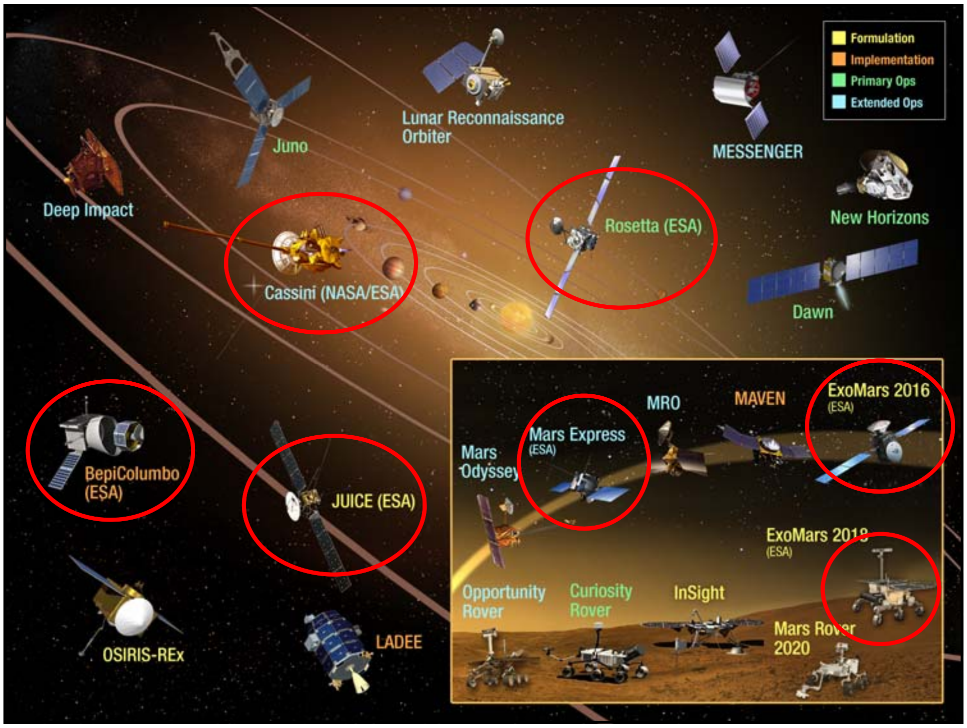
Planetary Science Division Update

Jim Green
Director, Planetary Science
April 29, 2013

Outline

- Mission Overview
- FY13 and FY14 Budgets
- Accomplishments and Opportunities
- ASRG and PU-238 Status and Plans
- Mars Program

2



FY13 and FY14 Budgets

4

FY 2013 Budget

Continuing Resolution (H.R. 933) signed March 26

- Total NASA funding: $17.8 B
- Total Science funding: $5.1 B

However:

- There will be ~2% rescission across the government to match the discretionary funding limit specified in the fiscal cliff legislation signed in January
- There will be ~5% reduction due to sequestration
- There have been identified high priority Agency activities that must stay on budget and schedule therefore these activities will not take rescission or sequestration reductions

FY 2013 Budget

Continuing Resolution (H.R. 933) signed March 26

- Total NASA funding: ~~$17.8 B~~ ~$16.6B
- Total Science funding: ~~$5.1 B~~ ~$4.8B

NASA is completing the analysis on the full impact of the rescission and sequester

This will be delineated in an Operating Plan change to be given to Congress by mid-May

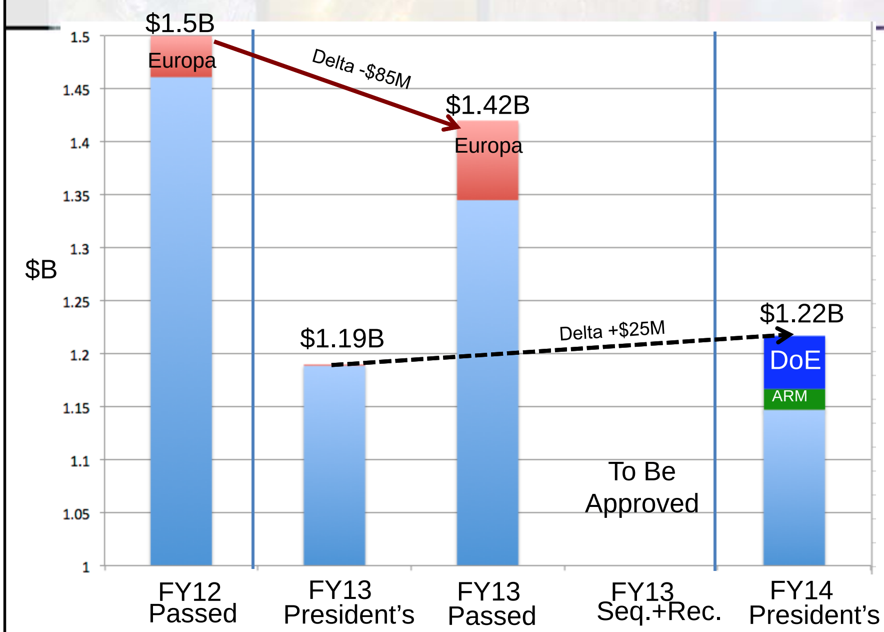
Summary of FY2013 Passed Budget for PSD

- Planetary budget $1,415M with the following features:
  - Planetary Planetary Research: $192M
  - Discovery: $244M
  - New Frontiers: $175M
  - Mars: $450.8M
  - Outer Planets: $159M
- For the outer planets $75M to be used for Europa
  - "shall be for pre-formulation and/or formulation activities in support of a mission that achieves the scientific goals laid out in the Jupiter Europa section of the most recent planetary science decadal survey."
- Remaining actions: Rescission & sequestration reductions

President's FY14 Planetary Science Budget

Planetary Science Division	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018
Planetary Research	$174,087		$220,600	$233,300	$229,100	$230,400	$232,200
Lunar Quest	$139,972		$17,700	$0	$0	$0	
Discovery	$172,637		$257,900	$268,200	$242,300	$187,500	$215,000
New Frontiers	$143,749		$257,500	$297,200	$266,500	$151,000	$126,200
Mars Exploration	$587,041		$234,000	$227,700	$318,400	$504,700	$513,200
Technology	$161,899		$150,900	$142,800	$144,700	$154,400	$140,000
Outer Planets	$122,054		$79,000	$45,600	$24,400	$26,400	$26,000
	$1,501,439	**$0**	**$1,217,600**	**$1,214,800**	**$1,225,400**	**$1,254,400**	**$1,252,600**

Planetary's Recent Budget Timeline



Planetary Budget Features: What's the Same

- Continuation of missions in development (LADEE , MAVEN) and formulation (OSIRIS-REx and InSight)
- Continuation of operating science missions, but with reduced budget for extended missions per Senior Review
    - Prime Ops: Curiosity, Dawn, Juno, New Horizons
    - Extended Ops: MESSENGER, LRO, MRO, Odyssey, Opportunity, Cassini
    - ESA partnered missions: Venus Express, Mars Express, Rosetta
- Continue to completion the Radioisotope Power Systems (RPS) Advanced Stirling Radioisotope Generator (ASRG) ready for flight later this decade
- Support of Planetary missions with navigation, data archiving, and sample curation
- Continuation of supporting research and technology selections and awards

