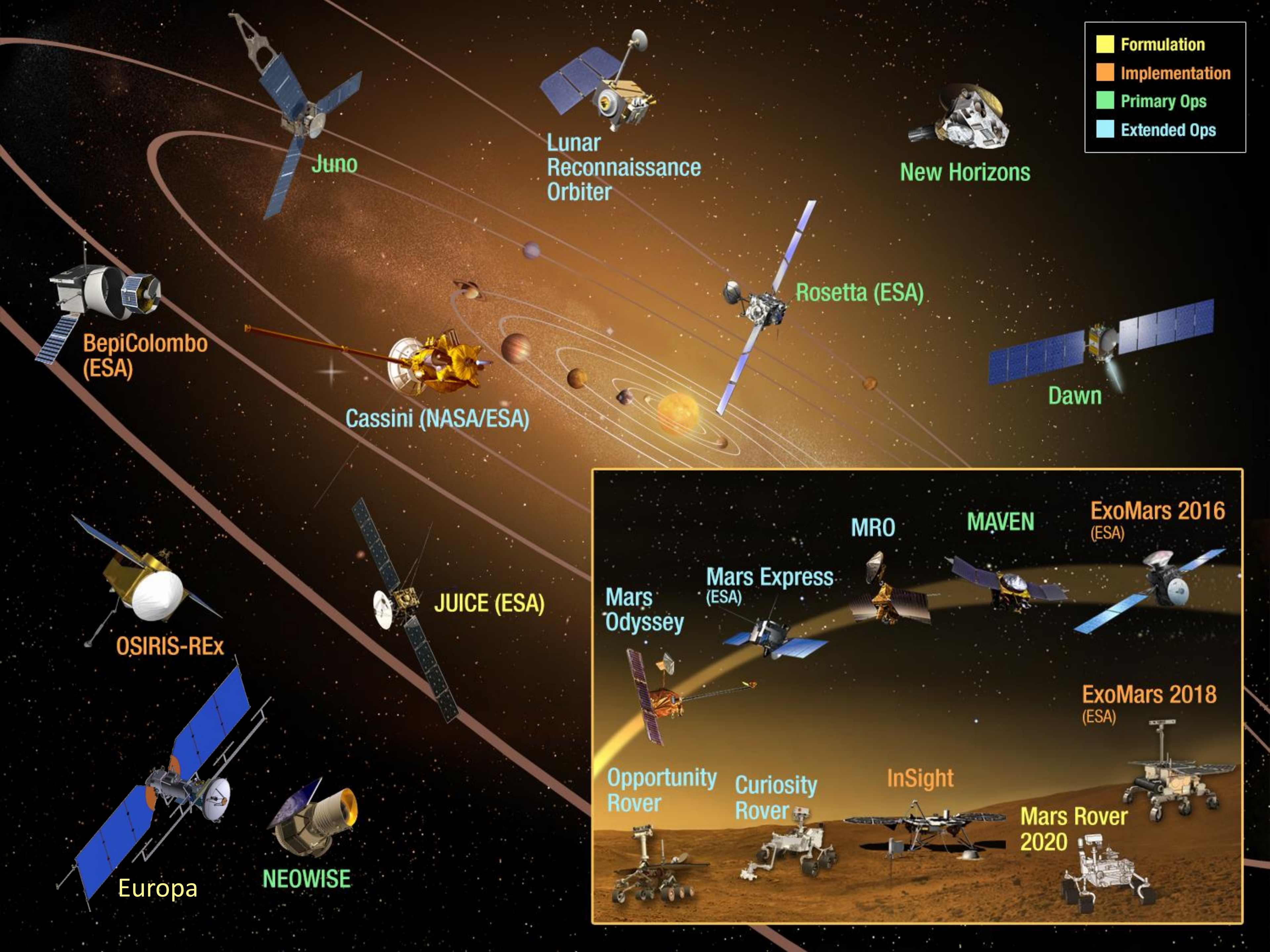
Planetary Science Division Status Report

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

Presentation at Science NAC

Outline

- Mission events & Highlights
- Discovery and New Frontiers Status
- Recent Europa Activities
- Mars Program Status



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

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

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

March 4 – Launch of *InSight*

July 4 – *Juno* inserted in Jupiter orbit

September – Discovery 2014 Step 2 selection

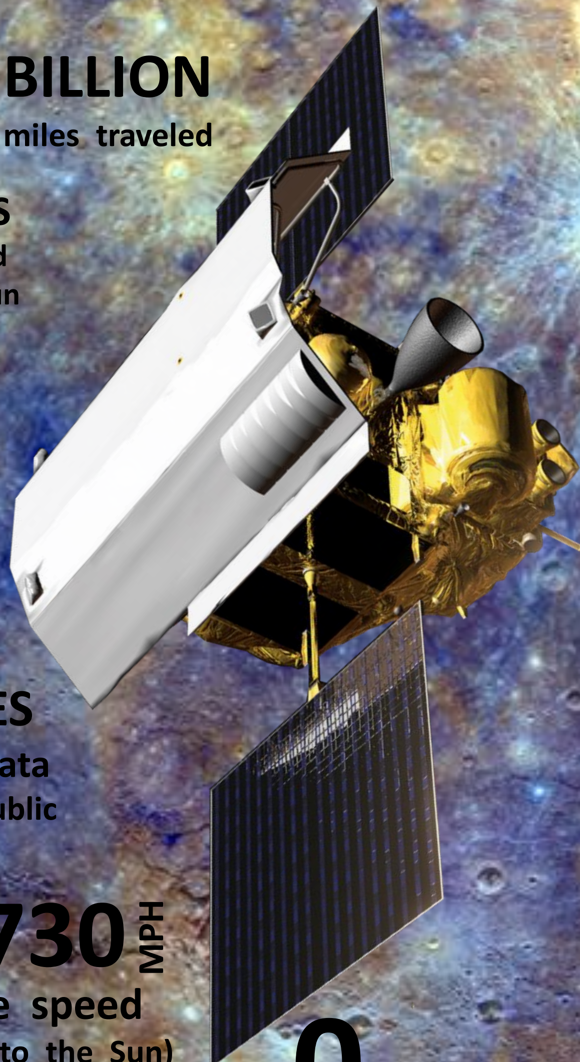
September – *InSight* Mars landing

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

September – *Cassini* begins to orbit between Saturn's rings & planet

MESSENGER: BY THE NUMBERS

NASA



8.73 BILLION miles traveled

32.5 TRIPS around the Sun

291,008 IMAGES returned to Earth

10 TERABYTES of science data released to public

91,730 MPH average speed (relative to the Sun)

