Vision and Voyages

For Planetary Science in the Decade 2013-2022

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

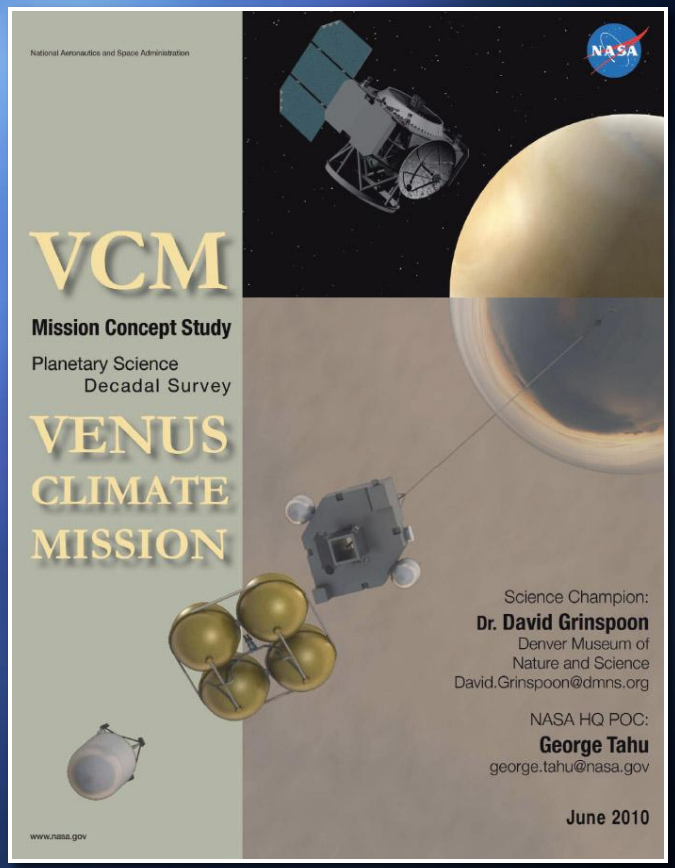
Committee Organization

Inputs From The Community

- The goal of the decadal survey is to seek out the community's views, and build a consensus around those views.
- More than a dozen town hall meetings were held: AGU (twice), LPSC (twice), DPS (twice), EPSC, RAS, AbSciCon, NLSI, LEAG, VEXAG, OPAG, MEPAG, CAPTEM, etc.
- The community submitted 199 white papers with 1669 individual authors and endorsers.
- The white papers were the main input to the decadal process, and many white paper authors were invited to present at panel meetings.
- Open sessions of meetings were webcast and put online.
- Draft report was reviewed by 18 peer reviewers.

Mission Studies

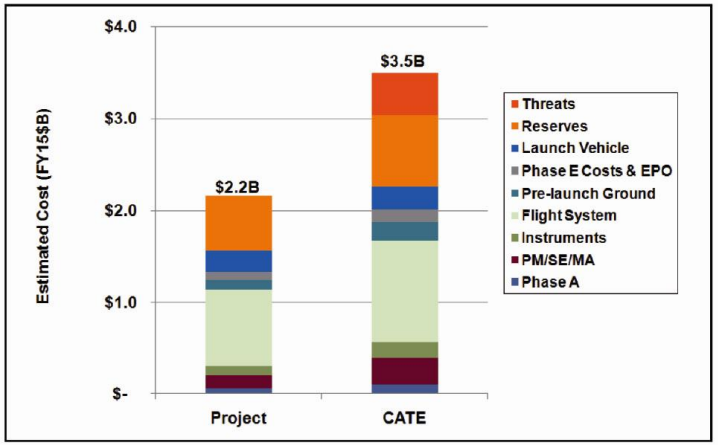
- Based on the science identified via white papers and other community inputs, 25 mission candidates were chosen for detailed study.
- Studies were performed by APL, GSFC, and JPL. Each study team included at least one science representative from the appropriate panel.
- The studies involved considerable time and effort. All study reports have been posted on the Web and are included in the decadal survey report.