10

Planetary Budget Features: What's Changed

- Mars 2020 mission, based on Curiosity architecture, under definition
- Provides for MOMA instrument on ESA's 2018 ExoMars rover
- Provides the Electra communications package for ESA's 2016 ExoMars orbiter
- Selected InSight (Discovery-12 mission) for flight
- Selected US investigations on the ESA's JUICE flagship mission
- Funding to support production and management of Pu-238 in partnership with DOE
- Support Balloon observations of Comet ISON in October 2014
- Complete instrument studies and continue Europa mission pre-formulation activities
- Enhanced NEO survey and characterization in support of agency initiatives and to protect the Earth – in support of the Asteroid Retrieval Mission (ARM)

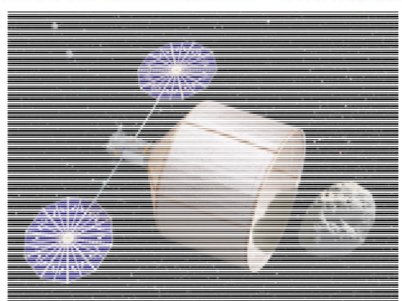
Accomplishments and Opportunities

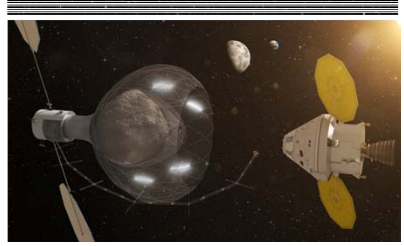
Major Recent Accomplishments-Science

- Curiosity landed safely in Gale Crater on an ancient river bed. Analysis indicates that Mars had a habitable environment about the same time as Earth, several billion years ago
- GRAIL found a network of huge near-vertical wall-like body of volcanic rock intruded into cracks in older rock just under the lunar upper crust
- Dawn mapped Vesta's gravity field revealing significant anomalies and a large iron core – showing the structure of a planetesimal – a planet building block
- MESSENGER revealed volatiles trapped in Mercury's permanently shadowed craters at the north pole
- Discovered micro-organisms in a sub-glacial lake in the Antarctica – a potential analog of Europa
- Cassini captured seasonal changes on Titan:
  - Escaping hydrocarbons spread tones of prebiotic material per day into Saturn system
  - Mid-latitude streams and methane lakes appeared
  - Hydrocarbon ices appeared on Titan's northern lakes
  - Atmospheric haze drops in altitude by 120 km near equinox to 380 km

Capture and Retrieve an Asteroid

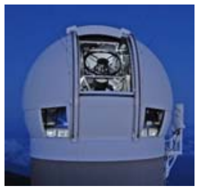
- Capture and transport a 7-meter diameter, 500-1000 ton near-Earth asteroid (NEA) to cis-lunar space
- Enable astronaut missions to the asteroid by as early as 2021
- Obtain valuable information for exploration, planetary defense, science, and *in situ* resource utilization (ISRU)
- Parallel and forward-leaning development approach





Asteroid Mission Would Consist of Three Main Segments

Identify



Asteroid Identification Segment:

Ground and space based NEA target detection, characterization and selection

Redirect

Asteroid Redirection Segment:

Solar electric propulsion (SEP) based asteroid capture and maneuver to trans-lunar space

Explore HG(1

Asteroid Crewed Exploration Segment:

Orion and SLS based crewed rendezvous and sampling mission to the relocated asteroid

Lunar Atmosphere and Dust Environment Explorer

Objective:
- Measure the lofted Lunar dust
- Composition of the thin Lunar atmosphere

Instruments:
- Science: NMS, UVS, and LDEX
- Technology: Laser Communications

Launch: August 2013 Wallops Flight Facility
- Currently working a launch conflict

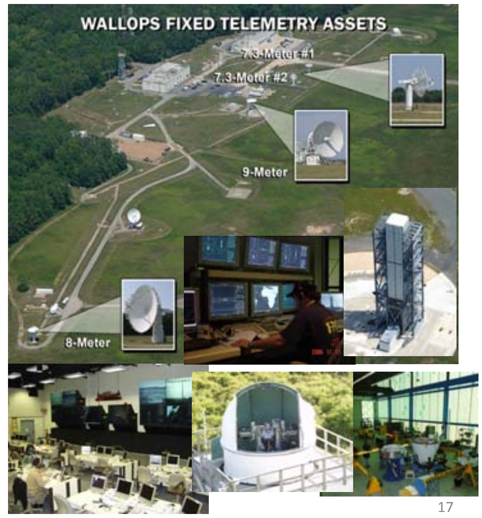
Slide 15

HG(1 Replace "Explore" photo with contemporary image.
Hautaluoma, Grey (HQ-NG000), 4/8/2013

LADEE Launches out of Wallops Island

WFF preparing to launch ● 1st Deep Space/Lunar mission from WFF ●Ames' 1st in-house built spacecraft ● 1st Minotaur IV/V (Peace Keeper family) launch from WFF

LADEE Pathfinder activities - View towards the south after gantry roll-away on newly enlarged Pad 0B w/ Min V mockup.



17

Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx)

Science Objectives:

- Return and analyze a sample of pristine carbonaceous asteroid
- Map the global properties, chemistry, and mineralogy
- Document in situ the properties of the regolith at the sampling site
- Characterize the integrated global properties to allow comparison with ground-based telescopic data of entire asteroid population
- Measure the Yarkovsky effect

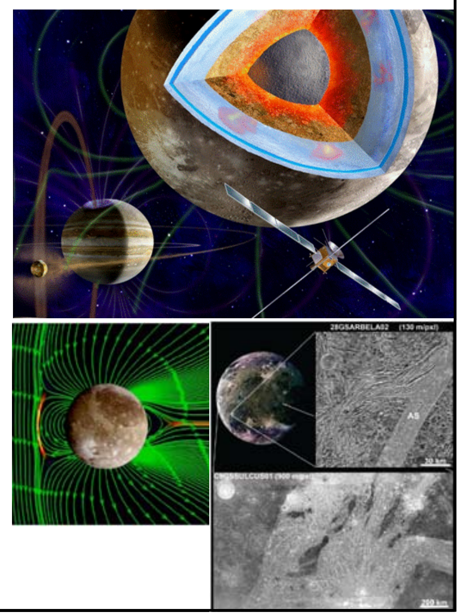
Mission Overview:

- Launch in September 2016
- Encounter asteroid (101955) 1999 RQ36 in October 2019
- Study RQ36 for up to 505 days, globally mapping the surface
- Obtain at least 60 g of pristine regolith/surface material
- Return sample to Earth in September 2023 in a Stardust-heritage capsule
- Deliver samples to JSC curation facility for world-wide distribution

