National Aeronautics and Space Administration

EXPLORE SOLAR SYSTEM & BEYOND

Lori S. Glaze, Ph.D.
NASA Planetary Science Division Director

PAC Meeting
June 14, 2021

Budget

Planetary Science Budget Features

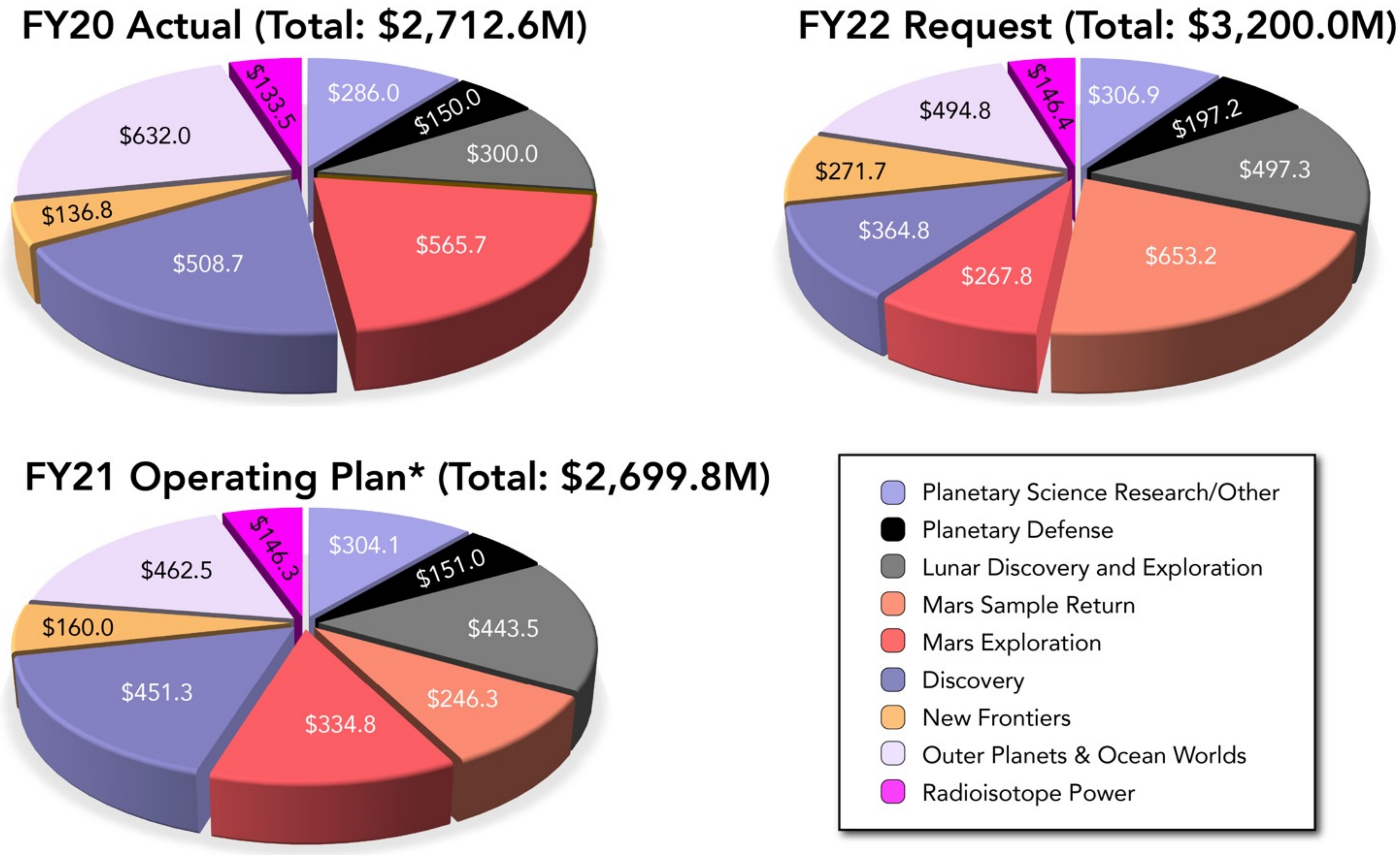
What's Changed

- Mars Sample Return established as a new program, funded at Independent-Review-Board-recommended level, for sample return as early as 2031
- NEO Surveyor mission budget increased to support launch as early as 2026
- VIPER and Lunar Trailblazer confirmed to enter development
- Dragonfly launch readiness date moved to June 2027
- DART launch date moved to the secondary launch window (November 24, 2021 to February 15, 2022)
- FY22 increases to R&A, to maintain adherence to Decadal recommendation, including new investments in laboratory facilities and a proactive emphasis on enabling more diverse groups of researchers to have greater access to laboratory facilities
- Decreases to Discovery Future; budget still sufficient to support two recent selections
- COVID impacts added for Clipper, Psyche
- New Frontiers 5 Announcement of Opportunity delayed to no later than 2024

