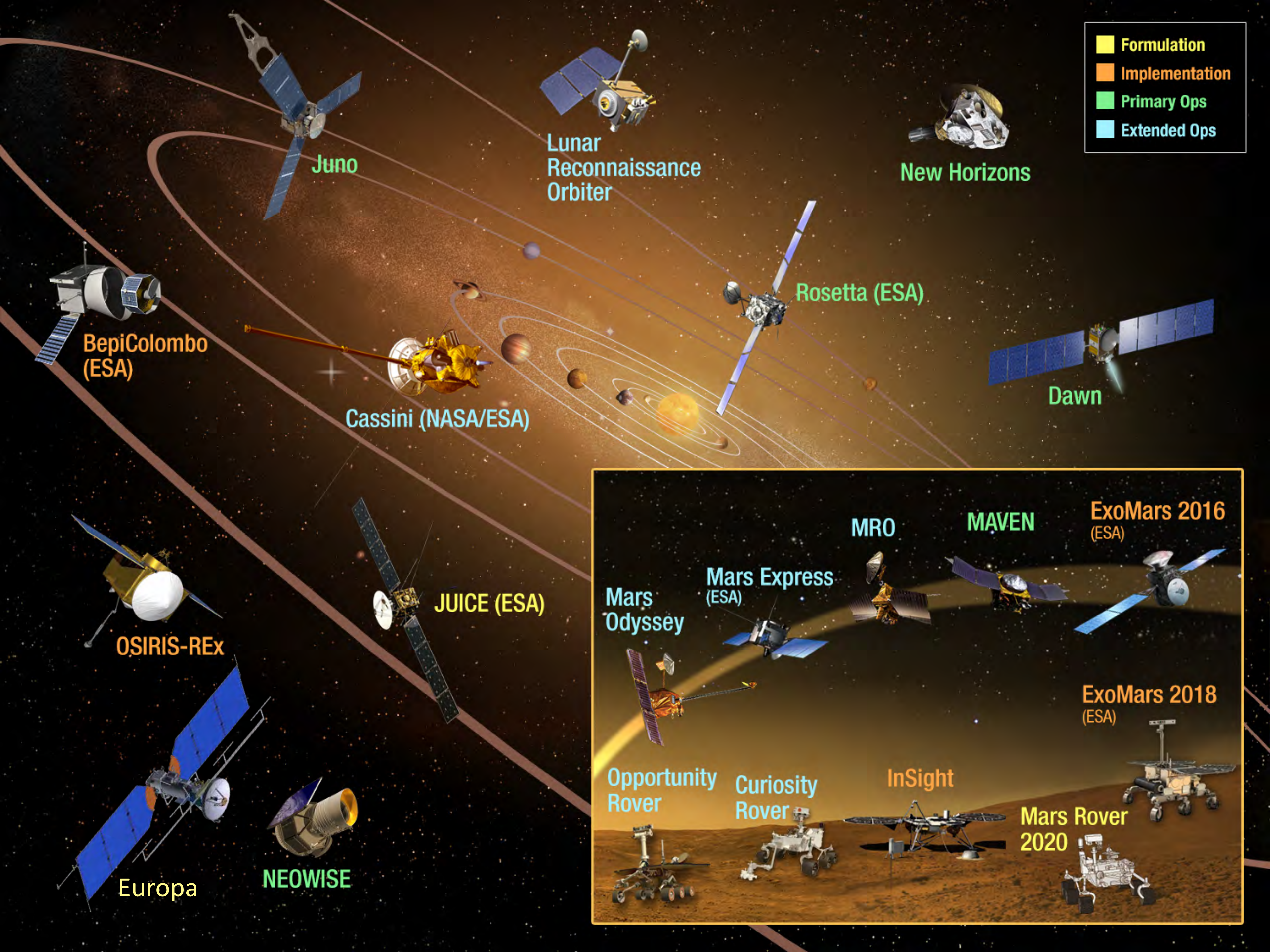
Planetary Science Division Status Report

James L. Green
NASA, Planetary Science Division
October 20, 2015

Presentation at LEAG



Formulation
Implementation
Primary Ops
Extended Ops
Juno
Lunar Reconnaissance Orbiter
New Horizons
Rosetta (ESA)
BepiColombo (ESA)
Cassini (NASA/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

Outline

- Mission Events Overview
- Discovery, New Frontiers & Mars Exploration Programs
- Europa Mission Status
- New Cubesat Selections
- New NRC Study
- New Communication Policy
- PSD Response to LEAG findings

Planetary Science Missions Events

2014

July – *Mars 2020* Rover instrument selection announcement

* **Completed**

August 6 – 2^{nd} 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 JU_3

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 7 – Akatsuki inserted into orbit around Venus

2016

March – Launch of ESA's *ExoMars Trace Gas Orbiter*
March 4 – Launch of *InSight*
July 4 – *Juno* inserted in Jupiter orbit
September – *InSight* Mars landing
September – Launch of Asteroid mission *OSIRIS – REx* to asteroid Bennu
September – *Cassini* begins to orbit between Saturn's rings & planet
(TBD) – Discovery 2014 Step 2 selection

Discovery and New Frontiers Status

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
- **$850M** cap per mission excluding launch vehicle and operations phase (FY15$)
- 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)

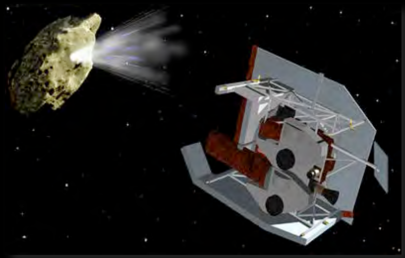
Solar wind sampling:
Genesis (2001-2004)

Completed

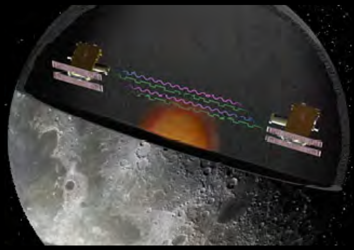
Comet diversity:
CONTOUR (2002)

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

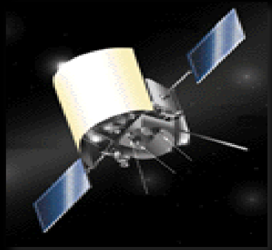
Comet internal structure:
Deep Impact (2005-2012)



