

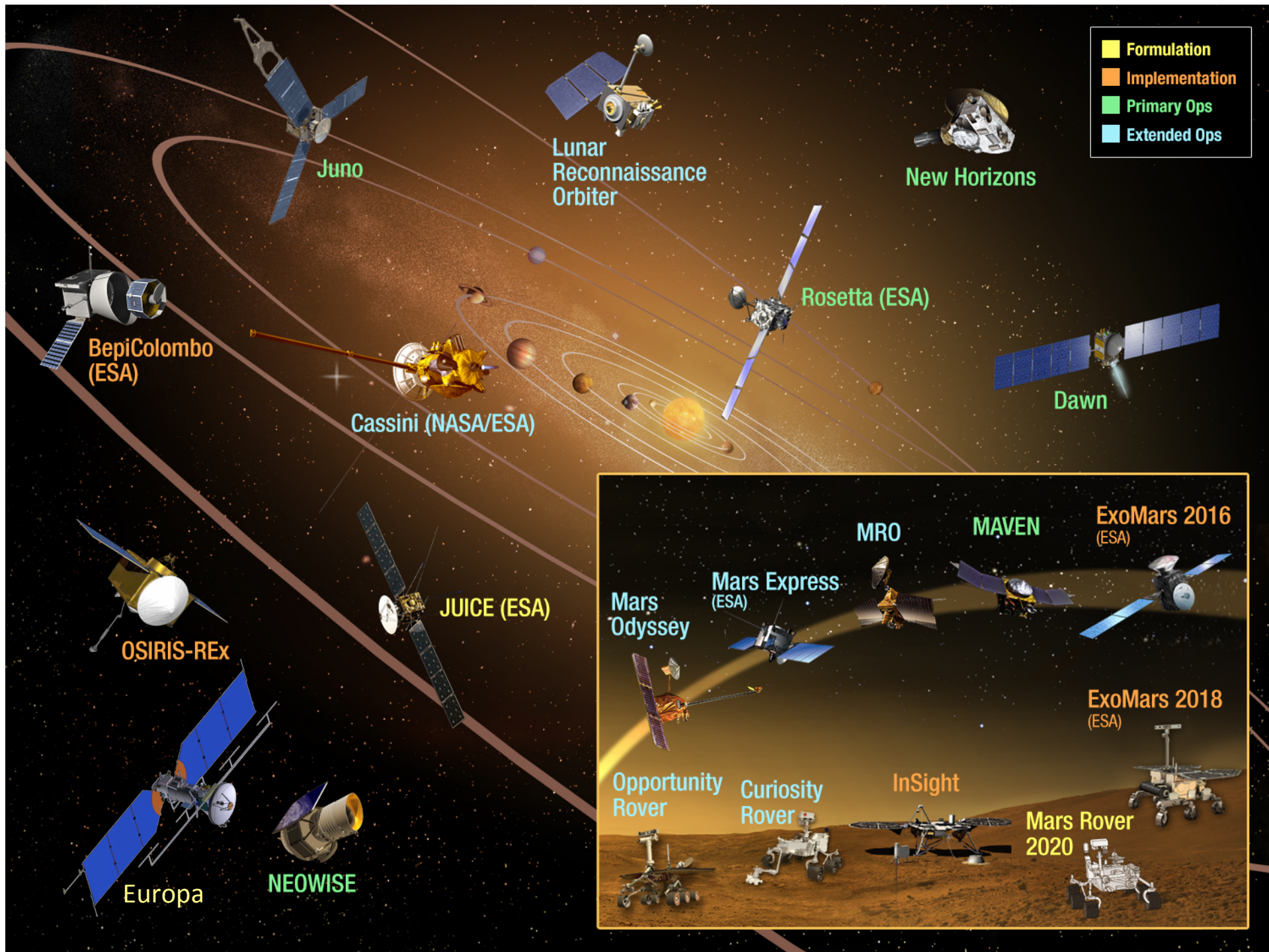
Planetary Science Division Status Report

James L. Green
NASA, Planetary Science Division
October 27, 2015

Presentation at VEXAG

Outline

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



Planetary Science Missions Events

2014

- July – *Mars 2020* Rover instrument selection announcement * Completed
- 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

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

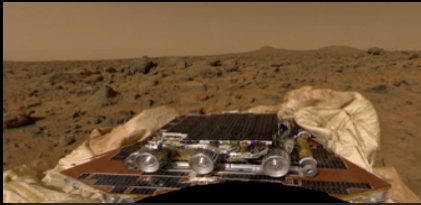


- ◆ Established in 2003
- ◆ **\$850M cap** per mission excluding launch vehicle and operations phase (FY15\$)
- ◆ Addresses high-priority investigations identified by the National Academy of Sciences