6 FLYBYS of the inner planets

41.25 MILLION SHOTS by the Mercury Laser Altimeter

8 MERCURY SOLAR DAYS and **1,504 EARTH DAYS** in orbit

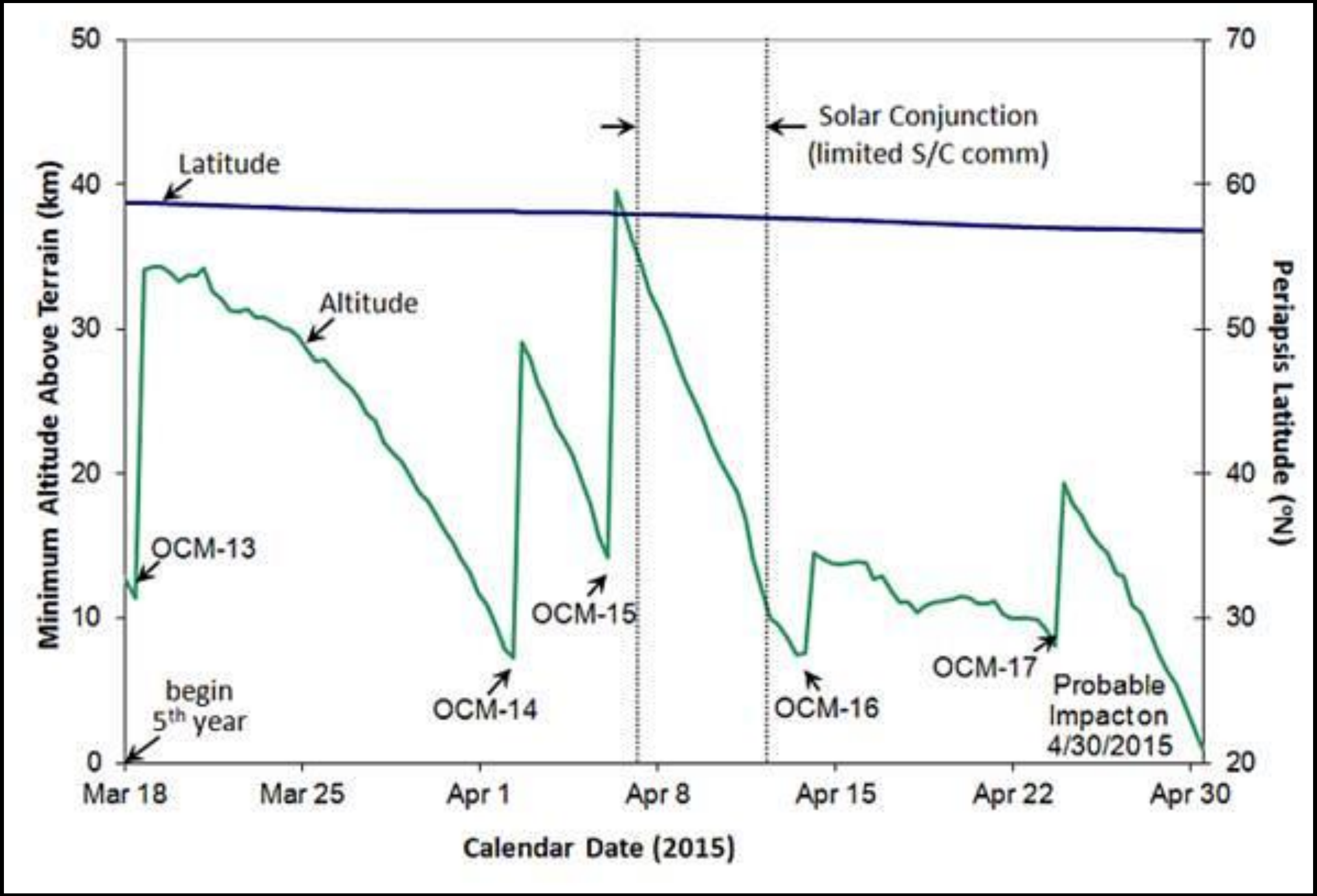
4,100 ORBITS of Mercury completed

0 MILES lowest altitude above Mercury

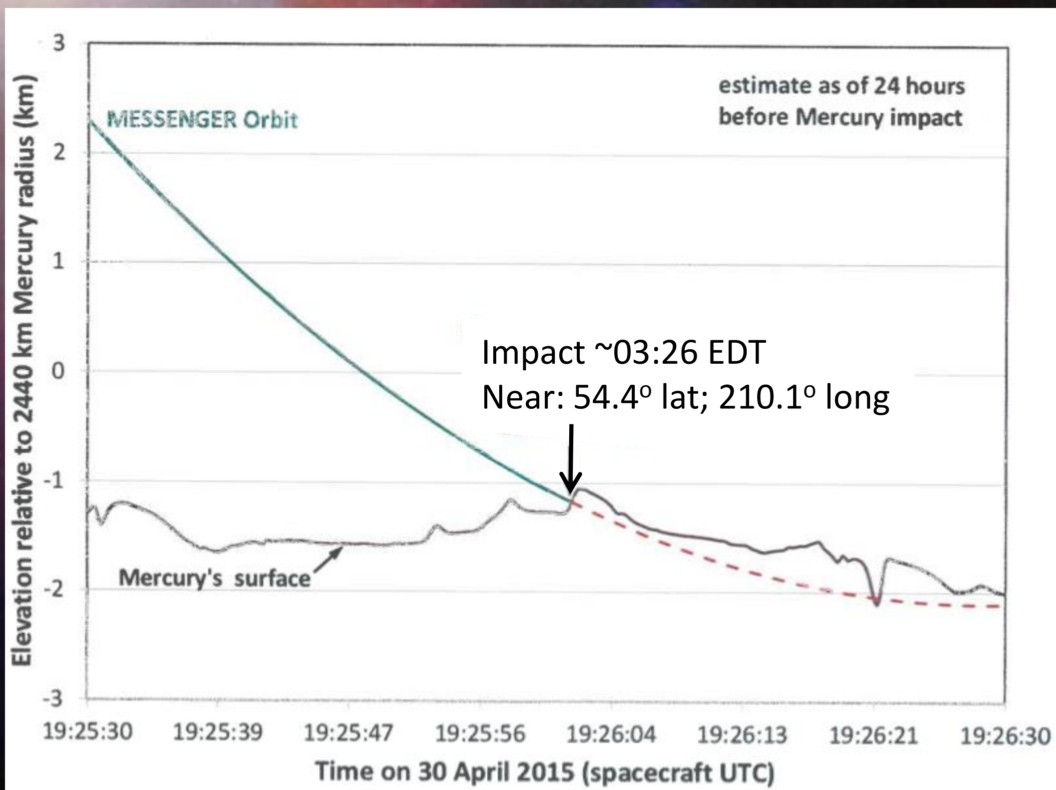
APL JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

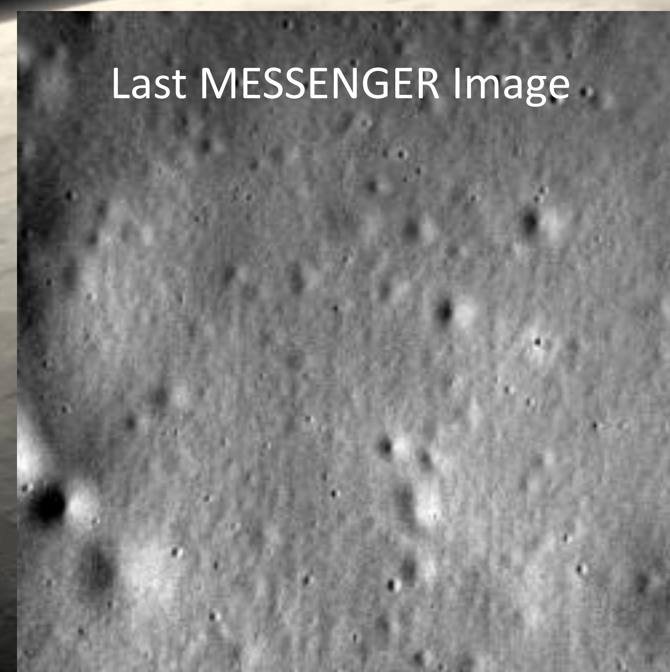
CARNEGIE INSTITUTION FOR SCIENCE

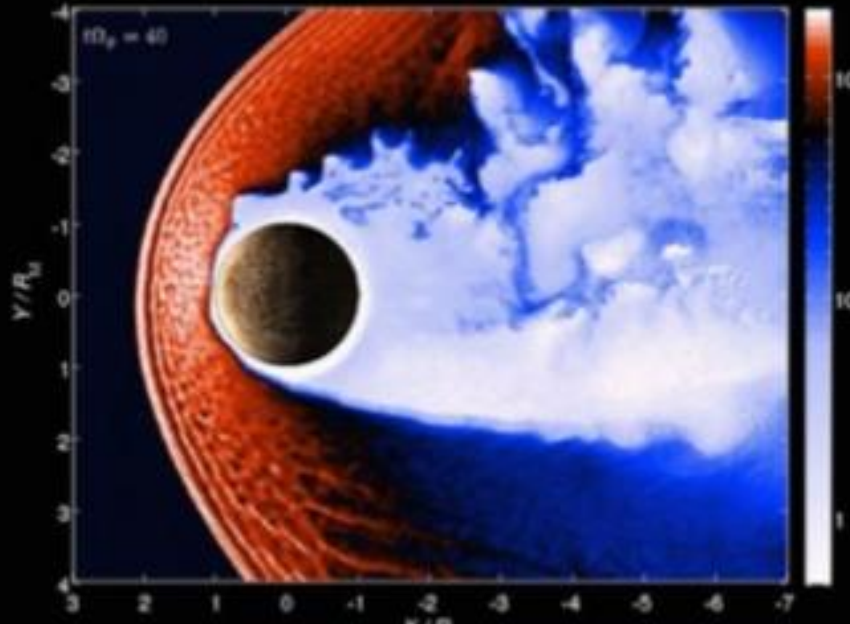
MESSENGER


Solar Conjunction
(limited S/C comm)
Latitude
Altitude
OCM-13
OCM-14
OCM-15
OCM-16
OCM-17
begin
5th year
Probable
Impact on
4/30/2015
Minimum Altitude Above Terrain (km)
Periapsis Latitude (°N)
Calendar Date (2015)
Mar 18
Mar 25
Apr 1
Apr 8
Apr 15
Apr 22
Apr 30
0
10
20
30
40
50
20
30
40
50
60
70

