



NASA Planetary Science Division Budget Update

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29 November 2017



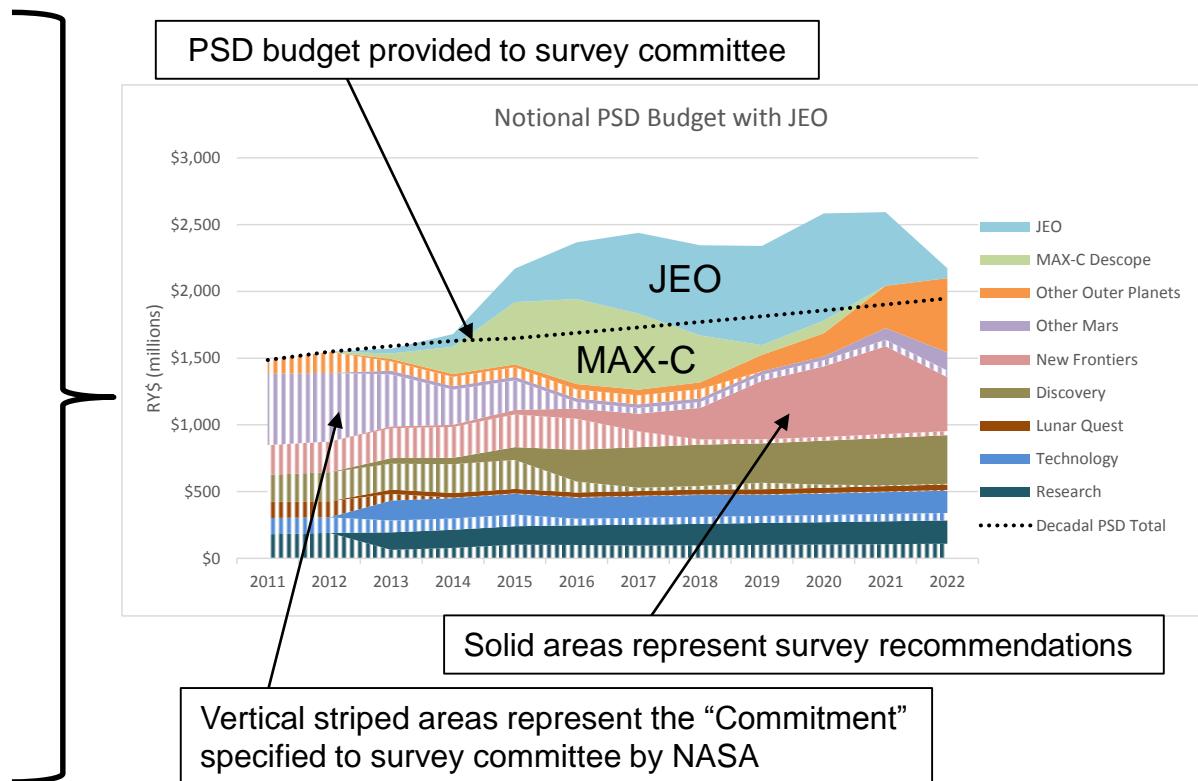
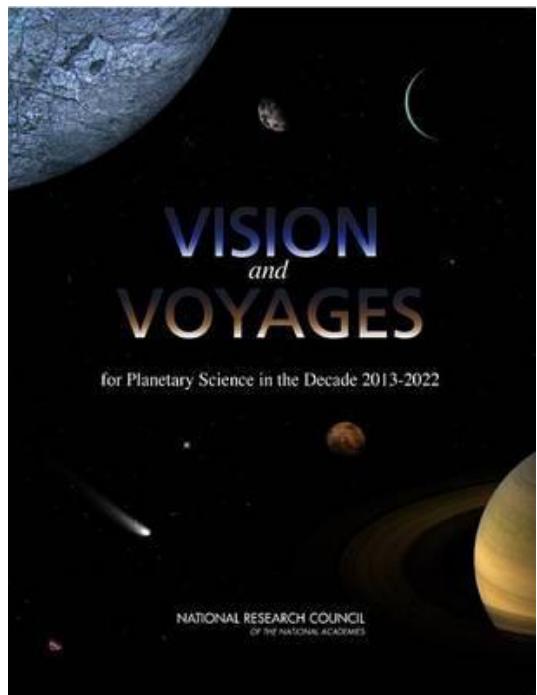
Topics

- Planetary Science Division Budget Overview
- Focus Areas
 - *Research*
 - *Mars 2020*
 - *Europa*
 - *Discovery*
 - *New Frontiers*

PSD Budget Recommended by Decadal Survey

2011

- MAX-C highest priority large mission
- JEO was included, but only if cost could be reduced and PSD budgets increased