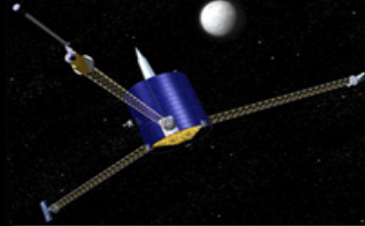
Discovery Program

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

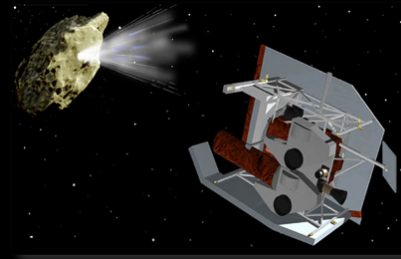
**Comet diversity:
CONTOUR (2002)**



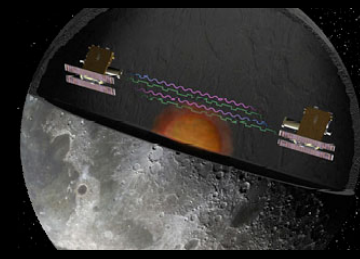
**Nature of dust/coma:
Stardust (1999-2011)**



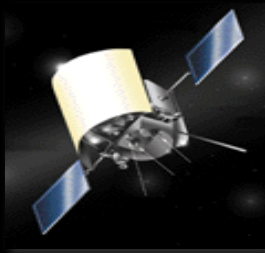
**Comet internal structure:
Deep Impact (2005-2012)**



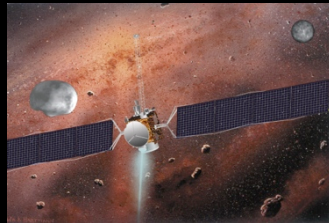
**Lunar Internal Structure
GRAIL (2011-2012)**



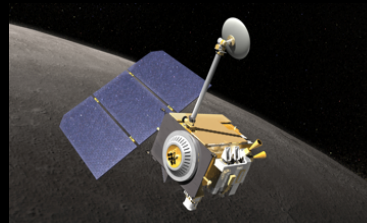
**Mercury environment:
MESSENGER (2004-2015)**



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



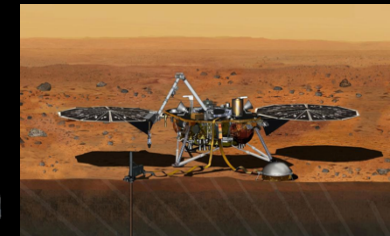
**Lunar surface:
LRO (2009-TBD)**



**ESA/Mercury Surface:
Strofió (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

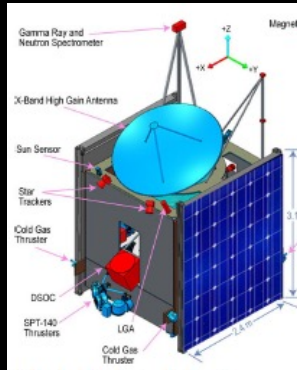
Missions in Operation

- *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

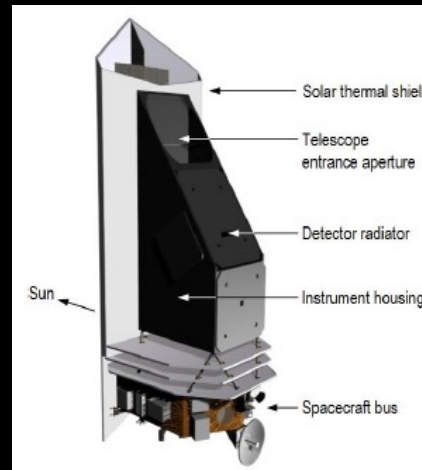
Discovery Selections



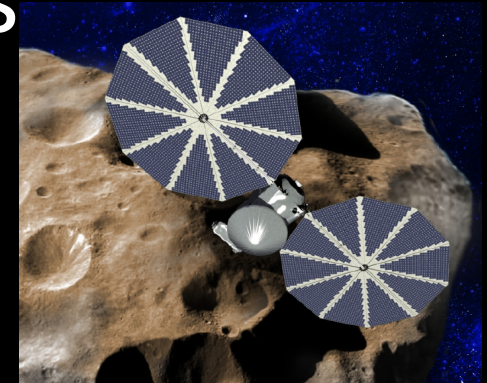
Psyche: Journey to a Metal World
 PI: Linda Elkins-Tanton, ASU
 Deep-Space Optical Comm (DSOC)



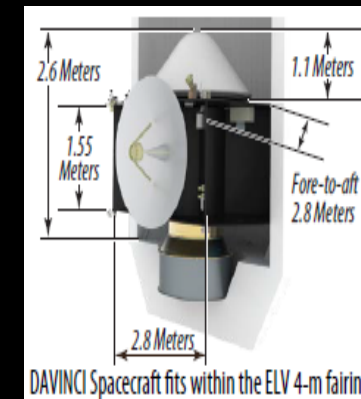
VERITAS: Venus Emissivity, Radio Science, InSAR, Topography, And Spectroscopy
 PI: Suzanne Smrekar, JPL
 Deep-Space Optical Comm (DSOC)