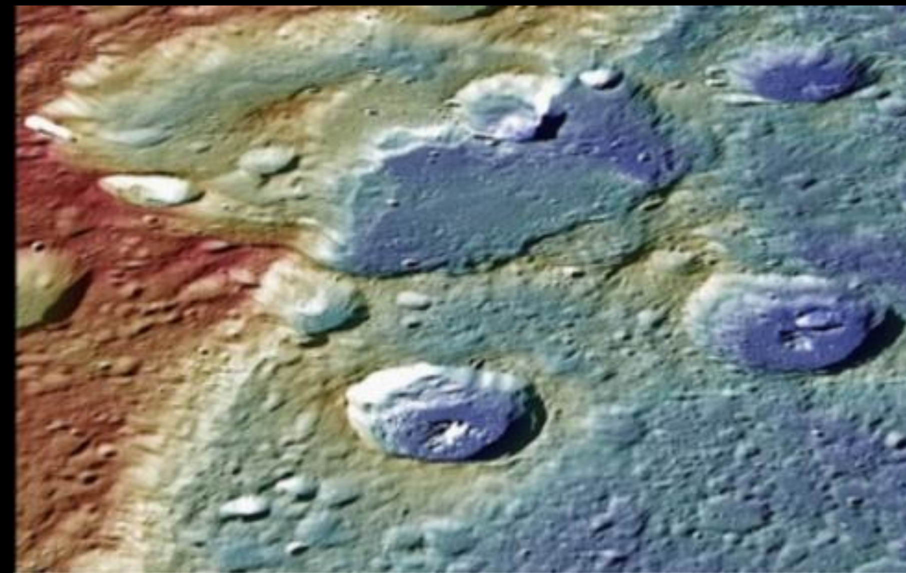
EOM for MESSENGER





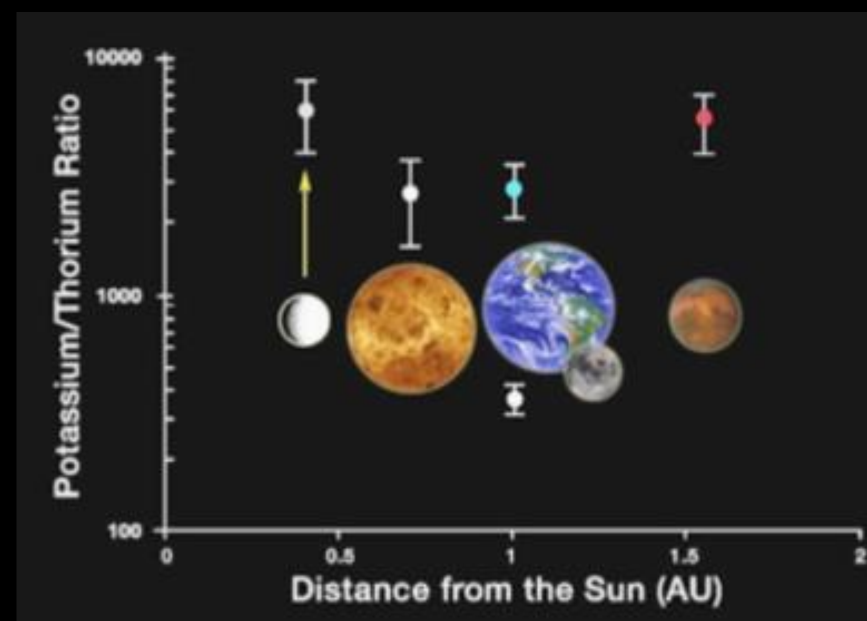


Dynamic Magnetosphere



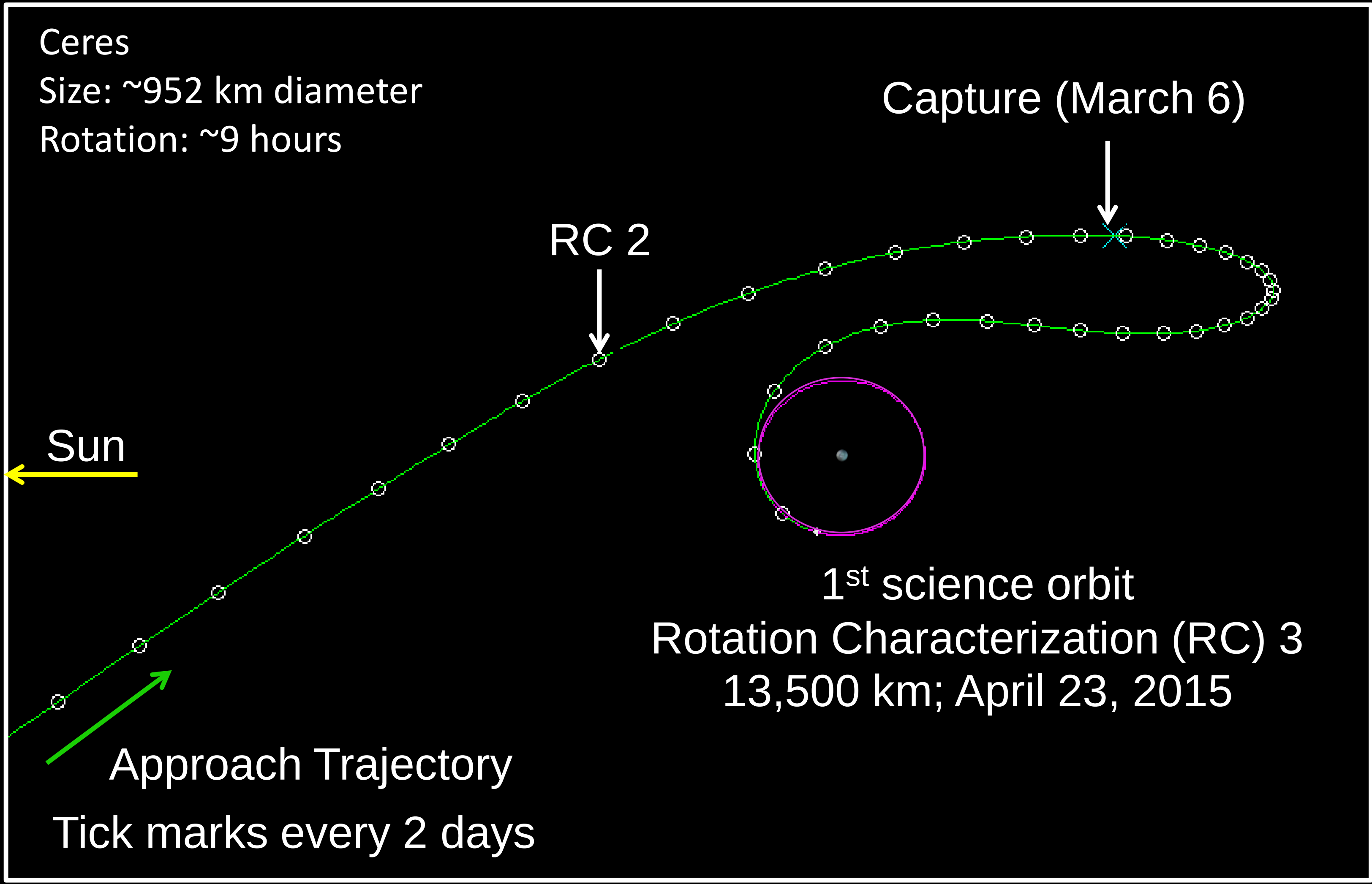
Global Contraction

Polar Deposits



Volatile-Rich Planet

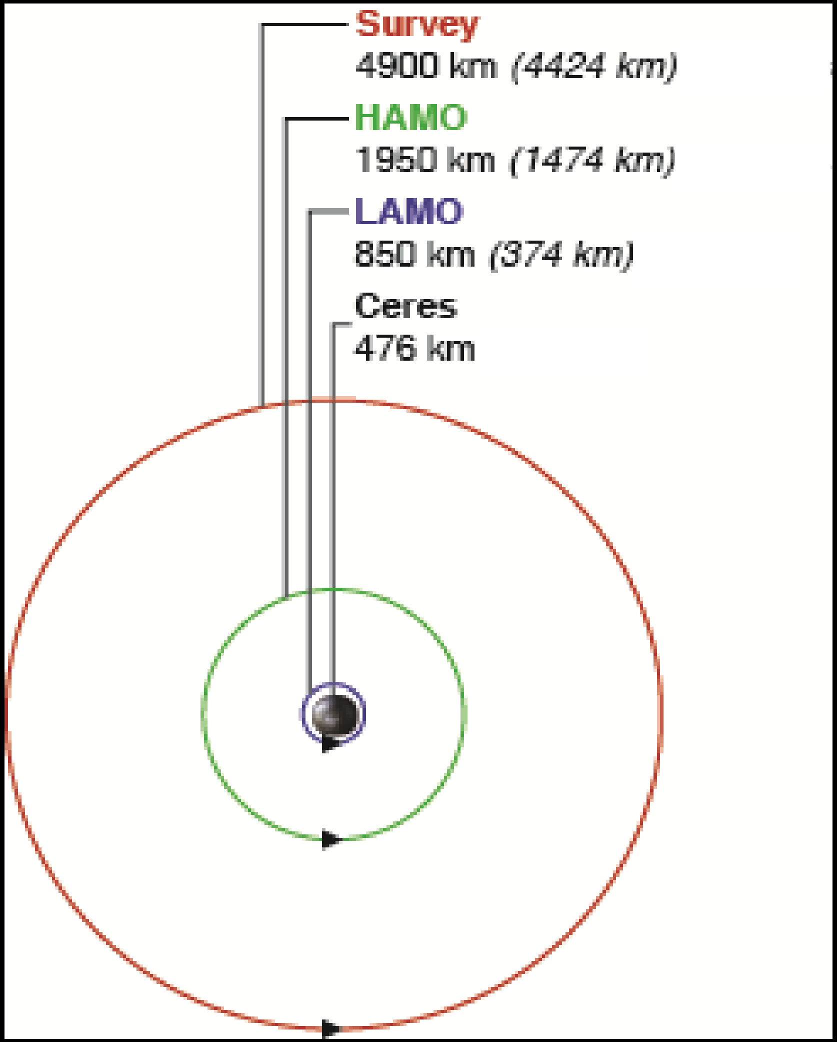
Dawn's Approach



Ceres Science Orbits

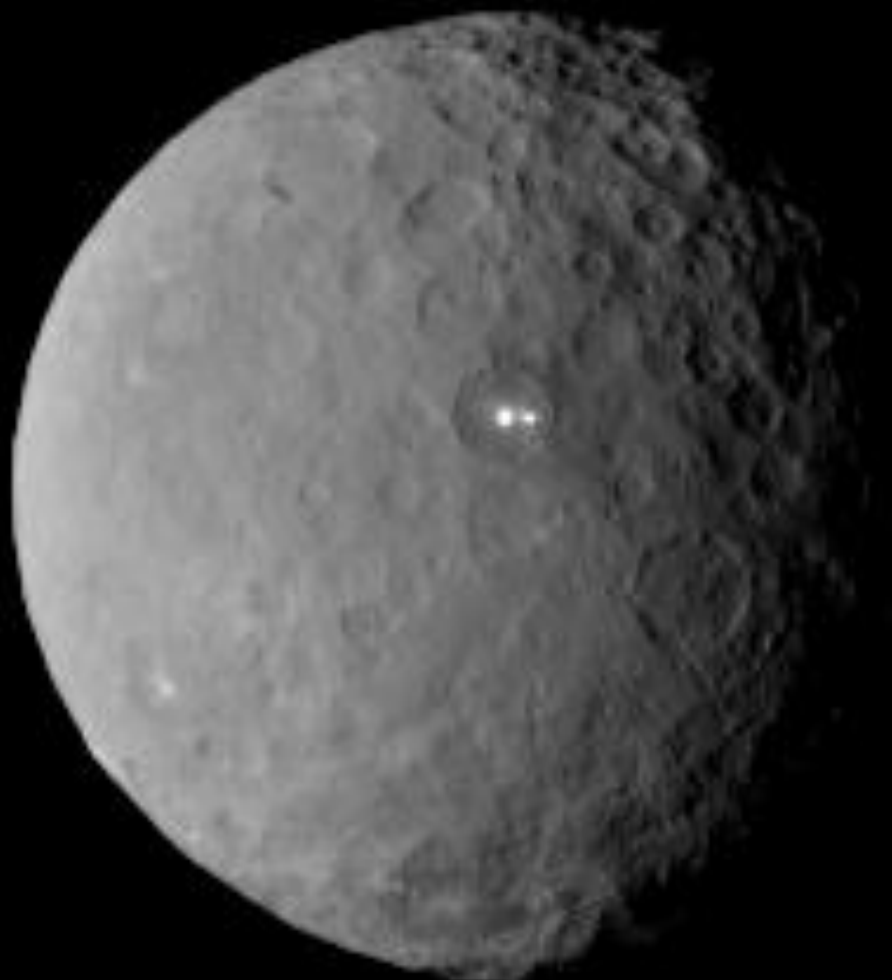
- Rotation Characterization 3
  - Duration 1 orbit (20 days)