NASA Budget Cycle

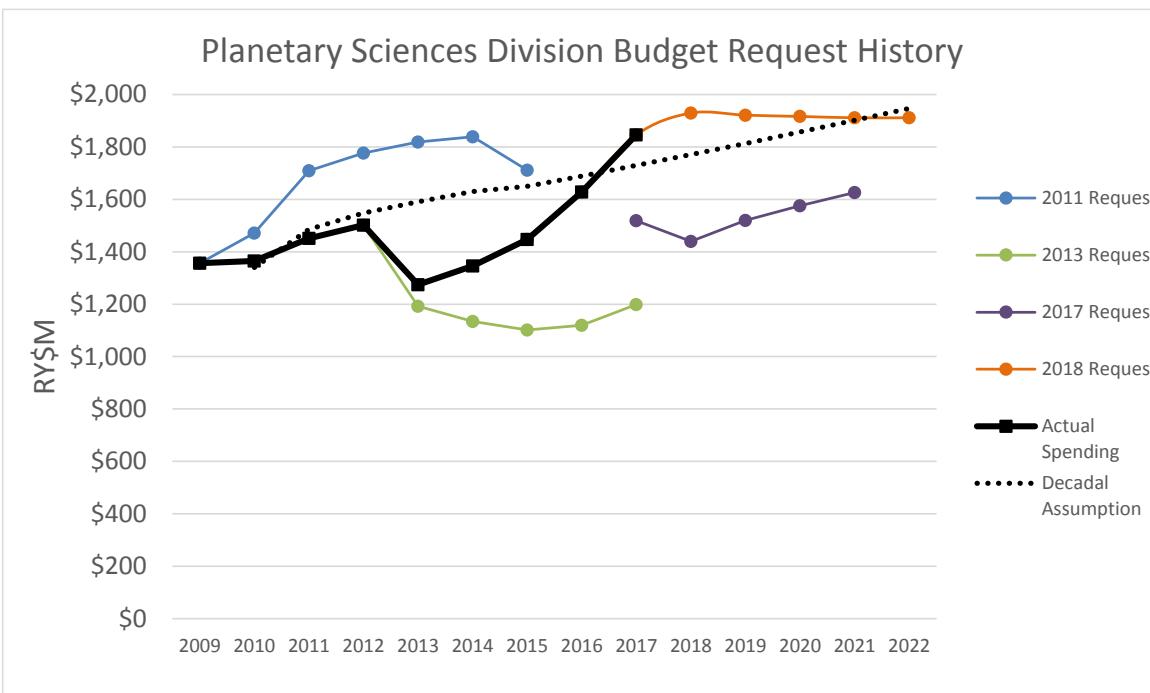
- NASA request is for following fiscal year (FY18 request released in FY17)
 - *Tables in document (sample below) show actuals from previous fiscal year*
 - *Along with enacted budget for current fiscal year and “notional” request for 4 future years*
 - Enacted column will be blank when operating under a continuing resolution



Budget Authority (in \$ millions)	Actual	Enacted	Request	Notional			
	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Planetary Science Research	274.0	--	291.5	295.1	298.4	298.9	304.7
Discovery	189.0	--	306.1	425.4	488.3	376.8	375.2
New Frontiers	194.0	--	82.1	121.7	169.4	227.8	307.0
Mars Exploration	513.0	--	584.7	562.5	530.4	356.9	450.7
Outer Planets and Ocean Worlds	261.0	--	457.9	318.1	229.3	446.2	267.2
Technology	197.0	--	207.2	198.6	200.6	204.8	206.6
Total Budget	1628.0	--	1929.5	1921.4	1916.4	1911.4	1911.4

PSD Budget Has Fluctuated

- Total current budget for 2013 to 2022 is roughly the same as the Decadal assumption
 - *Currently \$17.1B compared to \$17.6B Decadal assumption*
- However, large fluctuations occurred
 - *Sharply down in 2013, then recovering to close to assumed levels in 2016*
 - *Big jump between FY17 budget request and FY18 budget request*



Source: 2011 – 2018 NASA budget requests (only showing select years – other years are available)



