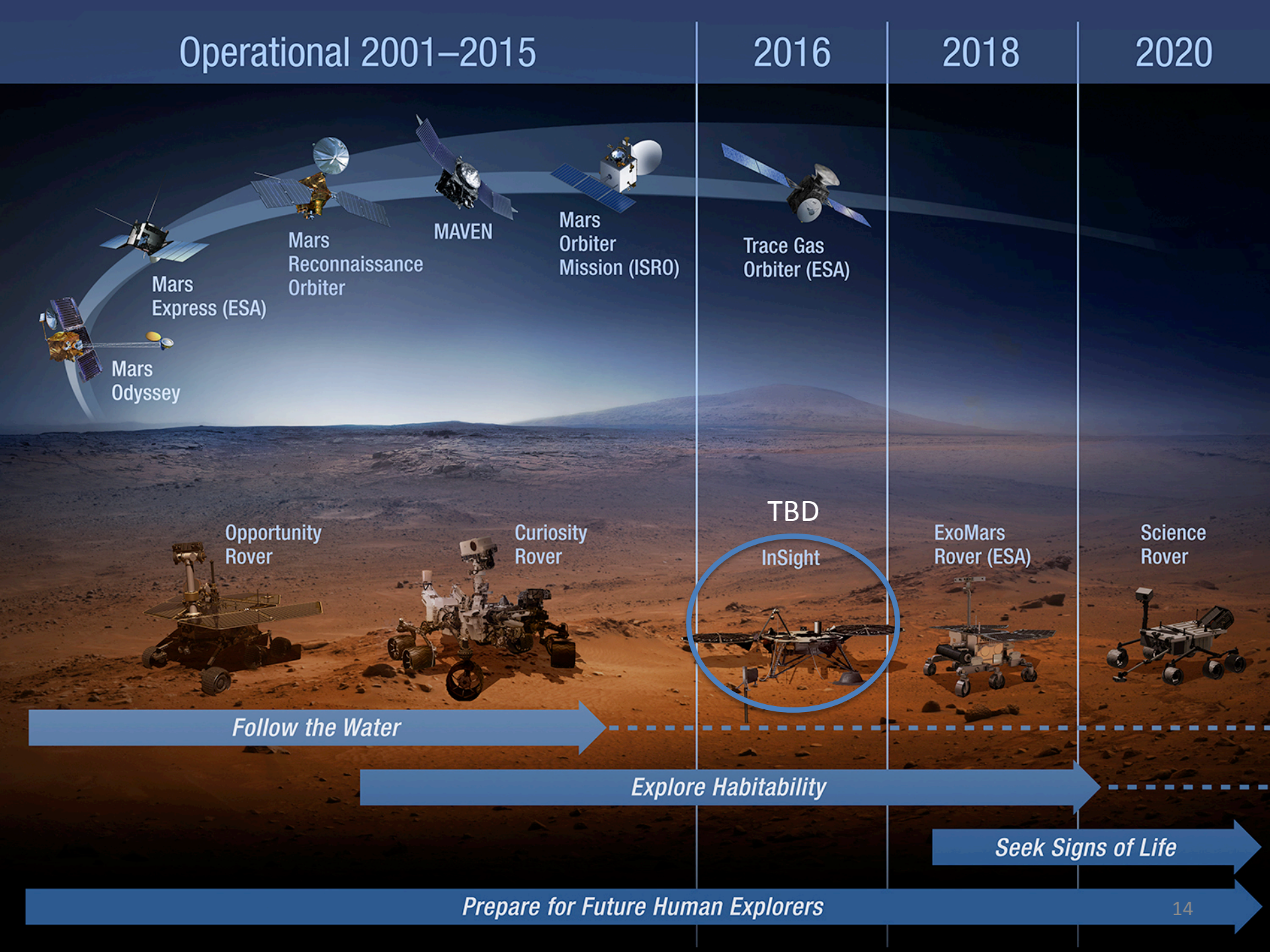
- New Horizons:
  - Pluto system encounter July 14, 2015
  - NH targeted to a small Kuiper Belt object 2014 MU69
  - Will be in the 2016 Senior Review
- Juno:
  - Spacecraft is ~54 million miles from Jupiter
  - Orbit insertion is July 4, 2016