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

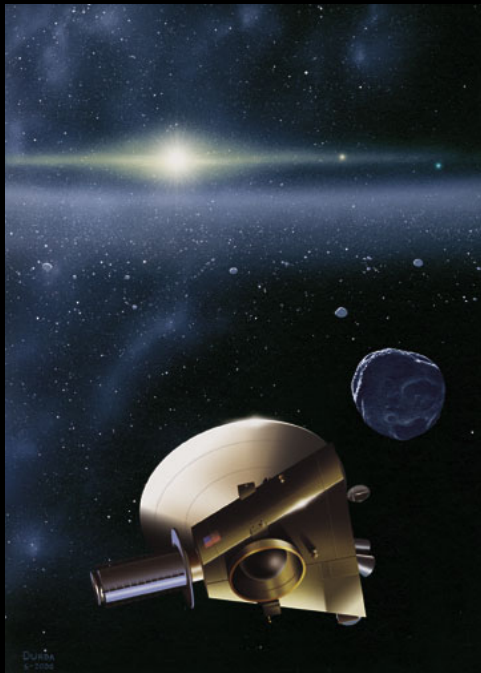


DAVINCI: Deep Atmosphere Venus Investigations of Noble gases, Chemistry, and Imaging
 PI: Lori Glaze, GSFC

New Frontiers Program

1st NF mission
New Horizons:

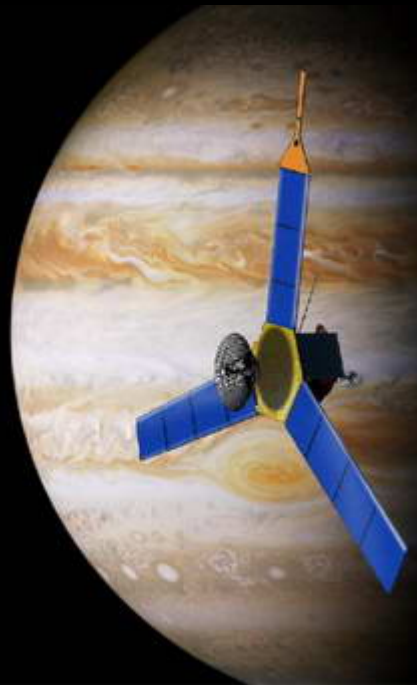
Pluto-Kuiper Belt



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

2nd NF mission
Juno:

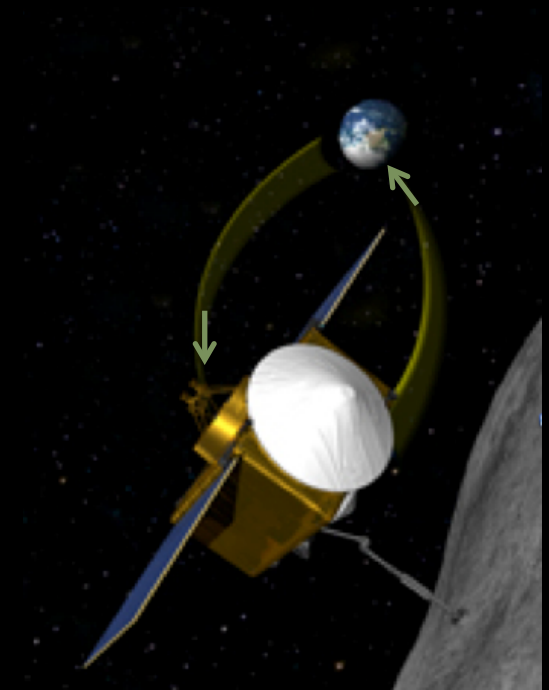
Jupiter Polar Orbiter



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

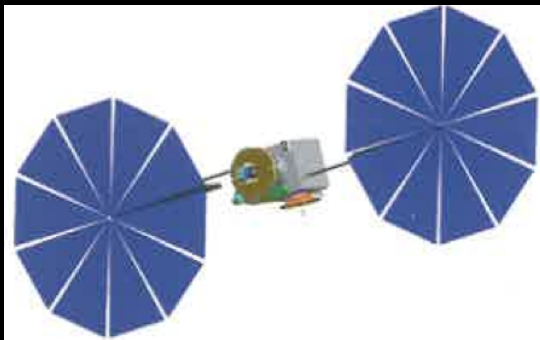
Homesteader Program Overview

- 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 Amzajerjian	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