18

The JUpiter ICy moons Explorer Mission

- On May 2, 2012, ESA selected JUICE as the first Large-class mission in ESA's Cosmic Vision Program
- The JUICE mission will investigate the emergence of habitable worlds around gas giants, characterizing Ganymede, Europa and Callisto as planetary objects and potential habitats.
- JUICE will first orbit Jupiter for ~2.5 years, providing 13 flybys of Callisto and 2 of Europa, and then will orbit Ganymede for 9 months
- Launch is scheduled for 2022 with Jupiter arrival in 2030, Ganymede orbit insertion in 2032, and Ganymede impact in 2033
- NASA and ESA released coordinated AOs in June 2012 to solicit the JUICE payload

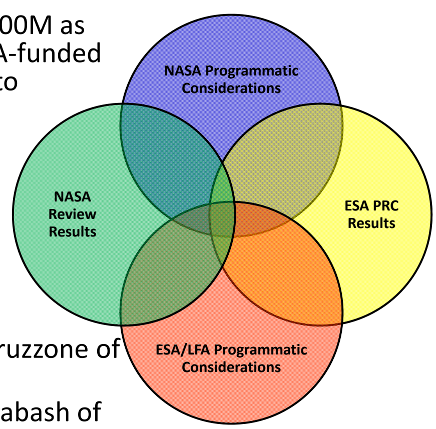


NASA Contributions to JUICE Mission

- NASA and ESA announced the collaboratively selected payload for the JUICE mission
  - NASA offered to contribute up to $100M as either NASA-led instrument(s), NASA-funded instrument component(s) provided to European-led instrument(s)

- NASA selected: *Ultraviolet Spectrometer instrument investigation*
  - PI: Randy Gladstone, (SWRI)

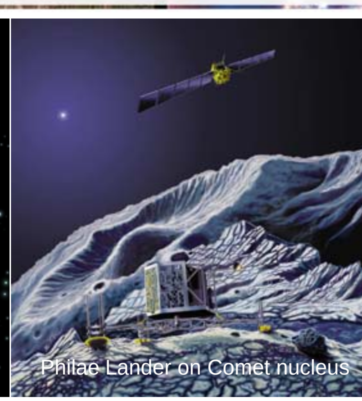
- NASA will fund contributions to:
  - Radar for Icy Moon Exploration (PI Bruzzone of Italy, US Lead Jeff Plaut of JPL)
  - Particle Environment Package (PI Barabash of Sweden, US Lead Pontus Brandt of APL)



FY13 Europa Mission Opportunity

- FY13 Funding direction from Congress to proceed with Europa studies
- Continue Clipper Pre-Formulation activities (JPL/APL)
  - Preliminary design and risk reduction (more detail from Curt Niebur tomorrow)
- Release NRA: Instrument Concepts for Europa Exploration
  - Instruments must advance Europa Clipper science objectives
  - Select instruments in the model payload
  - 10-15 selections with a target budget of $750K-$1M for a one year grant
- See PEN and NSPIRES notices for more details

ESA's Rosetta Mission

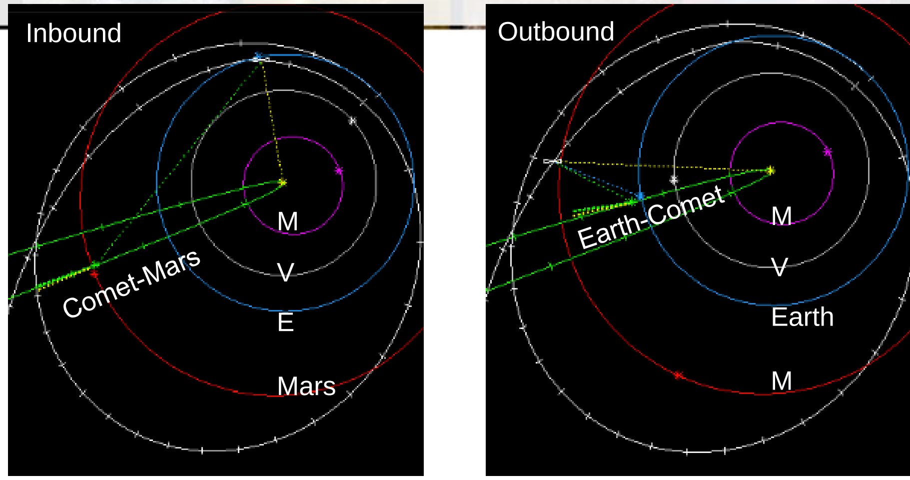


Philae Lander on Comet nucleus

- Rosetta will arrive at Comet Churyumov–Gerasimenko in Aug 2014 spending 2 years at the Comet
  - Has 11 instruments on the orbiter and 10 on the lander
  - NASA has 3 PI instrument and many CoIs
- Drop off the Philae lander and follow the comet into perihelion
  - Comet CG has an orbital period of 6.45 years

22

Comet ISON Potential Observations



- In: Mars-Comet closest approach ~0.08 AU (Oct 4)
- Out: Earth-Comet closest approach ~0.44AU (Jan 2)

SSERVI
Solar System Exploration Research Virtual Institute (SSERVI)

- **SSERVI expands on the success of NLSI to include all near term targets for human exploration**
  - Target bodies: Moon, NEAs, Phobos and Deimos
  - Anticipate selecting 7 teams at level of $1-1.5M/yr for 5 yrs
  - New Cooperative Agreement Notice (CAN) anticipated every 2-3 yrs
- **Substantial HEOMD/SMD collaboration**
  - Addresses key HEOMD Strategic Knowledge Gaps (SKGs)
  - Focus on planetary and exploration science along with astrophysics and heliophysics research uniquely enabled by the target bodies
- **Time Line:**
  - CAN released Jan 10th 2013
  - 32 NOI's received as of Feb
  - Proposals Due April 10th
  - Panel Review (target) late July
  - Teams announced at DPS in October
  - Teams funded and initial SSERVI launch Dec 2013

ASRG and PU 238

ASRG and Pu-238 Production

Advanced Stirling Radioistope Generator (ASRG)

- After Discovery 12 selection, working to identify next ASRG mission
  - Expectation is that Discovery 13 will provide similar opportunities to test mission enabling technologies (ie: ASRG, NEXT…)
- Two ASRG flight units (F1 and F2) will be completed in 2016
  - The completed flight units will go into bonded storage, unfueled, pending a mission decision for flight use