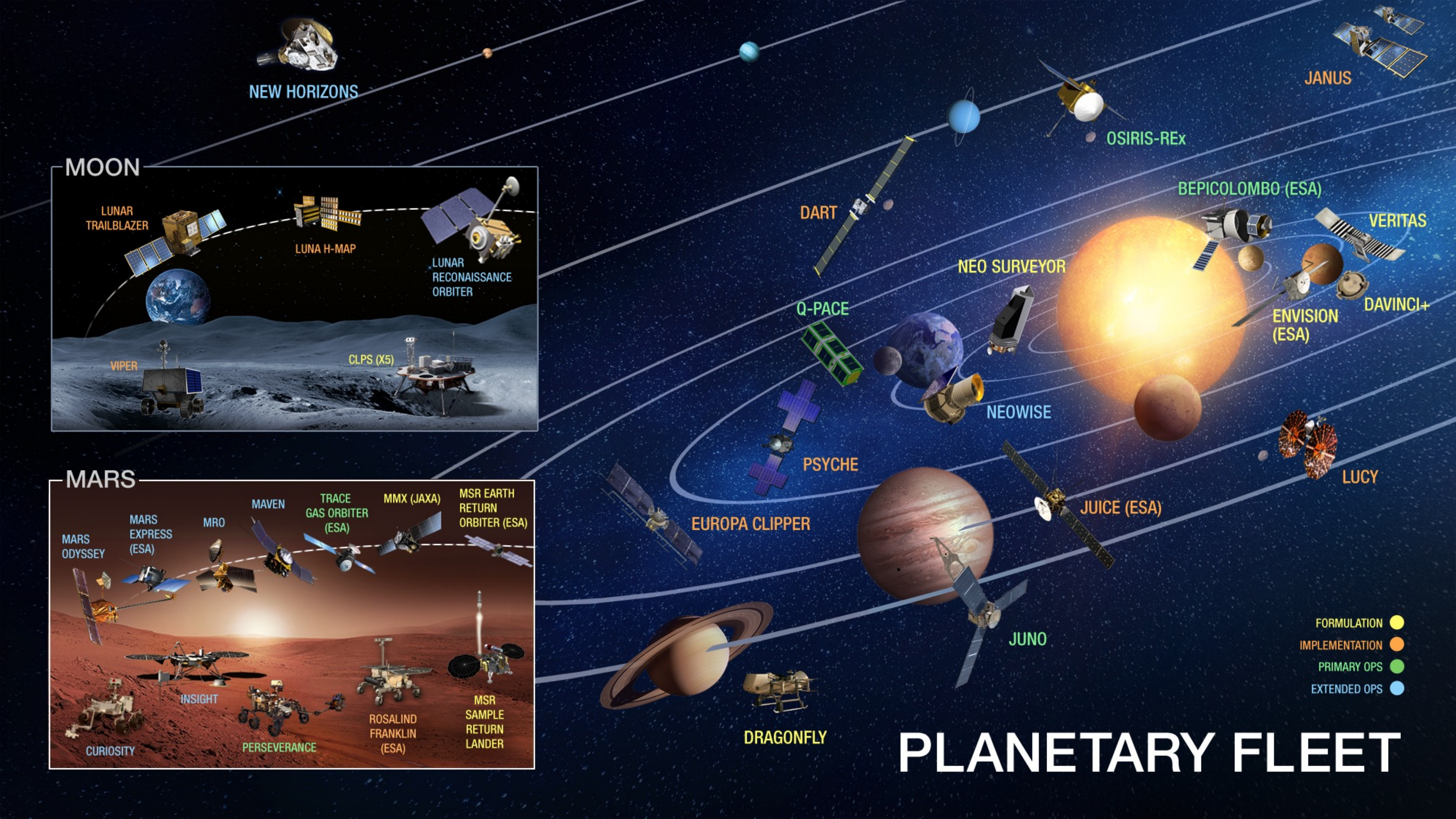
What's the Same

- Continues multiple missions in operations and development including Mars 2020, OSIRIS-REx, Europa Clipper, and Psyche, as well as instruments on ExoMars 2022 (ESA), JUICE (ESA), and MMX (JAXA)
- Clipper launch in 2024 on a commercial vehicle
- NASA contributions to international Mars Ice Mapper mission
- Continues CLPS cadence of partner selections and plans for two launches per year
- Maintains radioisotope power system capability, in coordination with DOE

PSD Budget Breakdown



Mission Updates


PLANETARY FLEET
NEW HORIZONS
JANUS
OSIRIS-REx
MOON
LUNAR TRAILBLAZER
LUNA H-MAP
LUNAR RECONAISSANCE ORBITER
VIPER
CLPS (X5)
DART
BEPICOLOMBO (ESA)
VERITAS
NEO SURVEYOR
DAVINCI+
ENVISION (ESA)
Q-PACE
NEOWISE
PSYCHE
LUCY
EUROPA CLIPPER
JUICE (ESA)
JUNO
DRAGONFLY
MARS
MARS ODYSSEY
MARS EXPRESS (ESA)
MRO
MAVEN
TRACE GAS ORBITER (ESA)
MMX (JAXA)
MSR EARTH RETURN ORBITER (ESA)
INSIGHT
CURIOSITY
PERSEVERANCE
ROSALIND FRANKLIN (ESA)
MSR SAMPLE RETURN LANDER
FORMULATION
IMPLEMENTATION
PRIMARY OPS
EXTENDED OPS

VERITAS

Venus Emissivity, Radio Science, InSAR, Topography, & Spectroscopy

What makes a rocky planet habitable?

Like Earth, Venus started with all the building blocks of a habitable world. How was habitability lost?

Science Goals

1 Rocky planet evolution

1a igneous rock type, surface-atmosphere interaction
1b ancient geologic processes
1c volcanic history
1d subduction, origins of plate tectonics

2 Active processes

Active and recent volcanism, tectonics?

3 Past and present water

3a continents from a wetter past?
3b current volcanic outgassing of water?

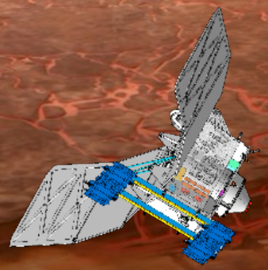
Mission Overview

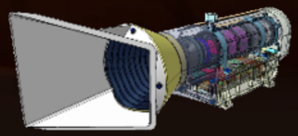
Launch Date: May 2025

Venus Orbit Insertion: Dec 2025

3 years of science operations from orbit

>40 Tb of science data returned





High-Resolution Global Reconnaissance

1. *VISAR* (Venus Interferometric Synthetic Aperture Radar)
   - Highest resolution global topography for terrestrial planets
   - 1st planetary active deformation map
   - Global data sets:
     - Topography: 250 m horiz, 5 m vertical
     - SAR imaging: 30 m
   - Targeted data sets:
     - SAR imaging: 15 m
     - Surface deformation: 1.5 cm vertical
2. *VEM* (Venus Emissivity Mapper)
   1st near-global map of igneous rock type, weathering
   - 6 NIR surface bands with robust SNR
   - 8 atmospheric bands for calibration / water vapor
3. ***Gravity Science Investigation***
   1st global maps of derived elastic thickness & core size

PI: Sue Smrekar, JPL; Managed by JPL

Dr. James B. Garvin, NASA GSFC, Principal Investigator
Drs. Stephanie Getty and **Giada Arney**
NASA GSFC, Deputy Principal Investigators