- Survey Orbit – starting June 5th
  - Duration 7 orbits (~22 days)
- *Currently at: ~2900 km*
- High Altitude Mapping Orbit (HAMO)
  - Duration 70 orbits (56 days)
- Low Altitude Mapping Orbit (LAMO)
  - Duration 404 orbits (92 days)

Total of 406 days of operations are planned at Ceres

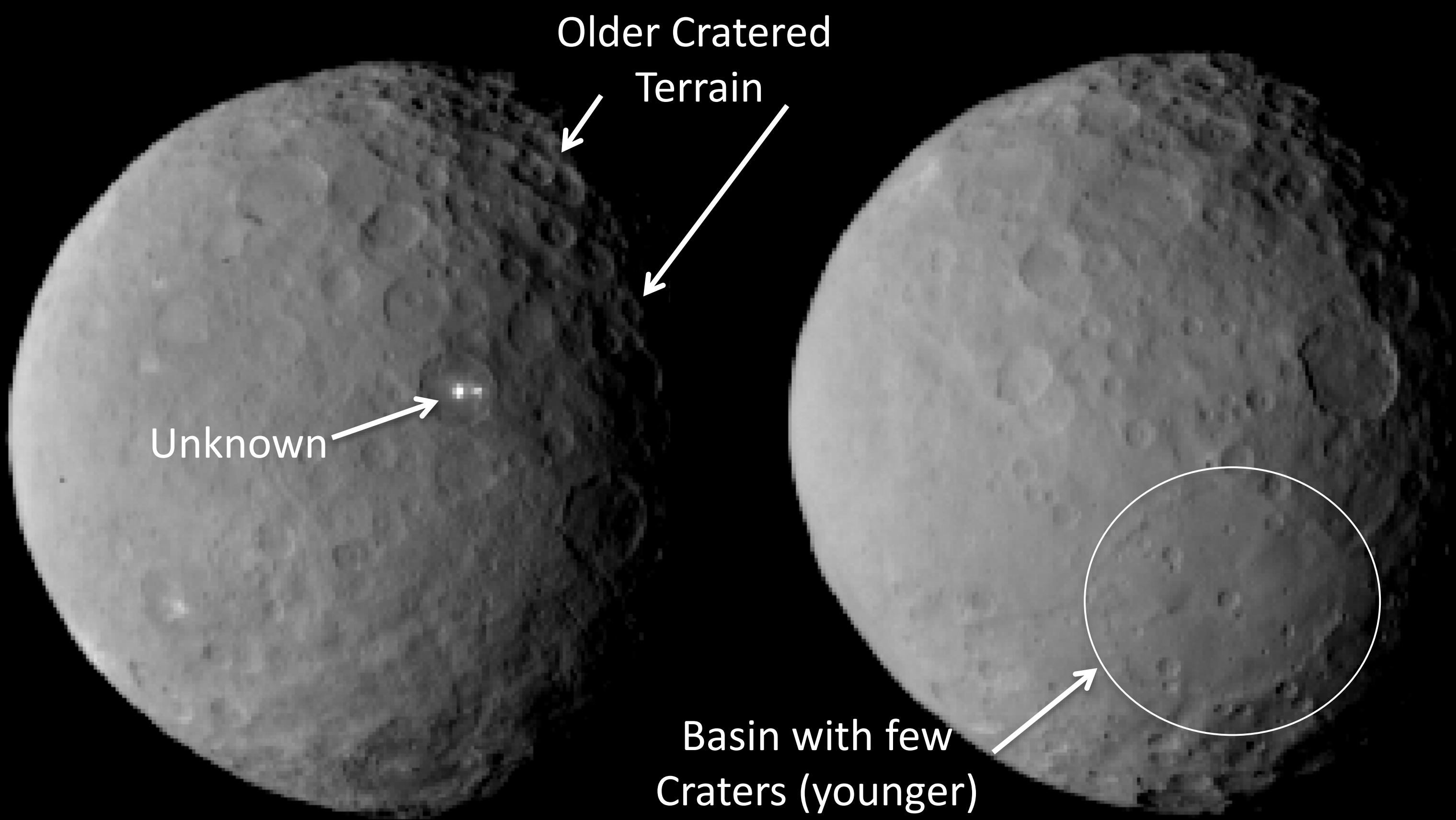


RC 2
Feb 19

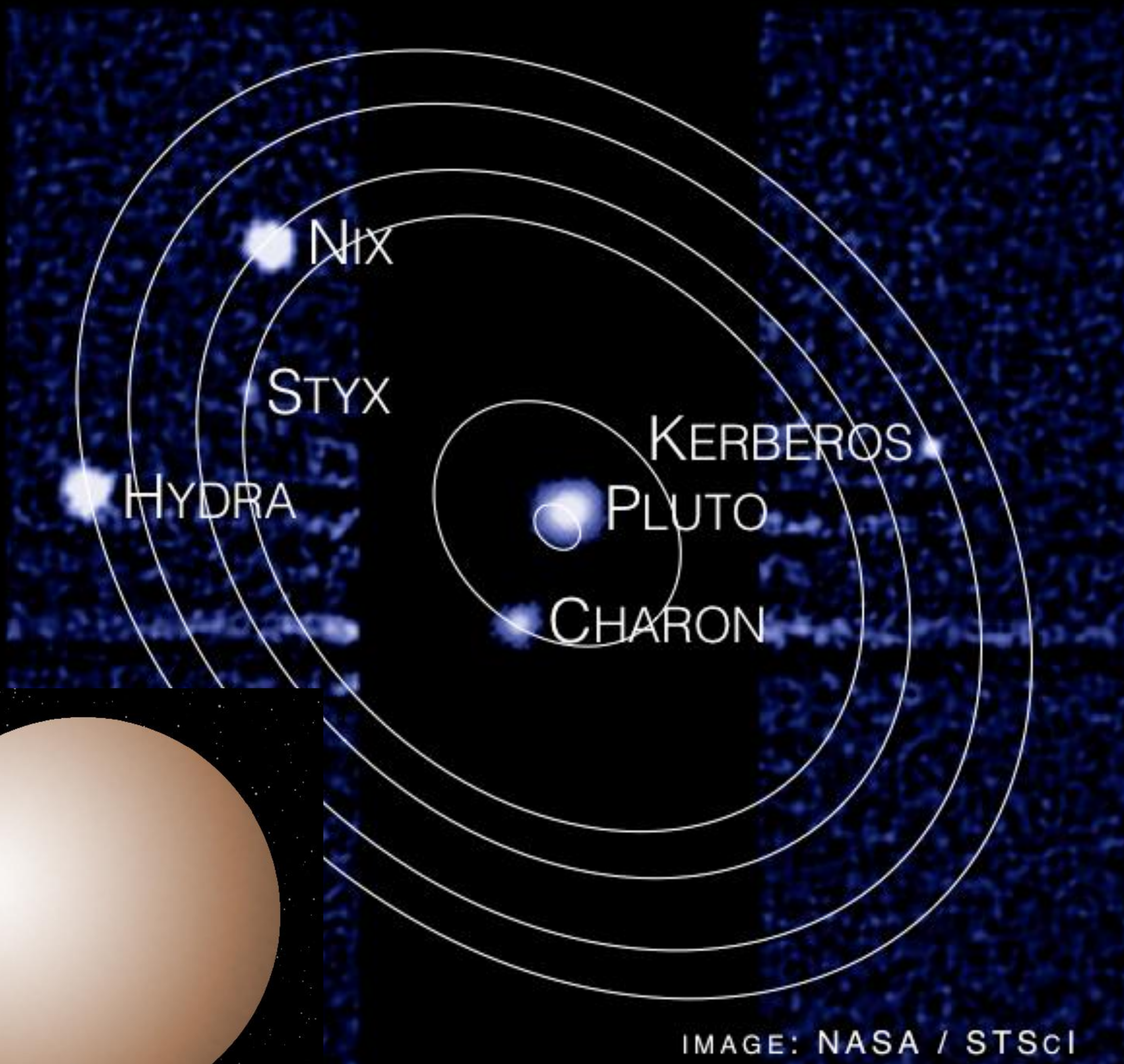
7 x Hubble
Resolution
(4 km/pixel)