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 (*2016-TBD*)

Mars Interior:
InSight (2016-*TBD*)

Status of Discovery Program

Discovery 2014 – Selections announced September 30

- About 3-year mission cadence for future opportunities

Missions in Development

– *InSight*: Launch window opens March 4, 2016 (Vandenberg)
– Strofio: Delivered to SERENA Suite (ASI) for BepiColombo

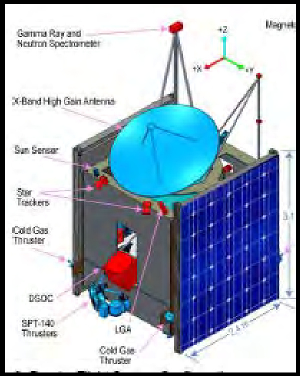
Missions in Operation

– *Dawn*: Science observations now in HAMO

Missions in Extended Operations

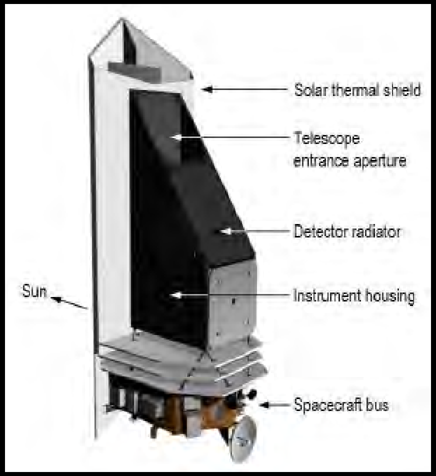
– *MESSENGER*: Completed low altitude science operations before impact with Mercury
– *LRO*: In stable elliptical orbit, passing low over the lunar south pole

Discovery Selections



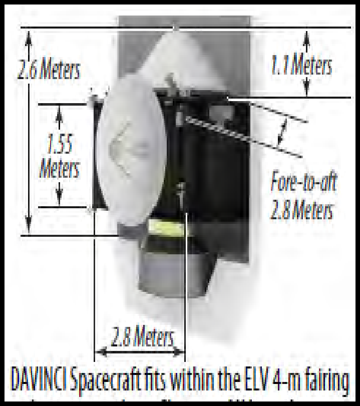
Psyche: Journey to a Metal World
PI: Linda Elkins-Tanton, ASU
Deep-Space Optical Comm (DSOC)

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

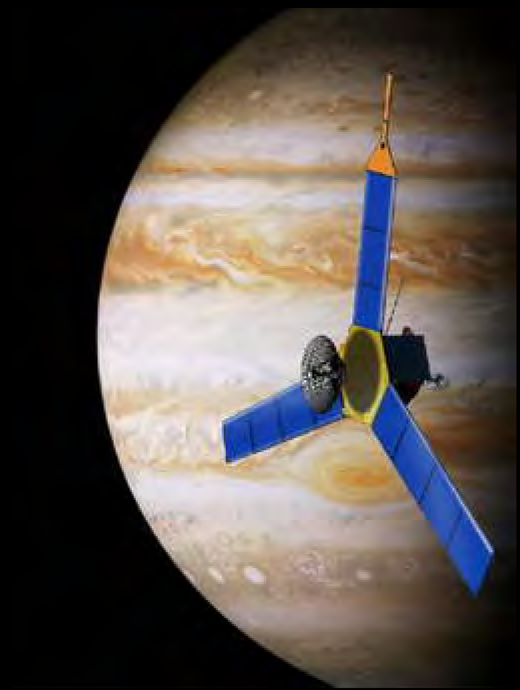
1st NF mission
New Horizons:

Pluto-Kuiper Belt

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

2nd NF mission
Juno:

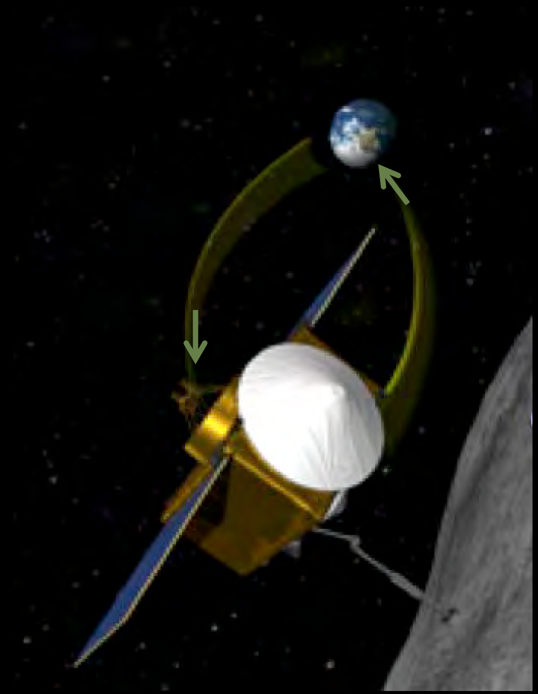
Jupiter Polar Orbiter



Launched August 2011
Arrives July 2016
PI: Scott Bolton (SwRI-TX)

3rd NF mission
OSIRIS-REx:

Asteroid Sample Return



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

Status of New Frontiers Program

Next New Frontiers AO - to be released by end of Fiscal Year 2016

- New ROSES call for instrument/technology investments released

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
  - HST identified 2 KBO's beyond Pluto for potential extended mission
  - NH approved to target small Kuiper Belt object 2014 MU69
- Juno:
  - Spacecraft is 5.01 AU from the sun and 1.02 AU from Jupiter
  - Orbit insertion is July 4, 2016

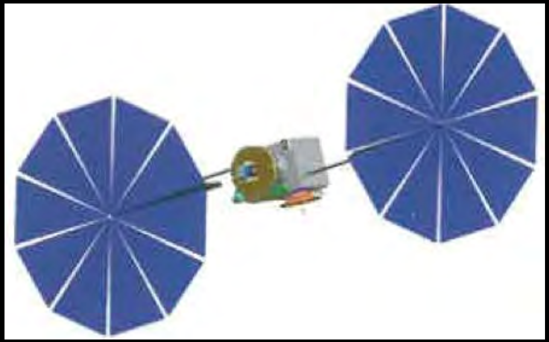
Homesteader Program Overview

- The goal of the Homesteader program is to mature technologies such that they can be included as part of a selectable, low risk mission concept proposal submitted in response to the NF AO.
  - The program supports the advanced development of technology relevant to mission concepts for the next two New Frontiers (NF) AOs.
  - 134 Step 1 and 84 Step 2 proposals were received; 8 proposals **totaling $7.9M** were selected