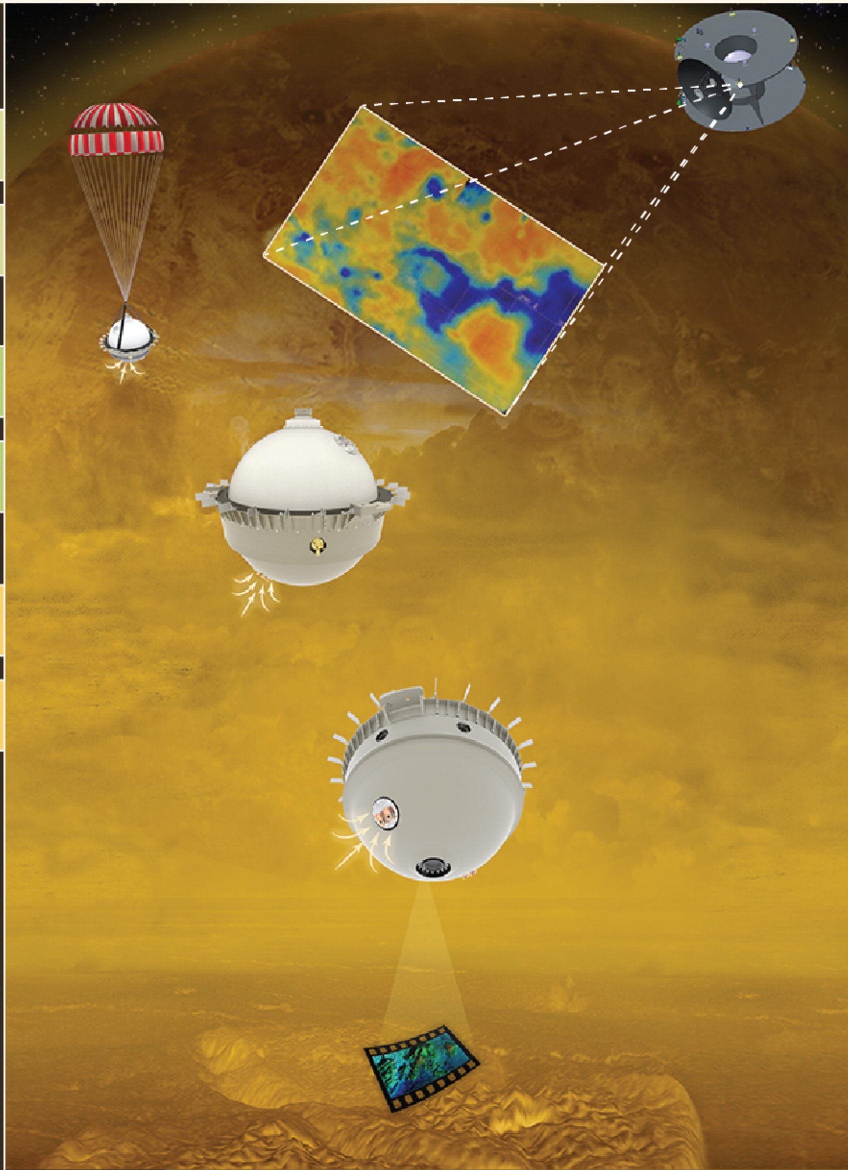
DAVINCI+

Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging Plus

Atmospheric Origin & Evolution	What is the origin of the Venus atmosphere and how has it evolved?
	How and why is Venus different or similar to Earth, Mars, and analog exoplanets?
Atmospheric Composition & Surface Interaction	Was there an early ocean on Venus? If so, when and where did it go?
	What is the rate of volcanic activity on Venus?
Surface Properties	What exactly are the tesserae highlands, including origin and history?
	How do they compare with major highlands, such as Ishtar Terra?

2027	2028	2029...
Flyby Phase	Probe Descent	Orbital Phase

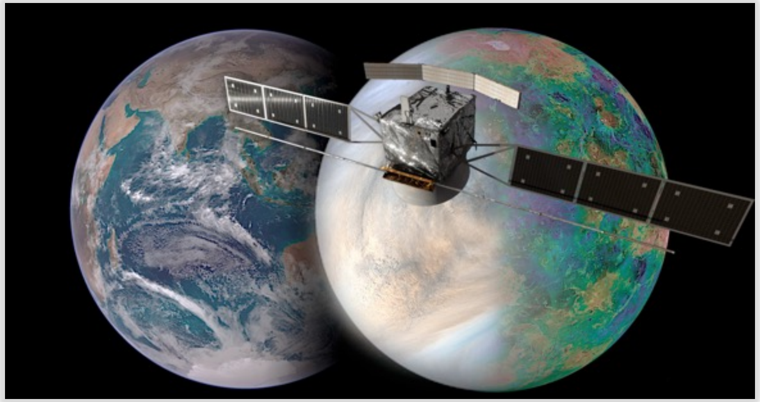
Major partners: Lockheed-Martin • JPL • MSSS • LaRC • ARC • APL • KinetX • University of Michigan



EnVision

- Venus orbiter mission that will determine the nature and current state of Venus' geological evolution and its relationship with the atmosphere, to understand how and why Venus and Earth evolved so differently
- ESA Medium-Class mission for Cosmic Vision Programme (M5)
  - As of October 2020, two mission concepts were in competition (EnVision and THESEUS)
- Selection announced June 10, 2021 for launch in 2032
- NASA has two members on the Science Study Team and a radar scientist as a member of the System Engineering Working Group
- NASA contribution includes a Synthetic Aperture Radar (VenSAR), DSN support, and support for US scientists. A draft solicitation for the VenSAR Team was released in April 2021
- EnVision Assessment Study Report ('Yellow book'): https://sci.esa.int/web/cosmic-vision/-/envision-assessment-study-report-yellow-book

ENVISION
Europe's Revolutionary Mission to Venus

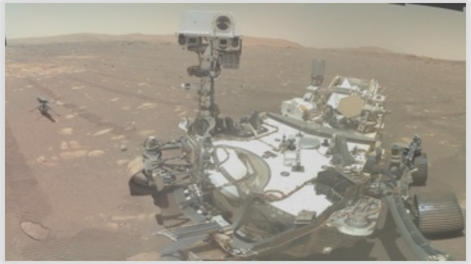


Mission goals

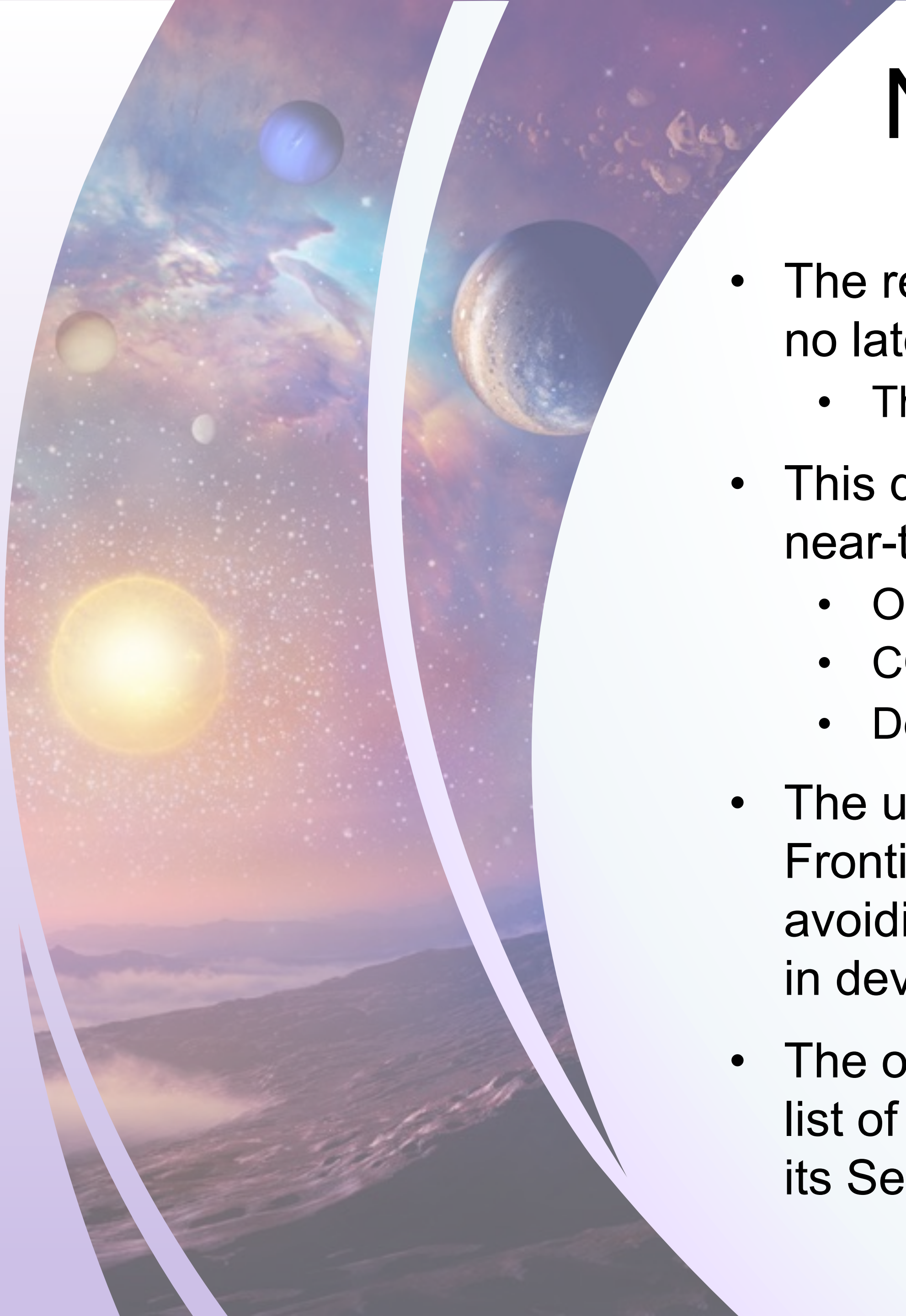
- Determine the level and nature of current activity
- Determine the sequence of geological events that generated its range of surface features
- Assess whether Venus once had oceans or was hospitable for life
- Understand the organizing geodynamic framework that controls the release of internal heat over the history of the planet