FY18 PSD Budget Status

As of 8/7/17

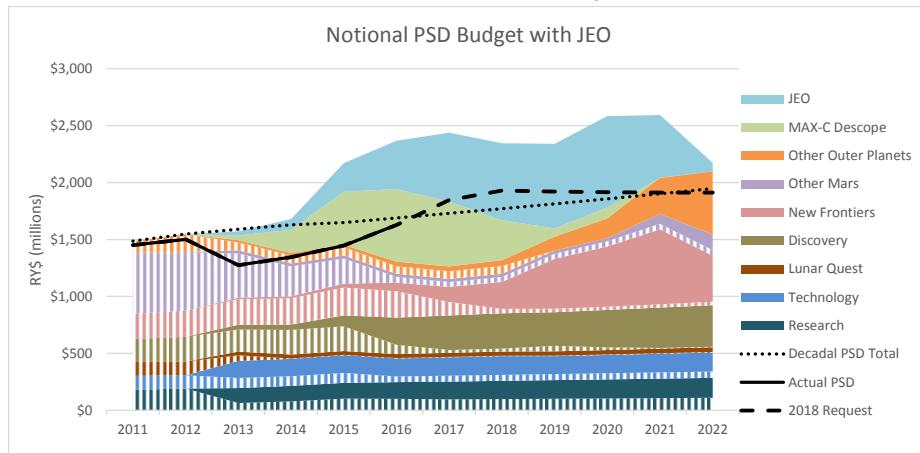
- FY18 budget is difficult to predict at this point
 - *Earmarks for Europa Clipper and Lander can have a large impact*

Source	PSD Budget Total
FY16 Actual	\$1,628M
FY17 Enacted	\$1,846M
FY18 Request	\$1,930M
FY18 House Bill	\$2,121M
FY18 Senate Bill	\$1,612M

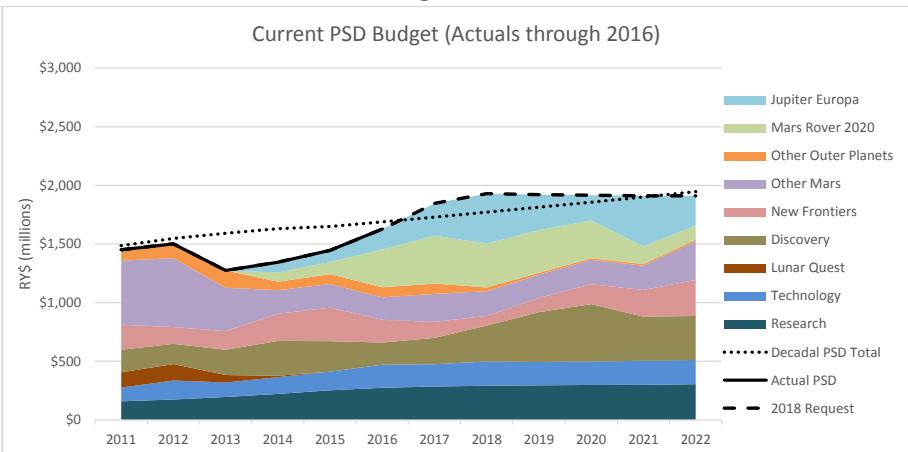
Planetary Science Division Budget Comparison

- MAX-C, now Mars2020 has been sufficiently funded even with 2013 to 2016 shortfall
 - *Launch date moved from 2018 to 2020*
- JEO has been partially funded by Congress
- Lack of funding delayed New Frontiers NF-4 and NF-5
 - *NF-4 Step 1 selection planned for FY18*
 - *Downselect in FY19*

From Decadal Survey (2011)



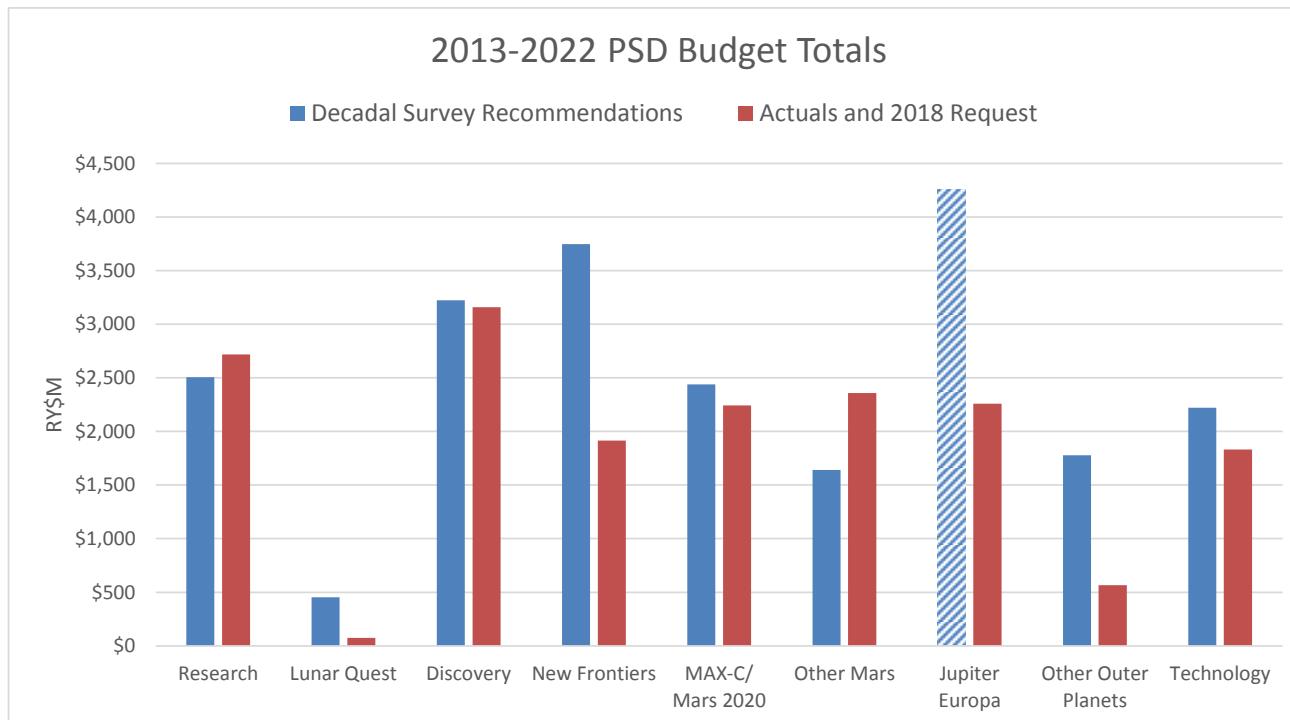
From FY18 Budget Request (2017)