PI	Institution	Title	Technology
Steve Squyres	Cornell Univ.	Sample Acquisition, Containment, and Thermal Control Technology for Comet Surface Sample Return	Sample Acquisition
Lori Glaze	GSFC	Venus Entry Probe Prototype	Extreme Environ.
Ryan Park	JPL	Advanced Pointing Imaging Camera (APIC)	Instrument
Farzin Amzajerdian	LaRC	Navigation Doppler Lidar Sensor for Reliable and Precise Vector Velocity and Altitude Measurements	EDL
Elena Adams	APL	A small low-cost hopping lander (POGO) for asteroid exploration	Probe
Stojan Madzunkov	JPL	Atmospheric Constituent Explorer System for Planetary Probe Missions	Instruments
Scott Singer	SpectroLab	Active-tracking MEMS Micro-Concentrator for LILT Missions	Power
Chris Webster	JPL	Tunable Laser Spectrometer Risk Reduction for Saturn Probe and Venus In Situ Explorer NF Missions	Instrument

New Frontiers #4 Focused Missions

Comet Surface Sample Return

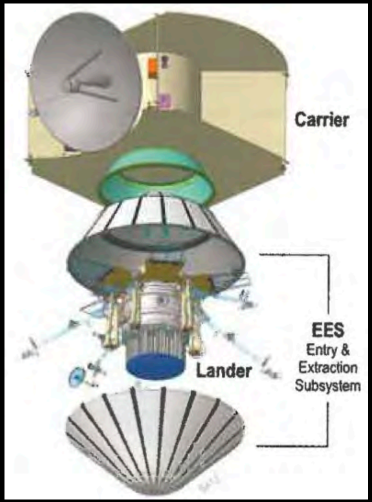


Lunar South Pole Aitken Basin Sample Return

Trojan Tour & Rendezvous

Saturn Probes

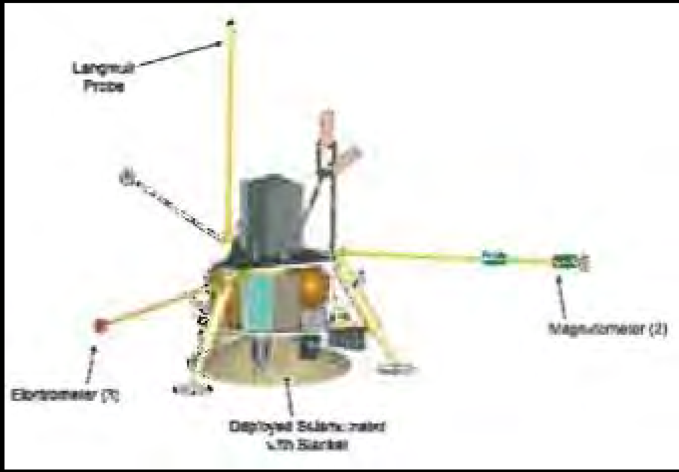
Venus In-Situ Explorer



New Frontiers #5 Focused Missions

- Added to the remaining list of candidates:

Lunar Geophysical Network

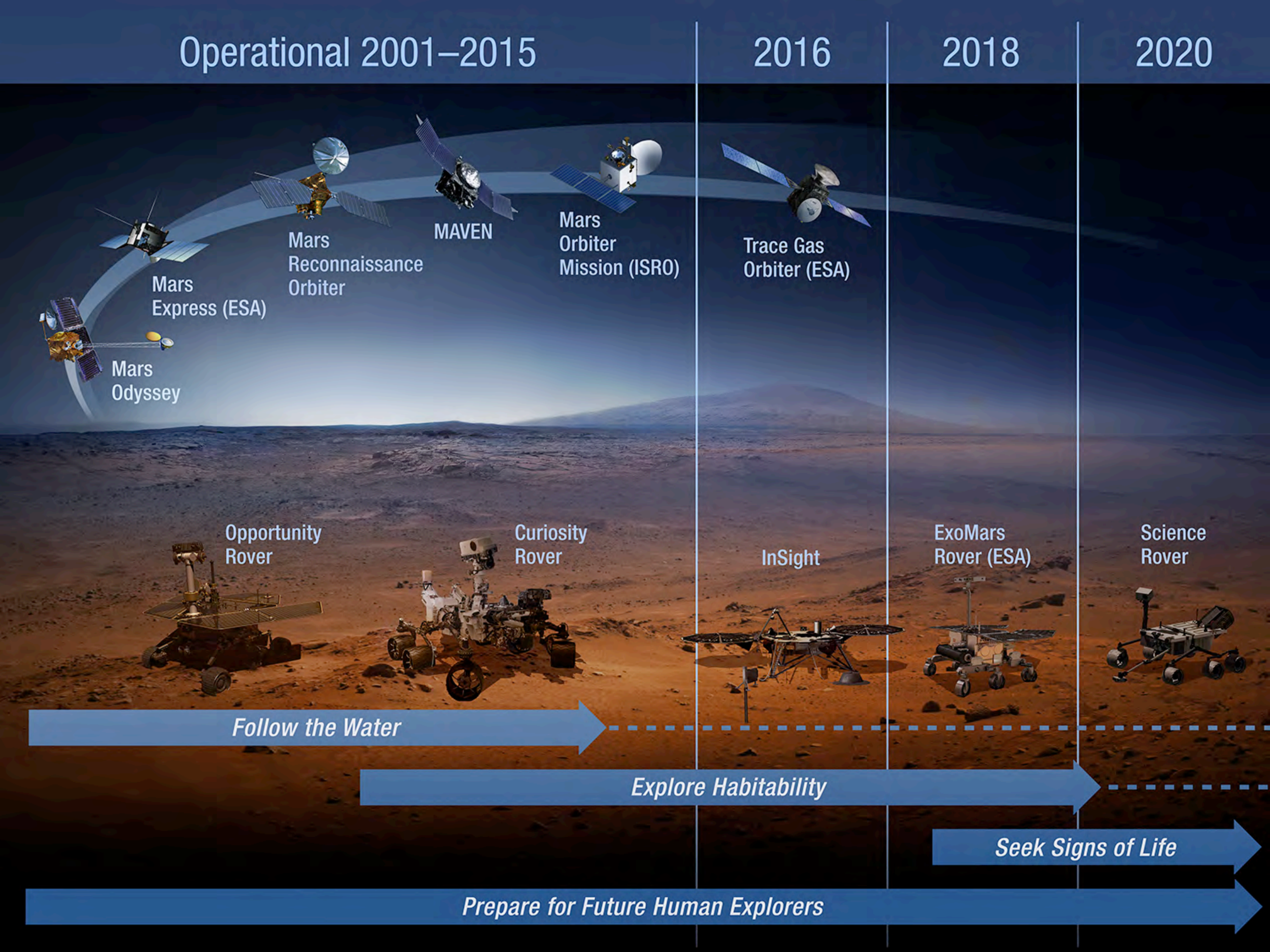


Io Observer

RPS Mission Planning

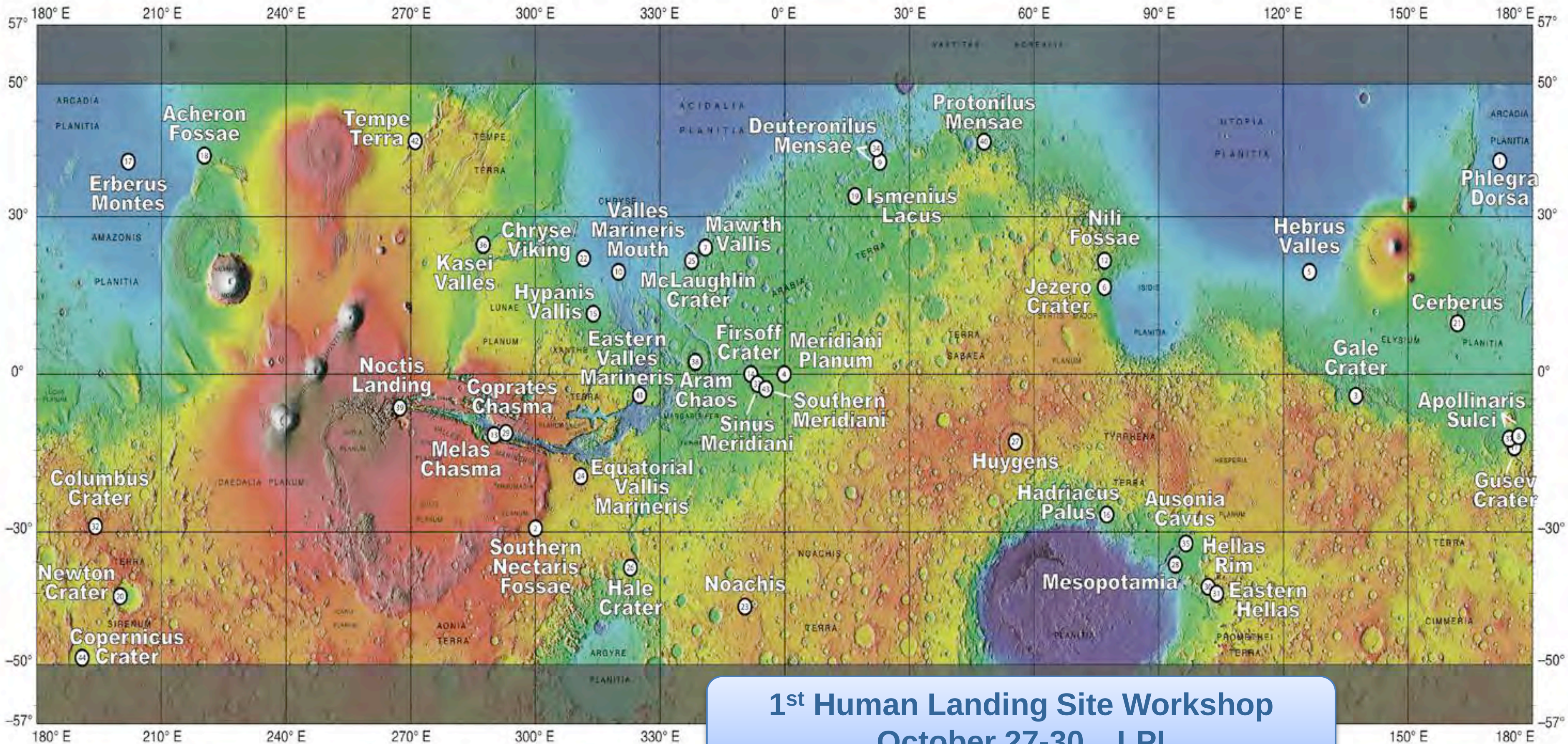
Strategic / New Frontiers / Discovery / Mars / Lunar / Other	Projected Launch Year	Power Reqmnt (W_e)	RPS Type (Flight + Spare)	Pu-238 Availability
Mars Science Lab **Operational**	2011	100	1 MMRTG	Yes
Mars 2020 **In Development**	2020	120	1 MMRTG + Spare	Yes
New Frontiers 4 **In Planning**	2024	300	3 MMRTG or 2 eMMRTG	Yes
New Frontiers 5 **Notional**	2030	300	TBD	Requires new

- Potential 5-6 year-cadence for New Frontier mission opportunities
  - RPS not required for all mission concepts
- Radioisotope heater units may be used on missions that do not require RPS
- Strategic missions often require RPS; 2 highest priority strategic missions in current decadal (Mars 2020 and Europa) are already in work
  - Mars 2020 will us an MMRTG
  - Europa mission will be solar powered



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
InSight
ExoMars Rover (ESA)
Science Rover
Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers

Potential Exploration Zones for Human Missions to the Surface of Mars



1st Human Landing Site Workshop
October 27-30 LPI

(00) Exploration Zones proposed for humans to Mars. At the equator, circles are ~100km radius

version 2.0 Sept 11, 2015

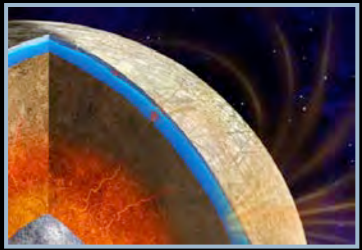
Prepared By: Lindsay Hays, Mars Program Office
lhays@jpl.nasa.gov

Europa Activities

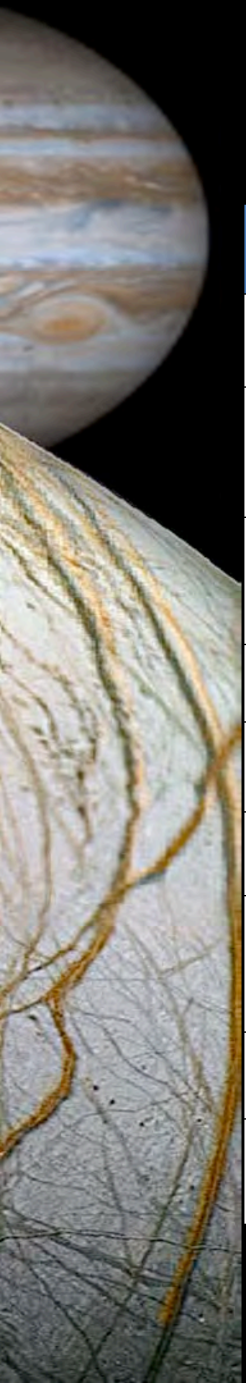
Now in Formulation (Phase A)

Europa Multi-Flyby Mission Science Goal & Objectives

- *Goal:* **Explore Europa to investigate its habitability**
- *Objectives:*
  - **Ice Shell & Ocean:** Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, 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
  - **Reconnaissance:** Characterize scientifically compelling sites, and hazards, for a potential future landed mission to Europa

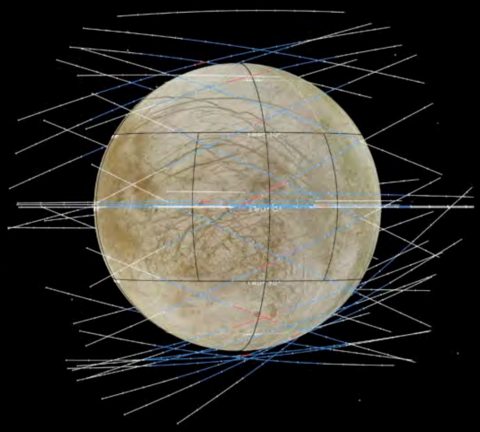


Overview of Selected Proposals



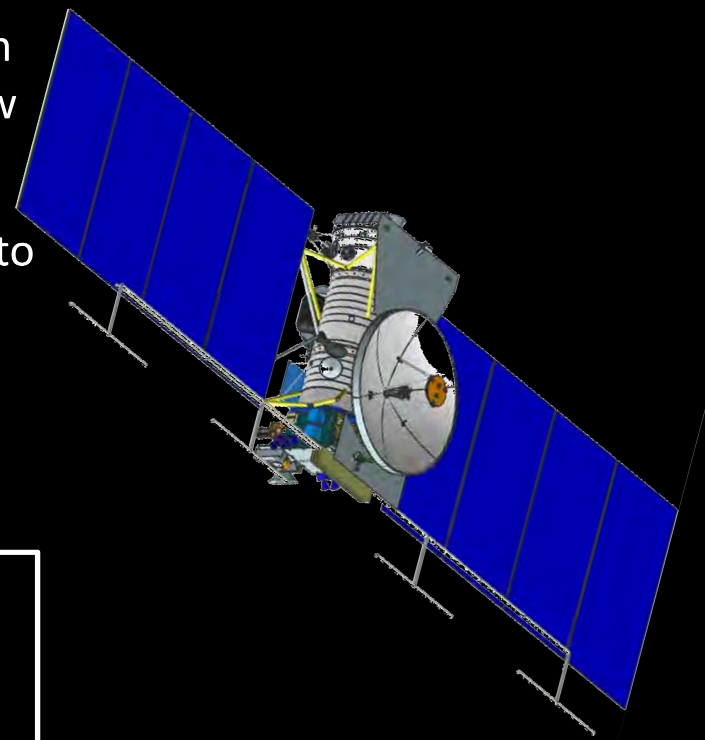
Instrument Type	Name	PI	instituion
Plasma	PIMS	Joseph Westlake	APL
Magnetometer	ICEMAG	Carol Raymond	JPL
Shortwave IR Spectrometer	MISE	Diana Blaney	JPL
Camera	EIS	Elizabeth Turtle	APL
Ice Penetrating Radar	REASON	Don Blankenship	Univ. Texas/JPL
Thermal Imager	E-THEMIS	Phil Christensen	ASU/Ball
Neutral Mass Spectrometer	MASPEX	Hunter Waite	SWRI
UV Spectrograph	E-UVS	Kurt Retherford	SWRI
Dust Analyzer	SUDA	Sascha Kempf	Univ. Colorado

Europa Multi-Flyby Mission Concept Overview



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

- 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
- Traded enormous amounts of fuel used to get into Europa orbit for shielding (lower total dose)
- Simpler operations strategy
- No need for real time down link