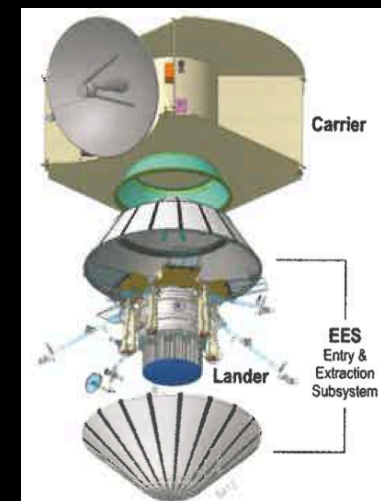
Trojan Tour &
Rendezvous



Saturn Probes



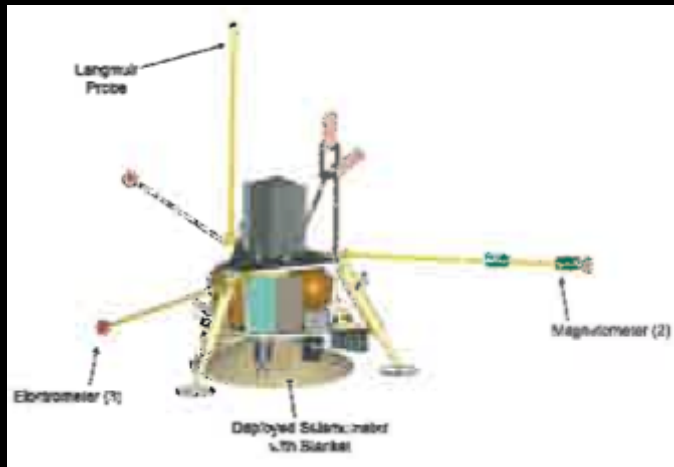
Venus In-Situ Explorer



New Frontiers #5 Focused Missions

- Added to the remaining list of candidates:

Lunar Geophysical Network



Io Observer



RPS Mission Planning

<div> <div> <div>Strategic</div> <div>New Frontiers</div> <div>Discovery</div> </div> <div> <div>Mars</div> <div>Lunar</div> <div>Other</div> </div> </div>		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

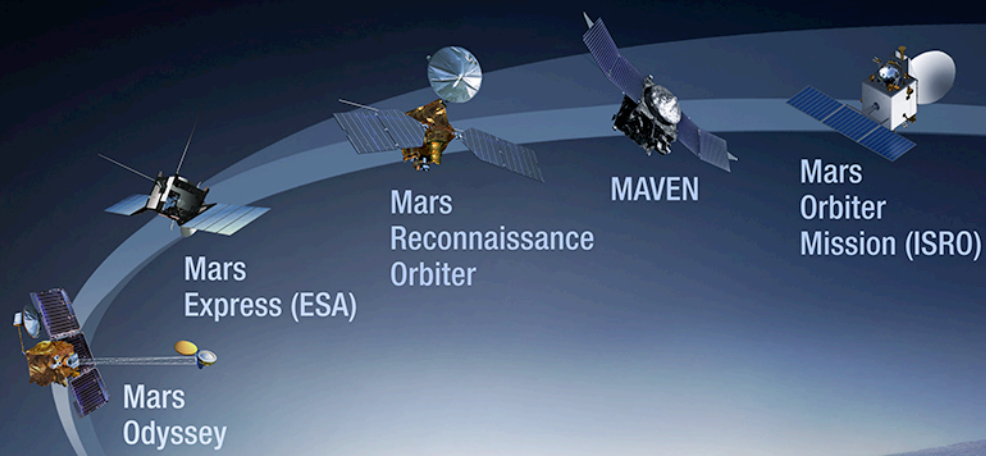
- Potential 5-6 year-cadence for New Frontier mission opportunities
 - RPS not required for all mission concepts
- Radioisotope heater units may be used on missions that do not require RPS
- Strategic missions often require RPS; 2 highest priority strategic missions in current decadal (Mars 2020 and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