PSD Budget Allocations

- Many elements are funded close to Survey recommendations
 - *Funding for Europa Clipper and Lander has been included*
 - JEO was entirely outside Survey budget assumptions
 - *Funding for New Frontiers and Other Outer Planets is less than recommended*





Topics

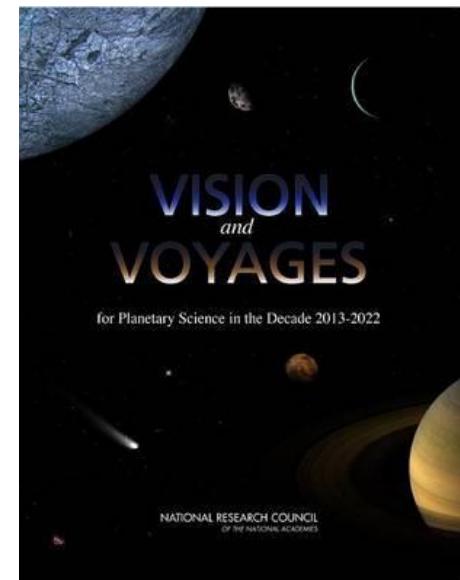
- Planetary Science Division Budget Overview



- Focus Areas
 - *Research*
 - *Mars 2020*
 - *Europa*
 - *Discovery*
 - *New Frontiers*

Question on PSD Research Spending

- Question: Has the NASA Planetary Science Division met the recommendations of the Vision and Voyages report for Research spending?
 - *“...the committee recommends that NASA increase the research and analysis budget for planetary science by 5% above the total finally approved FY2011 expenditures in the first year of the coming decade, and increase the budget by 1.5% above the inflation level for each successive year of the decade.”**
- **Answer: Yes, the actual Research spending through 2016 is ahead of V&V recommendations despite the overall PSD budget in those years being lower than anticipated**
- Caveat: Different people have different opinions about what “counts” as research
 - *Choice of which budget elements to include could influence the answer*



*Vision and Voyages, Pg. 7



The Math

- “5% above the total finally approved FY2011 expenditures in the first year of the coming decade*”
 - *First year of the coming decade assumed to be 2013*
- “Increase the budget by 1.5% above the inflation level for each successive year*”
 - *2016 NASA New Start Inflation Index used for inflation factors*
 - *Ranges from 1.5% to 2.1% per year*
- 2016 value should be 15% higher than 2011
 - *Assuming 2012 as first year of the coming decade increases value to 19%*

	2013	2014	2015	2016
V&V Recommendation	5%	1.5%	1.5%	1.5%
Inflation		2.1%	1.5%	1.5%
Total Escalation	5%	3.6%	3.0%	3.0%
Cumulative Escalation	5%	8.8%	12.0%	15.4%