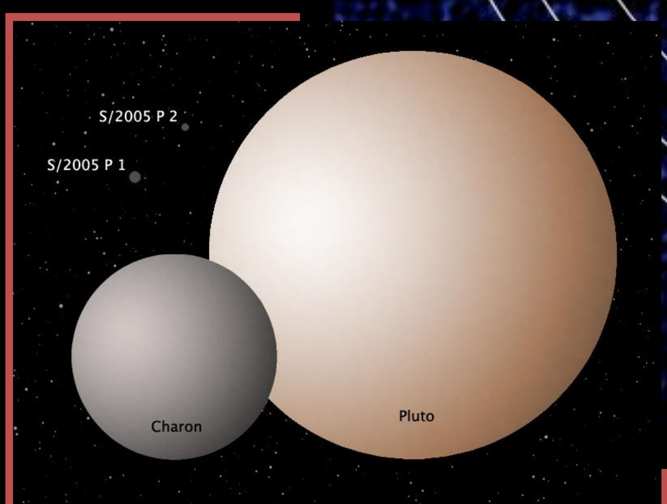


The Types of Terrain

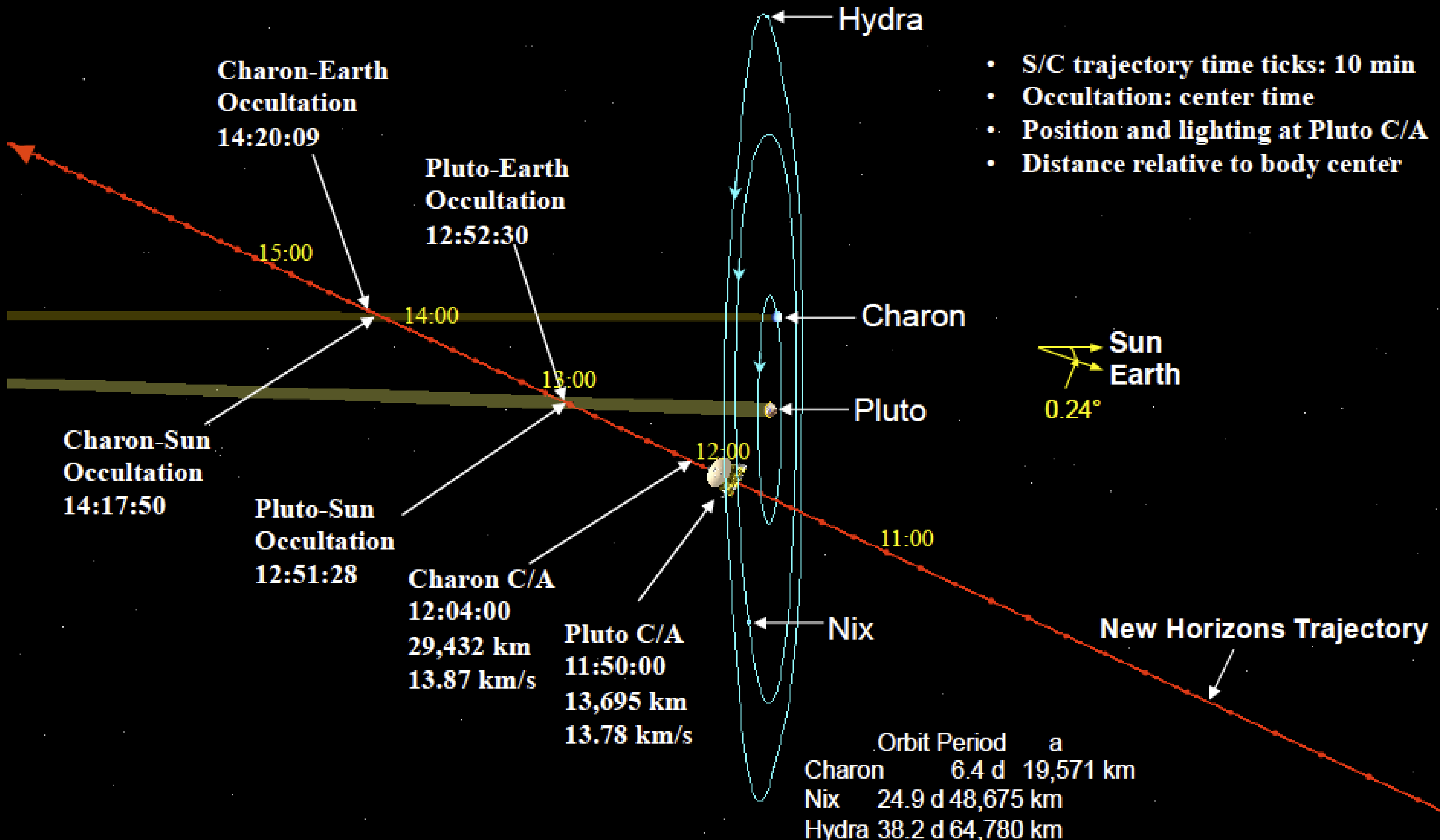


The New Pluto System

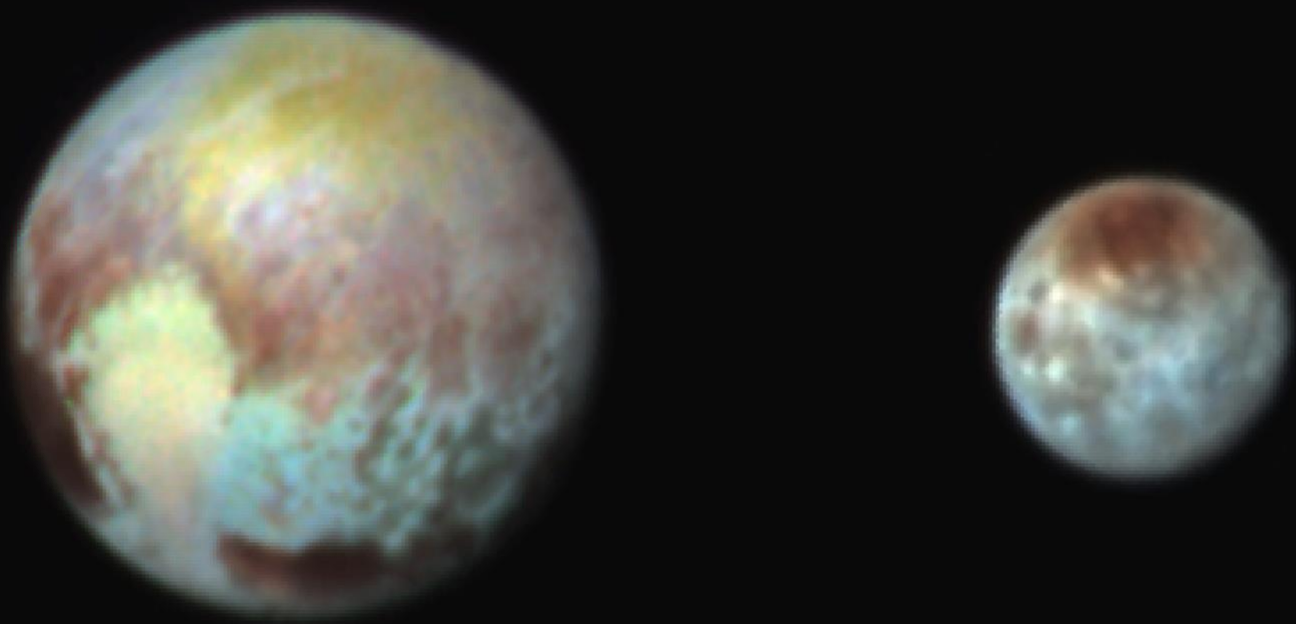




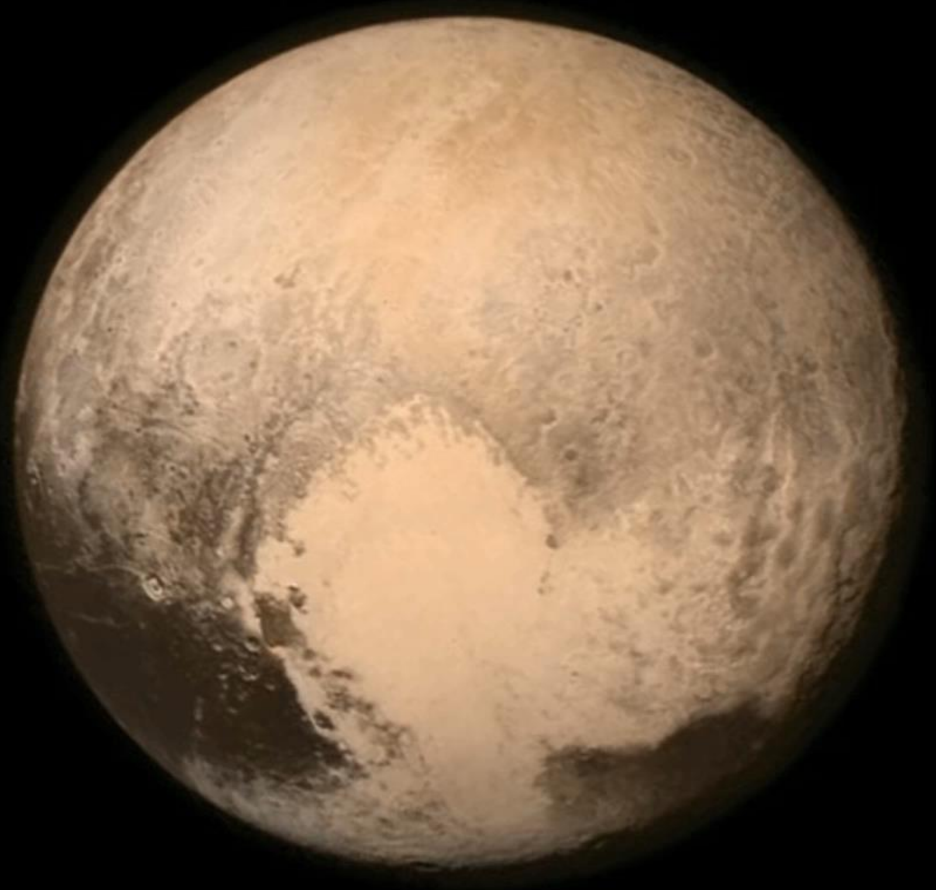
Closest Approach On July 14, 2015



Pluto and Charon



Pluto July 14, 2015

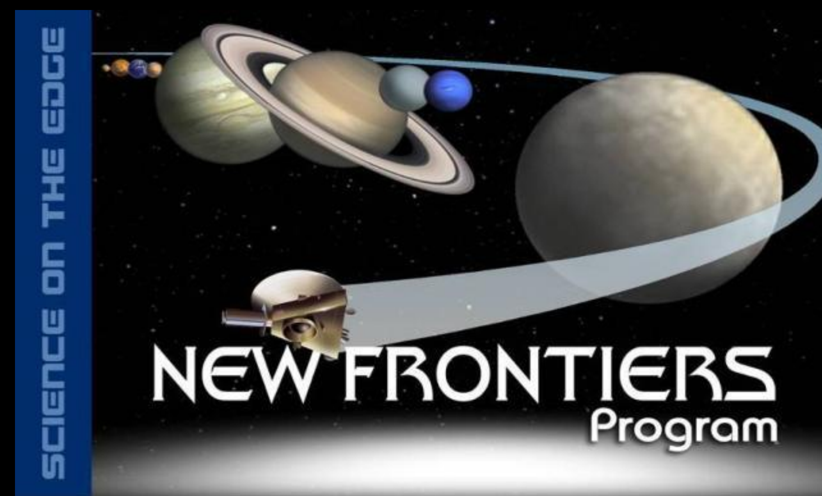


Discovery and New Frontiers Status

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)

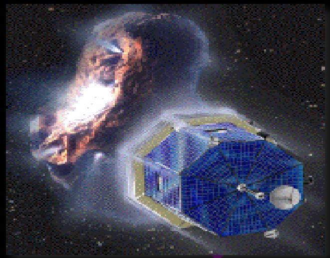
Lunar formation:
Lunar Prospector (1998-1999)

NEO characteristics:
NEAR (1996-1999)

Solar wind sampling:
Genesis (2001-2004)

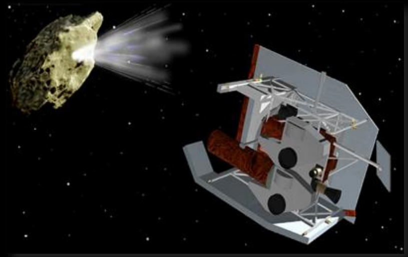
Completed

Comet diversity:
CONTOUR (2002)

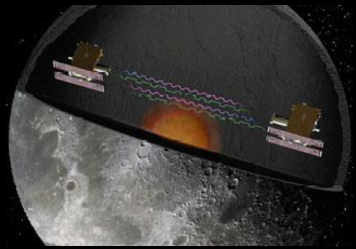


Nature of dust/coma:
Stardust (1999-2011)

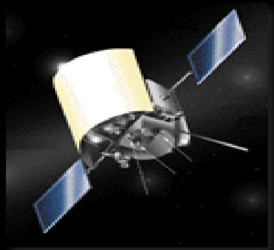
Comet internal structure:
Deep Impact (2005-2012)



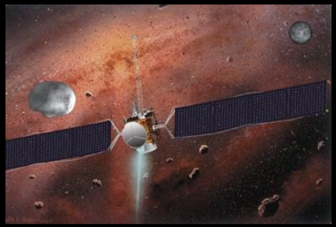
Lunar Internal Structure
GRAIL (2011-2012)



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 - Proposals in review for September Selection

- About 3-year mission cadence for future opportunities

Missions in Development

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

Missions in Operation

- *Dawn*: In orbit around Ceres as of March 6