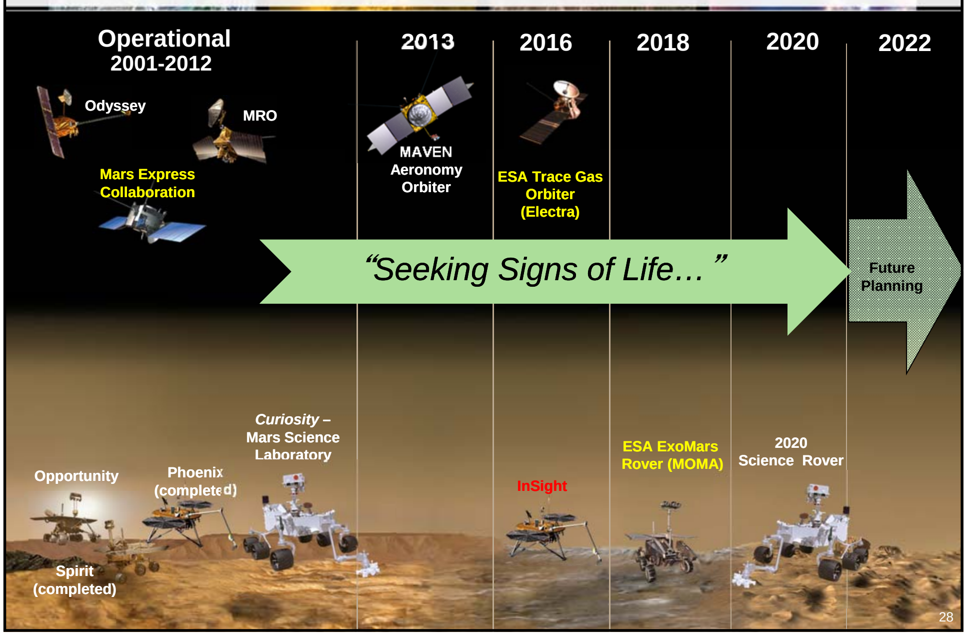
Plutonium-238

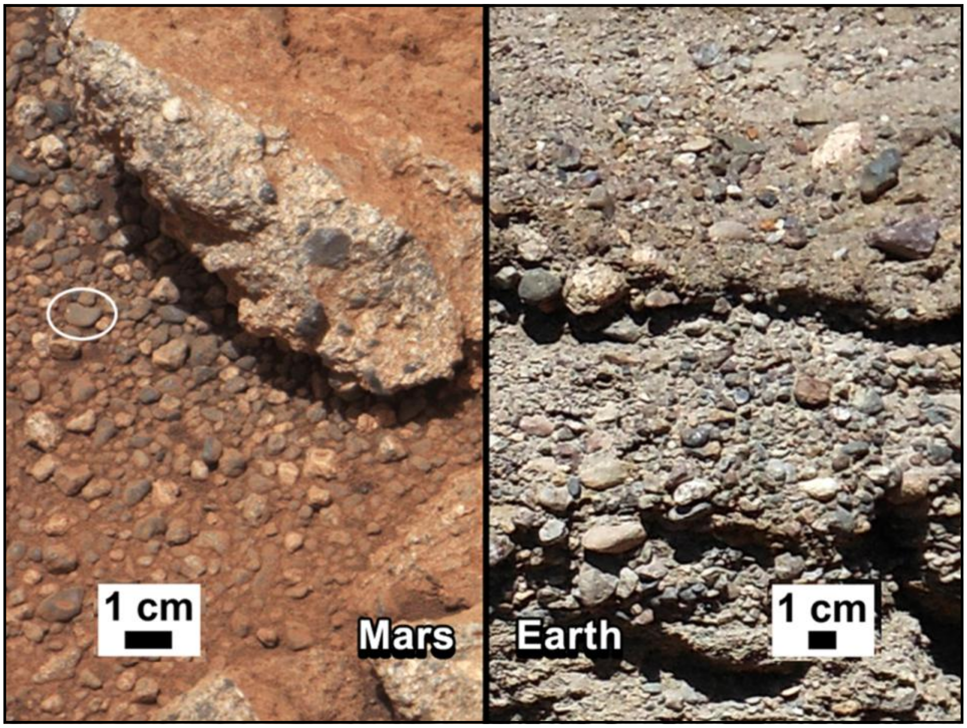
- Technology demonstration activities include:
  - A qualified Neptunium-237 target for irradiation in the High Flux Isotope Reactor *(First Np-237 targets irradiated)*
  - A qualified process for post-irradiation target processing
  - A qualified Pu-238 product
  - A project plan for scale-up to full-scale production at 1.5-2.0 kg/year
- Project baseline and confirmation by December 2013