Status of New Frontiers Program (2/2)

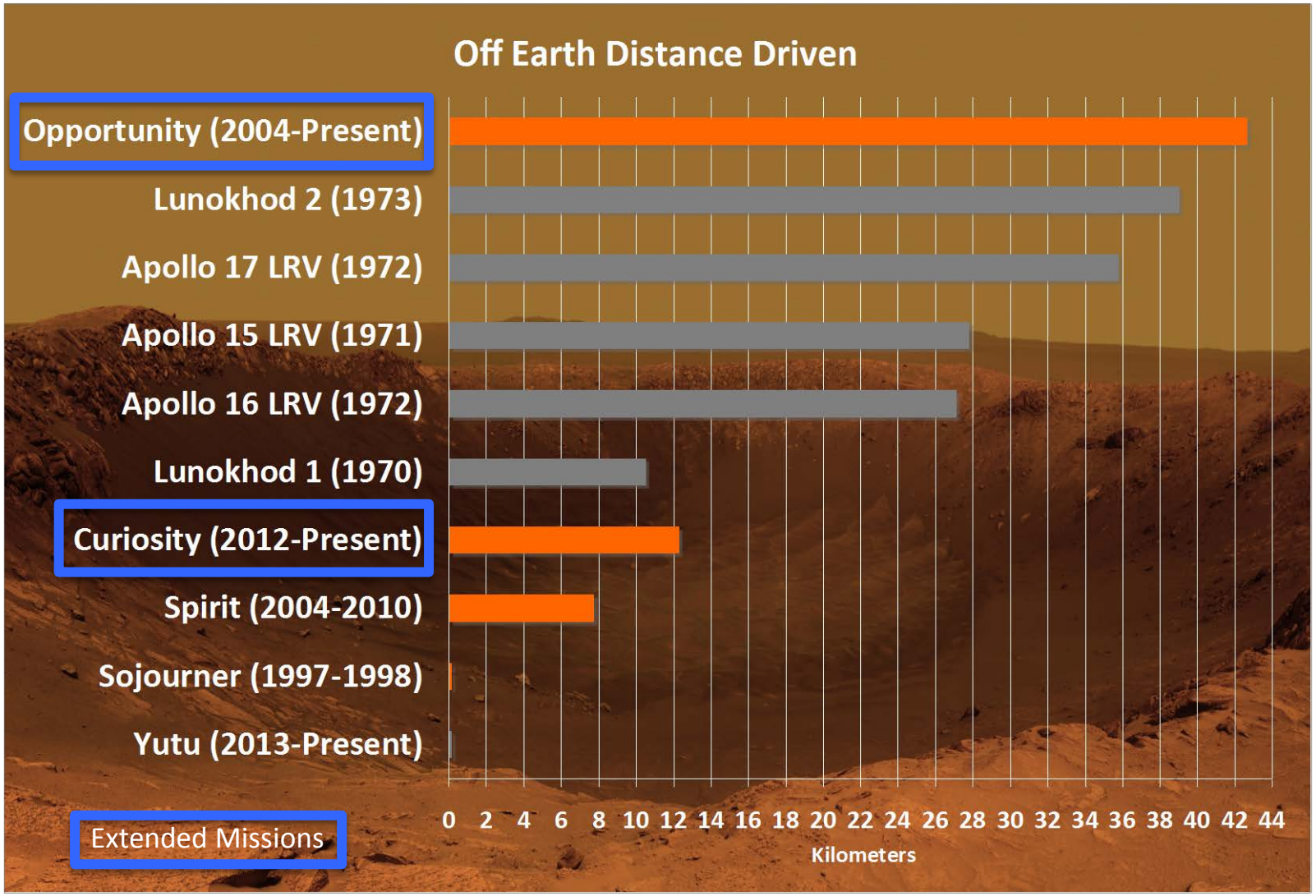
Next New Frontiers AO

- Draft to be released by end of Fiscal Year 2016
- Community Announcement Regarding New Frontiers Program Jan. 2016
- Investigations are limited to the following mission(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.