*Vision and Voyages, Pg. 7



PSD Research Spending

- NASA PSD spending data from NASA budget requests

	RY\$M	2011	2012	2013	2014	2015	2016
All Research Total	\$ 245	\$ 245	\$ 256	\$ 275	\$ 281	\$ 308	
Planetary Science Research Budget Line	\$ 159	\$ 174	\$ 196	\$ 222	\$ 253	\$ 274	
Planetary Science Research and Analysis	\$ 122	\$ 122	\$ 129	\$ 130	\$ 162	\$ 163	
Other Missions and Data Analysis	\$ 24	\$ 27	\$ 43	\$ 47	\$ 46	\$ 58	
Education and Directorate Management	\$ 5	\$ -	\$ -	\$ -	\$ -	\$ -	
Near Earth Object Observations	\$ 8	\$ 20	\$ 21	\$ 41	\$ 40	\$ 50	
Directorate Management	\$ -	\$ 4	\$ 4	\$ 4	\$ 4	\$ 3	
Other Research Total	\$ 86	\$ 71	\$ 60	\$ 53	\$ 28	\$ 34	
Lunar Science Research	\$ 32*	\$ 20*	\$ 11*	\$ 4*	\$ - *	\$ - *	
Discovery Research	\$ 17	\$ 15	\$ 15	\$ 14	\$ 10	\$ 16	
New Frontiers Research	\$ 1	\$ 0	\$ -	\$ -	\$ -	\$ -	
Mars Research and Analysis	\$ 17	\$ 19	\$ 19	\$ 20	\$ 10	\$ 10	
Outer Planets Research	\$ 18*	\$ 16*	\$ 15*	\$ 16	\$ 9	\$ 9	

* Value not provided in NASA budget requests. Value shown in table was provided by Jonathan Rall.



PSD Research Spending Has Increased

- Recent PSD budgets have contained 6-7 major categories
 - One is “Planetary Science Research”*
 - Spending on this line has grown significantly since 2011 (+73%)
 - There is also research listed under other categories*
 - For example: “Mars Research and Analysis” is under “Mars Exploration”
 - The spending for the total of these elements has shrunk (-60%)*
 - Total of all categories described above has increased (+26%)*

	2011	2016	Change
Planetary Science Research Line	\$159M	\$274M	73%
Other Research Total	\$86M	\$34M	-60%
Lunar Science Research	\$32M*	-*	-100%
Discovery Research	\$17M	\$16M	-9%
New Frontiers Research	\$1M	-	-100%
Mars Research and Analysis	\$17M	\$10M	-43%
Outer Planets Research	\$18M*	\$9M	-51%
All PSD Research	\$238M	\$313M	26%

* Value not provided in NASA budget requests. Value shown in table was provided by Jonathan Rall.

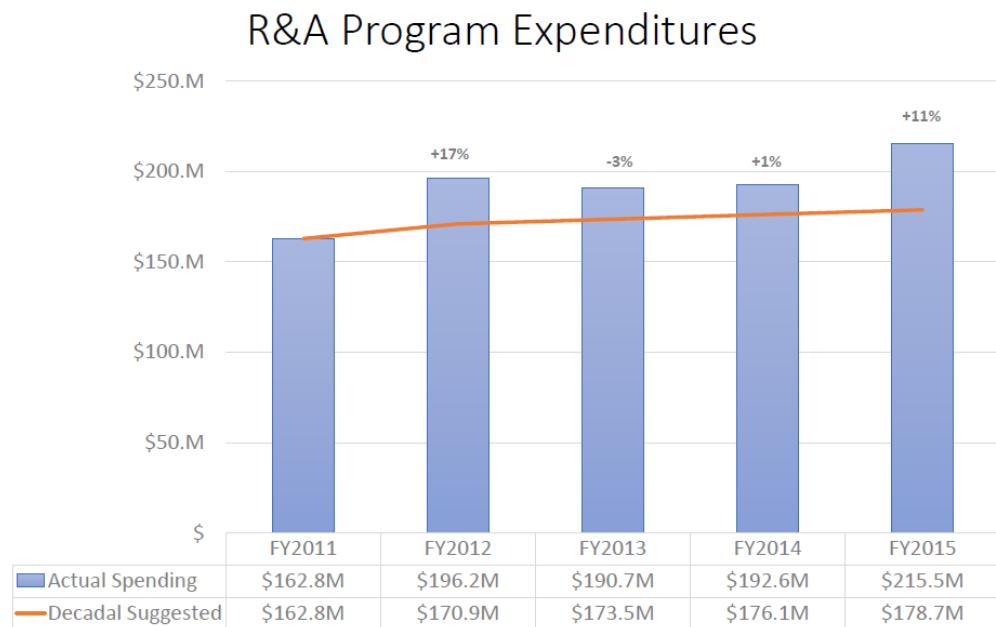


Mark Sykes White Paper and Spreadsheet

- Spreadsheet that accompanies the white paper has considerable detail beyond what is provided in NASA budget requests
 - *BUT, it is not a complete PSD budget and does not include some items that fall under “Research” in the NASA budget requests*
- Some or all of this may be intentional
 - *Dr. Sykes describes some efforts to remove non-competeted elements*
 - *For example, he separates “TECH” and does not include that spending in his calculations*
- There is significant growth in some elements that are excluded
 - *Near Earth Object Observations*
 - Grows from \$8M in 2011 to \$50M in 2016
 - Sykes spreadsheet shows growth from \$5M to \$9M
 - *Other Missions and Data Analysis*
 - Grows from \$24M in 2011 to \$58M in 2016
 - Growth from items including Joint Robotics Program for Exploration, Science Innovation Fund, and Science Data & Computing
 - These items do not appear in the Sykes spreadsheet