Mars Program

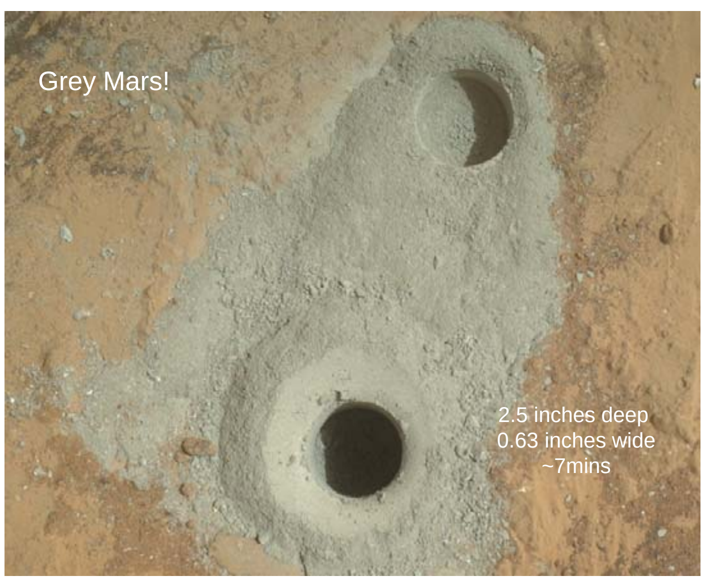
27

NASA's Future Mars Missions



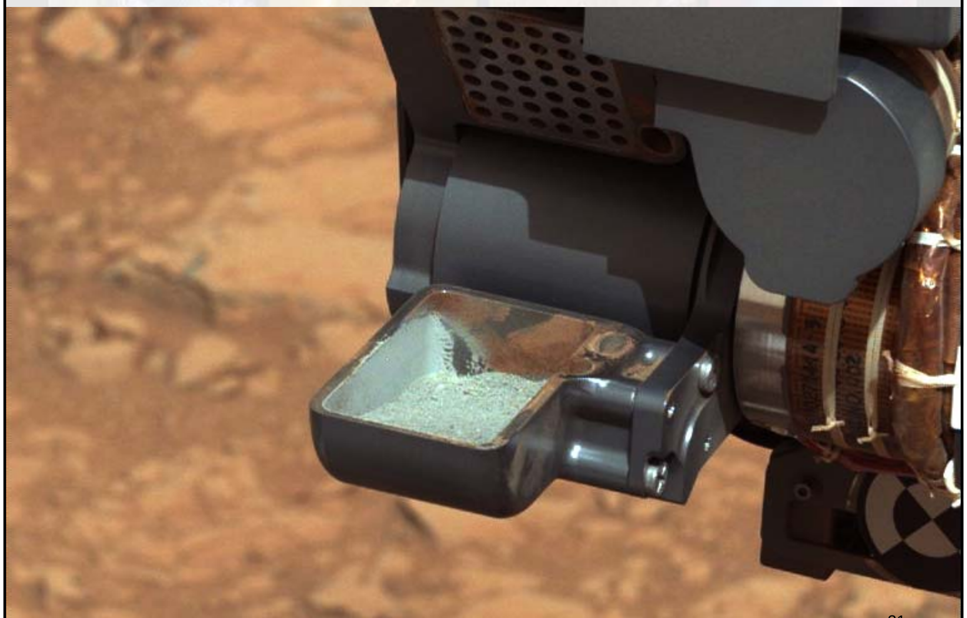


Drilling into Rock

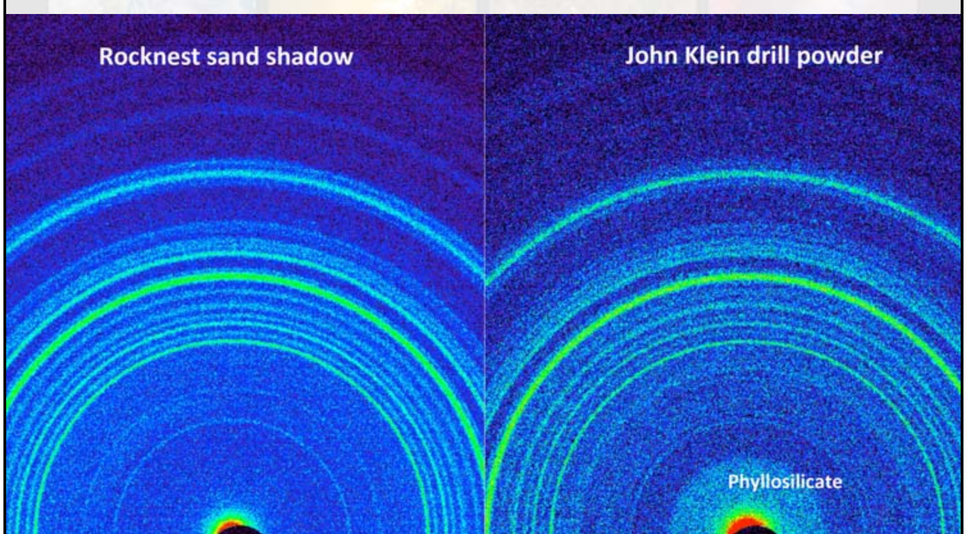


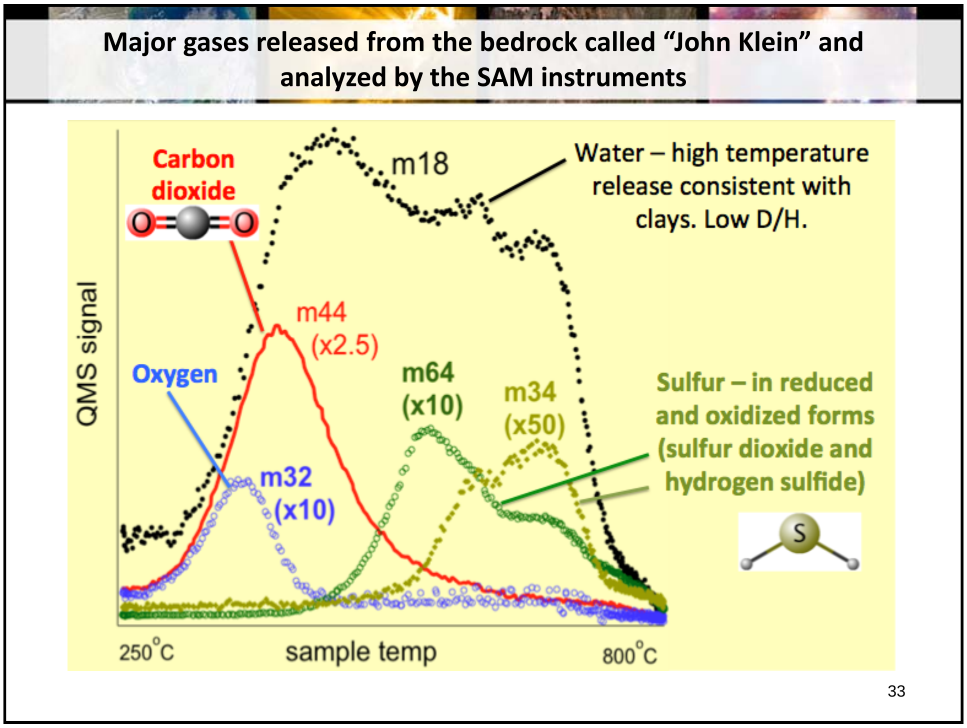
30

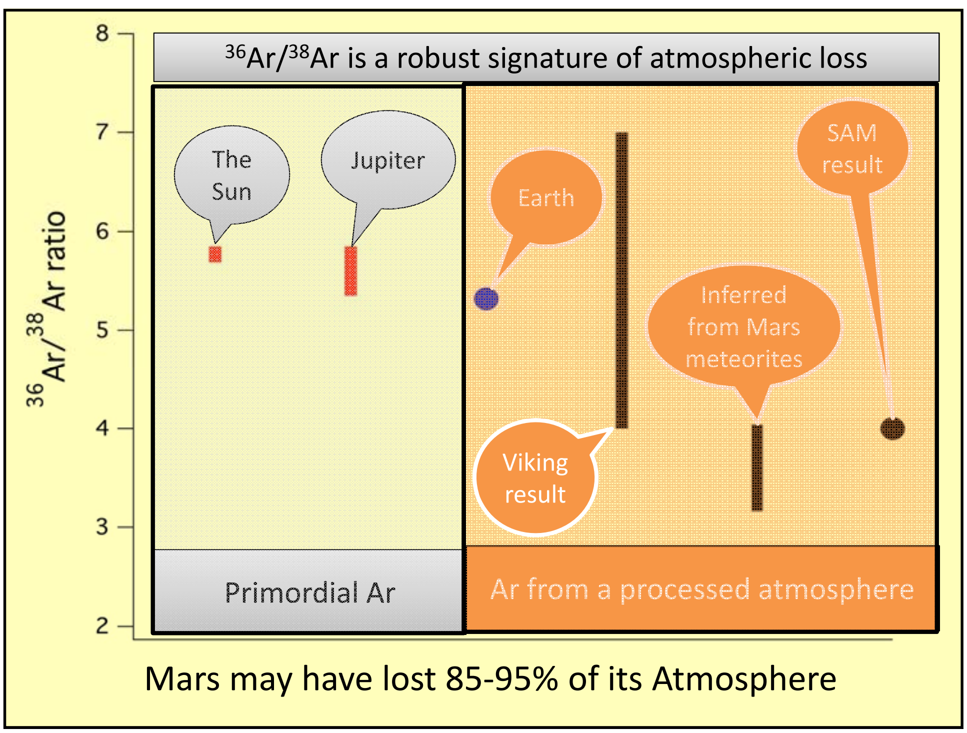
Drill Sample



31




Major gases released from the bedrock called "John Klein" and analyzed by the SAM instruments
Carbon dioxide
O=C=O
m18
Water – high temperature release consistent with clays. Low D/H.
m44 (x2.5)
Oxygen
m32 (x10)
m64 (x10)
m34 (x50)
Sulfur – in reduced and oxidized forms (sulfur dioxide and hydrogen sulfide)
S
QMS signal
250°C
sample temp
800°C
33