Operational 2001–2015

2016

2018

2020



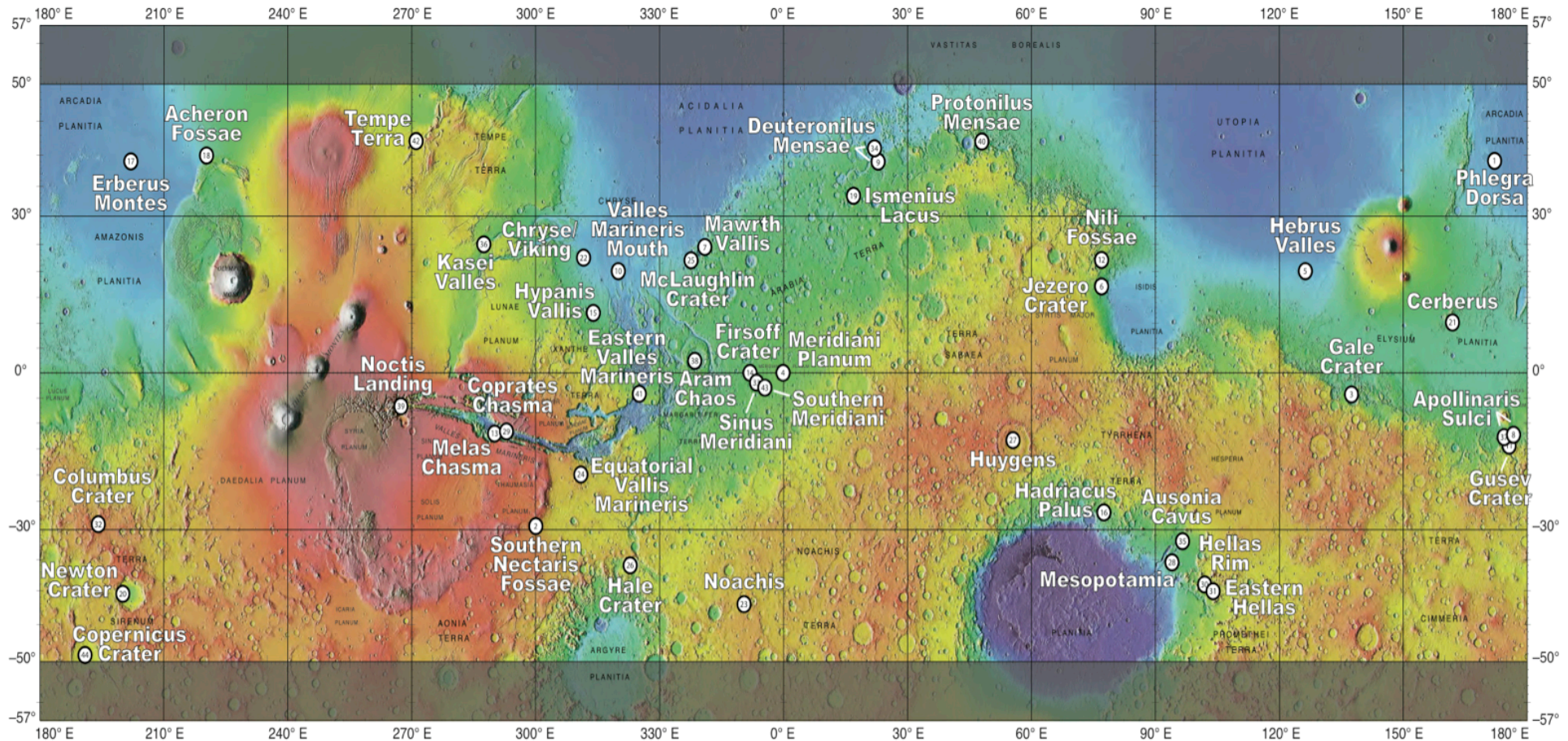
Follow the Water

Explore Habitability

Seek Signs of Life

Prepare for Future Human Explorers

Potential Exploration Zones



1st Human Landing Site Workshop
October 27-30 at LPI

#JOURNEYTOMARS

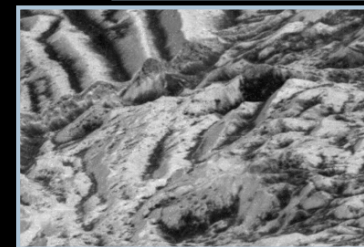
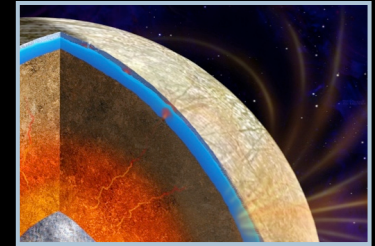


Europa Activities

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

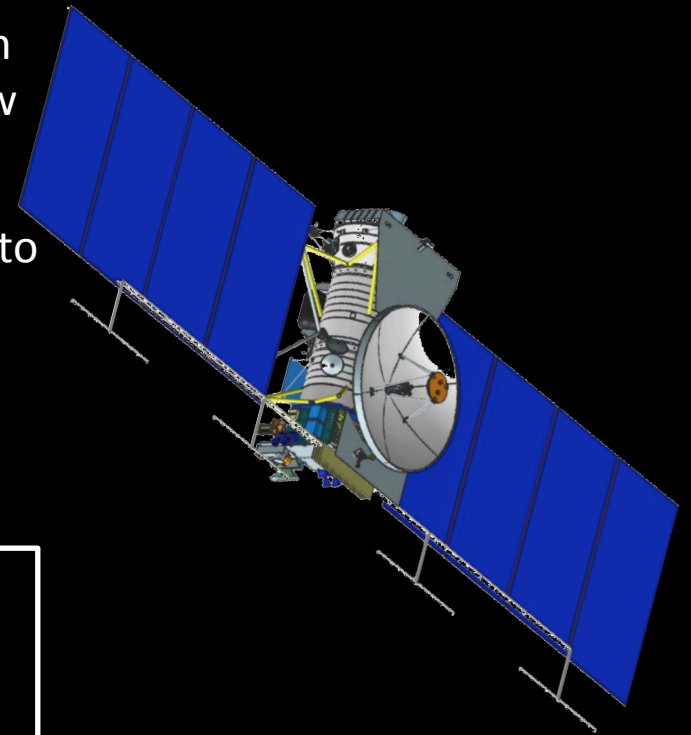
Objective	Description
Ice Shell & Ocean	Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange
Composition	Understand the habitability of Europa's ocean through composition and chemistry.
Geology	Understand the formation of surface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