Some Mission Highlights

- **Mars 2020**
  - **Perseverance:** returning images and scientific data; plan to take first soil samples this summer
  - **Ingenuity:** successfully completed five flights during tech demo; transitioned to operational demonstration phase
- **OSIRIS-REx:** departed Bennu and began journey back to Earth on May 10, 2021 (arrives September 2023)
- **Europa Clipper:** continues toward launch in 2024; RFP for launch vehicle has been released (decision due December 2021)
- **NEO Surveyor:** passed KDP-B; will continue to mature preliminary design, with target to complete Phase B in 2023
- **Lucy:** due to ship to Cape Canaveral late July; launch window opens October 2021
- **DART:** progressing well, launch window opens November 2021
- **Psyche/Janus:** scheduled for launch September 2022
- **VIPER:** Critical Design Review planned for fall of 2021




New Frontiers 5



New Frontiers 5 AO

- The release of the final New Frontiers 5 AO has been delayed to no later than fall 2024
  - The release was originally anticipated in fall 2022
- This delay is the result of several interlocking factors affecting the near-term PSD portfolio, including:
  - Other missions currently or recently in peak development periods
  - COVID-related impacts
  - Delay of the Dragonfly launch to June 2027
- The updated AO schedule allows selection of the fifth New Frontiers mission at around the time of Dragonfly’s launch, avoiding the budget strain of having two New Frontiers missions in development at the same time.
- The ongoing Decadal Survey has announced that it will retain the list of mission themes for NF-5 previously provided by NASA in its Second Community Announcement on November 5, 2020

IDEA

Promote Diversity and Equity in Science

SMD FY22 budget support for promotion of diversity and equity in science

- Diversity of thought, backgrounds, and perspectives continue to be welcomed and celebrated as critical to SMD mission success
- Systems in place to proactively expand participation of Minority Serving Institutions and Historically Black Colleges and Universities through bridge partnerships and with SMD Science Activation Program
- Implementing policy changes to systemically value inclusion such as modifying requirements for Announcements of Opportunities and implement Dual Anonymous Peer Reviews
- Continually addressing the impact of COVID on diversity, specifically gender diversity and early career

SMD IDEA Working Group

Divisional IDEA

IDEA Programming
Andrew Garza

Science Engagement
Kirsten Petree

Research and Analysis
Kevin Reath

Inclusion/ Culture
Lucian Cox

Leadership Council
Doris Daou (PSD)
Tresa Mitchell

Recruiting and Hiring
Nicole Rayl

Leadership Development
Kartik Sheth

IDEA WG Senior Champion
Karen Flynn

Mission, Programs, Projects
Lucas Paganini (PSD)

IDEA Advisors
Paula Evans
James Woodard

Current PSD IDEA Activities

- Regular conversations around IDEA topics at PSD- and SMD-levels
- Internal PSD trainings to improve awareness (e.g., Bystander Awareness Training)
- PSD supervisors will be accountable for IDEA objectives (internal and external goals)
- Support of SMD's PI Launchpad
- Participation in SMD's Engagement Strategy efforts (geared toward listening sessions with underrepresented parts of the community, and learning how to minimize entry barriers)
- Implicit bias training for SMD reviewers
- Dual-Anonymous Peer Review (Habitable Worlds in ROSES-20; all DAPs & XRP in ROSES-21)
- Review of R&A/AO proposal panels for panel-diversity awareness and of language in mission AOs
- Historical encouragement of participation of diverse groups: SSERVI, NASA Astrobiology Institute (NAI)/Interdisciplinary Consortia for Astrobiology Research (ICAR)
- ROSES programs explicitly supporting diverse and inclusive communities: FINESST, PSD Early Career Award
- Here to Observe (H_2O) Pilot Program

Here to Observe (H_2O) Pilot Program

- **Goal:** Spark and maintain an interest for underrepresented students considering STEM careers
- **Approach:** Commit PSD to sustained, cultivated partnerships with non-traditional institutions paired with our NASA missions through:
  1. Providing access for undergraduate student observers
  2. Supporting meaningful mentorship activities
  3. Encouraging peer cohort-building at the institution level
- **Scope:** three missions (Europa Clipper, Dragonfly, Lucy) and three partnerships for 12-month pilot program, starting in summer 2021
  - Confirmed partners: Howard University, University of Puerto Rico, Virginia State University
- **Co-creation:** if successful, H_2O will be scaled up later (all PSD missions, more institutions) after refinement based on feedback from pilot
- **Core activities:** biannual mission science team meetings, AG meetings, and other mission meetings
- **Supplemental activities:** icebreakers, social events (launch parties), mission-led seminars, student-led seminars, career panels
- Led by David J. Smith and Curt Niebur

Response to March 2021 Findings

Finding 1: Perseverance Landing

Finding: The PAC congratulates the Mars 2020 team and PSD on its successful landing of the rover, including spectacular footage of its descent and deployment. The PAC applauds the worldwide excitement over the landing and looks forward to the science that will come from the mission. Additionally, the PAC congratulates PSD's many mission teams for progressing toward launches despite the ongoing impacts of the global COVID crisis.