Five themes are described in the Planetary Science Decadal Survey. The Ocean Worlds theme for this announcement is tentatively focused on the search for signs of extant life and/or characterizing the potential habitability of Titan or Enceladus. The draft AO will fully elucidate information on the mission themes.


Operational 2001–2015
2016
2018
2020
Mars Odyssey
Mars Express (ESA)
Mars Reconnaissance Orbiter
MAVEN
Mars Orbiter Mission (ISRO)
Trace Gas Orbiter (ESA)
Opportunity Rover
Curiosity Rover
TBD
InSight
ExoMars Rover (ESA)
Science Rover
Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers

Off-Earth Odometry Records



January 2016

Purpose of a Senior Review

- All missions are executed with planned budget through their prime operations
  - Necessary to complete their Level 1 requirements
- For missions that have completed their prime that are healthy and can continue to be scientifically productive a Senior Review is required by law
  - Follow up on unexpected discoveries
  - Use remaining fuel to obtain an important new view
  - Provide important correlative measurements with other missions
- Decision for extended missions requires:
  1. Favorable Senior Review – addresses decadal survey objectives and builds on new discoveries
  2. Programmatic Decisions include: Available budget, role in providing support for other missions, international commitments
  3. Any Congressional Direction

PY15 budgets by Division and Category

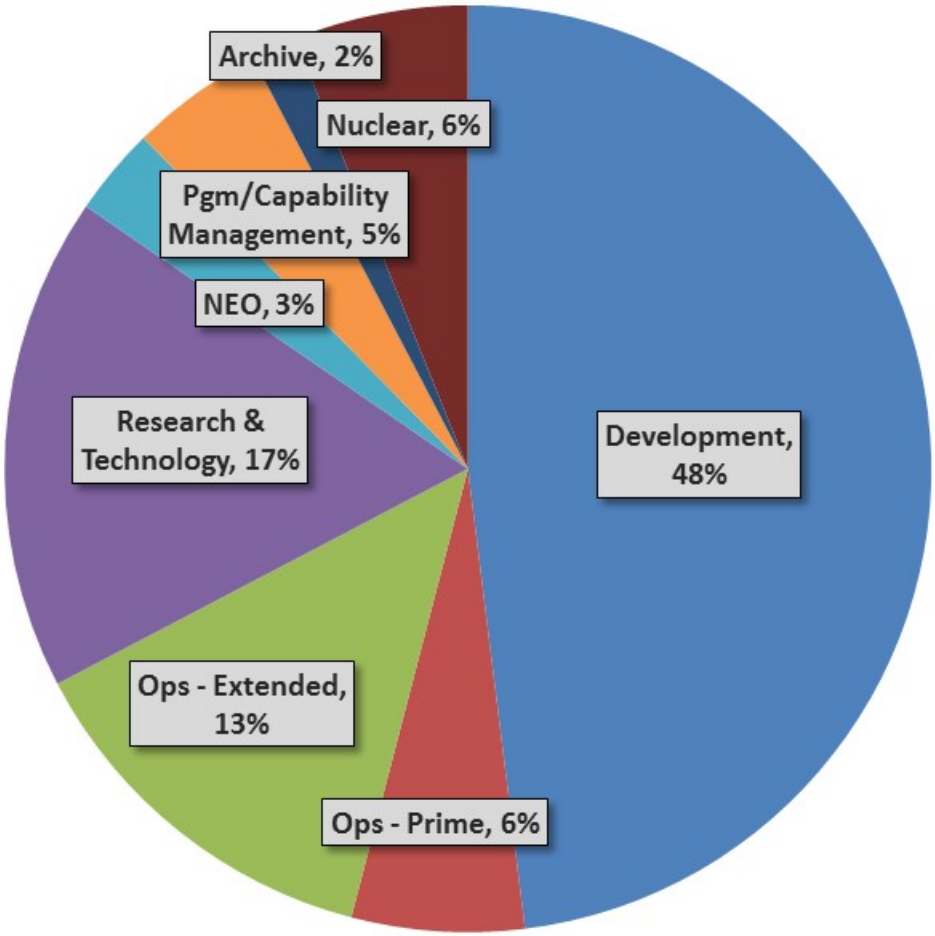
PY15 Budgets by Division and Category ($M)