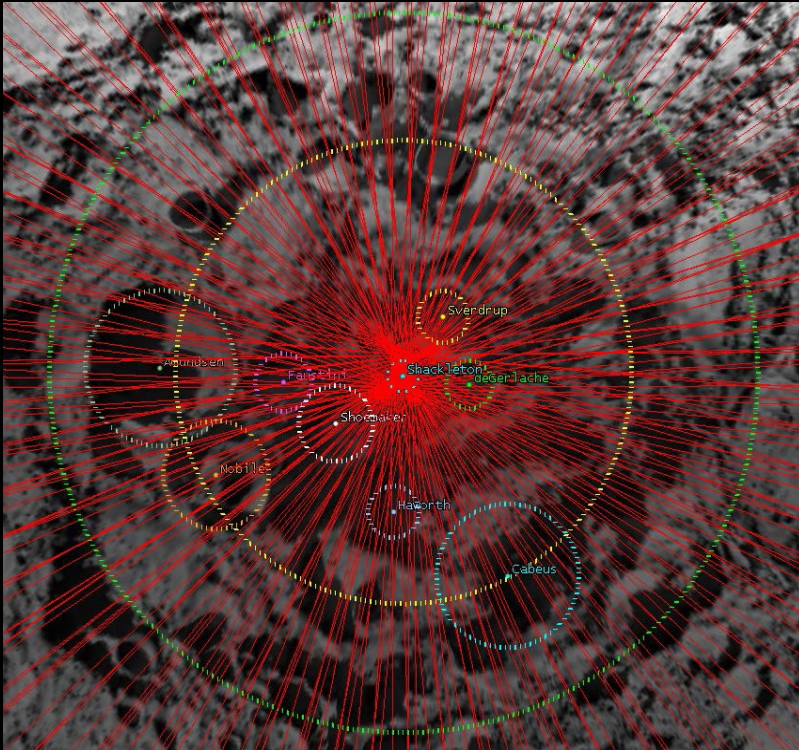
* Depends on Launch Opportunity and Launch Vehicle



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

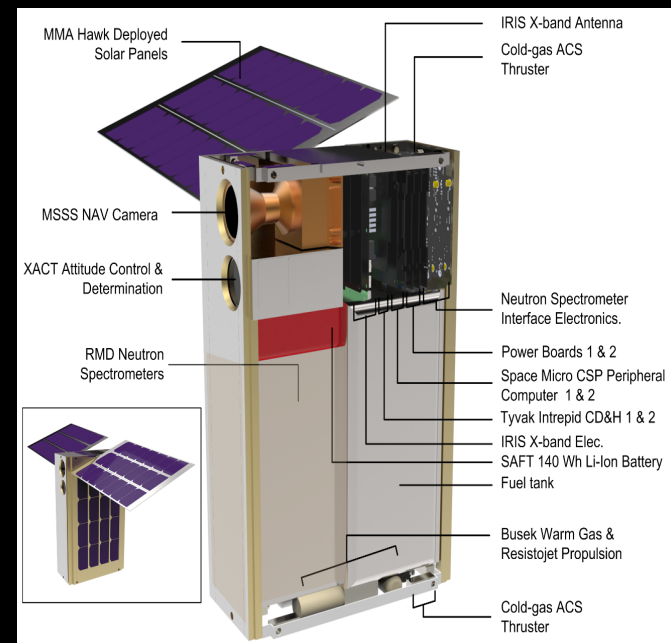
LunaH-Map: Lunar Polar Hydrogen Mapper

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



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.

(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.



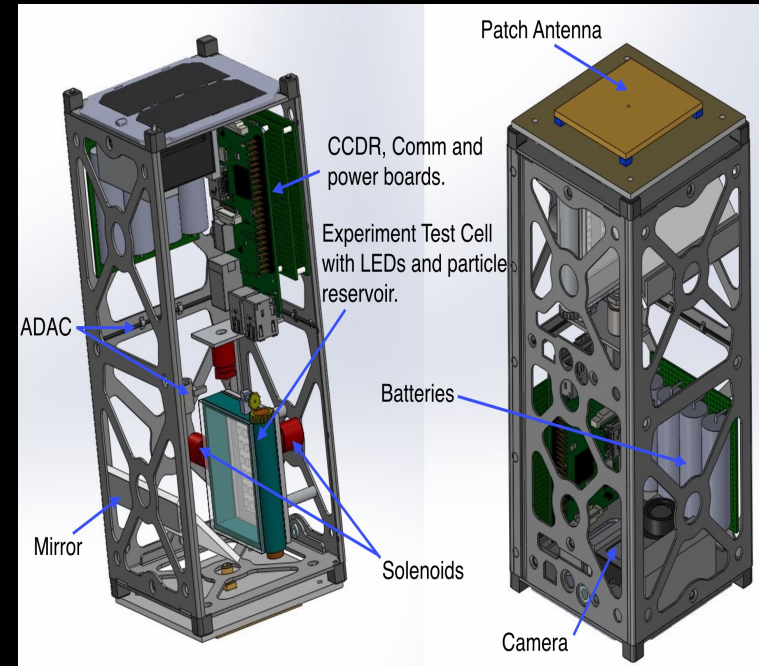
(Q-PACE): CubeSat Particle Aggregation and Collision Experiment

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.

