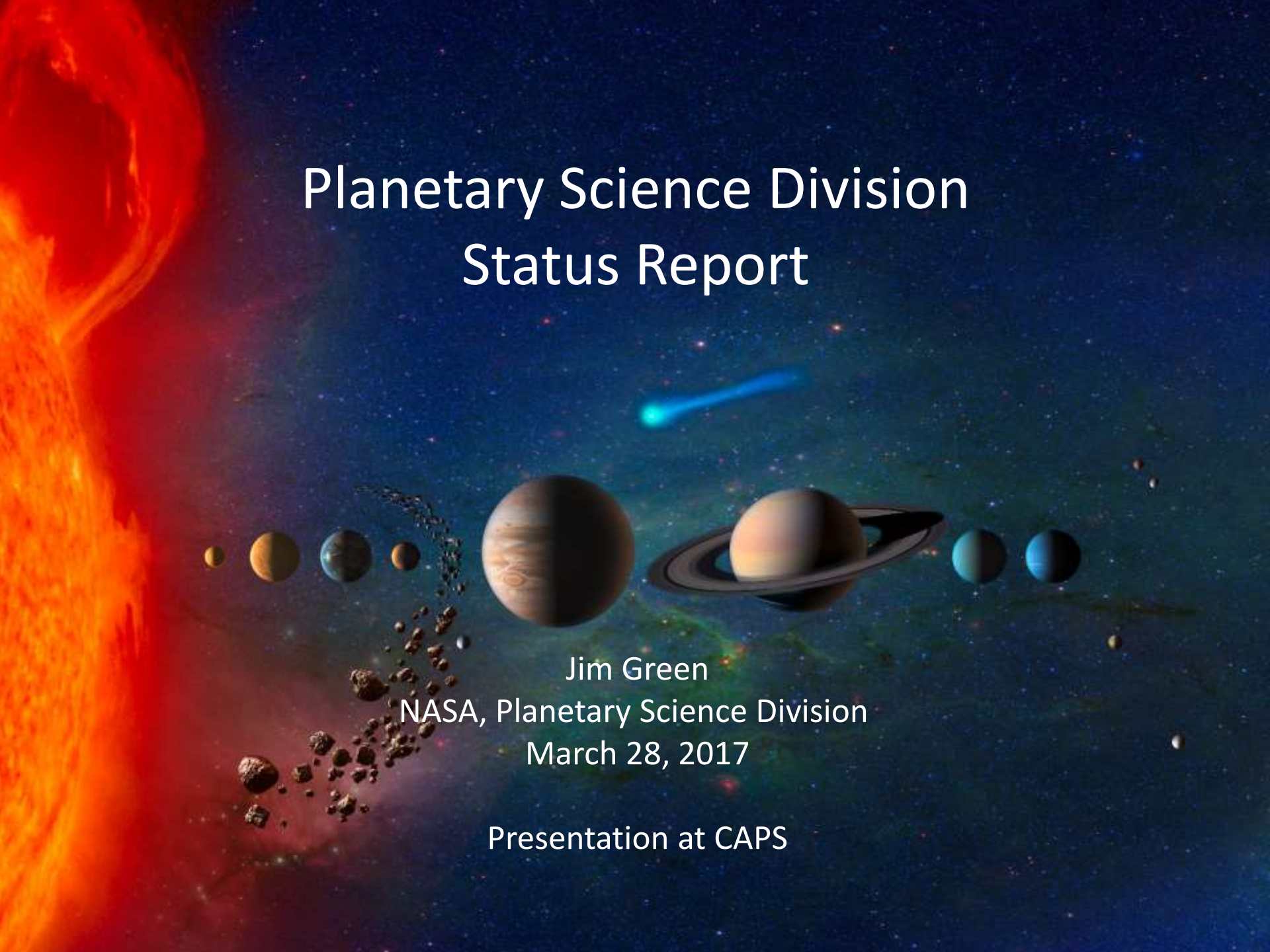
Planetary Science Division Status Report



Jim Green
NASA, Planetary Science Division
March 28, 2017

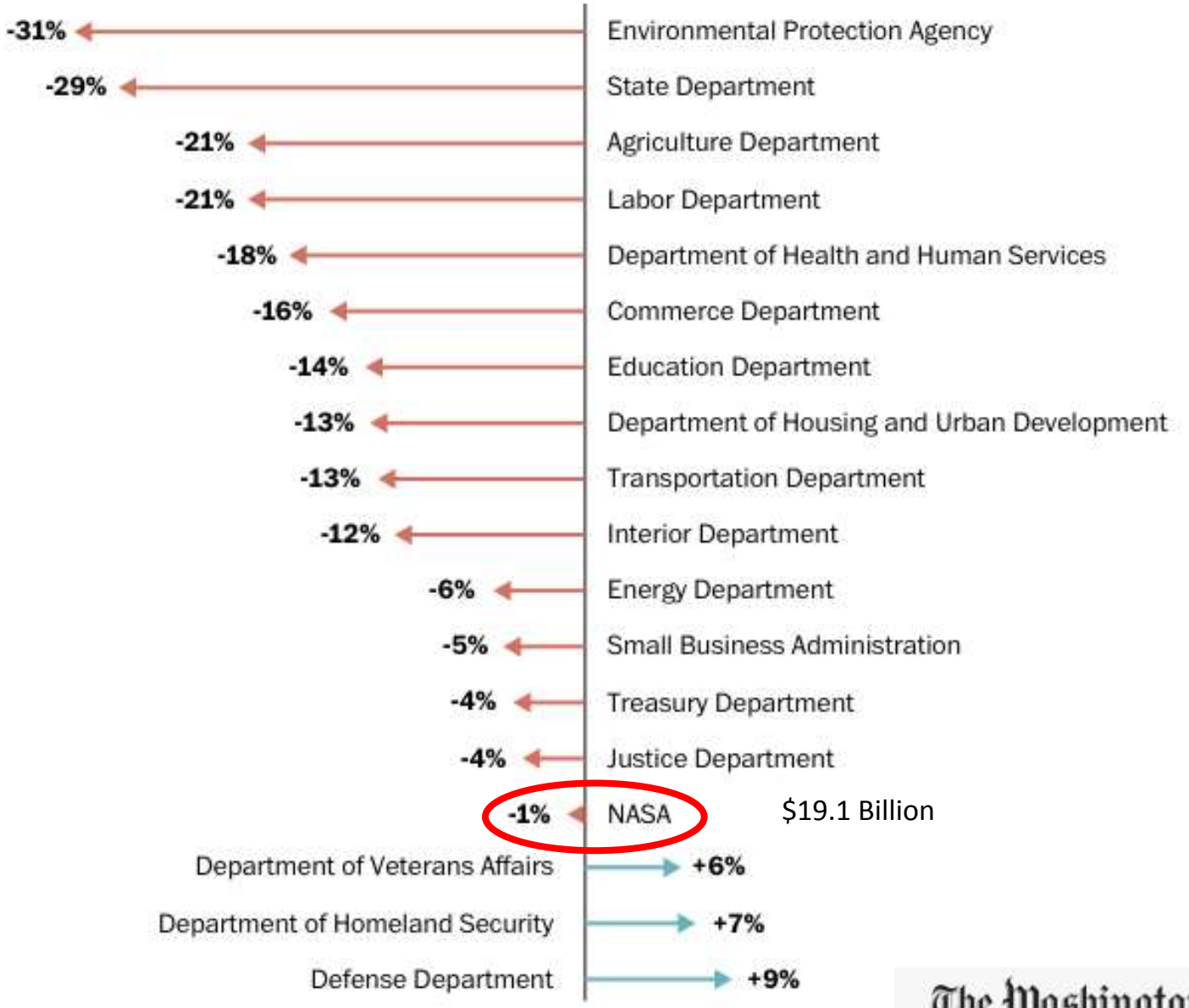
Presentation at CAPS

Outline

- President's FY18 Budget Blueprint
- Mission Events Overview
- 2016 Senior Review Results
- Discovery, New Frontiers, Mars Program, Outer Planets Missions
- Research and Analysis Program
- Mission Studies: Getting ready for the next Decadal

President’s FY18 Budget Blueprint

President's FY18 Budget Blueprint



$19.1 Billion

The Washington Post

FY18 Budget Blueprint

- **Human exploration:** $3.7 billion for continued development of the Space Launch System that will power astronauts into deep space and the Orion capsule that will carry them safely to Martian orbit.
- **Commercial activities:** Creates new opportunities for collaboration with industry.
- **Planetary science:** $1.9 billion to move ahead with the launch of a Mars rover by 2020 and the launch of the Clipper spacecraft to orbit around Jupiter in order to perform a detailed investigation of the giant planet's moon Europa.
- **Earth science:** $1.8 billion; terminates four Earth science missions (PACE, OCO-3, DSCOVR Earth-viewing instruments, and CLARREO Pathfinder) and reduces funding for Earth science research grants.
- **Aeronautics:** $624 million for research and development for faster and safer supersonic flights.
- **Education:** Eliminates the NASA Office of Education – This is the Education Office NOT our SMD Education Activities
- Further budget details are expected to be released in May
- Continuing Resolution goes until April 28th

Planetary Science Missions Events

2016

March – Launch of ESA's *ExoMars Trace Gas Orbiter*

July 4 – *Juno* inserted in Jupiter orbit

September 8 – Launch of Asteroid mission *OSIRIS – REx* to asteroid Bennu

September 30 – Landing *Rosetta* on comet CG

October 19 – *ExoMars EDM* landing and *TGO* orbit insertion

*** Completed**

2017

January 4 – Discovery Mission selection announced

February 9-20 - *OSIRIS-REx* began Earth-Trojan search

April 22 – *Cassini* begins plane change maneuver for the "Grand Finale"

September 15 – *Cassini* crashes into Saturn – end of mission

September 22 – *OSIRIS-REx* Earth flyby

2018

May 5 - Launch *InSight* mission to Mars

August – *OSIRIS-REx* arrival at Bennu

October – Launch of ESA's *BepiColombo*

November 26 – *InSight* landing on Mars

2019

January 1 – *New Horizons* flyby of Kuiper Belt object 2014MU69

Results of the 2016 Planetary Mission Senior Review (PMSR)

Senior Review Summary

- Top Recommendation: “The Panel unanimously believes that all (missions) should be approved for extension.”