Key Technical Margins

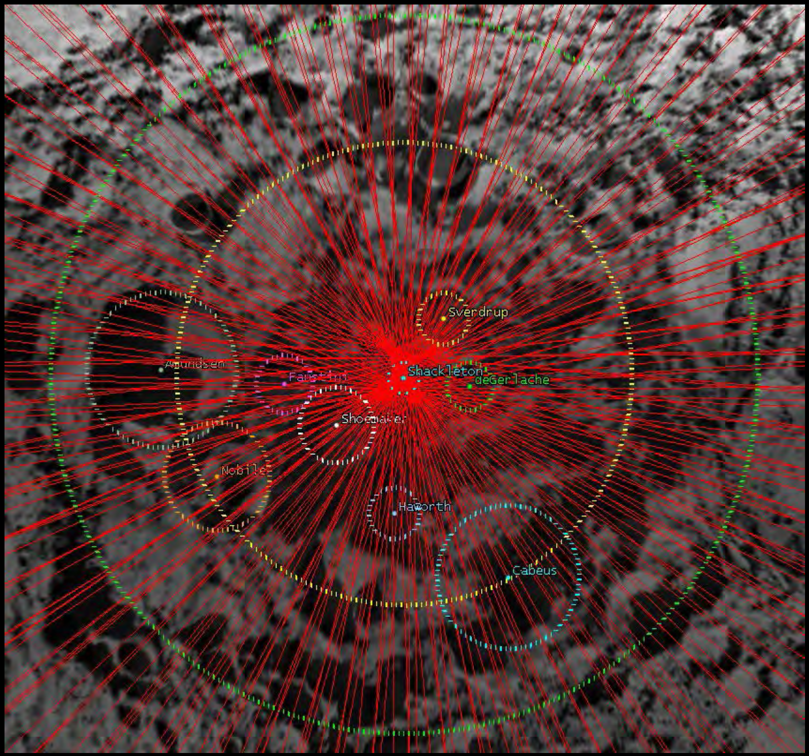
*37 - 41%	40%
Mass	**Power**

* Depends on Launch Opportunity and Launch Vehicle

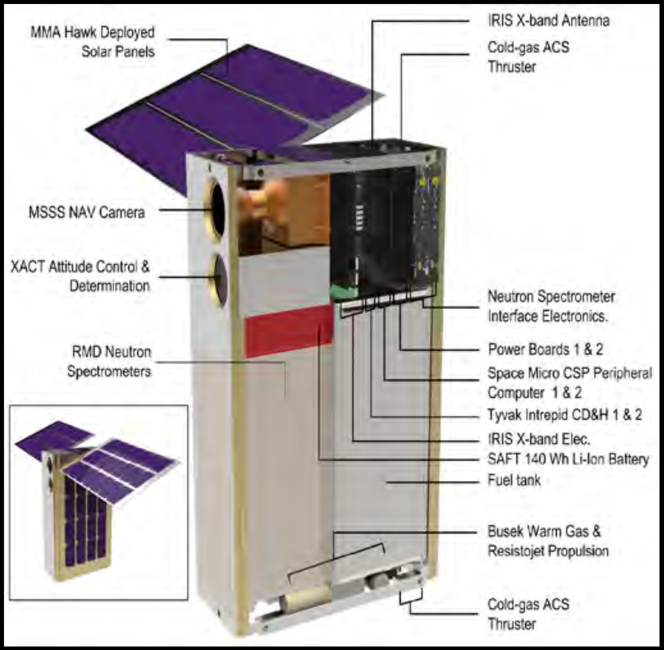
Small Innovative Missions for Planetary Exploration
(SIMPLEx-2014)
New Awards in FY15

LunaH-Map: Lunar Polar Hydrogen Mapper

PI: Craig Hardgrove, ASU School of Earth and Space Exploration



(LunaH-Map) is a 6U CubeSat that will enter a polar orbit around the Moon with a low altitude (5-12km) perilune centered on the lunar South Pole. LunaH-Map carries two neutron spectrometers that will produce maps of near-surface hydrogen (H). LunaH-Map will map H within permanently shadowed craters to determine its spatial distribution, map H distributions with depth (< 1 meter), and map the distribution of H in other permanently shadowed regions (PSRs) throughout the South Pole.



Orbit ground track shown for entire 60 (Earth) day science phase: 141 passes over target area initially (and periodically) centered on Shackleton Crater with close-approach of 5 km at each perilune crossing. Yellow circle denotes LunaH-Map altitude of 8 km; green circle denotes LunaH-Map altitude of 12 km.

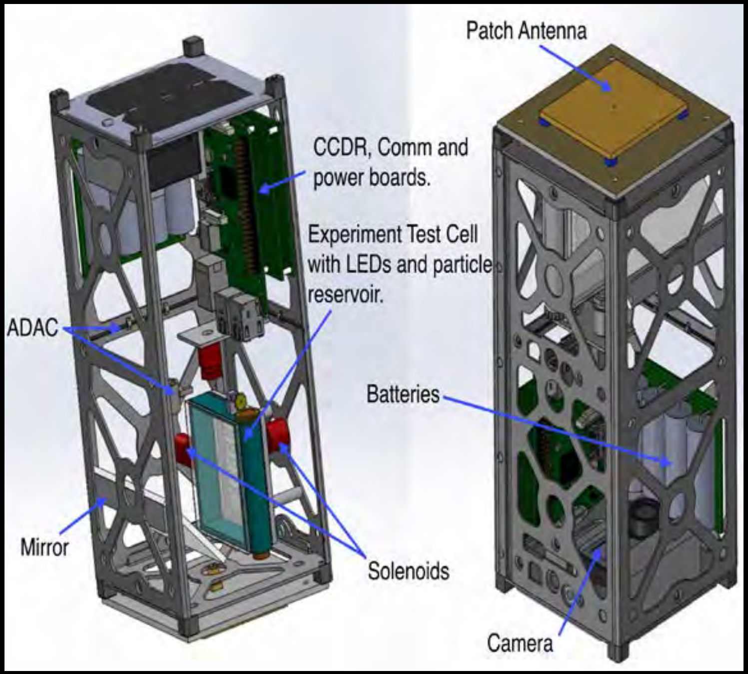
(Q-PACE): CubeSat Particle Aggregation and Collision Experiment

PI: Josh Colwell, University of Central Florida

Q-PACE is a thermos sized, LEO CubeSat, that will explore the fundamental properties of low-velocity (< 10 m/s) particle collision in a microgravity environment in an effort to better understand the mechanics of early planetoid development.

Q-PACE is a 2U CubeSat with a collision test cell and several particle reservoirs that contain meteoritic chondrules, dust particles, dust aggregates, and larger spherical monomers. Particles will be introduced into the test cell for a series of separate zero gravity experimental runs. The test cell will be mechanically agitated to induce collisions, which will be recorded by on-board video for later downlink and analysis.

Q-PACE has been accepted by the NASA CubeSat Launch Initiative program in the 2015 round of selections.