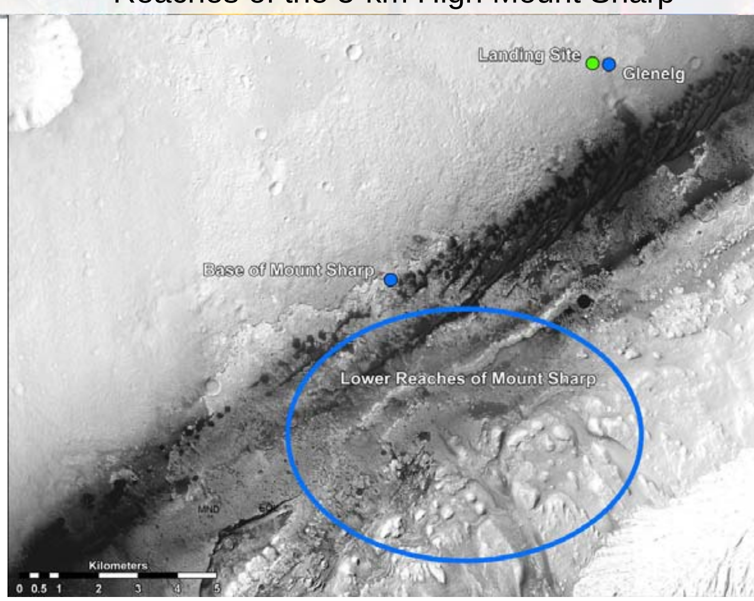

$^{36}Ar/^{38}Ar$ is a robust signature of atmospheric loss
8
7
6
5
4
3
2
$^{36}Ar/^{38}Ar$ ratio
The Sun
Jupiter
Earth
SAM result
Inferred from Mars meteorites
Viking result
Primordial Ar
Ar from a processed atmosphere
Mars may have lost 85-95% of its Atmosphere

An Ancient Habitable Environment at Yellowknife Bay

- **The regional geology and fine-grained rock suggest that the John Klein site was at the end of an ancient river system or within an intermittently wet lake bed**
- **The mineralogy indicates sustained interaction with liquid water that was not too acidic or alkaline, and low salinity. Further, conditions were not strongly oxidizing**
- **Key chemical ingredients for life are present, such as carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur**
- **The presence of minerals in various states or oxidation would provide a source of energy for primitive biology**

35

Curiosity's Ultimate Goal is to Explore the Lower Reaches of the 5-km High Mount Sharp



Curiosity's Status

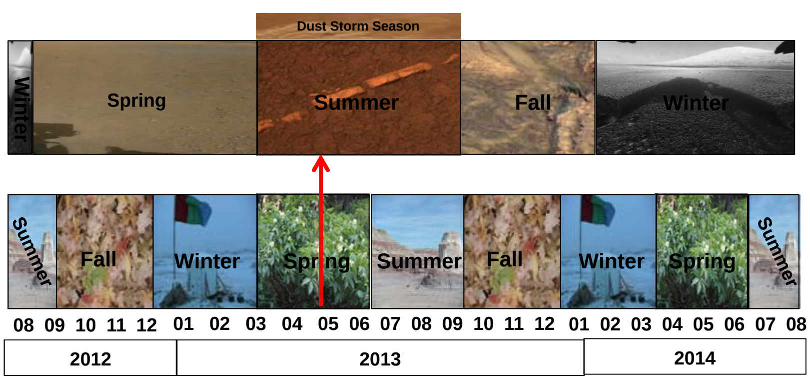
- Mars behind the Sun (April 4 – May 1) – *Conjunction*
- Rover:

  - Drive distance: 730 meters
  - Arm motions: 6300 (vs 2000 for Opportunity in Victoria Crater)
- Instruments:
  - CheMin: 1 soil sample, 1 rock sample
  - SAM: 4 soil samples, 2 rock samples, 7 atm samples
  - ECAM/RMI: 7000 images
  - MSSS Cameras: 20,000 images
  - APXS: 39 measurements (same as Spirit & Opp combined)
  - DAN: 360 measurements (~700k neutron pulses)
  - REMS: 4.5M seconds of data
  - ChemCam: 1700 LIBS analyses (~40K laser shots)0
  - RAD: 4000 measurements in first 100 sols

37

Curiosity's Seasons on Mars compared to Earth

ONE MARS YEAR

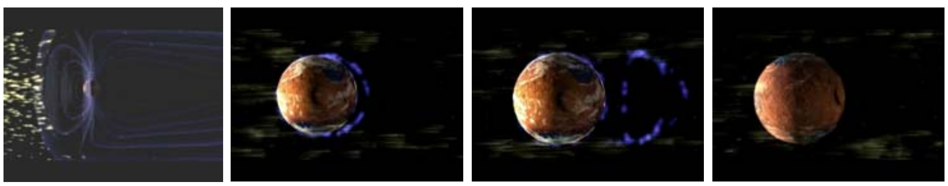


CORRESPONDING EARTH MONTH AND YEAR

What will MAVEN Accomplish?

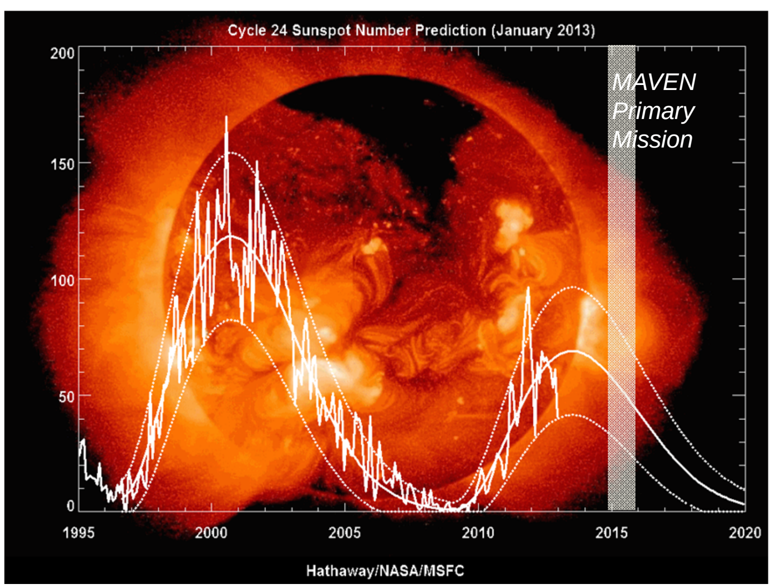
MAVEN will answer questions about the history of Martian volatiles and atmosphere and help us to understand the nature of planetary habitability.