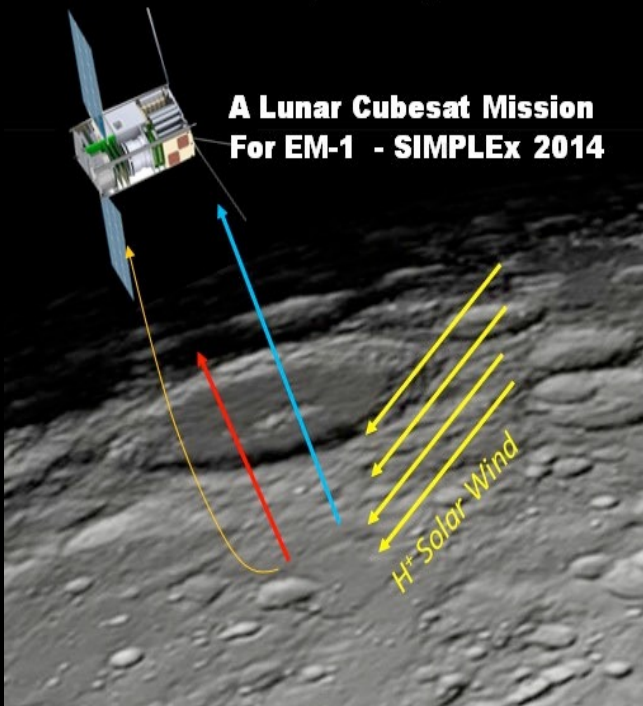
Simplex Cubesats
Approved for Tech Development (1 year) Study ONLY

HALO: Hydrogen Albedo Lunar Orbiter

PI: Michael Collier, NASA GSFC

Hydrogen Albedo Lunar Orbiter (HALO)

A Lunar Cubesat Mission
For EM-1 - SIMPLEx 2014



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

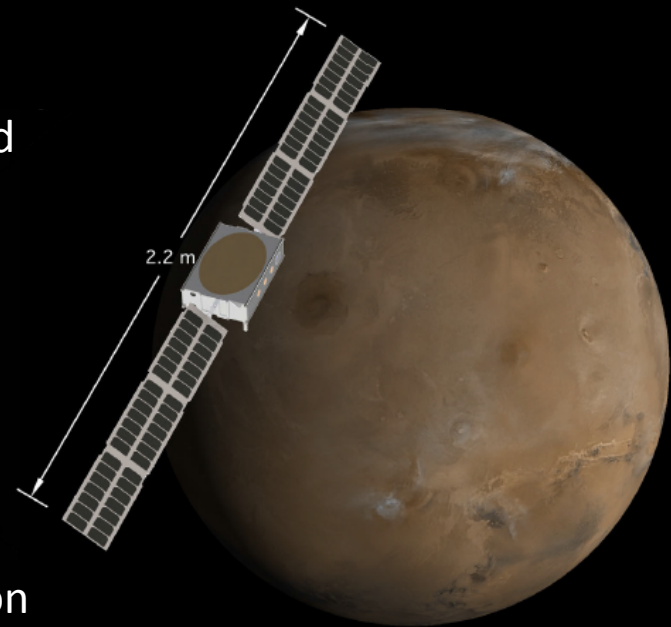
PI: Michael Malin, Malin Space Science Systems

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.



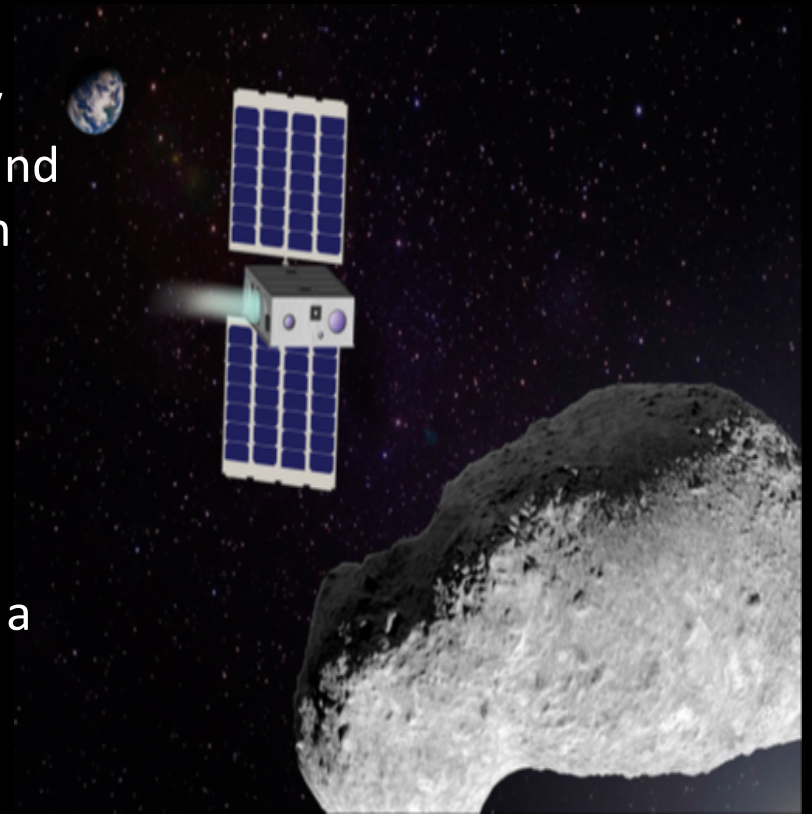
DAVID: Diminutive Asteroid Visitor using Ion Drive