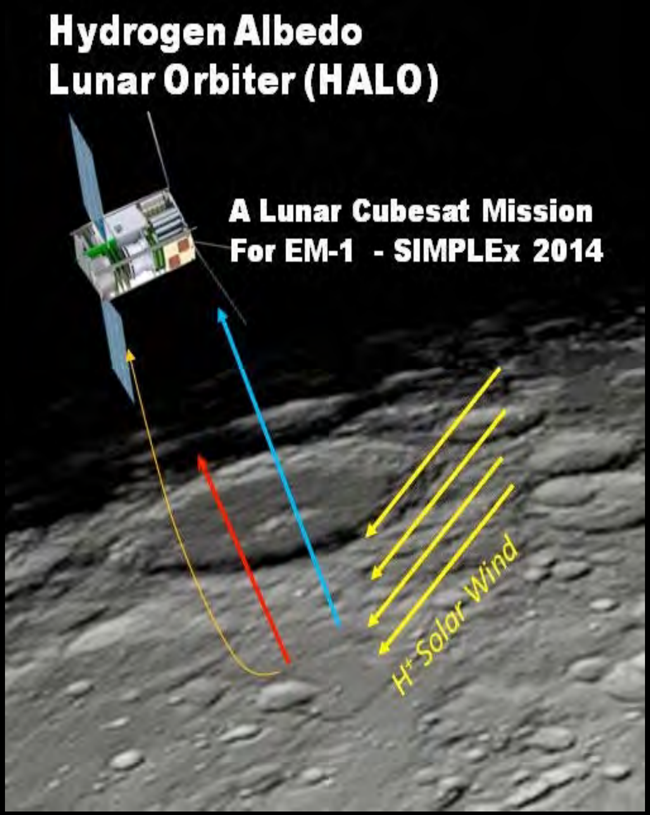


Q-PACE from opposite ends with the outer walls and solar panels removed to reveal the spacecraft components.

Simplex Cubesats

Approved for Tech Development (1 year) Study ONLY

HALO: Hydrogen Albedo Lunar Orbiter
PI: Michael Collier, NASA GSFC



HALO is a propulsion-driven 6U CubeSat with an ion spectrometer that simultaneously observes the impinging solar wind and the reflected ion component with a nadir-facing low-energy neutral atom imager that observes the upward moving neutral hydrogen.

The HALO mission will survey the surface of the Moon for a minimum of 3 months, allowing it to measure multiple trajectories of the solar wind, follow the moon into the wake region of the Earth's magnetosphere, and sample meteoric impact.

The goal is to measure the flux as a function of location, solar phase angle, subsurface mineralogy, magnetic anomaly condition, and under meteor shower conditions in order to map the potential for the formation of water and OH in the lunar regolith.

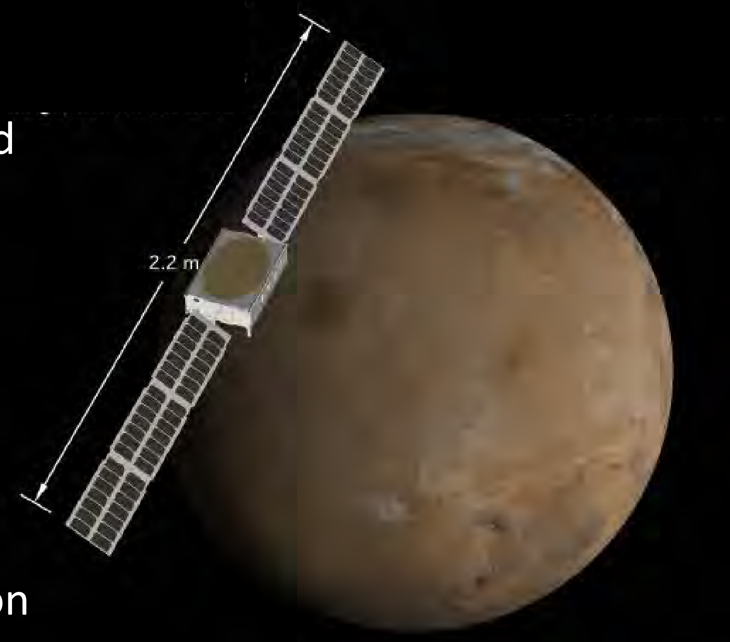
Mars Micro Orbiter

PI: Michael Malin, Malin Space Science Systems

The **Mars Micro Orbiter (MMO)** mission uses a 6U-class Cubesat to measure the Mars atmosphere in visible and infrared wavelengths from Mars orbit.

These science measurements will:

(1) Extend the temporal coverage of the global synoptic meteorological record of Mars, which includes atmospheric thermal structure, dust and condensate clouds, and seasonal and perennial polar cap behavior,
(2) Characterize the dynamics and energy budget of the current Mars atmosphere,
(3) Support present and future Mars missions
(4) Characterize present-day habitability



The CubeSat can also act as an orbital communication relay for Mars surface-based missions.

DAVID: Diminutive Asteroid Visitor using Ion Drive

PI: Geoffrey Landis, NASA Glenn Research Center

DAVID is a 6U CubeSat mission that will investigate an asteroid much smaller than any investigated by previous spacecraft missions and will be the first NASA mission to investigate an Earth-crossing asteroid.

Despite its small size, the DAVID CubeSat will have three primary instruments that would operate for a short-duration flyby, including a wide-field camera, a narrow-field camera and a point VNIR spectrometer.

DAVID will provide critical first-order data on 2001–GP2’s size, shape, composition, and source region in the main belt, while scouting its rotational state and physical properties.

New NRC Study

National Academy R&A Study

Objective: Examine the program elements of the PSD R&A programs, as they currently exist following restructuring, for their consistency with past NRC advice.

The committee will address the following questions:

1. Are the PSD R&A program elements appropriately linked to, and do they encompass the range and scope of activities needed to support, the NASA Strategic Objective for Planetary Science and the PSD Science Goals, as articulated in the 2014 *NASA Science Plan*?

2. Are the PSD R&A program elements appropriately structured to develop the broad base of knowledge and broad range of activities needed both to enable new spaceflight missions and to interpret and maximize the scientific return from existing missions?