- Determine the structure and composition of the Martian upper atmosphere today
- Determine rates of loss of gas to space today
- Measure properties and processes that will allow us to determine the integrated loss to space through time



Turn-off of the Martian magnetic field allowed turn-on of solar-EUV and solar-wind stripping of the atmosphere approximately 3.7 billion years ago, resulting in the present thin, cold atmosphere.

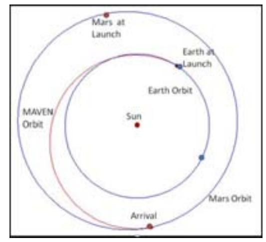
MAVEN's Timing in the Solar Cycle

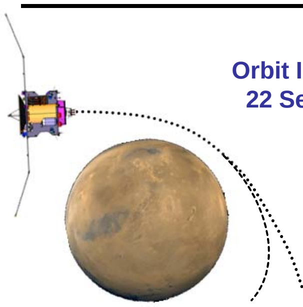


MAVEN Mission Architecture

20-Day Launch Period:
November 18 –
December 7, 2013

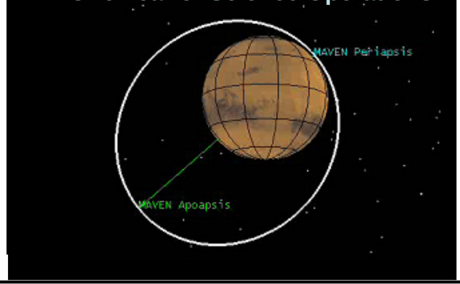
Ten-Month Ballistic Cruise to Mars





Orbit Insertion:
22 Sept 2014

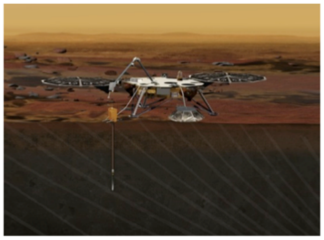
One Year of Science Operations



MAVEN with Arrays Deployed:

On track to ship to the Cape in August

InSight: Interior Structure from Seismic Investigations, Geodesy and Heat Transport

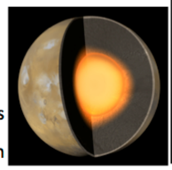


Mission & Science Team:
PI: Bruce Banerdt, JPL
PM: Tom Hoffman, JPL
Deputy PI: Sue Smrekar, JPL
Management: JPL
Spacecraft: Lockheed-Martin
Operations: JPL/LM
Payload: CNES (France), DLR (Ger.), JPL

Mission:
- Geophysical lander mission on Mars using Phoenix heritage spacecraft

Goals:
- Understand formation/evolution of terrestrial planets via interior structure/processes of Mars
- Determine present tectonic activity and meteorite impact rate

Payload:
- Seismic Experiment for Interior Structure (SEIS)
- Rotation & Interior Structure Experiment (RISE)
- Heat Flow & Physical Properties Probe (HP³)
- Instrument Deployment System



Mission Details:
- Flight: 3/2016 launch w/ELV, 4m fairing; 9/2016 landing; ~6.5 mo cruise, 1 Mars yr surface ops
- System Features (Phoenix-based design): Phoenix EDL architecture, solar power, UHF relay comm with X-band backup, updated RAD 750-based avionics
- Mass: 597.6kg dry launch, margin ≥31% (depending on ELV)
- Schedule: 43.5 mo B/C/D, 105 days sched. reserve
- Threshold Mission: Descope: HP³, SEIS SP sensors

Discovery Mission

43

2020 Rover - SDT Charter Mission Objectives

A. Explore an astrobiologically relevant ancient environment on Mars to decipher its geological processes and history, including the assessment of past habitability and potential preservation of possible biosignatures.

B. In situ science: Search for potential biosignatures within that geological environment and preserved record.

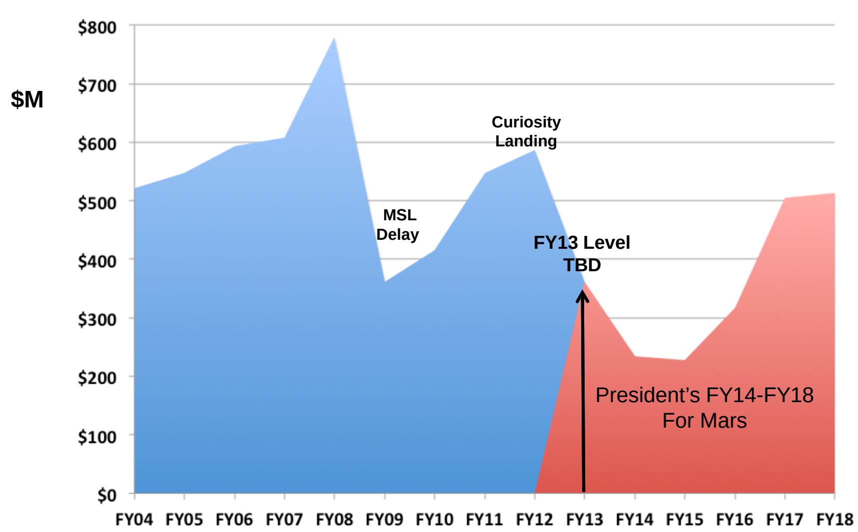
C. Demonstrate significant technical progress towards the future return of scientifically selected, well-documented samples to Earth.

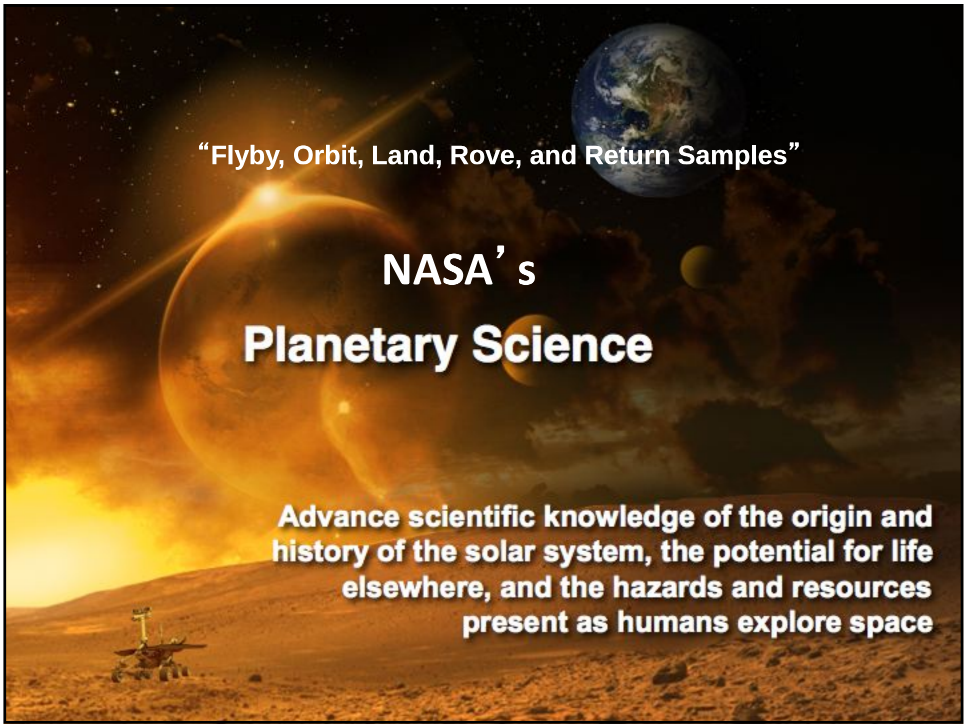
D. Provide an opportunity for contributed HEOMD or Space Technology Program (STP) participation, compatible with the science payload and within the mission's payload capacity.