Category	Earth	Planetary	Astro/JW	Helio	Admin *	Total
Form/Dev	677.8	654.1	806.0	289.5		2427.4
Prime	110.6	95.7	70.0	52.4		328.7
Extended	116.0	221.3	218.2	80.2		635.7
Data/Computing	222.6	23.6	18.6	16.4		281.3
SR&T/Suborb	530.5	406.6	169.6	136.9		1243.7
Mgmt/Other	71.4	45.4	36.6	53.9	118.8	326.2
Total	1729.1	1446.7	1319.1	629.4	118.8	5243.0

Percentages of budget, by category

Category	Earth	Planetary	Astro/JW	Helio	Admin *	Total
Form/Dev	39%	45%	61%	46%		46%
Prime	6%	7%	5%	8%		6%
Extended	7%	15%	17%	13%		12%
Data/Computing	13%	2%	1%	3%		5%
SR&T/Suborb	31%	28%	13%	22%		24%
Mgmt/Other	4%	3%	3%	9%	100%	6%
Total	100%	100%	100%	100%	100%	100%

FY16 Planetary Science Budget Fractions



FY16 Budget	1628M	100%
Development	782M	48%
Ops - Prime	98M	6%
Ops - Extended	216M	13%
Research & Technology	281M	17%
NEO	50M	3%
Pgm/Capability Management	76M	5%
Archive	26M	2%
Nuclear	99M	6%

Previous Senior Reviews

Planetary Mission Senior Review (PMSR)

2012 Review	2014 Review
Cassini	Cassini
	Curiosity
Lunar Reconnaissance Orbiter	Lunar Reconnaissance Orbiter
Mars Odyssey	Mars Odyssey
Mars Express	Mars Express
Mars Reconnaissance Orbiter	Mars Reconnaissance Orbiter
Opportunity	Opportunity

Mission Transition from Prime to Extended

- Planetary missions require time to get to their destination, only then can they make their observations to complete Level 1 requirements and to develop new science objective that are uncovered during their prime
- MAVEN & Dawn would complete their prime mission during the review period (FY15-16), at the time of the review, they had not arrived at their primary targets and had not started making measurements to satisfy their Level 1 requirements
    - MAVEN orbit insertion at Mars was in Sept 19, 2014
    - Dawn orbit insertion at Ceres was March 6, 2015
- Therefore, MAVEN and Dawn were excluded from the PMSR 2014 review process
- PSD requested a 3 years proposal instead of 2 from Cassini to account for the “Grand Finale” rather than asking them to write a one year SR proposal in FY16

Senior Review 2014
Implementation & Results

PMSR 2014 Report Contents

- Science Merit Evaluation and Rationale
  - Adjectival rating
  - Strengths & Weaknesses
- Criterion: Science Merit
  - Extent to which the proposed extended mission addresses PSD objectives as described in the Decadal Survey 2013-2022
  - Potential for ground-breaking science
  - Scientific significance, productivity, and uniqueness of investigation(s)
  - Opportunities for new investigators
  - Availability and usability of the data in PDS (including past performance, if any)
  - Extent to which the science community, beyond the mission science team, uses past mission data and conduct research (if applicable)
  - Capability of instruments and spacecraft to collect the proposed data
  - Effect on science by any significant degradation in instrument & spacecraft performance

PMSR 2014 Adjectival Grading

Excellent

- A comprehensive, thorough, and compelling proposal of exceptional science/technical merit as documented by numerous or significant strengths and having no major weaknesses.