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.

New Frontiers Program

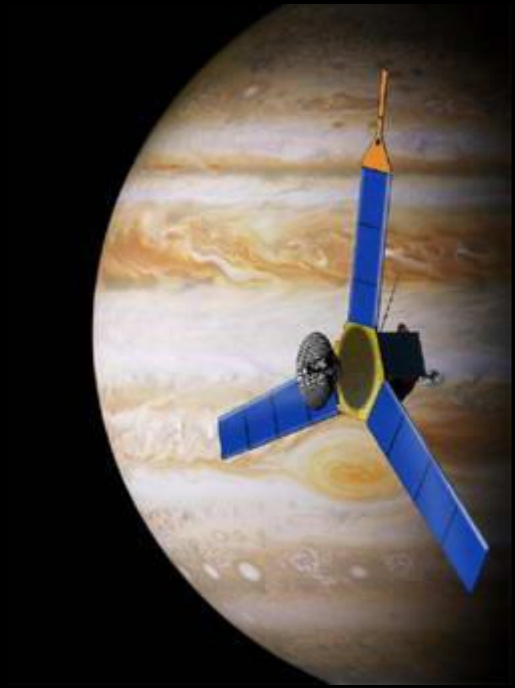
1st NF mission
New Horizons:

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
- Candidate mission list and nuclear power sources under consideration

Missions in Development – OSIRIS-REx

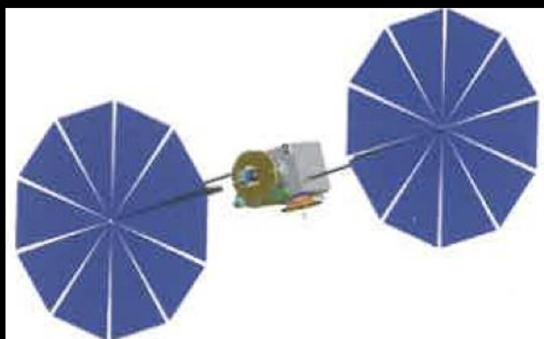
- Launch in Sept 2016 & encounter asteroid Bennu in Oct 2018.
- Operate at Bennu for over 400 days.
- Returns a sample in 2023 that scientists will study for decades with ever more capable instruments and techniques.

Missions in Operation

- New Horizons:
  - Pluto system encountered July 14, 2015
  - HST identified 2 KBOs beyond Pluto for potential extended mission
- Juno:
  - Spacecraft is 4.9 AU from the sun and 1.16 AU from Jupiter
  - Orbit insertion is July 4, 2016

New Frontiers #4 Focused Missions

Comet Surface Sample Return

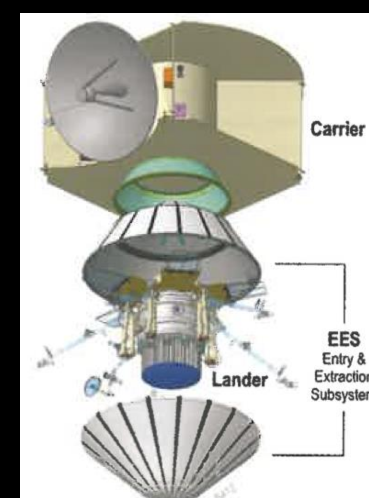


Saturn Probes

Lunar South Pole Aitken Basin Sample Return

Trojan Tour & Rendezvous

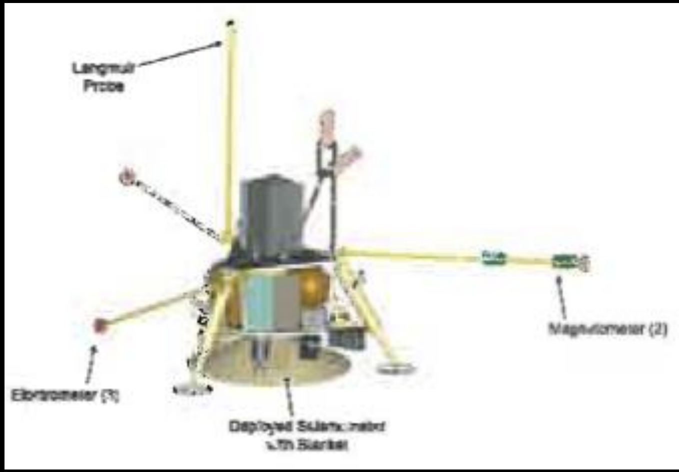
Venus In-Situ Explorer



New Frontiers #5 Focused Missions

- Added to the remaining list of candidates:

Lunar Geophysical Network



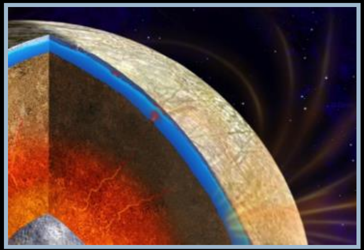
Io Observer

Europa Activities

Now in Formulation (Phase A)