SDT Primary Assumptions and Guidelines

- The mission will launch in 2020
- The total cost of the instruments limited to ~$100M (including margin/reserves). Includes:
  - Development and implementation costs of US instruments (~$80M)
  - Estimated costs of any contributed elements (~$20M), but not including surface operations costs.
  - Science support equipment, such as an arm, is ***not*** included in the ~$100M/$80M limit
- Mars Science Laboratory (MSL) SkyCrane-derived entry, descent, and landing flight systems, and *Curiosity*-class roving capabilities.
  - Consideration of scientific value and cost implications of improving access to high-value science landing sites should be provided by the SDT in consultation with the pre-project team.
- Mission lifetime requirement is one Mars year (~690 Earth Days) surface ops
- Pre-project activities will provide additional constraints on payload mass, volume, data rate, and configuration solutions to establish realistic boundary conditions for SDT consideration.
- Final Report: July 1, 2013
- Analysis of Final Report leads to an AO for instruments (early Fall 2013)

Mars Budget Analysis FY04 through FY18





Planetary Science Program Content

	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018
				(FY15-18 estimates are notional)			
Planetary Science	**1501.4**		**1217.5**	**1214.8**	**1225.3**	**1254.5**	**1253.0**
Planetary Science Research	174.1		220.6	233.3	229.1	230.4	232.2
Planetary Science Research and Analysis	122.3		130.1	131.0	131.3	132.2	132.5
Near Earth Object Observations	20.4		40.5	20.5	20.5	20.5	20.5
Other Missions and Data Analysis	27.4		46.0	74.5	70.2	70.3	71.8
Rosetta	8.0		16.5	12.8	7.6	0.5	
Planetary Data System	13.6		13.7	13.8	13.8	13.9	13.9
Astromaterial Curation	5.8		5.8	5.8	5.8	5.8	5.8
Joint Robotics Program for Exploration			10.0	10.0	10.0	10.0	10.0
Planetary Science Directed R&T				32.1	32.9	40.1	42.1
Directorate Management	4.0		4.0	7.3	7.1	7.4	7.4
Directorate Management	0.1			3.3	3.3	3.3	3.3
Robotics Alliance	3.9		4.0	4.0	3.8	4.1	4.1
Lunar Quest Program	139.9		17.7				
Lunar Science	66.7		15.3				
Lunar Reconnaissance Orbiter	43.7		11.5				
Lunar Science	20.5		3.8				
Lunar Management	2.6						
LADEE	70.4		2.4				
Surface Science Lander Technology	2.8						

48

Planetary Science Program Content (cont'd)

	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018
				(FY15-18 estimates are notional)			
Discovery	172.6		257.9	268.2	242.3	187.5	215.0
InSight	42.1		193.3	175.2	116.5	15.2	10.6
Other Missions and Data Analysis	130.6		64.6	93.0	125.8	172.3	204.4
Discovery Future	19.2		22.3	55.0	92.3	138.9	176.2
Dawn	14.3		9.8	11.0	0.1	4.8	
MESSENGER	34.9		4.9				
Strofio	1.6		1.3	0.7	0.8	0.8	0.5
ASPERA-3	0.9		0.6				
Gravity Recovery and Interior Laboratory	29.8						
Deep Impact	4.0						
Discovery Management	10.5		11.8	12.3	17.5	12.2	12.2
Discovery Research	15.4		13.9	14.1	15.2	15.6	15.6
New Frontiers	143.7		257.5	297.2	266.5	151.0	126.2
OSIRIS-REx	99.8		218.7	244.1	204.4	30.9	21.1
Other Missions and Data Analysis	43.9		38.8	53.1	62.1	120.1	105.1
New Frontiers Future Missions					8.2	76.3	79.7
Juno	14.4		17.7	21.4	29.5	33.4	19.5
New Horizons	26.5		16.4	26.8	18.5	4.6	
New Frontiers Management	3.0		4.7	4.9	5.9	5.8	6.0

49

Planetary Science Program Content (cont'd)

	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018
				(FY15-18 estimates are notional)			
Mars Exploration	587.0		234.0	227.7	318.4	504.7	513.2
MAVEN	245.7		50.1	20.2	6.6		
Other Missions and Data Analysis	341.4		183.9	207.6	311.8	504.7	513.2
Curiosity (MSL)	174.0		47.1	5.7			
Mars Organic Molecule Analyzer	12.6		20.0	20.0	10.0	5.0	1.0
ExoMars			5.1	3.4	2.6	1.3	1.4
Mars Future Missions	8.0		10.7	54.7	166.1	360.0	376.4
Mars Reconnaissance Orbiter 2005	39.9		30.5				
Mars Exploration Rover 2003	15.0		14.7				
Mars Odyssey 2001	13.3		12.8				
Mars Express	2.1		2.2				
Mars Extended Operations				82.3	91.3	97.3	93.3
Mars Mission Operations	1.8		1.8	1.9	1.9	1.9	1.9
2016 ExoMars Trace Gas Orbiter	27.1						
Mars Research and Analysis	19.3		19.5	19.5	19.5	19.5	19.5
Mars Technology	5.0		4.0	4.0	4.0	4.0	4.0
Mars Program Management	23.4		15.5	16.1	16.4	15.7	15.6

50

Planetary Science Program Content (cont'd)

	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018
				(FY15-18 estimates are notional)			
Outer Planets	122.1		79.0	45.6	24.4	26.4	26.4
Cassini	61.4		58.1	19.1			
JUICE - Jupiter Icy Moons Explorer			5.3	10.5	8.0	10.0	10.0
Outer Planets Flagship Mission	44.8						
Outer Planets Research	15.9		15.5	16.0	16.4	16.4	16.4
Technology	161.9		150.9	142.8	144.7	154.4	140.0
Radioisotope Pow er System Development	100.1		47.5	50.8	55.6	59.2	59.2
DOE RPS Infrastructure			50.0	50.0	50.0	50.0	50.0
Plutonium	10.0		16.4	12.8	9.6	15.8	1.3
Advanced Multi-Mission Operation Systen	35.2		33.7	29.3	29.4	29.5	29.5
In-Space Propulsion	12.4		3.2				
Technology Planning	4.2						