MISSION	Panel Rating
Mars Reconnaissance Orbiter (MRO)	EXCELLENT
New Horizons	EXCELLENT
Lunar Reconnaissance Orbiter (LRO)	EXCELLENT/Very Good
Mars Atmosphere & Volatile EvolutioN (MAVEN)	EXCELLENT/Very Good
Opportunity/Mars Exploration Rover	EXCELLENT/Very Good
Curiosity/Mars Science Laboratory	Very Good
DAWN - Ceres	Very Good/Good
Odyssey	Very Good/Good
Mars Express (MEx)	Good

All 9 missions have been directed to plan for continued operations through FY18 (NH through 2021), subject to availability of appropriated funds and the outcome of the annual budget process

Discovery Program

Discovery Program

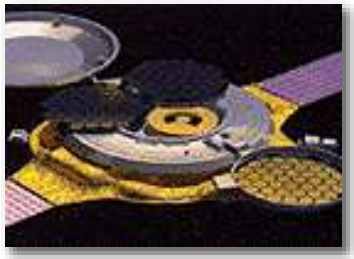
Completed

Mars evolution:
Mars Pathfinder (1996-1997)

Lunar formation:
Lunar Prospector (1998-1999)

NEO characteristics:
NEAR (1996-1999)

Solar wind sampling:
Genesis (2001-2004)

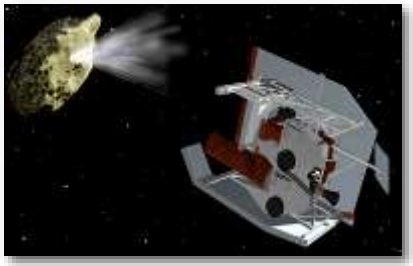


Completed

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*)

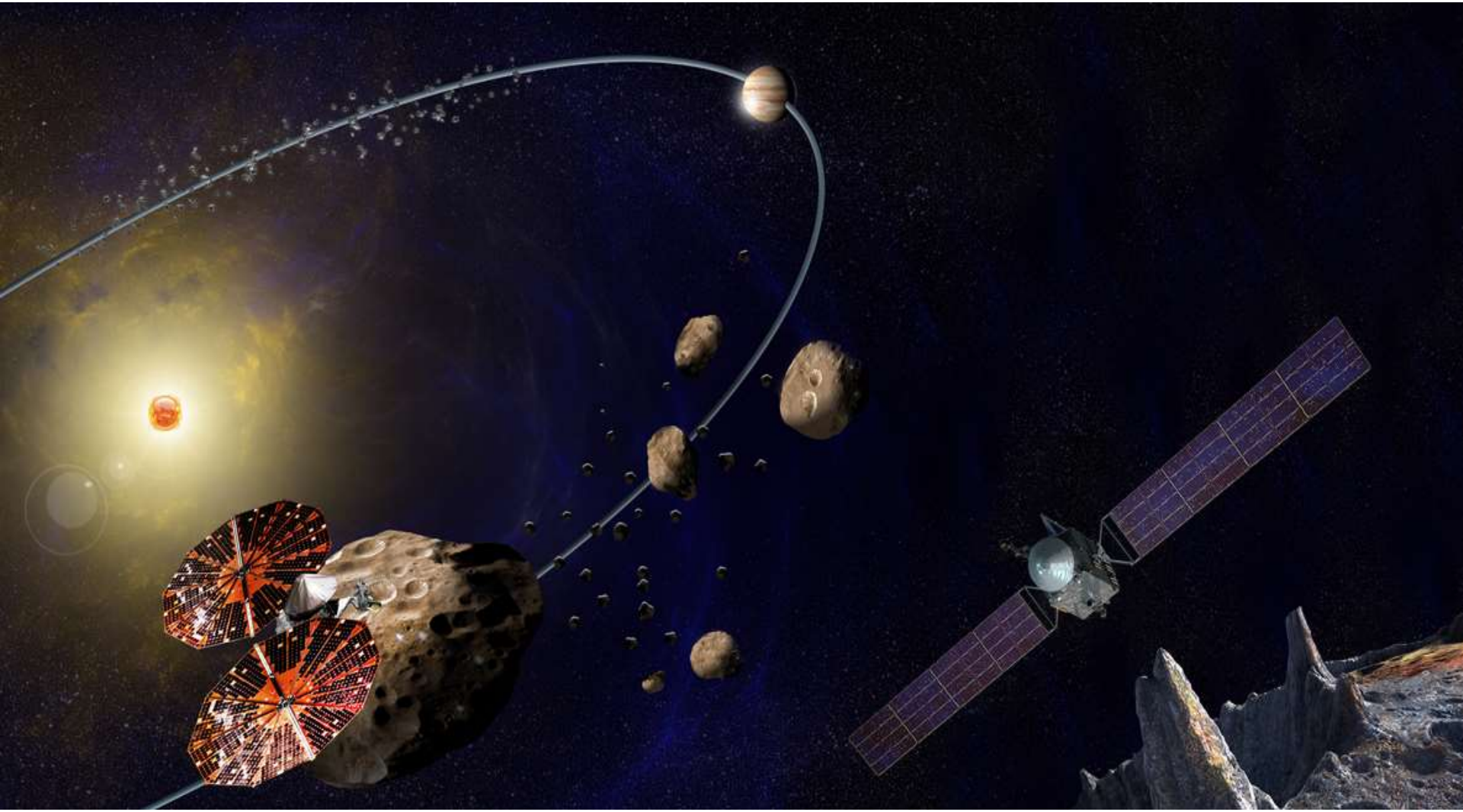
Main-belt asteroids:
Dawn (2007-*TBD*)

Lunar surface:
LRO (2009-*TBD*)

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

Mars Interior:
InSight (*2018*)

Discovery Selections 2017



Lucy: Surveying the Diversity of Trojan Asteroids
PI: Harold Levison, SwRI

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

Discovery Selections 2017

NEOCam:
Near-Earth Object Camera
PI: Amy Mainzer, JPL

The Discovery Program selection of NEOCam for an extended Phase A effort is an acknowledgement that, even though it was not selected for full mission implementation, it is an important capability for the Agency that will continue formulation efforts to address issues identified in the Discovery evaluation process.

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)

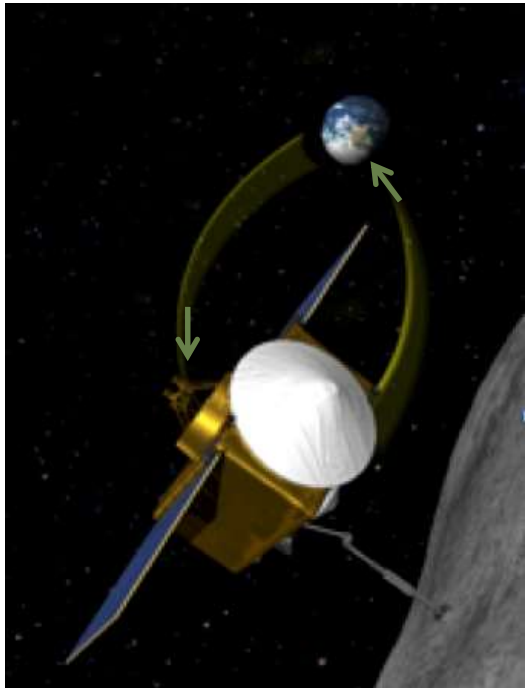
2nd NF mission
Juno:

Jupiter Polar Orbiter

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

3rd NF mission
OSIRIS-REx:

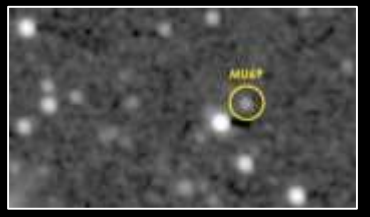
Asteroid Sample Return

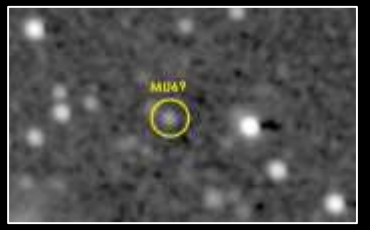


Launched September 2016
PI: Dante Lauretta (UA)

New Horizons

MU69 Next KBO Target

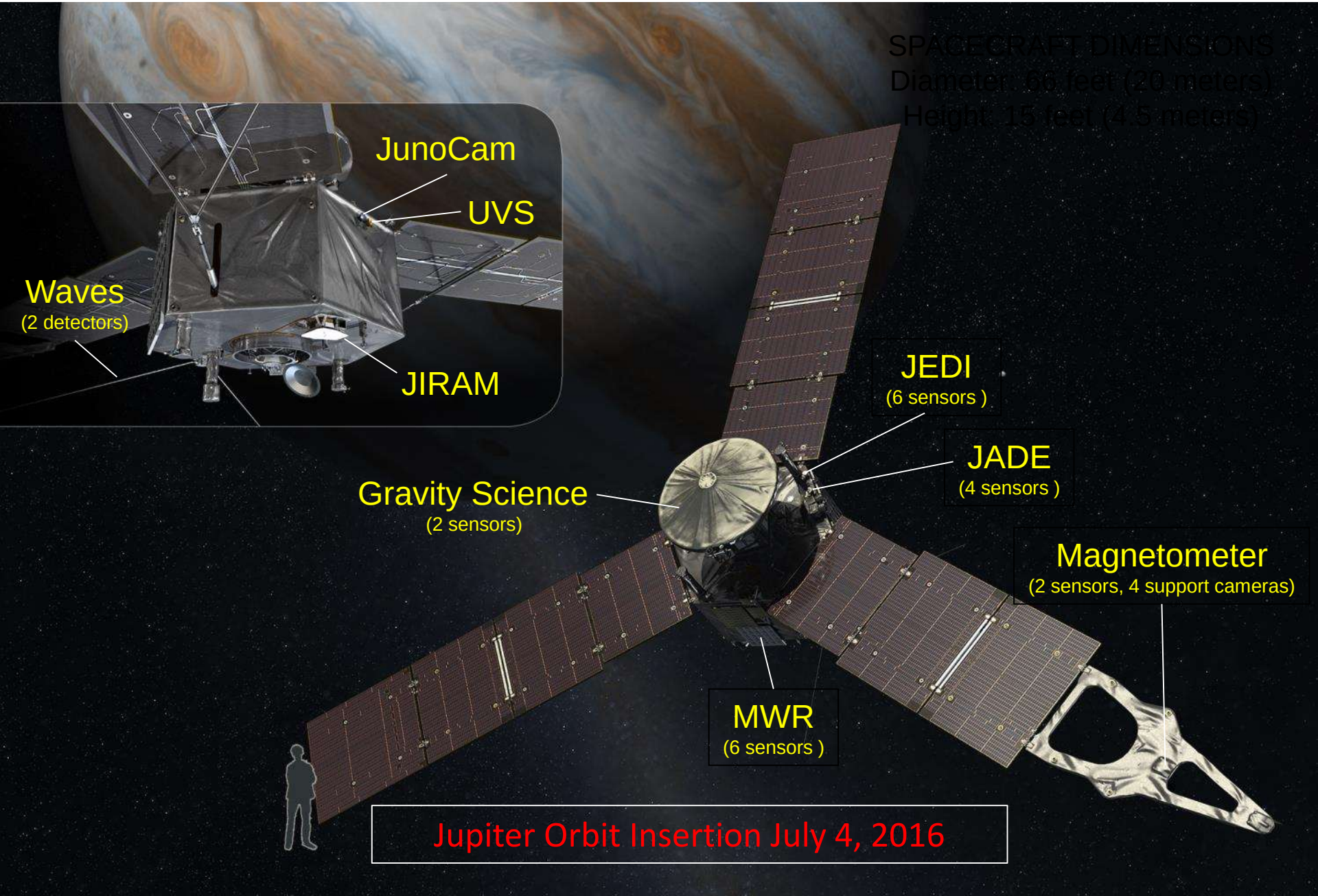




NASA, NH team, and the IAU Will be working together to Name MU69 this year. More Details to Follow.