Europa Multi-Flyby Mission Science Goal & Objectives

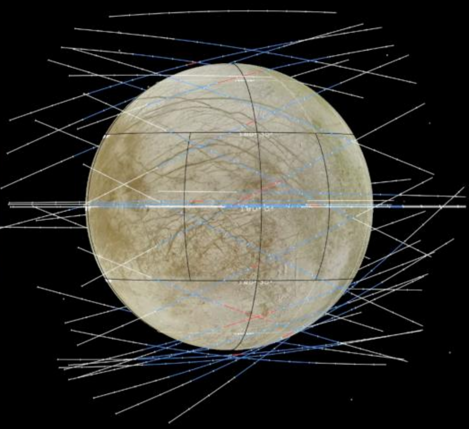
- *Goal:* **Explore Europa to investigate its habitability**
- *Objectives:*
  - **Ice Shell & Ocean:** Characterize the ice shell and any subsurface water, including their heterogeneity, ocean properties, and the nature of surface-ice-ocean exchange
  - **Composition:** Understand the habitability of 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

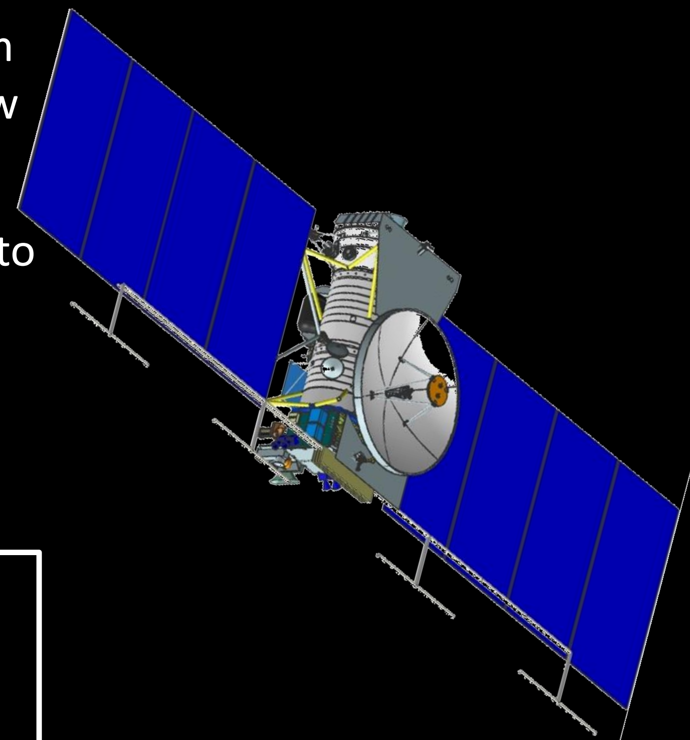
Instrument Type	Name	PI	instituion
Plasma	PIMS	Joseph Westlake	APL
Magnetometer	ICEMAG	Carol Raymond	JPL
Shortwave IR Spectrometer	MISE	Diana Blaney	JPL
Camera	EIS	Elizabeth Turtle	APL
Ice Penetrating Radar	REASON	Don Blankenship	Univ. Texas/JPL
Thermal Imager	E-THEMIS	Phil Christensen	ASU/Ball
Neutral 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



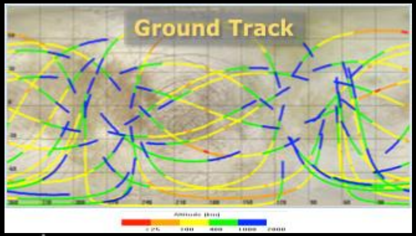
Key Technical Margins

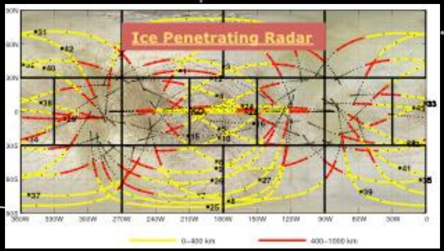
*37 - 41%	40%
Mass	**Power**

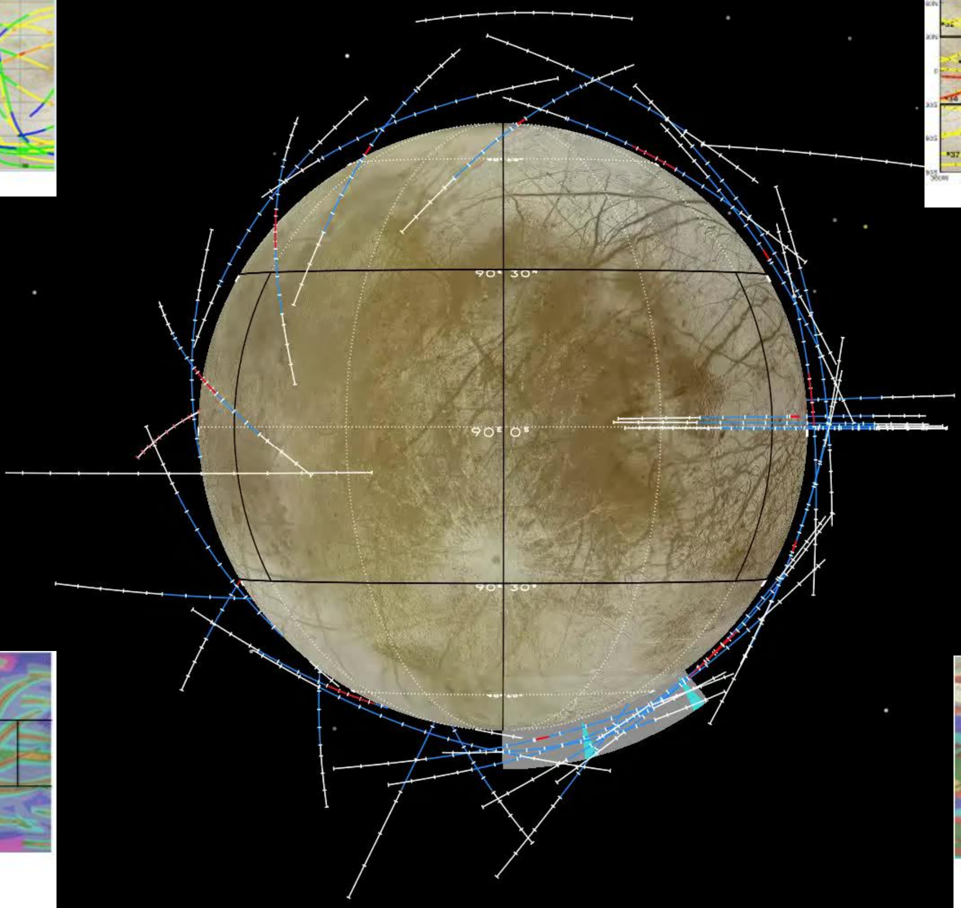
* Depends on Launch Opportunity and Launch Vehicle

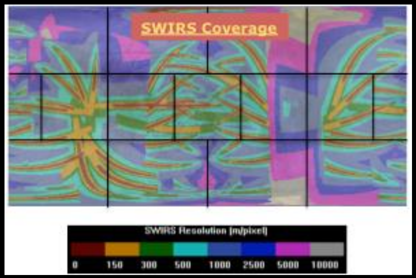
Europa Multi-Flyby Mission Coverage

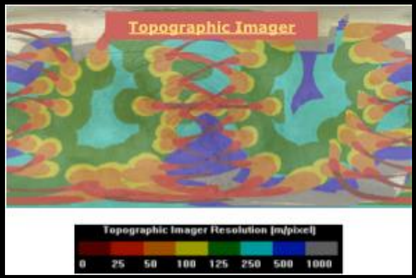
13F7-A21 Trajectory











- **Above 1,000 km → 2**
- 250 km to 750 km → 6
- 80 **km to 100 km → 9**
- 50 km → 18
- **25 km → 10**