Jim Green Plot

- Jim Green presented the plot below at the May committee meeting*
- From discussions with Jim Green and Jonathan Rall, this plot is based on a keyword search of NASA WBS elements to find items that represent competed research and technology
- Also shows increasing spending since 2011



Note: Orange “Decadal Suggested” line is calculated assuming the first year is 2012 and does not include inflation for the remaining years. Adding inflation raises 2015 suggested level to \$188M. Changing first year to 2013 and adding inflation raises 2015 to \$182M. In all cases, the actual spending reported is higher than the calculated suggested level.



Mars Rover Developments since the Survey

- In 2012, NASA examined several Mars rover concepts
 - *Rover A and B based on MER*
 - *Rover C based on MSL*
 - *CATE Assessments performed for all 3*
- Rover C evolved to Mars 2020
- Progressing on schedule for a 2020 launch
 - 2013 – *MCR and KDP-A*
 - 2015 – *SRR/MDR and KDP-B*
 - 2016 – *PDR and KDP-C*
 - 2017 – *CDR*
- FY18 Budget Request shows current budget is \$2.4B (~\$2.2B in FY15\$)



Design Evolution from MAX-C to Mars 2020

Concept	MAX-C	MAX-C Descope	Mars Rover C	Mars 2020	Mars 2020	Mars 2020
Date of concept	2010	2010	2012	2013	2015	2016
Context	Decadal Survey	Decadal Survey	Concept Study	MCR/KDP-A	SRR-MDR/KDP-B	PDR/KDP-C
Launch Year	2018	2018	2020	2020	2020	2020
Rover Power	Solar	Solar	Solar	RTG	RTG	RTG
EDL Concept	Shared landing pallet	MSL Build to Print	MSL Build to Print	MSL Build to Print	MSL Build to Print	MSL Build to Print
Science Payload	Pancam	Pancam	Pancam	MastCam	Mastcam-Z	Mastcam-Z
	NIR Point Spectrometer	NIR Point Spectrometer	NIR Point Spectrometer	NIR Spectrometer	SuperCam	SuperCam
	Microscopic Imager	Microscopic Imager	Microscopic Imager	MAHLI	PIXL	PIXL
	APXS	APXS	APXS	APXS		
	Raman/Fluorescence Instrument	Raman/Fluorescence Instrument	Mossbauer Spectrometer	Raman Spectrometer	SHERLOC	SHERLOC
	Sample Collection	Sample Collection	Sample Collection	Sample Collection	Sample Collection	Sample Collection
					RIMFAX	RIMFAX
					MOXIE	MOXIE
					MEDA	MEDA
Launch Dry Mass	3861 kg	3044 kg	3219 kg	3416 kg	3535 kg	3552 kg
Launch Wet Mass	4457 kg	3421 kg	3693 kg	3889 kg	3994 kg	4050 kg
Project Estimate (FY15\$B)	\$2.2				\$2.2*	\$2.2*
CATE/ICE Estimate (FY15\$B)	\$3.5	\$2.4				

*SMD Cost. Total NASA cost including contributions is \$2.5B.

- Key Changes
 - MAX-C to MAX-C Descope - removed Landing Pallet and ExoMars Rover
 - Rover-C to Mars 2020 - reverted from solar powered rover to MSL-based RTG powered rover
- Current Status for Mars 2020
 - CDR in February 2017
 - Launch planned for 2020

Planetary Decadal Report Language:

The committee recommends that NASA fly MAX-C in the decade 2013-2022, but only if it can be conducted for a cost to NASA of no more than approximately \$2.5 billion FY2015. If a cost of no more than about \$2.5 billion FY2015 cannot be verified, the mission (and the subsequent elements of Mars Sample Return) should be deferred until a subsequent decade or cancelled.*