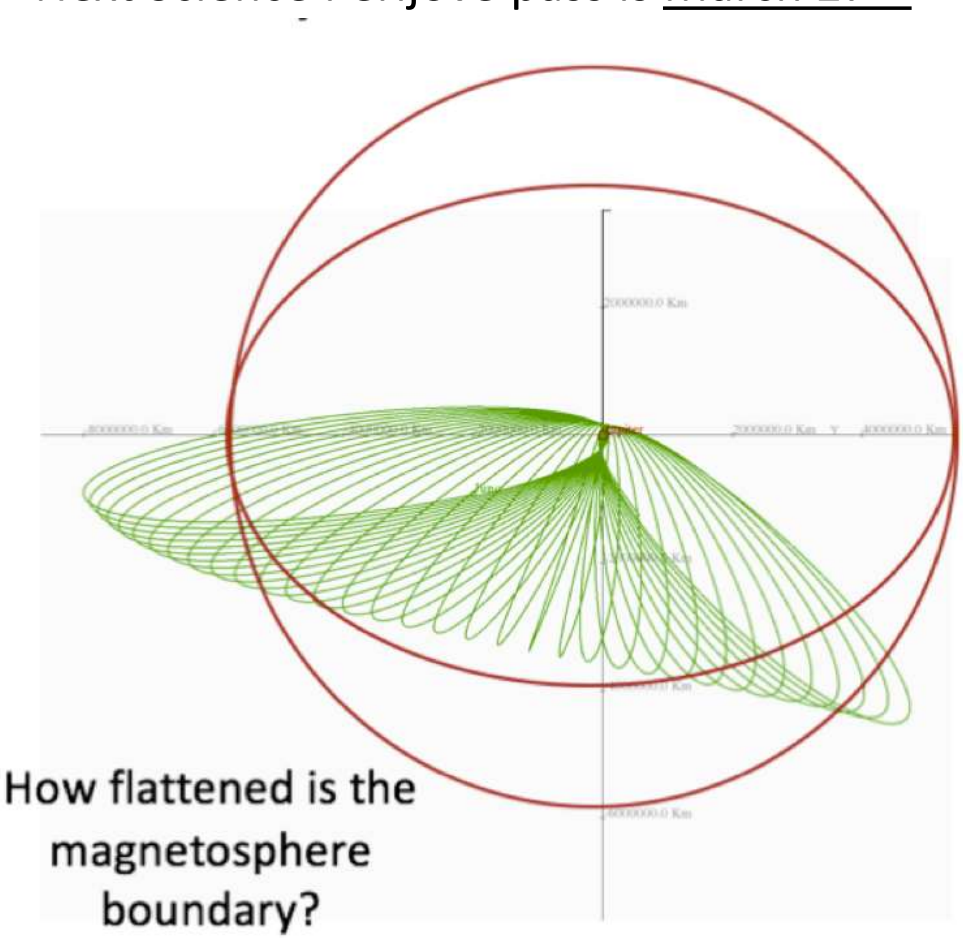
Flyby January 1, 2019

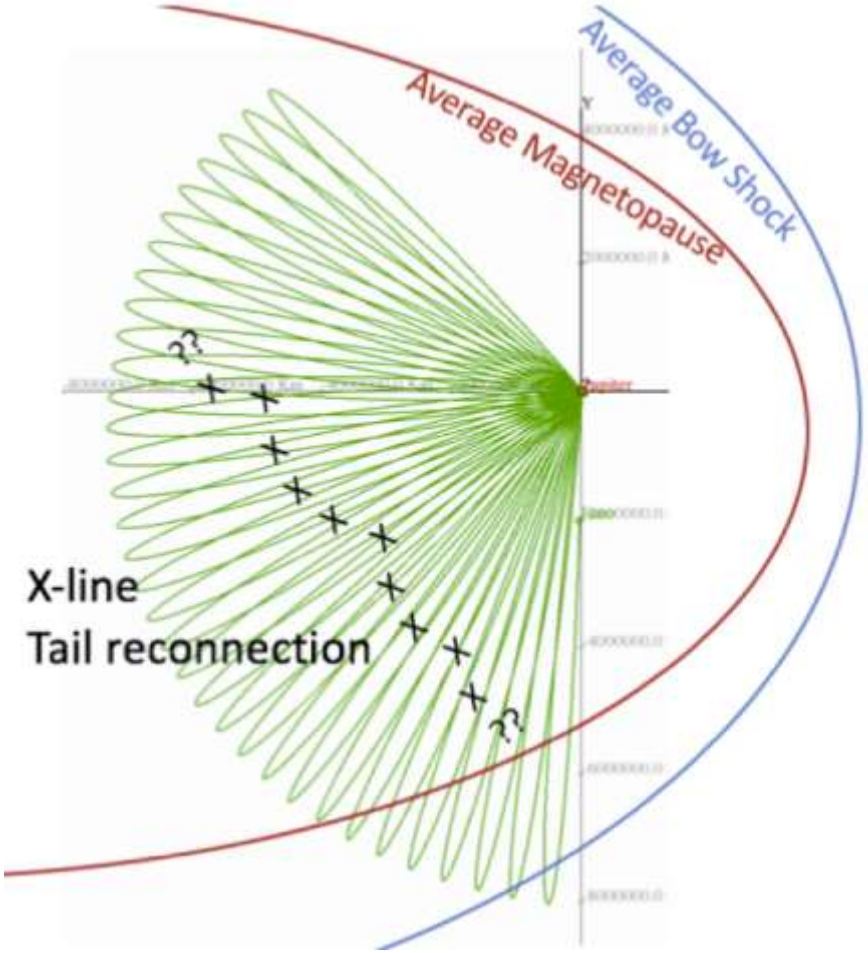
Juno Spacecraft and Payload



Decision: Juno will stay in the 53 Day Orbits

Next Science Perijove pass is <u>March 27th</u>



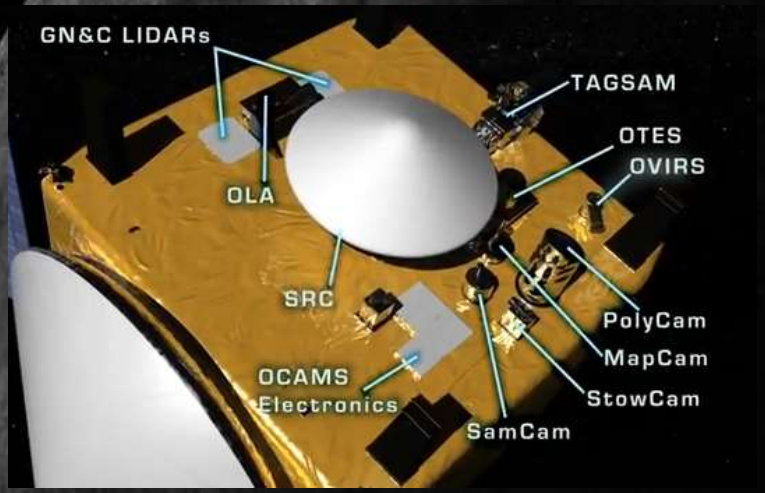


Working now with Heliophysics on a *joint* Participating Scientist Call

OSIRIS-REx

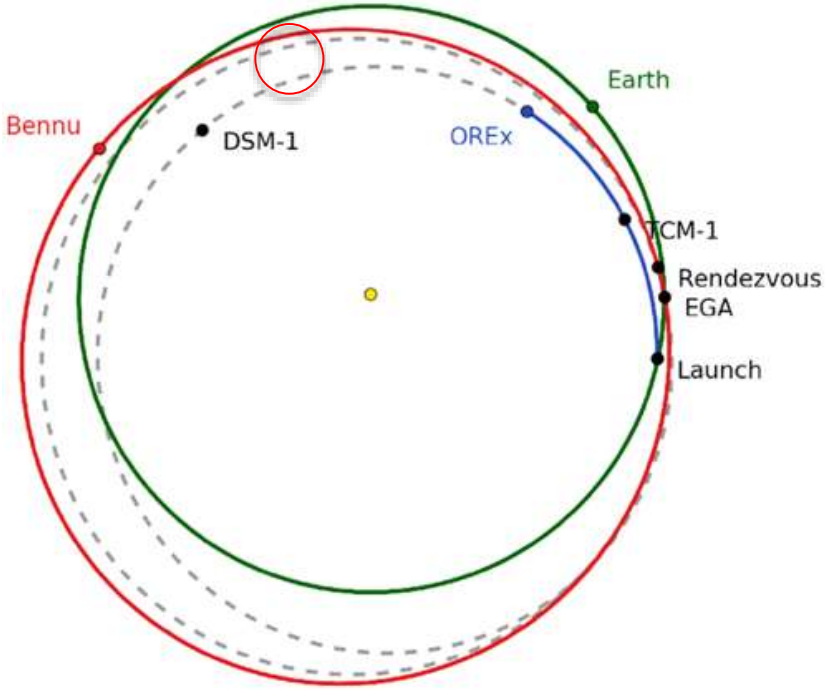
- Return and analyze a sample of Bennu's surface
- Map the asteroid & document the sample site
- Measure the Yarkovsky effect