Very Good

- A fully competent proposal of very high science/technical merit whose strengths fully outbalance any weaknesses.

Good

- A competent proposal having neither significant science/technical strengths nor weaknesses, or, whose science/technical strengths and weaknesses essentially balance.

Fair

- A proposal whose science/technical weaknesses outweigh any perceived strengths.

Poor

- A seriously flawed proposal having one or more major science/technical weaknesses and no offsetting strengths.

PMSR 2014 Schedule

The PMSR 2014 followed the format and process used for the PMSR 2012

- January 1: Draft guideline narrative released to flight projects for comments
- February 14: Comments received
- February 21: Final guideline released including budget targets
- April 11: Proposals submitted
- May: Review panel
- July: Results announced through a direction letter in time for developing projected budgets for the 5 year run out

PMSR 2014 Budget Guidelines

- PSD budget decline required extensive budget vs science trade offs to be made
- Three science budget scenarios were requested:
  - An In-guide budget
  - A multi-tiered de-scope budget (what science do we lose)
    - Flight Projects directed to de-scope until they hit a science floor for which there would be no value to continue science operations
  - An over-guide science budget was also allowed
- Identify budget for operating Mars orbiters as a relay that must be maintained

PMSR 2014 Review Panel

- Panelists selected from the Planetary Science Community based on their expertise in Lunar, Mars, and Outer Planets science related disciplines
- Several scientists also provided external reviews as non-voting members
- Two sessions: One for Cassini/LRO, one for Mars then a joint session (for ranking)
- The panel met prior to review via several telecons to discuss each Project proposal and to generate questions for the Projects.
- These questions formed the basis of the Project presentations to the PMSR Panel during the face-to-face meeting

PMSR 2014 Face-to-Face Review

- Each Flight Project was given two hours to present their response to the Panel's written questions (and ad-hoc questions asked in real-time during the review)
- The Panel broke into an Executive Session after each Flight Project presentation to discuss the proposal/presentation, conduct an initial grading of science merit, and generate any additional questions for the Flight Project
- Each Flight Project was then brought back into the meeting room and presented with the additional questions, which were either answered then or on the following day
- When satisfied with the answers to the questions, the Flight Projects were excused
- While performing the individual Flight Project evaluations, the Panel conducted additional votes as they deemed necessary to comment on over-guide or de-scope options
- PMSR Chair briefed PSD Management on June 25 via telecon.
- PMSR Panel Final report was submitted to PSD on July 18, 2014

PMSR 2014 Panel Results

- Panel Report: “The science value (or science per dollar) of the extended missions exceeds the science gain from any planned mission, and all have important strengths. That is, they all represent added value to the Planetary Science Division and the American taxpayer because they are essentially new missions without the development and launch costs.”
- Panel voted on Guideline proposal plus an alternate mission content covering over-guide or de-scope options as the panel found appropriate.

Mission	Guideline Proposal	Alternate
	Rating	Rating
Cassini	E	
LRO	VG/G	E/VG
Opportunity	E/VG	
MRO	E/VG	
MEX	G/F	VG
ODY	VG/G	VG
Curiosity	VG/G	VG/G

Senior Review 2016

Using the New SMD Extended Missions Procedure

PSD Senior Review Schedule: Approved

Discovery/NF/Outer Planets	2016	2017	2018	2019	2020	2021	2022
InSight (TBR)	Cruise	Prime	Prime	2018 PMSR		2020 PMSR	
OSIRIS-REx	Pre-Launch	Cruise	Cruise	Cruise	Prime	Prime	Prime
Bepi Columbo	Pre-Launch	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise
New Horizons	Prime	2016 PMSR				2020 PMSR	
Cassini	2014 PMSR						
Juno	Cruise	Prime	Special Review				
Dawn	Prime	Special Review					
Lunar Reconnaissance Orbiter	2014 PMSR	2016 PMSR		2018 PMSR		2020 PMSR	