New Communications Policy

NASA's Evolving Communications Policy

The role of science missions in NASA communications has evolved since missions were directed to propose and spend 1% of their total budget on education and public outreach (EPO). In 2014:

- NASA's policy documents established new definitions for communications.
  - Traditional news and social media, multimedia and public outreach and engagement were consolidated.
- EPO funding was removed from mission budgets.
- Education activities and funding were consolidated within SMD, under the Director for Science Engagement and Partnerships (see K. Erickson presentation)
  - Activities and funding were restructured along science disciplines, not missions.
  - The Director for Science Engagement and Partnerships has responsibility for integrated education strategies within SMD.

NASA's Definition of Communications

NASA has defined communications as follows:

- A comprehensive set of activities to effectively convey, and provide an understanding and inspiration about NASA's work, its objectives and benefits to target audiences, the public and other stakeholders, including NASA employees.
- These activities are intended to promote interest and foster participation in NASA's endeavors, and to develop exposure to, and appreciation for, Science, Technology, Engineering, and Math (STEM).

NOTE: This SMD policy does not cover technical communications directed at the scientific and technical community including scientific papers, technical reports, and web sites serving mission data and other technical information.

Roles and Responsibilities

<u>NASA Center or JPL Office of Communications</u>

- Missions must use the communications office of a NASA center or JPL to manage the communications plan and activities.
- These communications offices will be responsible for leading, coordinating, and executing mission communications activities -- in coordination with the mission's Principal Investigator (PI) for PI-led missions -- and with approval of Headquarters SMD and Office of Communications.
- The communications office develops the communications plan with the project and PI during Phase B of the mission.
- Mission-related communications are funded from the project budget (not within the PI's mission cost cap).

Roles and Responsibilities

<u>Principal Investigators</u>

- The PI is a key spokesperson for the mission – along with NASA officials -- and is integral in communicating mission updates, science, and new discoveries.
- The PI provides content, analysis, and context for communications activities to convey an understanding of the mission, its objectives and benefits to target audiences, the public, and other stakeholders.
- The PI coordinates with the designated NASA center communications office for all mission-related communications activities.
  - All mission news releases are reviewed by the PI (or designee).
  - In the case of incompatible views, NASA has final decision on release of public products, while ensuring that scientific and technical information remains accurate and unfiltered.

2014 LEAG Findings: PSD Response

2014 LEAG Meeting Findings!

The attendees of the 2014 LEAG Meeting endorse the following findings:

Volatile Resources.

- With an emphasis on polar volatiles as a potential resource, the potential for other non-polar deposits to yield significant resources should not be ignored (e.g., Fe-rich pyroclastic deposits).

Volatiles from the Lunar Interior.

- As with surface volatiles, our understanding of volatiles in the lunar interior, first observed in sample in 2008, is also rudimentary. Targeted sample return from pyroclastic deposits and basalt flows of various ages would significantly aid our comprehension of the role volatiles played in the magmatic evolution of the Moon.

2014 LEAG Meeting Findings!

The Future.

Momentum gained with recent lunar missions (LRO, LCROSS, LADEE, GRAIL, ARTEMIS) feed forward into key NASA science and exploration goals and horizons. It is critical that this pace of discovery be maintained to support our international partners, feed-forward technology, and operational developments for future crewed missions to Mars. A key finding from the 2014 LEAG meeting is that SMD and HEOMD, maintain a sustained program of lunar missions (e.g., Discovery; New Frontiers through SPA Sample Return & Lunar Geophysical Network; directed missions, etc.) focused on addressing key science, resource, and technology development issues in line with the decadal survey and to support long-term NASA goals.

2014 LEAG Meeting Findings!

LRO - Mini-RF.

- LEAG and the lunar community are concerned that the Mini-RF instrument is being terminated as part of the active payload for the LRO Extend Mission 2.
- Mini-RF in the Earth-based bistatic mode is the only instrument on the LRO payload that is capable of detecting the presence subsurface ice deposits, which are of extreme interest both scientifically and for exploitation as a potential resource. Data presented at the 2014 LEAG meeting highlighted this and these data demonstrate the programmatic importance of Mini-RF for identifying water ice deposits in permanently shadowed craters.
- We believe the termination of the Mini-RF experiment will result in a significant degradation of the potential to understand lunar polar volatiles.
- The SMD/PSD and HEOMD are encouraged to explore options to continue funding such targeted Mini-RF bistatic measurements during the second extended mission period or provide an opportunity to do so during the third LRO extended mission.

2014 LEAG Meeting Findings!

Planetary Cartography*.

- An oversight body for Planetary Cartography needs to be created that has the status of an Analysis Group (AG) and has representation on the Planetary Science Subcommittee of the NASA Advisory Council. This is needed in order to address cartographic planning and requirements and to enable consistent standards to be applied to various planetary datasets. The need for the establishment of such an AG is recognized and supported by the LEAG community in order to continue NASA's excellence in Planetary Cartography.

* follow up to Planetary Science Subcommittee finding, September 2014

2014 LEAG Meeting Findings!

Cube-Sats.

- The creation of opportunities for small (cube-sat) scale missions / experiments for the Space Launch System (SLS) and other launch opportunities is encouraged and should be widely advertised.
- The selection of Lunar Flashlight as a SLS-EM1 cube-sat payload through HEOMD is an excellent demonstration of the value of such a program. PSD is encouraged to explore avenues for community participation in this mission.

2014 LEAG Meeting Findings!

Enabling Infrastructure.

- There is a recognized need for orbital infrastructure to enable lunar missions (particularly surface missions at high latitude or on the far side) and efforts should be made to establish this. For example, an enabling technology that facilitates international cooperation and collaboration is communications relay capability from the lunar surface to Earth.

- This could be achieved by:
  - Expanding commercial RFI for communications relay at Mars to the Moon;
  - Re-start talks with international partners regarding enabling communications infrastructure at the Moon as was done for the International Lunar Network.

LEAG Ex-Comm Findings!

LEAG Charter and Operation.

- LEAG's joint charge by HEOMD and SMD should be confirmed.
- Any changes to the manner in which the Lunar and Small Bodies Analysis Groups (AGs) are run should be coordinated by both HEOMD and SMD.
- SMD and HEOMD should be able to independently task an AG, but the rules of operation should be consistent.

Questions?

Image by john doe