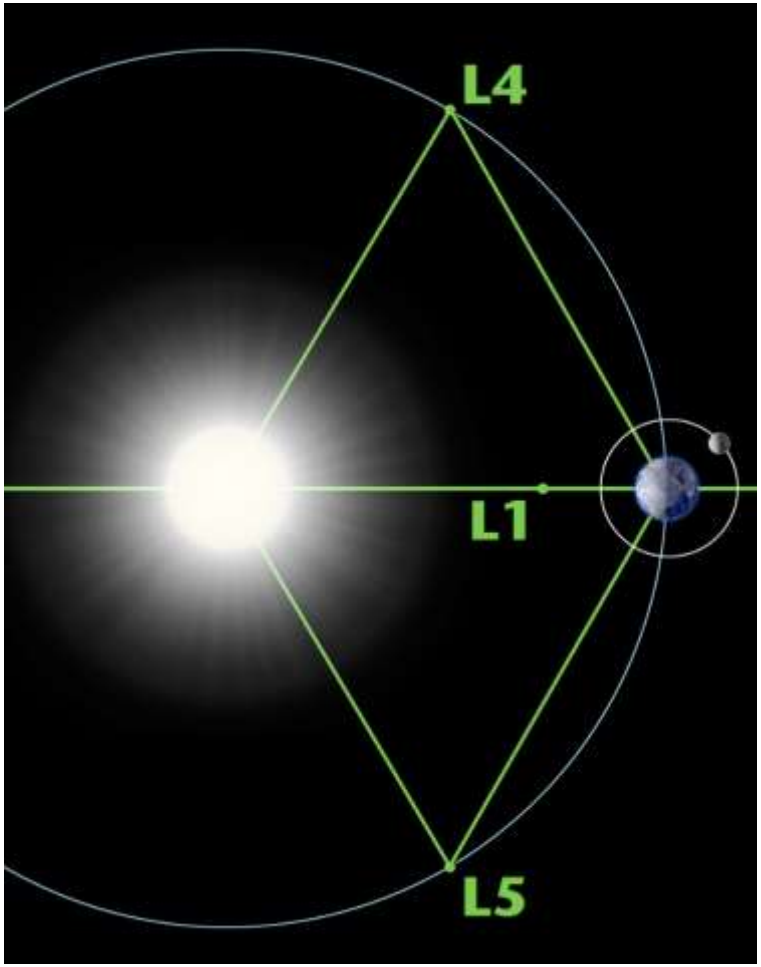
Launched Sept 2016



OSIRIS-REx

- Flight data as of 1300 UTC on Nov 10:
  - Distance from Earth: 25.4 M miles
  - One way light time: 2 min 16.3 sec
  - Distance to Bennu: 133.0M miles
- Feb 9-20, OSIRIS-REx activates its onboard camera suite and commence a search for Earth-Trojan asteroids at L4 – a good test of the system





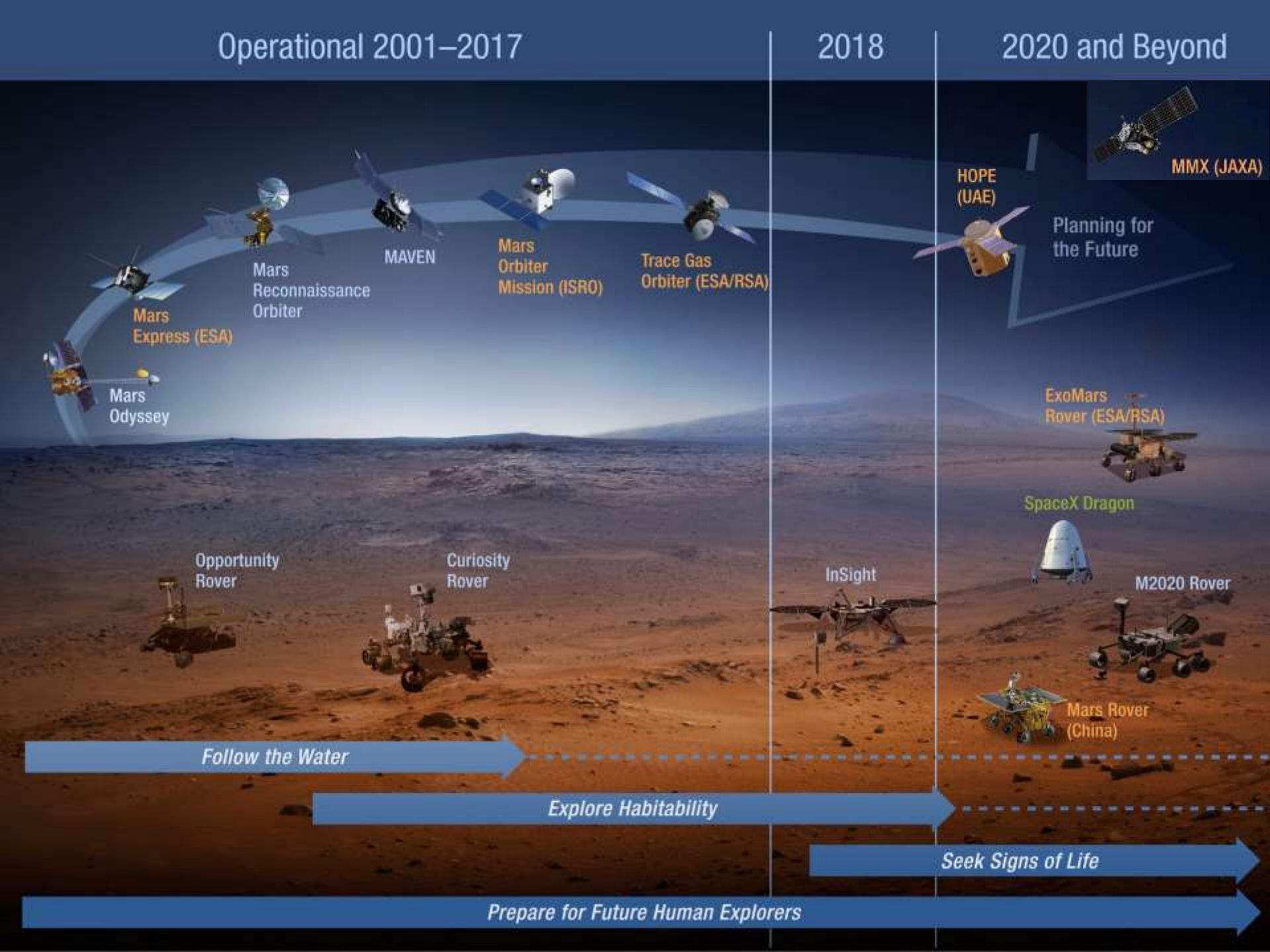
New Frontiers 4 AO

Investigations (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

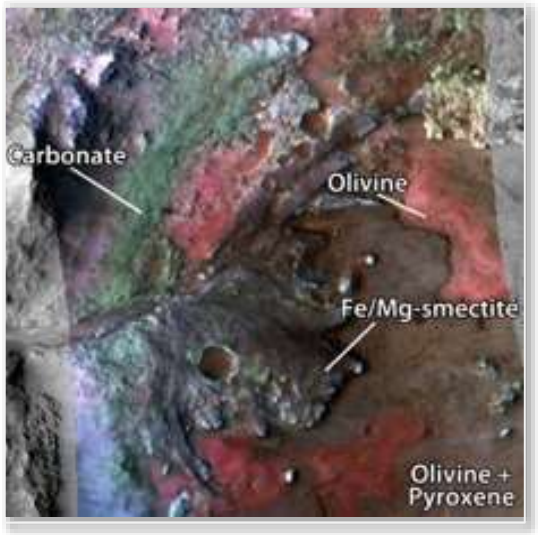
Release of final AO..... December 9, 2016
Preproposal Conference ..... January 20, 2016
Electronic Proposal Submittal Deadline..... April 28, 2017
Step-1 Selections Announced (target)..... November 2017
Phase A Concept Study Reports due..... December 2018
Downselection for Flight (target)..... July 2019 (target)
Launch Readiness Date..... NLT Dec. 31, 2025

Mars Exploration Program


Operational 2001–2017
2018
2020 and Beyond
MMX (JAXA)
HOPE (UAE)
Planning for the Future
Mars Express (ESA)
Mars Reconnaissance Orbiter
MAVEN
Mars Orbiter Mission (ISRO)
Trace Gas Orbiter (ESA/RSA)
Mars Odyssey
ExoMars Rover (ESA/RSA)
SpaceX Dragon
Opportunity Rover
Curiosity Rover
InSight
M2020 Rover
Mars Rover (China)
Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers

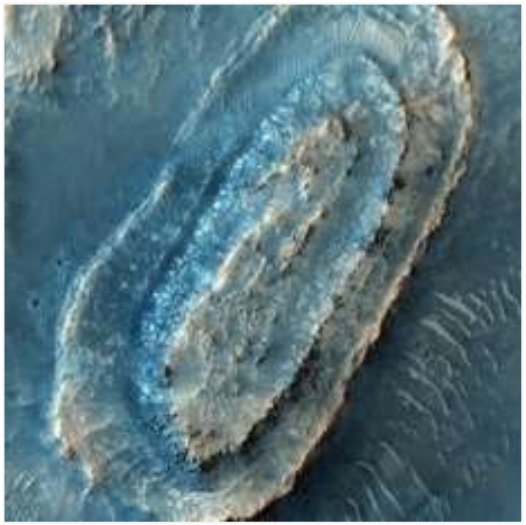
Mars 2020 Landing Site Workshop

Final Mars 2020 Candidate Landing Sites



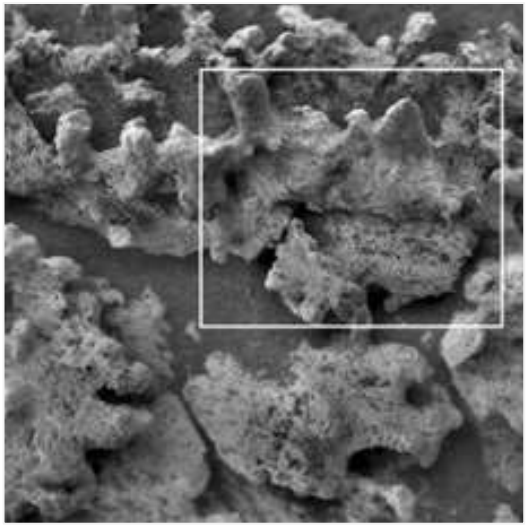
JEZERO

- Deltaic/lacustrine deposition with Hesperian lava flow and hydrous alteration
- Evidence for hydrous minerals from CRISM, *including carbonates*



NE SYRTIS

- Extremely ancient igneous, hydrothermal, and sedimentary environments
- High mineralogic diversity with phyllosilicates, sulfates, carbonates, olivine
- Serpentinization and subsurface habitability?