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 Studies

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?

Joint SDT for a Venus Mission

- A Science Definition Team (SDT) was established by NASA and the Russian Academy of Sciences' Space Research Institute (IKI) to examine potential future Venus mission scenarios that could prove of interest to both of our science communities
- The SDT held its first meeting in Moscow earlier this month to begin the exchange of ideas and will hold a second meeting in February 2016
- NASA will await the findings of this team before deciding on a next course of action

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

NASA Center or JPL Office of Communications

- 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

Principal Investigators

- 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.

12th VEXAG Findings: PSD Response

12th VEXAG Meeting – 9 April 2015

FINDING #1

VEXAG is enthusiastic about the science observations of the dynamic environment of Venus that can be made during the more than two dozen gravity-assist fly-bys that will occur through 2024 from ESA and NASA missions - Solar Orbiter, BepiColombo and Solar Probe Plus. These would be particularly valuable to maintain continuity of Venus observations until the next mission(s) to Venus. VEXAG appreciates the role that PSD played in identifying these opportunities and in supporting the assessment of possible science observations. VEXAG encourages PSD to identify future opportunities to include Venus science with missions that have other primary applications/targets.

Many mission trajectories include one or more Venus flybys and these opportunities may enable new low cost mission data. VEXAG also encourages PSD to consider secondary payloads for Venus observations that can take advantage of missions that may have excess launch mass capacity.

12th VEXAG Meeting – 9 April 2015

FINDING #2

VEXAG encourages PSD to create a sustained mechanism for the development/maturation of specialized spacecraft systems that will enable PSD to explore all the solar system, including the challenging yet scientifically significant atmosphere and surface of Venus. Future Venus missions can be enhanced or enabled by advanced technology. Some of these technologies are of a specialized nature with limited applications outside of planetary science and therefore unlikely to be developed or matured by others. Examples of technologies that are critical for future Venus exploration include high temperature electronics, high temperature power generation and storage systems, and high temperature mechanisms. Currently there is no mechanism for these technologies to get proposed or funded within PSD or elsewhere.

12th VEXAG Meeting – 9 April 2015

FINDING #3

VEXAG encourages PSD to explore the feasibility of STMD supporting technologies applicable to Venus missions. Some technologies could benefit from space demonstrations and could be prime candidates for consideration in the Technology Demonstration Mission program.

12th VEXAG Meeting – 9 April 2015

FINDING #4

VEXAG encourages PSD to support the further development of a new stratospheric observing asset that would be made available to the science community. The recent assessments and demonstrations of stratospheric balloon borne telescopes offer promise and could benefit the Venus community by providing science data such as day and night time winds, cloud properties, emissivity mapping, and more.

A facility balloon asset would provide frequent and much needed opportunities to engage in missions and science measurements. Competing the science and observing time through ROSES is encouraged to maximize community access and engagement, as well as the science returned.

12th VEXAG Meeting – 9 April 2015

FINDING #5

VEXAG continues to encourage NASA participation in future international partnerships including mission collaboration and participating scientist programs (e.g., Akatsuki and Venus Express). NASA support of the International Venus Exploration Working Group (COSPAR) will facilitate the needed dialog towards the exploration programs.

12th VEXAG Meeting – 9 April 2015

FINDING #6

VEXAG encourages PSD support for several upcoming opportunities and initiatives:

- a. Comparative Climatology of the Terrestrial Planets -2 (CCTP2), 8-11 September 2015, Ames Research Center, Moffett Field, CA.
 - i. VEXAG is encouraged by the broad support for this meeting from all four NASA science divisions
 - ii. Participation from students and early-career scientists whose research spans all four NASA HQ science divisions is expected. VEXAG anticipates travel support for these early career scientists to present the results of their research at this meeting

12th VEXAG Meeting – 9 April 2015

FINDING #6

VEXAG encourages PSD support for several upcoming opportunities and initiatives:

- b. 13th VEXAG Meeting, October 27 – 29, 2015, Washington, DC area
- c. Continued efforts to initiate the Extreme Environments Centennial Challenge
- d. A workshop focused on science results based on laboratory, theoretical modeling, and simulation studies of a broad range of Venus topics
- e. A future workshop to cross-fertilize technologies of interest to Venus exploration as well as other applications

Questions?



Image by john doe