NASA Response: NASA appreciates this acknowledgement and is glad the planetary science community and general public are so excited by the mission so far. We eagerly anticipate the mission's science results.

Finding 2: COVID Mitigation Efforts

Finding: The impact of COVID-19 on the planetary science community is an area of great concern to the PAC. We commend NASA's efforts to provide extensions and additional funding support to early career scientists in particular through the ROSES programs. We recommend that NASA look for additional opportunities to mitigate the negative effects of COVID on scientific productivity that can be implemented rapidly, including through joint activities with professional societies and other science agencies. Longer term, the PAC encourages NASA to find ways to assess the impact of COVID-19 on its planetary science objectives, employing the skills of social scientists as needed.

NASA Response: SMD will be considering whether further funding support to offset COVID impacts is needed in the coming months. SMD will also support the efforts of professional societies should partnering opportunities arise.

Finding 3: Astrobiology Infusion into Mission Teams and Decisions

Finding: Astrobiology is a key component of NASA's scientific research portfolio, and astrobiology is frequently mentioned by NASA as a motivating factor in its choice of missions. The Astrobiology program, as well as its Research Coordination Networks, are a resource outside of the traditional Assessment Group structure that provides a different and critical perspective on questions regarding life detection and how to address them. The PAC encourages NASA to ensure that astrobiology scientists and researchers are incorporated into mission definition teams and science teams that determine driving requirements for relevant large missions such as MSR to ensure that astrobiology-related objectives are met. Specifically, the PAC recommends that NASA continue and expand efforts to involve a broad group of lab scientists who are experts in establishing biogenicity of ancient Earth samples in the coming years of the M2020 mission through continuing Participating Scientist Program calls and seeking community input in design of laboratories for sample return analysis. The PAC particularly encourages recruitment of scientists from underrepresented groups that may not have previously been funded by the NASA Mars program.

NASA Response: NASA thanks the PAC for this finding and agrees that infusing astrobiology into future mission plans and teams is a vital strategy. For example, Dr Lindsay Hays has recently been appointed as the Deputy Program Scientist for Mars Sample Return. Her astrobiology expertise and community involvement will be a major asset to the mission team and its success. We are also considering ways to increase external astrobiology engagements.

Finding 4: MSR cost and impact on programmatic balance

Finding: MSR is estimated to cost $4.7B while still in Phase A, and the project seeks to launch by 2026. This will drive a very steep funding profile that will result in severe pressure on other elements within PSD, including R&A and missions to study other destinations. The PAC is concerned that the large cost of MSR will impact programmatic balance, including other scientific priorities identified by the Decadal Survey. The narrow focus and significant cost of MSR - large compared to previous PSD flagship missions - is very likely to impact PSD's ability to undertake missions that address a wide range of other science questions. Particularly given that the majority of the costs associated with MSR are engineering related (see Finding 5), the potential for impact to PSD's overall science program is high. The PAC recommends that PSD should look for ways to minimize the cost of MSR (identifying potential descopes) and/or reduce its annual cost impact by stretching out its schedule. Since it appears that many objectives of MSR and the Mars Ice Mapper mission overlap with those of HEOMD, PSD should investigate options for cost sharing.

NASA Response: MSR is committed to controlling cost growth. Through the collaboration established with ESA, the NASA cost for the MSR mission has been substantially reduced. Meaningful steps have already been taken to understand program cost much earlier in the development lifecycle than past projects. These include program initiation of two independent cost and schedule assessments, coupled with the Independent Review Board (IRB) during Pre-Phase A. Following the IRB, the program stood up its Standing Review Board (SRB) for the Mission Concept Review prior to entry into Phase A. Typically the SRB is not initiated until the KDP-B timeframe. The program created a Deputy Director-Business position at HQ to ensure rigorous cost and schedule management processes are established for the program. Additionally, MSR will be the first SMD program to perform a Joint cost and schedule confidence exercise prior to KDP-B.

Finding 5: Science involvement in planned Mars missions – (a) Mars Ice Mapper

Finding: The PAC continues to be concerned about the need for science community involvement in the definition of the Mars Ice Mapper (MIM) mission. As stated in a previous PAC finding, for MIM to be successful, it must have clearly defined science objectives, and it would be best to openly compete any instruments that are to be incorporated beyond the radar. The PAC requests continued updates from NASA on its plans to initiate a mission definition team that incorporates members of the broader science community, consistent with MEPAG's Finding regarding using the Mars science community to ensure that the mission concept is able to achieve its stated science aims. If the objectives of MIM partially or primarily stem from human spaceflight needs, the PAC recommends that NASA should make efforts to share costs with HEOMD.

NASA Response: PSD takes this finding seriously and are working to engage the science community in meaningful ways. For example, we are working with the MIM partners on assembling an International Recon/Science Measurement Definition Team. In addition, PSD has recently committed to adding a modest science enhancement to the Mars Ice Mapper mission and will engage with the Mars science community on how best to implement it. Please refer to more detailed slides in the Mars Exploration Program presentation.

Finding 5: Science involvement in planned Mars missions – (b) Mars Sample Return

Finding: The PAC is concerned about the potential lack of science involvement in elements of Mars Sample Return (MSR) beyond the Mars 2020 (M2020) rover. It was stated at the March 2021 PAC meeting that the elements of MSR outside of Perseverance have no science team. While it was asserted that a science team is not required because MSR components beyond M2020 merely retrieve samples selected by the Perseverance science team, science involvement throughout the entire MSR campaign is needed to determine threshold requirements, science costs of potential descopes, and mission success criteria. One can envision scenarios in which some segment of the sample return effort encounters an issue that could lead to failures to achieve its Level 1 requirements, and science input would be needed to determine an optimal response. In the absence of a separately competed, engaged science definition team, the Mars 2020 team are the de facto science team for MSR. However, the goals of MSR and Mars 2020 are not the same.

Particularly given the very large cost of MSR, clearly defined and carefully scoped Level 1 requirements, threshold requirements, and descope options for the non-M2020 elements of MSR are essential. These necessitate the input and peer review of multiple scientists from early stages of mission definition through operations. MSR represents such a large investment on the part of SMD that scientists must be involved throughout the sample return campaign to ensure its success, and must be in a position to influence decision making, which is beyond the scope of community meetings.