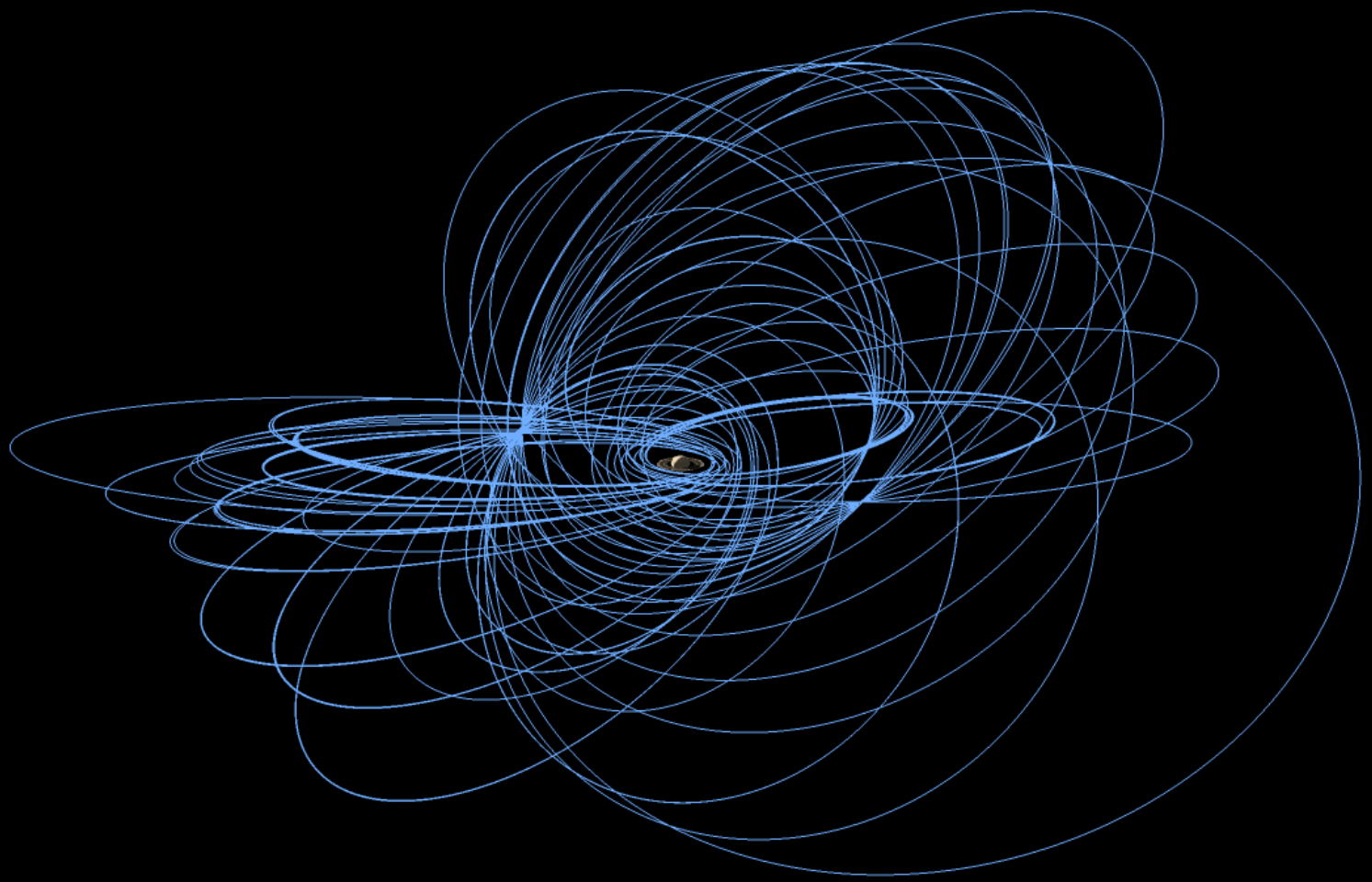


COLUMBIA HILLS

- Carbonate, sulfate, and silica-rich outcrops of possible hydrothermal origin and Hesperian lava flow
- Potential biosignatures identified
- Previously explored by MER

Outer Planets Program

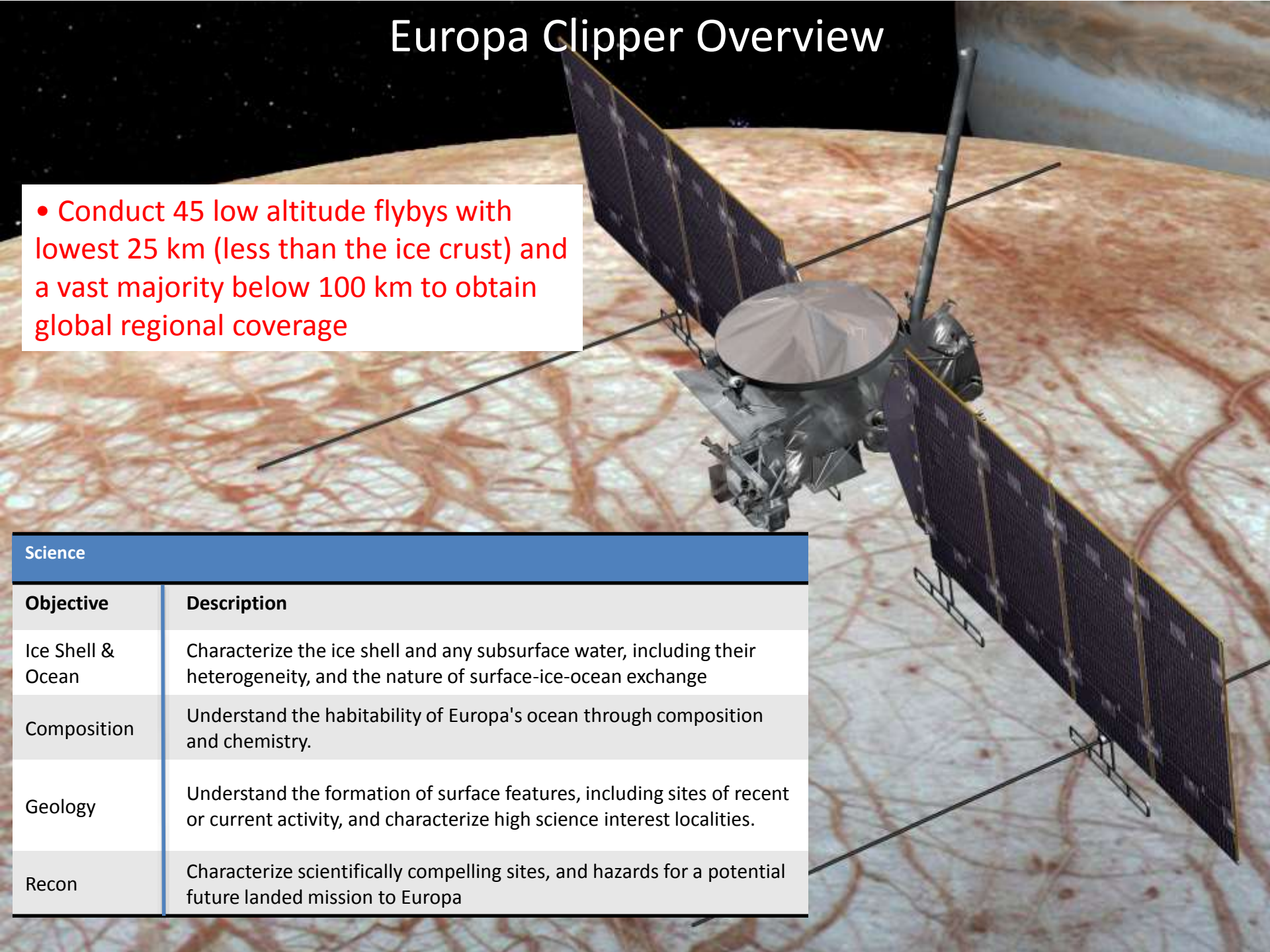
Cassini's Orbits (2004-Present)



Cassini's Final Orbits

April 22 – *Cassini* begins "Grand Finale"
September 15 – *Cassini* crashes into Saturn

Europa Clipper Overview



- Conduct 45 low altitude flybys with lowest 25 km (less than the ice crust) and a vast majority below 100 km to obtain global regional coverage