Spacecraft Trajectory

$25\ km \le r_{alt} \le 50\ km$

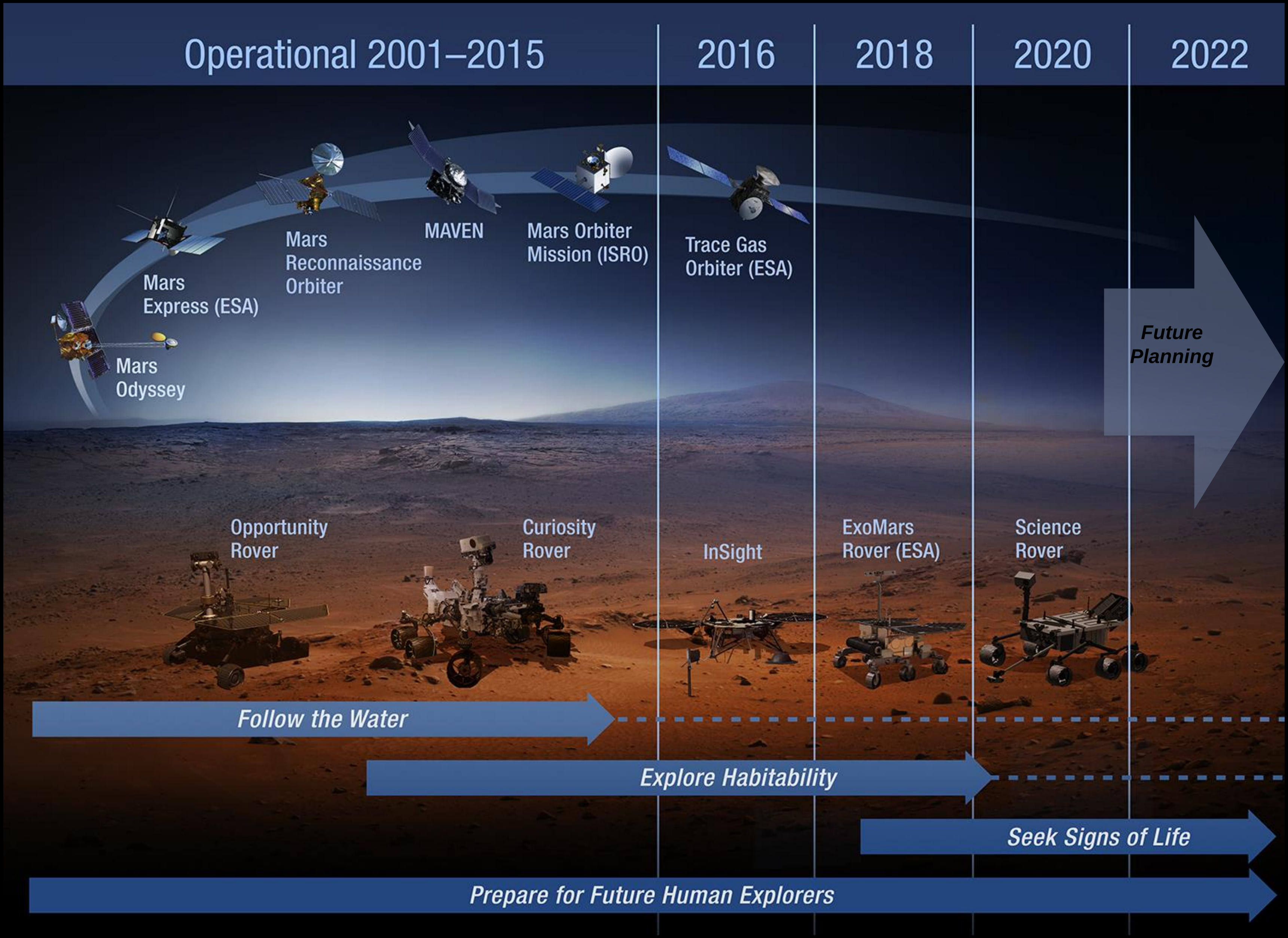
$50\ km < r_{alt} \le 400\ km$

$400\ km < r_{alt} \le 1000\ km$

$1000\ km < r_{alt} \le 4000\ km$

Mars Exploration Program

Mars Exploration in This Decade



Mars 2020 Status Update

- Successfully completed Key Decision Point B (KDP-B) on May 20
- Agreements in place for international contributions
- Continued good progress in development and testing of heritage subsystems
- Competitively selected contractor for robotic arm
- Sampling & Caching System architecture defined
  - Development laboratory and test-bed established
- 2nd Landing Site Workshop in Aug 2015
- Flight system design freeze in Aug 2015
- Mission PDR Dec 2015

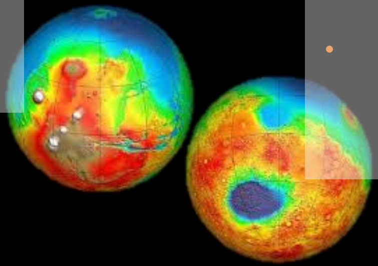
Engineering Contributions from Robotic Missions

Robotic missions inform the Engineering of future Human Missions with "Lessons Learned" from prior mission design & operations

Entry, Descent & Landing Phase

- *Vehicle/environment Interactions, e.g. Atmospheric profiles – Density, Pressure, Winds*
- *Hypersonic Entry Guidance*
- *Landing Site Altitudes – EDL Design drivers*
- *Design for Landing Site "Roughness" – Slopes / Hazards*

- Learned:
  - 1 mT Payload
  - ~10 km Accuracy
- To Learn:
  - 2-4 mT Payload (e.g. Supersonic Retro-propulsion)
  - <1 km Accuracy
  - ASCENT FROM MARS!



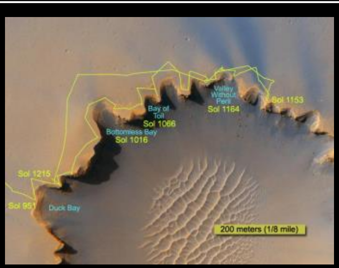
Design for the Martian Surface Environment

- *Wide-thermal range designs – Mechanical & Avionics*
- *Dust Accumulation Rates – Impacts on solar power systems*
- *Dust-tolerant Mechanisms*

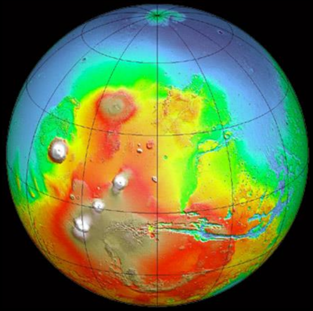
- Learned:
  - Dust impacts on Solar Power / Mechanisms
- To Learn:
  - Power sufficient for ISRU, Dust impacts on Suits & Seals

Operating on Mars

- *Surface Navigation & Operational Cartography*
- *"Mars Time / Earth Time" Operational Cadence*
- *Communications Relay Utilization Strategies*

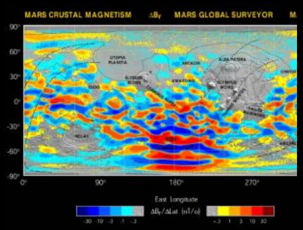


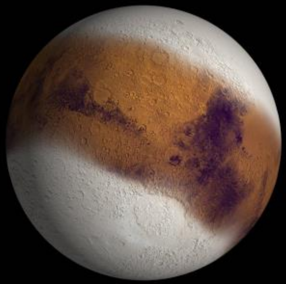
- Learned:
  - Relay strategies, Operations cadence
- To Learn:
  - Performance needed for Operational Video
  - Light-time delay for crew operations
  - Return flight from Mars to Earth
  - Orbital Rendezvous at Mars



Science at Mars

Robotic missions have informed us on many of the fundamental mysteries of Mars, but there are still significant gaps in our understanding critical to future Human Exploration

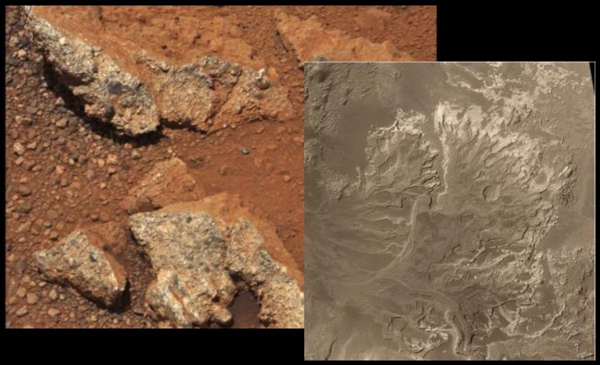




Mars Environment

- *Geodesy – global topography*
- *Geography – surface mineralogy*
- *Atmosphere - profile, content, wind, dust*
- *Thermal variations*

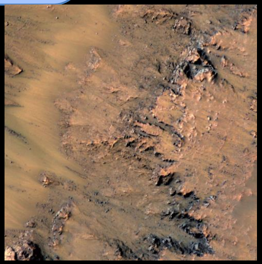
- Learned:
  - Surface map
  - Weather – general trends
  - Magnetics – remnant field persists but protective field gone
  - Climate change evidence points to potential for remnant ice
- To Learn:
  - Open SKGs
  - Phobos/Deimos characteristics



Mars Resources

- *Surface ice – polar regions*
- *Frost build-up and sublimation*
- *Surface/subsurface flow – seasonal, consistent with brine, but how?*

- Learned:
  - Mars has extensive water ice resources
- To Learn:
  - Location & abundance of near subsurface ice, particularly at low latitudes
  - Cause and make-up of seasonal flows



Mars Habitability

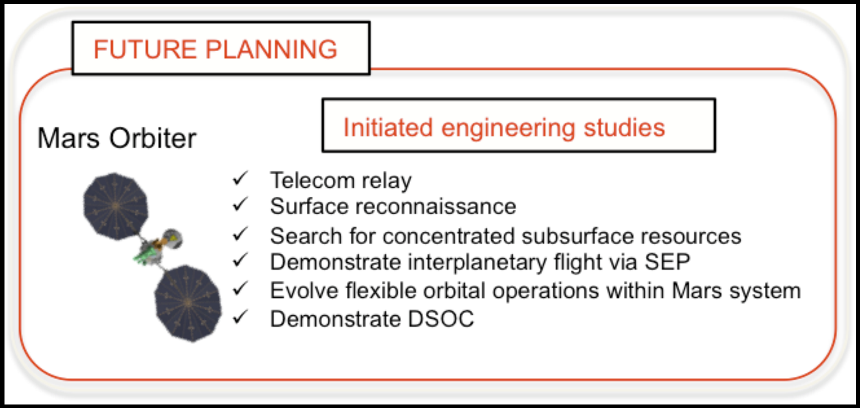
- *Water once flowed and was stable*
- *Methane gas variability observed*
  - *Biological?*
  - *Geochemistry?*
- *Search for remnant traces of chemical building blocks of life underway with MSL and M2020*

- Learned:
  - Mars was habitable – all the ingredients necessary found in ancient Gale Crater
- To Learn:
  - Extraterrestrial Life?
    - Possible in the past – but did it emerge?
    - Could there be life today?
  - Sample return - life, toxicity, back contamination
  - Implications for human explorers

Mars Future Missions Definition Status

- Multiple joint MEP/HEOMD/STMD trade studies in-work
  - Architecture Strategy
  - Human Landing Sites Workshop: October
    - Human Science Objectives Science Analysis Group
    - In-Situ Resource Utilization (ISRU)/Civil Engineering Working Group
  - Next Orbiter Science Analysis Group
  - Mars Surface/EDL pathfinder mission study
- Growing consensus emerging that science guided pathways provide natural precursor capability that could address early Exploration needs
  - Collaborating on Science/Exploration synergies to define and address next step priorities

An Orbiter appears to be the next logical step for MEP missions



Questions?