*Vision and Voyages, Pg. 4



Europa Developments since the Survey

- In 2012, NASA examined several Europa options under the Europa Habitability Missions study
 - *Conceptual designs were developed for Flyby, Orbiter, and Lander options*
- Europa Clipper is most similar to the Flyby option with additional science instruments
 - *KDP-A in 2014 and KDP-B in 2016*
- Starting in 2014, Congress has earmarked more for Europa than NASA has requested
 - *2014 - \$80M; 2015 - \$80M; 2016 - \$175M; 2017 - \$275M*
 - 2016 and 2017 appropriations specify an orbiter and lander with orbiter launch in 2022 on an SLS
 - *Current budget request for FY18 is \$425M which could support a Clipper launch in 2022, but does not fund any Lander work*
 - 2018 Budget Request for years beyond 2018 does not support 2022 launch and states: “*NASA does not recommend acceleration of the launch to 2022, given potential impacts to the rest of the Science portfolio. The Administration supports a balanced science program, as recommended in the Decadal Survey.*”*
 - Europa Clipper Project development schedule does support a 2022 launch
 - *Cost and availability of SLS is uncertain*

*FY 2018 Budget Estimates, Pg. PS-62



Design Evolution from JEO to Europa Clipper

Concept	JEO	EHM Orbiter	EHM Flyby	Europa Clipper	Europa Clipper
Date of concept	2010	2012	2012	2014	2016
Context	Planetary Decadal Survey	EHM Study	EHM Study	MCR/KDP-A	SRR-MDR/KDP-B
Launch Year	2020	2021	2021	2022	2022
Flight System	RTG Powered Orbiter	RTG Powered Orbiter	RTG Powered Multi-Flyby	Solar Powered Multi-Flyby	Solar Powered Multi-Flyby
Science Payload	Laser Altimeter	Laser Altimeter	Ion & Neutral Mass Spectrometer	Neutral Mass Spectrometer	MASPEX - Mass Spectrometer
	Ice Penetrating Radar	Mapping Camera	Ice Penetrating Radar	Ice Penetrating Radar	REASON - Ice Penetrating Radar
	Vis-IR Spectrometer	Langmuir Probe	IR Spectrometer	Short Wave IR Spectrometer	MISE - IR Spectrometer
	UV Spectrometer	Magnetometer	Topographical Imager	Topographical Imager	Europa UVS - UV Spectrometer
	Thermal Imager			Magnetometer	E-THEMIS - Thermal Imager
	Narrow Angle Imager			Langmuir Probe	EIS - Narrow Angle Camera
	Wide & Medium Angle Imager			Recon Camera	EIS - Wide Angle Camera
	Magnetometer			Thermal Imager	ICEMAG - Magnetometer
	Particle & Plasma Instrument				SUDA - Dust Analyzer
					PiMS - Faraday Cups
Launch Dry Mass	2300 kg	1706 kg	1776 kg	2202 kg	2962 kg
Launch Wet Mass	4745 kg	3748 kg	3203 kg	3860 kg	5343 kg
Project Estimate (FY15\$B)	\$3.4	\$1.9	\$2.2		
CATE/ICE Estimate (FY15\$B)	\$4.7	\$2.0	\$2.4		

- Key changes
 - *JEO to EHM – Split science into Orbiter (Ocean) and Flyby (Chemistry and Energy)*
 - *EHM Flyby to Clipper – Some Orbiter instruments added as Clipper evolved*
- Current Status for Europa Clipper
 - *PSD budget currently does not have adequate funding to support the 2022 LRD*
 - Updated cost estimates have not been publically released
 - *MDR in January 2017; KDP-B in February 2017*

*Vision and Voyages, Pg. 4

Planetary Decadal Report Language:

The second highest priority Flagship mission for the decade 2013-2022 is the Jupiter Europa Orbiter (JEO). However, its cost as currently designed is so high that both a decrease in mission scope and an increase in NASA's planetary budget are necessary to make it affordable. The projected cost of the mission as currently designed is \$4.7 billion FY2015. If JEO were to be funded at this level within the currently projected NASA planetary budget it would lead to an unacceptable programmatic imbalance, eliminating too many other important missions. Therefore, while the committee recommends JEO as the second highest priority Flagship mission, close behind MAX-C, it should fly in the decade 2013-2022 only if changes to both the mission and the NASA planetary budget make it affordable without eliminating any other recommended missions. These changes are likely to involve both a reduction in mission scope and a formal budgetary new start for JEO that is accompanied by an increase in the NASA planetary budget. NASA should immediately undertake an effort to find major cost reductions for JEO, with the goal of minimizing the size of the budget increase necessary to enable the mission.*



Status of Discovery Program

- From the Executive Summary of *Visions and Voyages*
 - *“Because there is still so much compelling science that can be addressed by Discovery missions, the committee recommends continuation of the Discovery program at its current level, adjusted for inflation, with a cost cap per mission that is also adjusted for inflation from the current value (i.e., to about \$500 million in fiscal year [FY] 2015). And so that the science community can plan Discovery missions effectively, the committee recommends a regular, predictable, and preferably rapid (≤24-month) cadence for release of Discovery Announcements of Opportunity and for selection of missions.”*
- Recommendation: “... continuation of the Discovery program at its current level, adjusted for inflation..*”
 - ***Finding: Although funding has fluctuated from year to year, the total funding from 2012-2016 has risen faster than inflation since 2011***
 - Future years request is much higher

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Discovery	\$192	\$173	\$216	\$297	\$260	\$189	\$225	\$306	\$425	\$488	\$377	\$375

**Vision and Voyages, Pg. 3*



Status of Discovery Program (con't.)