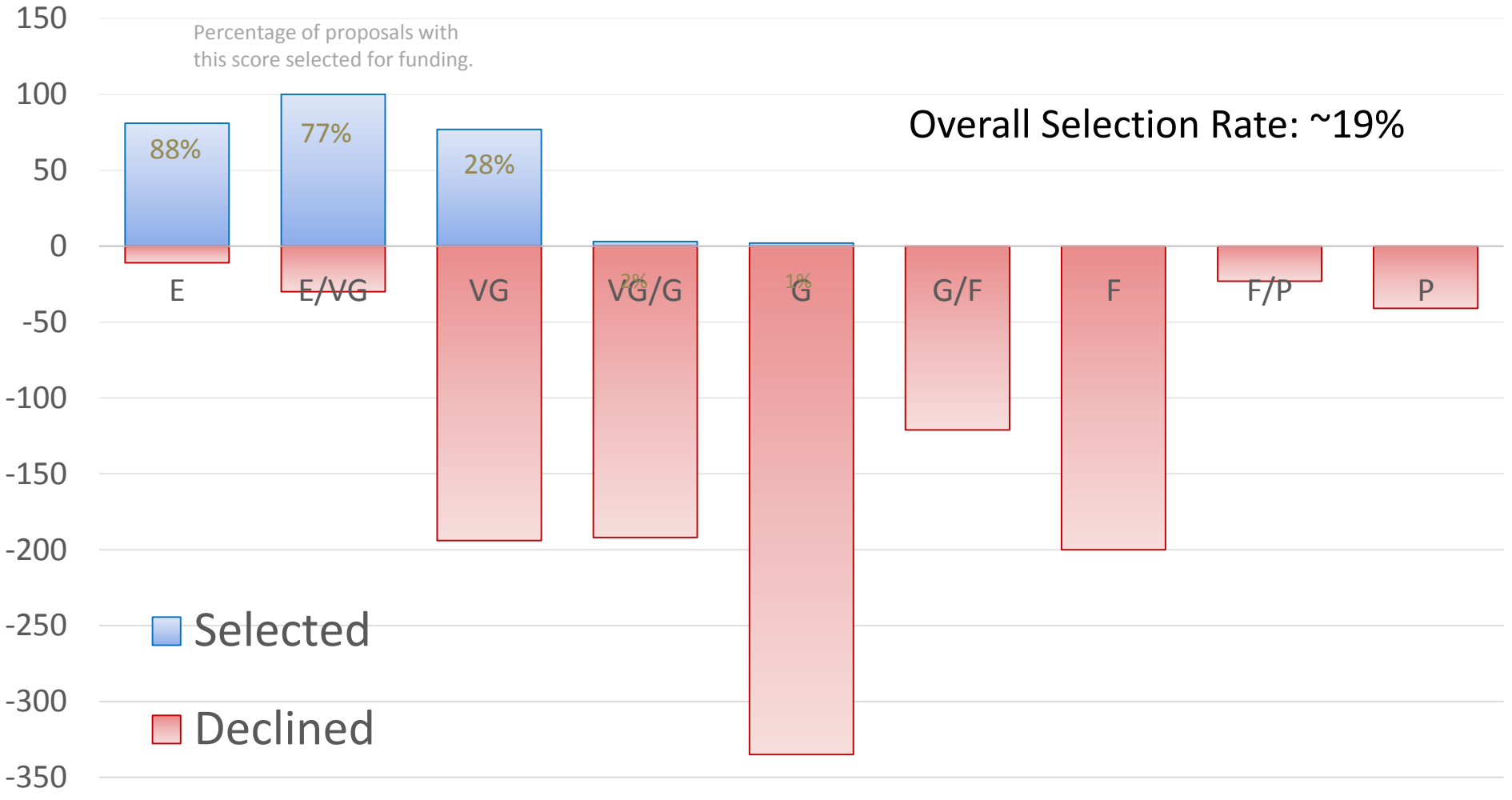
Science	
Objective	**Description**
Ice Shell & Ocean	Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange
Composition	Understand the habitability of Europa's ocean through composition and chemistry.
Geology	Understand the formation 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

New Opportunities and Research & Analysis Program

Upcoming New Opportunities

- ROSES 16: New Frontiers Data Analysis Program
  - STEP-1 (February 8) & STEP-2 (May 3)
- ROSES 17: Rosetta Data Analysis Program
  - STEP-1 (September 7) & STEP-2 (November 15)
  - Same deadlines as, and co-reviewed with, DDAP
- SALMON 3:JAXA Martian Moons eXploration (MMX)
  - Soliciting a Neutron and Gamma Ray Spectrometer instrument Released March 21st with preproposal briefing April 17th

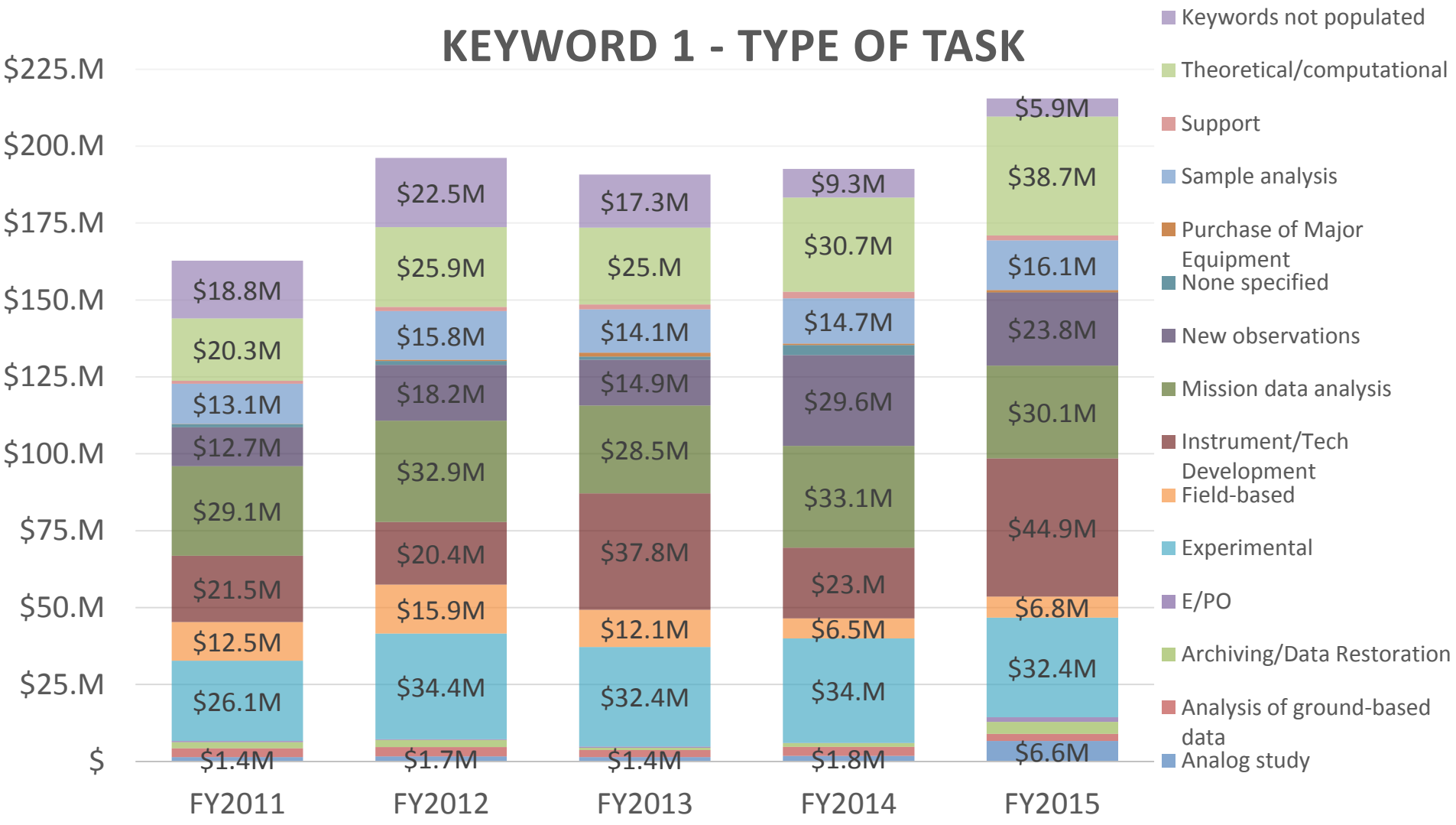
PSD R&A SELECTIONS - ROSES 2015



Metrics for proposals submitted to ROSES 2015, including all core programs (EW, SSW, HW, SSO, EXO) and all DAPs (MDAP, DDAP, LDAP, CDAPS)

Keyword Analysis

- Analysis of keyword distribution, 2011-2016 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