NASA Response: It is fully recognized that timely inputs from the science community will be crucial to the mission success of MSR beyond the Mars2020 mission. Given this, the MSR Science Planning Group Phase 2 (MSPG2) was established in April 2020 and reported out to NASA and ESA HQs in late May 2021. This international group consists of 31 members, a NASA/ESA coordination team, and 25 openly competed positions from amongst the science community. It was convened with the expressed purpose of defining an end-to-end MSR Science Program, highlighting a number of important issues that will influence the design and implementation of the Science Program and of the Sample Receiving Facility (SRF). Among the recommendations from MSPG2, is the establishment of a Campaign Science Group to manage the science of MSR, and whose membership would be a combination of agency appointment and members selected through open competition. Also, the lead scientist for Mars Sample Return and Mars Exploration Programs has been coordinating with ESA colleagues on the science for samples returned from Mars. Furthermore, in recognition of the need for additional science coordination, the MSR Program Office at JPL recently appointed Meenakshi Wadhwa as the MSR Program Scientist. In this role, Dr. Wadhwa will: provide scientific leadership in the execution of MSR Program activities; be responsible for the scientific integrity and overall scientific success of the MSR Campaign; provide a science voice in MSR Program decision making; and serve as the scientific spokesperson for the MSR Program. Her responsibilities will include interacting, on behalf of the MSR Program, with the Mars science and the return sample science communities, as well as convening community-wide discussions pertaining to the MSR science strategy and execution.

Finding 6: Planetary Defense & NEO Surveyor

Finding: The PAC notes that there is strong community support for this mission, including from a recent National Academies study that concluded that a space-based infrared survey can rapidly accelerate progress toward the Congressionally mandated objective of finding more than 90% of large near-Earth objects and can determine their diameters, which current or future ground-based surveys cannot. The PAC encourages NASA to make a decision about moving the project out of formulation.

NASA Response: NASA thanks the PAC for this finding and its support of the NEO Surveyor mission. We are pleased to report that NEO Surveyor has recently passed its KDP-B and will now continue to mature its preliminary design. Completion of Phase B will be targeted for 2023.

Finding 7: IDEA efforts in PSD

Finding: The PAC commends PSD for initiating an active inclusivity, diversity, equity, and accessibility (IDEA) effort in planetary science and appreciates the update on these efforts presented at the March 2021 meeting. The PAC was pleased to hear about the code of conduct that is being developed for NASA meetings and looks forward to hearing more about this in the future. The PAC recommends:

- That PSD continue to present regular IDEA-effort reports at future meetings to continue dialog on strategies for improving diversity and inclusivity within PSD.
- That we receive inputs from large community-driven IDEA efforts, including the cross-AG IDEA Working Group, and a selected subset of state-of-the-profession Decadal Survey white paper lead authors at future PAC meetings so that we can stay abreast of specific issues and work being done in this area.
- That NASA create a Chief Executive for IDEA, who is a member of the highest ranks of senior leadership at NASA. This practice, common now among large companies, helps to prioritize and implement IDEA-focused strategies, from and within the top leadership level.

NASA Response: NASA agrees that providing regular updates on PSD's IDEA-focused efforts is important and will be something that continues. For example, this PAC meeting includes an overview of SMD/PSD activities (this presentation) and a briefing from the cross-AG IDEA Working Group. Regarding the recommendation of a new NASA Chief Executive for IDEA, this was presented by the PAC Chair during the April 2021 NASA Advisory Council Science Committee meeting.

Finding 8: R&A

Finding: The PAC appreciated the dialog with NASA, initiated with specific discussion questions posed regarding PSD's research and analysis (R&A) programs, and we look forward to continuing this dialog to understand the forces driving proposal pressure and increased proposal costs, which in turn lead to lower selection rates. The PAC recommends:

- That PSD make efforts to help R&A scale up when the PSD budget grows, and keep it constant if the PSD budget shrinks. We are extremely grateful that PSD's budget has grown substantially in recent years, but the PAC notes that the percentage of funding devoted to R&A has declined from roughly 15% to 8%. This greatly impacts NASA's ability to maximize the science return from its planetary missions, especially as the volume of available observation data increases.

  NASA Response: We agree that the R&A budget needs to increase and are working to do that through the annual budget process.
- That NASA highlight the importance of the contributions of reviewers for its R&A programs at every opportunity when addressing the community, since quality reviews depend upon many scientists performing this community service. The PAC commends PSD for finding new ways to cultivate this culture of reviewing, for example by continuing to include an Executive Secretary role on panels, but other ideas would be welcome. The PAC recommends that NASA investigate ways of incentivizing reviewers where possible, including enabling appropriate compensation for the time needed to do the work (such as possibly allowing reviewer labor hours to be costed in its research grants).

  NASA Response: This is an excellent recommendation, and we will be exploring the options. Refer to the R&A update for more information.
- That NASA examine data on a Step 1/Step 2 triage process where possible, such as in other divisions where this has been tried previously, in an effort to decrease both total proposer and reviewer effort. As part of this process, NASA should estimate the fraction of proposals that would have to be triaged out to justify the resources required for the additional set of reviews and evaluate the potential for a reduced burden on the system via a simplified Step 1 process.

  NASA Response: The process has been tried several times in different divisions and has generally been found to be ineffective (with a few exceptions in the ESD portfolio). Refer to the R&A update for more information.
- That NASA should aim to issue calls for proposals every year where feasible, since reliability of calls is important to the community.

  NASA Response: We agree, but also need to acknowledge that there comes a point when the cost/benefit ratio becomes too high. Refer to the R&A update for more information.
- That proposers be sent a reminder at approximately 6 months before the end of a grant to archive related publications in PubSpace.

  NASA Response: We will engage NSSC to explore how this can be incorporated into the set schedule of reminders.

Back-up slides

Planetary Science Program Content

	Actual FY20	Enacted FY21	Request FY22	Out-Years FY23	FY24	FY25	FY26
Planetary Science	**$2,712.6**	**$2,699.8**	**$3,200.0**	**$3,196.3**	**$3,266.5**	**$3,226.9**	**$3,168.7**
Planetary Science Research	$286.0	$304.1	$306.9	$290.1	$300.1	$301.9	$301.2
Planetary Science Research and Analysis	*$209.8*	*$223.2*	*$221.9*	*$203.6*	*$206.3*	*$203.6*	*$203.6*
Other Missions and Data Analysis (research and management)	*$76.2*	*$80.9*	*$85.0*	*$86.5*	*$93.8*	*$98.4*	*$97.7*
Planetary Science Directed R&T	$0.0	$0.0	$0.0	$8.3	$15.6	$19.7	$19.5
Advanced Multi-Mission Operation System	$39.2	$39.9	$40.5	$37.9	$38.0	$38.0	$38.0
Planetary Data System	$19.2	$24.1	$24.6	$24.2	$23.8	$24.3	$23.7
Astromaterial Curation	$11.2	$12.9	$16.0	$12.1	$12.4	$12.4	$12.4
Robotics Alliance	$4.0	$4.0	$4.0	$4.0	$4.0	$4.0	$4.0
Science Data & Computing	$2.6	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Planetary Defense	$150.0	$151.0	$197.2	$220.7	$226.5	$224.2	$170.6
DART	*$72.4*	*$66.4*	*$11.1*	*$4.0*	*$0.0*	*$0.0*	*$0.0*
Other Missions and Data Analysis (development/formulation/technology)	*$77.6*	*$84.6*	*$186.1*	*$216.7*	*$226.5*	*$224.2*	*$170.6*
Near Earth Objects Surveyor	$0.0	$28.3	$143.2	$174.2	$184.0	$181.7	$128.1
(research and management)							
Lunar Discovery and Exploration (Cont.)	$300.0	$443.5	$497.3	$501.3	$458.3	$458.3	$458.3
VIPER	*$54.9*	*$99.1*	*$107.2*	*$102.0*	*$30.6*	*$0.0*	*$0.0*
Other Missions and Data Analysis (development/formulation/technology cont.)	*$245.1*	*$344.4*	*$390.1*	*$399.3*	*$427.7*	*$458.3*	*$458.3*
Lunar Instruments	$34.2	$13.7	$32.7	$54.6	$69.2	$74.4	$74.5
Commercial Lunar Payload Services	$184.6	$233.4	$254.0	$254.0	$254.0	$254.0	$254.0
Lunar Intl Mission Collaborations	$0.0	$0.5	$0.5	$0.5	$0.5	$0.5	$0.5
Lunar Trailblazer	$0.0	$23.2	$17.5	$1.2	$4.3	$3.4	$1.8