- Recommendation: "...a cost cap per mission that is also adjusted for inflation from the current value (i.e., to about \$500 million in fiscal year [FY] 2015).^{*}"
 - ***Finding: The cost cap for Discovery 2014 was raised to \$450M (FY15\$) for Phases A-D without Launch Vehicle***
 - Operations cost removed from the cost cap to not penalize missions with long cruise periods
 - ***Change in cost cap meets the intent of V&V recommendation***
 - V&V recommendation assumed to include Phase E/F
- Recommendation: "... a regular, predictable, and preferably rapid (\leq 24-month) cadence for release of Discovery Announcements of Opportunity...^{*}"
 - ***Finding: Around the time of the survey, an AO had been released in June 2010 that resulted in the InSight selection in August 2012***
 - Launch originally planned for March 2016, delayed to May 2018
 - ***Discovery 2014 AO released in Nov 2014 that resulted in selection of Lucy and Psyche in Jan 2017***
 - Lucy launch in 2021 and Psyche in 2023 (since changed to 2022)
 - ***2018 Budget Request says next Discovery AO planned for 2019***
 - ***Even considering that 2 missions were selected from the 2014 AO, NASA has not met the goal of an AO release every 24 months***

^{*}Vision and Voyages, Pg. 3



Status of New Frontiers Program

- From the Executive Summary of *Visions and Voyages*
 - *“The committee recommends changing the New Frontiers cost cap to \$1.0 billion FY2015, excluding launch vehicle costs.”*
 - *“The committee recommends that NASA select two additional New Frontiers missions in the decade 2013-2022.”*
 - *“New Frontiers Mission 4 should be selected from among the following five candidates:*
 - Comet Surface Sample Return,
 - Lunar South Pole-Aitken Basin Sample Return,
 - Saturn Probe,
 - Trojan Tour and Rendezvous, and
 - Venus In Situ Explorer.”
 - *“For the New Frontiers Mission 5 selection, the following missions should be added to the list of remaining candidates:*
 - Io Observer, and
 - Lunar Geophysical Network.”

**Vision and Voyages, Pg. 3*



Status of New Frontiers Program (con't.)

- Recommendation: “The committee recommends changing the New Frontiers cost cap to \$1.0 billion FY2015, excluding launch vehicle costs.*”
 - ***Finding: The AO for New Frontiers 4 set the cost cap at \$850M (FY15\$) for Phases A-D without Launch Vehicle***
 - Operations cost removed from the cost cap to not penalize missions with long cruise periods
 - ***Change in cost cap meets the intent of V&V recommendation***
 - V&V recommendation assumed to include Phase E/F
- “The committee recommends that NASA select two additional New Frontiers missions in the decade 2013-2022.*”
 - ***Finding: The AO for New Frontiers 4 was released in December 2016 with final selection planned for July 2019***
 - ***Jim Green's May 2017 presentation states, “On track to solicit NF-5 before 2023”***
 - Assumed to mean selection will be after 2022
 - ***NASA is unlikely to meet goal of selecting 2 New Frontiers missions in the decade 2013-2022***

*Vision and Voyages, Pg. 3



Status of New Frontiers Program (con't.)

- Recommendation: “New Frontiers Mission 4 should be selected from among the following five candidates:
 - Comet Surface Sample Return,
 - Lunar South Pole-Aitken Basin Sample Return,
 - Saturn Probe,
 - Trojan Tour and Rendezvous, and
 - Venus In Situ Explorer.*”
- ***Finding: The AO for New Frontiers 4 included those 5 candidates plus Ocean Worlds (Enceladus and/or Titan)***
 - Committee on Astrobiology and Planetary Science (CAPS) reviewed and approved that addition
- ***Recommendation: For the New Frontiers Mission 5 selection, the following missions should be added to the list of remaining candidates:***
 - Io Observer, and
 - Lunar Geophysical Network.*”
- ***Finding: Jim Green’s May 2017 presentation states that NF-5 to include Io Observer & Lunar Geophysical Network***

*Vision and Voyages, Pg. 3