KEYWORD 1 - TYPE OF TASK
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$200.M
$175.M
$150.M
$125.M
$100.M
$75.M
$50.M
$25.M
$
FY2011
$18.8M
$20.3M
$13.1M
$12.7M
$29.1M
$21.5M
$12.5M
$26.1M
$1.4M
FY2012
$22.5M
$25.9M
$15.8M
$18.2M
$32.9M
$20.4M
$15.9M
$34.4M
$1.7M
FY2013
$17.3M
$25.M
$14.1M
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$28.5M
$37.8M
$12.1M
$32.4M
$1.4M
FY2014
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FY2015
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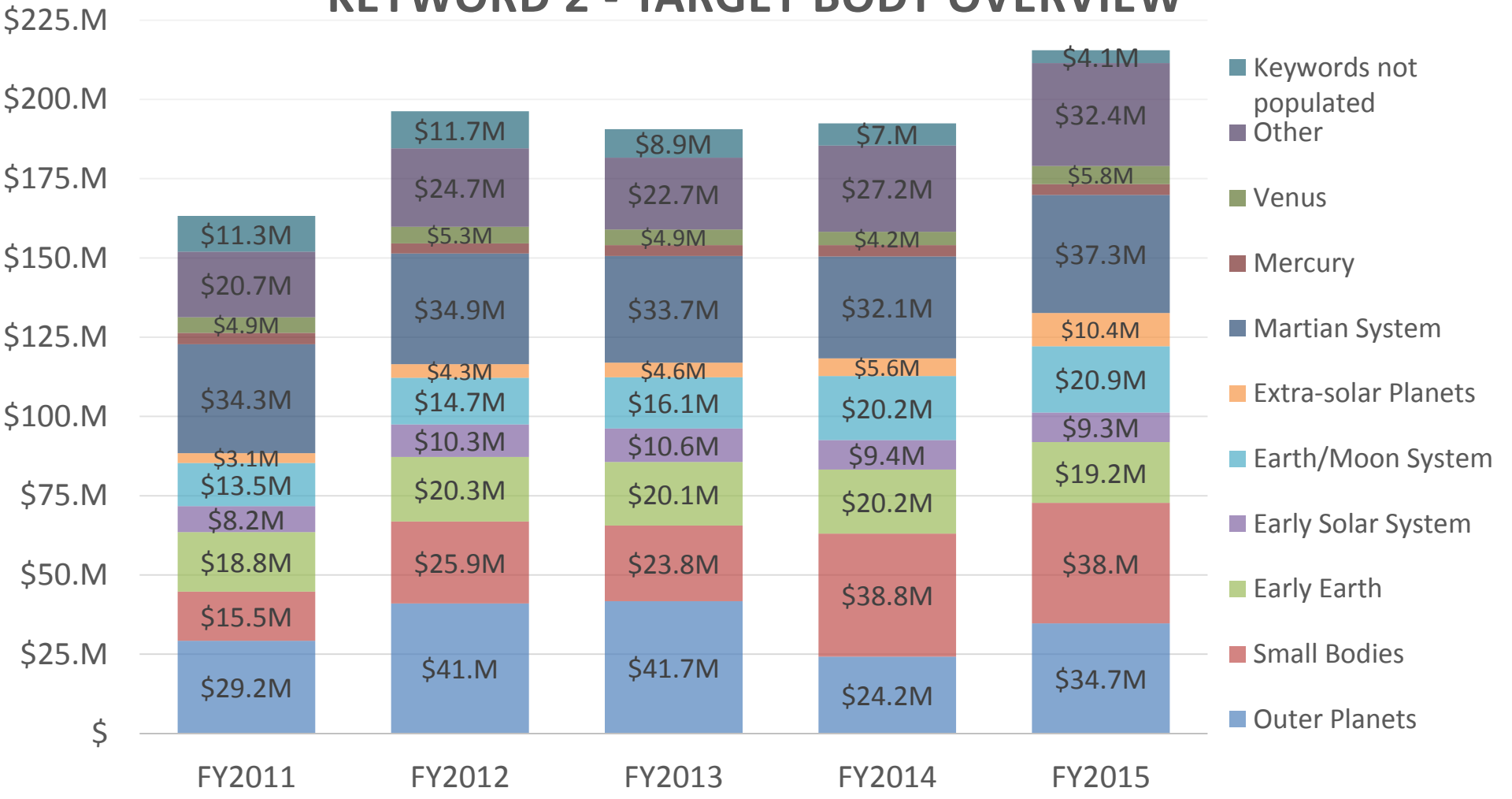
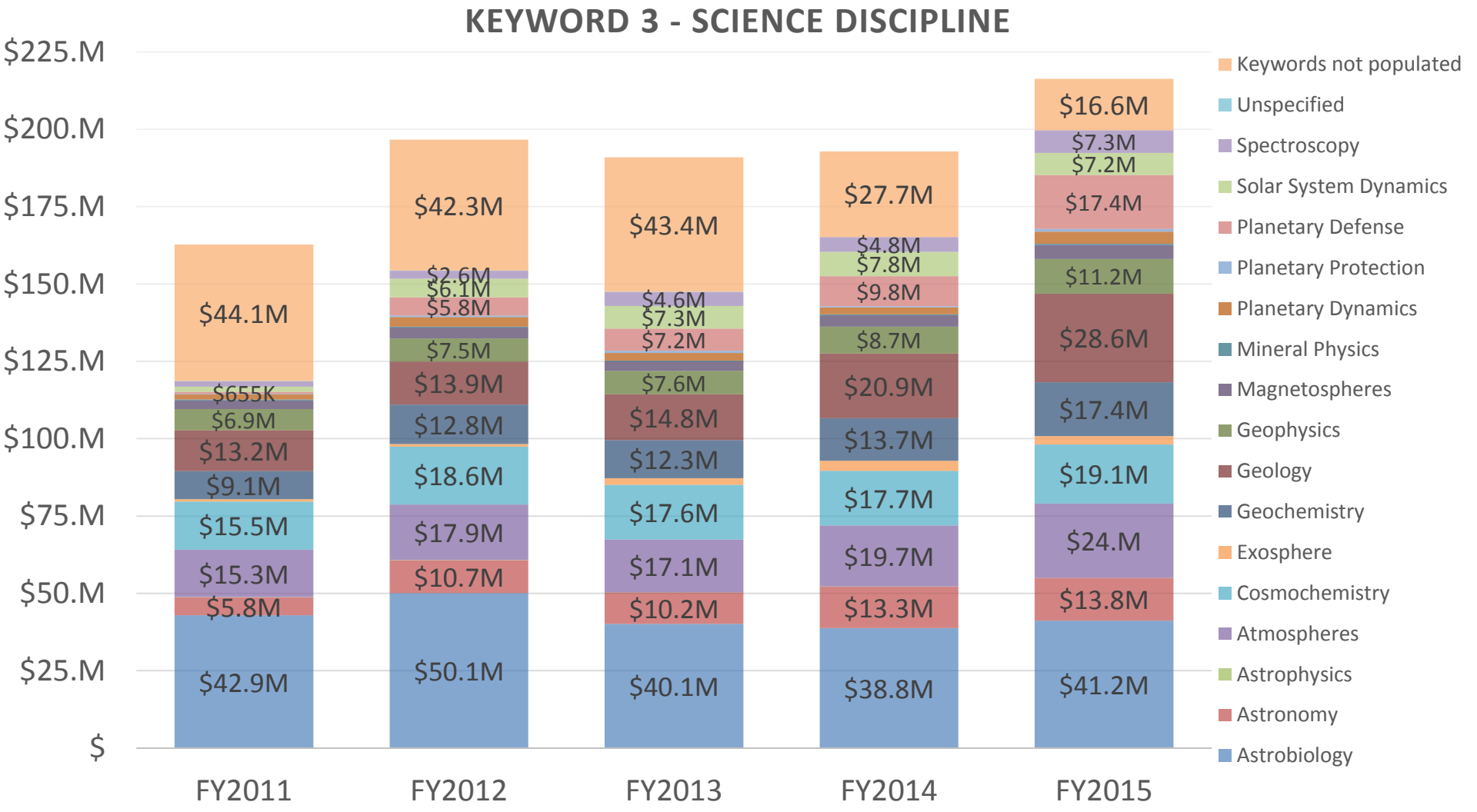
Support
Sample analysis
Purchase of Major Equipment
None specified
New observations
Mission data analysis
Instrument/Tech Development
Field-based
Experimental
E/PO
Archiving/Data Restoration
Analysis of ground-based data
Analog study

KEYWORD 2 - TARGET BODY OVERVIEW




KEYWORD 3 - SCIENCE DISCIPLINE
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$100.M
$75.M
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$25.M
$
FY2011
FY2012
FY2013
FY2014
FY2015
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$655K
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Keywords not populated
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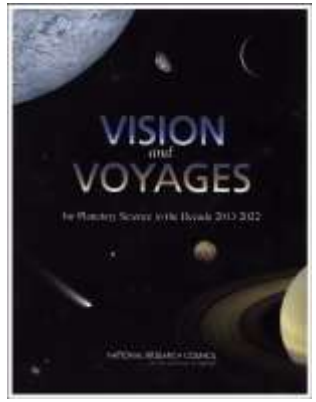
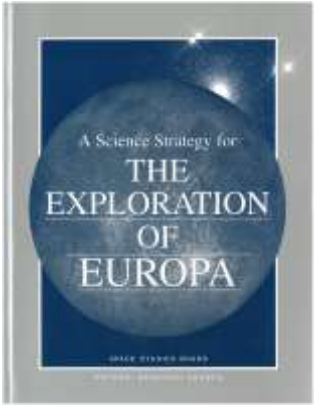
Spectroscopy
Solar System Dynamics
Planetary Defense
Planetary Protection
Planetary Dynamics
Mineral Physics
Magnetospheres
Geophysics
Geology
Geochemistry
Exosphere
Cosmochemistry
Atmospheres
Astrophysics
Astronomy
Astrobiology

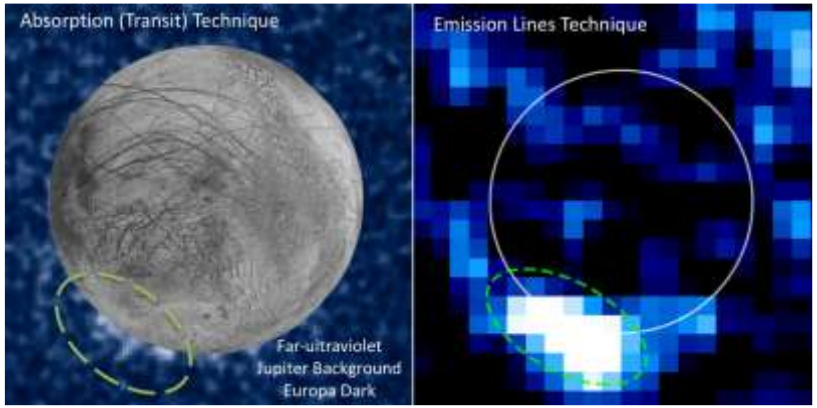
Mission Studies: Getting Ready for the Next Decadal

Exploration of Europa

- Europa on the list of Large-Class Flight missions in Planetary *Vision & Voyages* Decadal
- NAS/COMPLEX Report on Europa:
  - Combination of R&A, technology development, telescope observations, and missions
  - Recommended a staged series of missions be utilized to explore Europa
  - First mission focus on liquid water – *Clipper Orbiter*
  - Follow-on characterize surface material and access and study the liquid water - *Lander*
- Planetary Division's response:
  - Issued: ICEE & ColdTech instruments
  - Development of the Clipper mission
  - Europa lander SDT study completed
  - HST observations of Europa plumes
    - STSci Director's Committee on Future Observation Strategies to be released

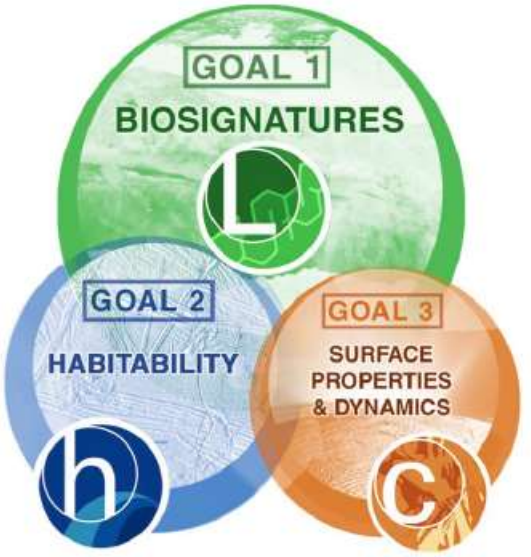


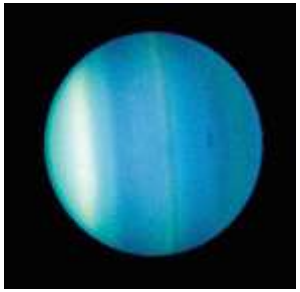




Europa Lander SDT

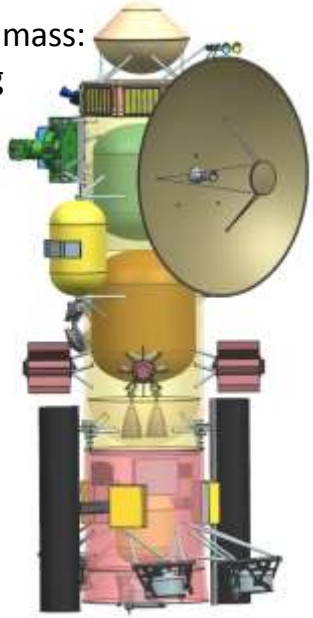
- Science Definition Team (SDT) delivered its report with 3 prioritized goals:
  1. Search for Evidence of Life
  2. Assess habitability
  3. Characterize surface and subsurface
- Applying lessons learned from Viking landers
- Used extreme, limited nutrient Earth environments as analogs
- Approach: Multiple line of evidence are needed to detect life
- Presented a decision framework for life detection to assess how results should be interpreted