Mars Exploration	2016	2017	2018	2019	2020	2021	2022
ExoMars Rover	Pre-Launch	Pre-Launch	Cruise	Prime	Special Review	2020 PMSR	
Mars Express	2014 PMSR	2016 PMSR		2018 PMSR		2020 PMSR	
Mars Reconnaissance Orbiter	2014 PMSR	2016 PMSR		2018 PMSR		2020 PMSR	
Opportunity	2014 PMSR	2016 PMSR		2018 PMSR		2020 PMSR	
Odyssey	2014 PMSR	2016 PMSR		2018 PMSR		2020 PMSR	
Curiosity	2014 PMSR	2016 PMSR		2018 PMSR		2020 PMSR	
MAVEN	Special Review	2016 PMSR		2018 PMSR		2020 PMSR	

- PSD has requested that the NH proposal encompass the flyby of 2014 MU69 in 2019
- Juno's lifetime is largely dependent on the Jovian radiation belt effects (unknown)
- Dawn may not have enough fuel to make it into FY2017 therefore a SR proposal is not needed
- ExoMars is an ESA technology demonstration mission
- MAVEN's special review is completed, aligning it with the others in the PMSR 2016

Senior Review 2016

PMSR Plan approved by SMD AA in accordance with SMD Handbook guidance

Eight missions subject to Review:

- NH, LRO, MEX, MRO, MER, ODY, MSL, MAVEN
- Two panels (Mars, Solar System Exploration)

Exempt from 2016 Review:

- Cassini approved to the end of its mission (FY17)
- Dawn (completing in FY17)
- Pre-launch or prime (Insight, Juno, ExoMars)

Senior Review 2016

Largely Unchanged since 2014 PMSR

- Evaluation criteria
- Overguide/guideline/"peel-the-onion" de-scope options
- Panel structure

PI Transition Option - *new*

- Current mission PIs are encouraged to mentor mission/instrument scientists for future eligibility as mission PI, or to initiate a transition to a new PI during this mission extension

Schedule for 2016 PMSR

• Draft Call for Proposals issued:	November 24, 2015
• Comments due from Project Offices:	December 15, 2015
• Distribution of Final Guidelines:	January 15, 2016
• Final Proposal Submissions to NRESS:	April 15, 2016
• Questions from Panel to Project Offices:	2 weeks prior to Face-to-Face
• Face to Face visit / oral presentation:	TBD, May 2016
• Senior Review Report submitted to PSD:	TBD, May 2016
• NASA response/direction to Projects:	TBD, June 2016

Lessons Learned

Planetary Science Perspective (1/2)

- NRC: What is your perspective on the current senior review processes – for example, what works, what doesn't, is the cadence of senior reviews close to optimal, what might be improved, etc.?

- Planetary Missions have significant differences from other discipline missions
  - PSD position: a mission should not be asked to be in a SR without having adequate time to complete its prime mission
  - "Special Reviews" are needed to align future SRs to the required two year boundary
  - Some planetary missions have a limited life (<< 2 yrs) beyond their prime mission – Do we ask them for a full up SR proposal? – No!
  - Some planetary missions require time to get into position that extends through the 2 year SR boundaries (ex: NH take nearly 3.5 years to get to the new KBO) - Do we put them through multiple SRs? – No!

Planetary Science Perspective (2/2)

- NRC: Are there general principles and innovative ideas that can be applied to reduce costs and increase the science cost-effectiveness of extended missions? How do you assess the potential for increased risk associated with such approaches?
- Planetary Missions have significant differences from other discipline missions making them hard to reduce cost based on some formula
  - Cassini has no scan platform (complex operations)
  - MERS (90 day missions extended 10 yrs+)
  - Light travel time (4 -22mins) to Mars makes rover driving challenging
  - PSD has held “engineering reviews” designed to see how operations can be streamlined and costs reduced prior to SR