Planetary Science Program Content

	Actual FY20	Enacted FY21	Request FY22	Out-Years FY23	FY24	FY25	FY26
Lunar Discovery and Exploration (Cont.)	$300.0	$443.5	$497.3	$501.3	$458.3	$458.3	$458.3
Payloads and RI on Surface of the Moon	$0.0	$21.0	$25.4	$21.5	$8.5	$0.0	$0.0
Development and Advancement of Lunar Ins	$0.0	$20.4	$14.7	$15.0	$15.0	$15.0	$15.0
Lunar Future	$4.3	$6.3	$19.6	$26.9	$45.1	$85.1	$86.7
(operating)							
Lunar Reconnaissance Orbiter (LRO)	$22.0	$22.2	$22.1	$22.0	$22.0	$22.0	$22.0
(research and management)							
Lunar Management	$0.0	$3.7	$3.5	$3.5	$9.0	$3.8	$3.8
Mars Sample Return	$0.0	$246.3	$653.2	$772.3	$800.0	$700.0	$600.0
Mars Sample Return	*$0.0*	*$246.3*	*$653.2*	*$772.3*	*$800.0*	*$700.0*	*$600.0*
Discovery (Cont.)	$508.7	$451.3	$364.8	$227.6	$303.8	$529.4	$750.5
Lucy	*$208.6*	*$143.6*	*$77.3*	*$18.0*	*$20.2*	*$24.5*	*$41.7*
Psyche	*$214.0*	*$169.6*	*$139.7*	*$28.7*	*$29.0*	*$32.0*	*$32.0*
Other Missions and Data Analysis	*$86.1*	*$138.1*	*$147.8*	*$180.8*	*$254.6*	*$472.9*	*$676.8*
(development/formulation/technology)							
Mars-moon Exploration with GAmma Rays	$8.1	$12.2	$7.9	$2.8	$2.6	$2.8	$3.2
Planetary SmallSats	$15.6	$7.9	$9.3	$0.9	$0.1	$0.0	$0.0
Venus Technology	$0.0	$4.9	$7.9	$8.9	$8.2	$1.5	$0.0
Janus	$0.0	$23.7	$15.3	$1.2	$0.6	$0.6	$1.1
International Mission Contributions (IMC)	$9.4	$12.9	$16.6	$20.1	$19.2	$38.1	$69.1
Discovery Future	$20.2	$29.8	$53.7	$103.5	$179.9	$383.6	$562.1

Planetary Science Program Content

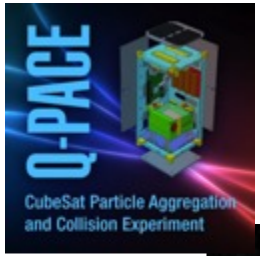
	Actual	Enacted	Request	Out-Years			
	FY20	FY21	FY22	FY23	FY24	FY25	FY26
Discovery (Cont.)	$508.7	$451.3	$364.8	$227.6	$303.8	$529.4	$750.5
(operating)							
Strofio	$1.3	$1.3	$1.0	$0.9	$1.0	$1.8	$1.2
InSight	$13.6	$14.9	$8.8	$8.8	$9.0	$9.0	$9.0
(research and management)							
Planetary Management	$11.1	$22.0	$17.8	$24.0	$24.1	$24.1	$18.7
Discovery Research	$6.9	$8.4	$9.5	$9.7	$10.0	$11.5	$12.5
New Frontiers	$136.8	$160.0	$271.7	$446.8	$500.4	$494.9	$372.3
Dragonfly	*$41.0*	*$86.0*	*$201.1*	*$370.3*	*$411.4*	*$332.3*	*$257.2*
Other Missions and Data Analysis	*$95.8*	*$74.0*	*$70.6*	*$76.5*	*$89.0*	*$162.6*	*$115.1*
(development/formulation/technology)							
New Frontiers Future Missions	$1.7	$4.3	$1.5	$2.4	$11.9	$90.8	$60.3
(operating)							
Origins Spectral Interpretation Resource	$37.1	$19.5	$17.2	$26.1	$29.1	$25.0	$20.0
New Horizons	$17.3	$12.5	$9.5	$12.5	$12.5	$12.5	$12.5
Juno	$33.8	$30.9	$32.0	$25.0	$25.0	$25.0	$13.0
(research and management)							
New Frontiers Research	$5.9	$6.9	$10.4	$10.5	$10.5	$9.3	$9.3