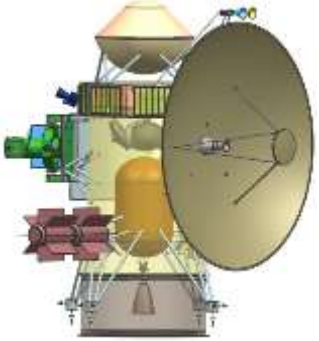


ICE Giants Study: Uranus & Neptune

Launch mass:
7364 kg

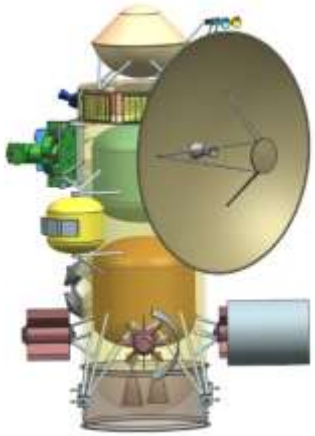


Neptune Orbiter with Probe, SEP, and 50 kg payload



Launch mass:
1525 kg

Uranus Flyby with Probe and 50 kg payload



Launch mass:
4345 kg

Uranus Orbiter with Probe and 50 kg payload

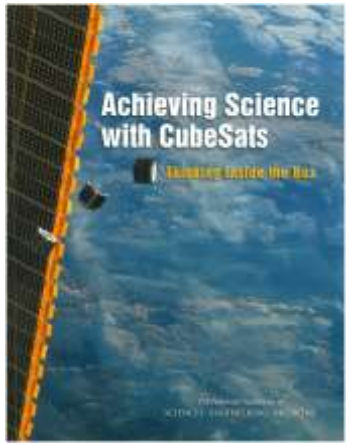
Launch mass:
4718 kg

Uranus Orbiter with 150 kg payload

Uranus on the list of Large-Class Flight mission in the Vision & Voyages Decadal

SMD CubeSat/SmallSat Approach

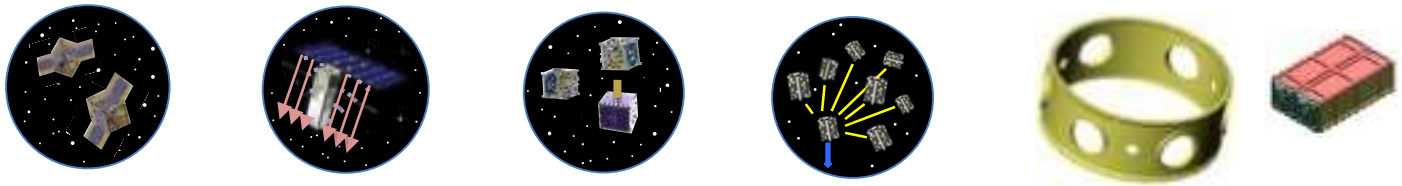
- A National Academies Report (2016) concluded that CubeSats have proven their ability to produce high-value science.
- In particular, CubeSats are useful as targeted investigations to augment the capabilities of larger missions or to make a highly-specific measurement.
- Constellations of 10-100 CubeSat/SmallSat spacecraft have the potential to enable transformational science.



- SMD is developing a directorate-wide approach that has four objectives:
  - Identify high-priority science objectives in each discipline that can be addressed with CubeSats/SmallSats
  - Manage program with appropriate cost and risk
  - Establish a multi-discipline approach and collaboration that helps science teams learn from experiences and grow capability, while avoiding unnecessary duplication
  - Leverage and partner with a growing commercial sector to collaboratively drive instrument and sensor innovation

Planetary Science Deep Space SmallSat Studies

- ROSES Appendix C.23 was released on August 19, 2016
  - NOI/STEP 1 : September 30, 2016 ➔ 107 Submissions
  - STEP 2 : November 18, 2016 ➔ 102 Submissions
- Solicited concept studies for potential CubeSat and SmallSat
  - Concepts sought for 1U to ESPA-class missions
  - Up to $100M mission concept studies considered
  - Not constrained to fly with an existing mission
- PSDS3 Objectives:
  - What Planetary Science investigations can be done with smallsats?
  - What technology development is needed to enable them?
  - What's the anticipated cost range?



Planetary Science Deep Space SmallSat Studies

Venus

Christophe Sotin, Cupid's Arrow

Valeria Cottini, CUVE - Cubesat UV Experiment

Moon

Suzanne Romaine, CubeSat X-ray Telescope (CubeX)

Tim Stubbs, Bi-sat Observations of Lunar Atmosphere above Swirls (BOLAS)

Asteroids

Jeffrey Plescia, APEX: Asteroid Probe Experiment

Benton Clark, CAESAR: CubeSat Asteroid Encounters for Science & Recon

Mars

David Minton, Chariot to the Moons of Mars

Tony Colaprete, Aeolus - to study the thermal and wind environment of Mars

Icy Bodies and Outer Planets

Kunio Sayanagi, SNAP: Small Next-generation Atmospheric Probe

Robert Ebert, JUpiter MagnetosPheric boundary ExploreR (JUMPER)

Questions?

CAPS Charge

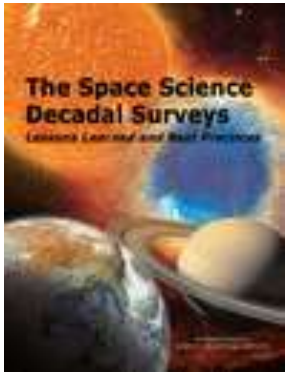
The Committee on Astrobiology and Planetary Science will draft a very brief report addressing the following topics:

1. Determine what publically available studies of future flagship- and New Frontiers-class missions NASA has initiated since the completion of Vision and Voyages;
2. Identify priority areas—as defined in Vision and Voyages—where publically-available mission studies have not been undertaken;
3. Discuss appropriate mechanisms by which mission-study gaps might be filled in the near- to mid-term future; and
4. Suggest other activities that might be undertaken in the near- to mid-term future to optimize and/or expedite the work of the next planetary science decadal survey committee.

The Space Science Decadal Surveys: Lessons Learned and Best Practices

Committee on Survey of Surveys (Chair: Alan Dressler)

The National Academies, 2015



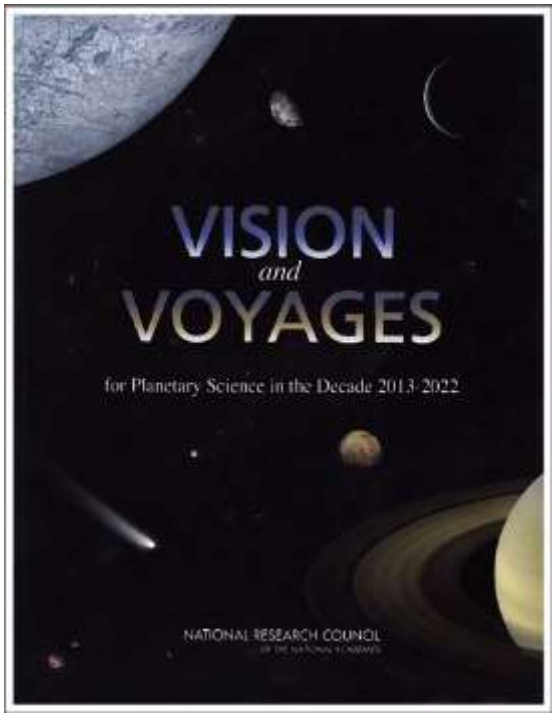
Lesson Learned: Providing scores or grades in a midterm assessment report can result in unintended consequences when used by a wide audience. When grades are used, it is best if narrative text clearly indicates the desired response to a good or bad grade.

Best Practice: Midterm assessment reports are most useful when they engage and inform the broad community by providing a progress report on implementing the decadal program, together with sufficient context to understand the rationale behind the program's current implementation strategy.

Lesson Learned: Midterm assessments offer an opportunity to initiate the process of concept development for the next decadal survey. While primarily serving to provide a report on progress to date, the assessments can also act as forward-looking documents in the preparation for future decadal planning.

Timeline of NAS 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:
  - Tasked August 13, 2015
  - Report due to NASA April 2017
- Large Strategic NASA Science Missions
  - Tasked December 23, 2015
  - Report due to NASA August 2017
- Midterm evaluation:
  - Tasked August 26, 2016 with 1st meeting May 4-5, 2017
  - Cubesats, EX Missions, R&A Restructuring, Large Strategic Missions - will be input
  - Expect report due December 2017 or early 2018
- Sample Analysis Future Investment Strategy (Tasked Sept 23, 2016)
- Next Committee on Astrobiology & Planetary Science – CAPS (March 28-31, 2017)
- 3rd Planetary Decadal: 2023-2032
  - To be tasked *before* October 2019
  - Expect report to NASA due 1st quarter 2022



NASA Authorization Act of 2017

NASA Authorization Act of 2017

The SMD-related portion of this bill includes several PSD-related reporting requirements:

- Sec. 511 requires OSTP & NASA to submit a report on how the Administration will accomplish the George Brown survey of NEOs larger than 140 meters in size; this initial report is due 1 year after enactment (~March 2018);
- Sec. 511 also requires NASA, with other relevant agencies, to do an assessment of how to accelerate and expand the NEO search activities; a report on this assessment is due 270 days after enactment (~December 2017);
- Sec. 512 requires NASA to submit a report on how we plan to expand public-private partnerships in NASA's NEO search program; a report on this topic is due 180 days after enactment (~September 2017);
- Sec. 511 also requires annual progress reports on the George Brown survey of NEOs larger than 140 meters in size (starting ~ March 2019);

- Sec. 510 requires a report on how NASA plans to expand public-private partnerships in astrobiology; this report is due 180 days after enactment (~September 2017);
- Sec. 509 requires NASA to task the National Academies to develop a science strategy for astrobiology; this strategy is due 18 months after enactment (~September 2018);

- Sec. 516 requires NASA to task the National Academies to assess NASA's Mars exploration architecture; this report is due 18 months after enactment (~September 2018);

- Sec. 508 requires NASA to task the National Academies to develop a science strategy for the study and exploration of extrasolar planets; this strategy is due 18 months after enactment (~September 2018).

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?
- What is the current sample laboratory support infrastructure and does NASA's investment strategy meet 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?

Sample Analysis Instrumentation Evolution