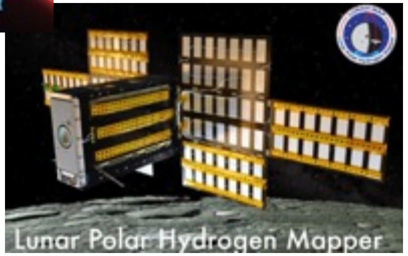
Planetary Science Program Content

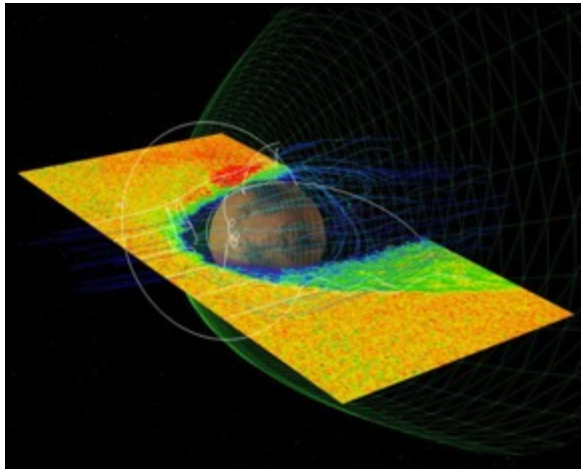
	Actual	Enacted	Request	Out-Years			
	FY20	FY21	FY22	FY23	FY24	FY25	FY26
Mars Exploration	$565.7	$334.8	$267.8	$251.9	$249.1	$228.1	$229.8
Other Missions and Data Analysis	*$565.7*	*$334.8*	*$267.8*	*$251.9*	*$249.1*	*$228.1*	*$229.8*
(development/formulation/technology)							
Mars Ice Mapper	$0.0	$7.2	$15.0	$40.0	$40.0	$30.0	$30.0
Mars Organic Molecule Analyzer (MOMA)	$7.3	$5.1	$4.9	$7.3	$6.5	$3.0	$0.0
Mars Future Missions	$65.5	$23.3	$7.5	$5.8	$15.0	$13.0	$15.0
Mars Technology	$3.7	$8.5	$3.2	$5.0	$6.0	$6.0	$6.0
(operating)							
Mars Rover 2020	$353.0	$150.0	$95.7	$60.0	$60.0	$60.0	$60.0
ExoMars	$1.9	$2.2	$2.0	$2.0	$2.0	$2.0	$2.0
2011 Mars Science Lab	$47.0	$47.5	$45.0	$40.0	$30.0	$20.0	$20.0
Mars Reconnaissance Orbiter 2005 (MRO)	$26.9	$27.0	$26.0	$25.5	$24.5	$24.5	$25.0
Mars Odyssey 2001	$11.7	$11.0	$11.0	$11.0	$11.0	$11.0	$11.0
Mars Express	$1.1	$0.0	$0.3	$0.3	$0.3	$0.3	$0.3
Mars Mission Operations	$5.9	$6.7	$6.7	$5.5	$5.5	$5.5	$5.6
Mars Atmosphere & Volatile EvolutioN	$20.5	$21.0	$23.0	$23.0	$23.0	$24.0	$24.0
(research and management)							
Mars Program Management	$11.2	$11.2	$12.5	$10.9	$9.6	$13.2	$15.3
Mars Research and Analysis	$9.9	$14.0	$15.0	$15.7	$15.7	$15.7	$15.7

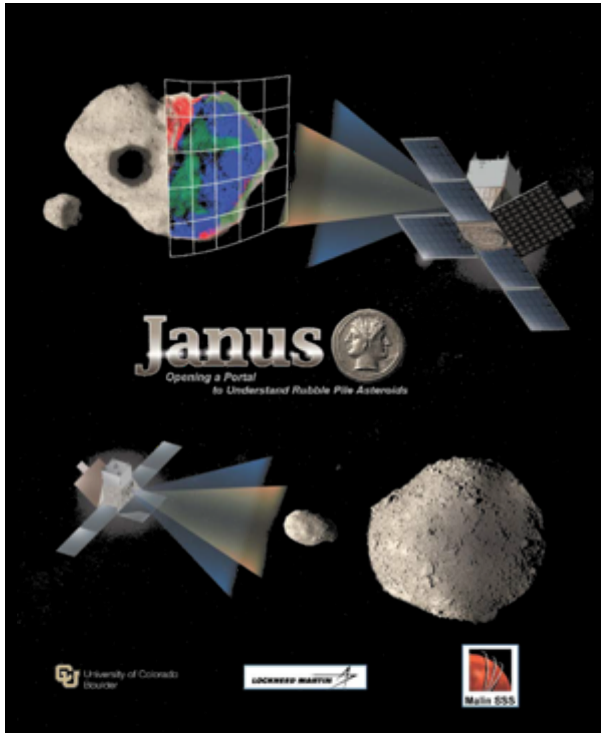
Planetary Science Program Content

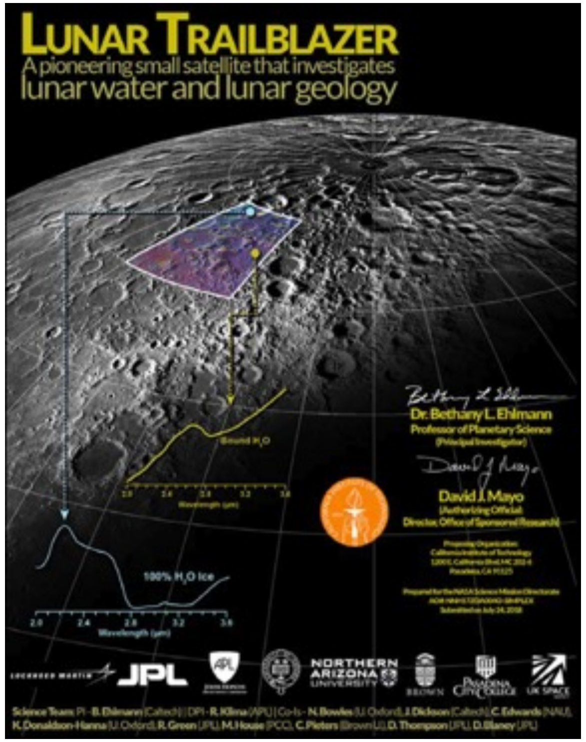
	Actual FY20	Enacted FY21	Request FY22	FY23	Out-Years FY24	FY25	FY26
Outer Planets and Ocean Worlds	$632.0	$462.5	$494.8	$331.2	$265.5	$135.7	$115.7
Jupiter Europa	*$592.6*	*$434.8*	*$472.1*	*$305.0*	*$240.0*	*$110.1*	*$90.1*
Europa Clipper	$592.6	$434.8	$472.1	$305.0	$240.0	$110.1	$90.1
Other Missions and Data Analysis	*$39.4*	*$27.7*	*$22.7*	*$26.2*	*$25.5*	*$25.6*	*$25.6*
(development/formulation/technology)							
JUICE - Jupiter Icy Moons Explorer	$18.2	$3.7	$2.8	$1.4	$0.8	$0.8	$0.8
Icy Satellites Surface Technology	$14.2	$14.2	$10.0	$15.0	$15.0	$15.0	$15.0
(research and management)							
Outer Planets Research	$7.0	$9.8	$9.8	$9.8	$9.8	$9.8	$9.8
Radioisotope Power	$133.5	$146.3	$146.4	$154.6	$162.8	$154.4	$170.4
DOE Operations and Analysis	$85.5	$88.1	$90.3	$91.2	$103.7	$92.8	$112.7
Radioisotope Power System	$48.0	$58.2	$56.1	$63.4	$59.1	$61.6	$57.7











SIMPLEx

SIMPLEx-1

Q-PACE:

- Launched on Virgin Orbit's LauncherOne January 17
- As of June 1, the spacecraft's beacon has not been detected despite multiple attempts

LunaH-Map:

- Will launch on Artemis-1, NET November 2021
- Delivery scheduled for July 2021

SIMPLEx-2

Janus (Psyche rideshare):

- Passed KDP-C in September; CDR held February

Lunar Trailblazer (IMAP rideshare):

- Passed KDP-C in November; CDR will be in June

EscaPADE (TBD rideshare):

- KDP-C will be summer 2021