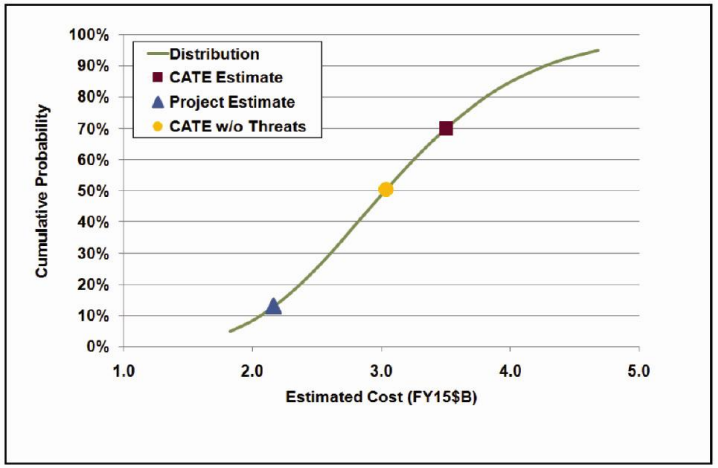
Cost and Technical Evaluations

- After studies were completed, high-priority mission candidates were subjected to a detailed Cost and Technical Evaluation (CATE) by Aerospace Corporation.
- CATE estimates are based on multiple methodologies, including actual costs of analogous past missions, to avoid the optimism inherent in other cost estimation processes.
- The result is some sticker shock! But realism is essential.
- All costs are in $FY'15.

Key Cost Element Comparison



Cost Risk Analysis S-Curve



Mission Prioritization

- Criteria
  - Science return per dollar
  - Programmatic balance
  - Technological readiness
  - Availability of appropriate trajectories

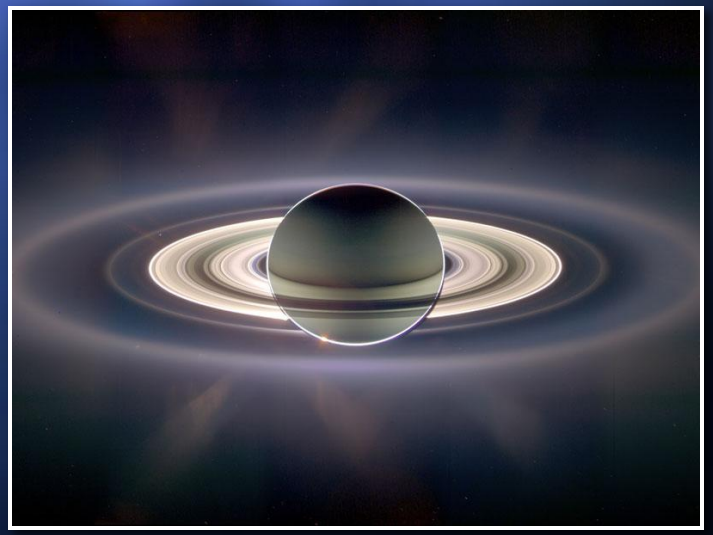
- Process
  - All priorities and recommendations were guided strongly by community inputs.
  - Prioritization within the subject area of each panel was done by the panel.
  - Cross-panel prioritization was done by the steering group.
  - All priorities and recommendations were arrived at by achieving strong consensus.

Recommendations of the Decadal Survey

Ongoing and Approved Missions

- *Continue missions in development, and missions in flight subject to senior review.*

- Discovery:
  - MESSENGER (in flight)
  - Dawn (in flight)
  - Kepler (in flight)
  - GRAIL (in development)
- New Frontiers:
  - NF-1: New Horizons (in flight)
  - NF-2: Juno (in development)
  - NF-3: TBD (to be selected soon)
- Others:
  - Cassini (in flight)
  - ODY/MRO/MER (in flight)
  - MSL/MAVEN (in development)
  - LADEE (in development)



Research and Analysis Program

- *Increase the NASA planetary R&A budget by 5% above the total finally approved FY'11 expenditures in the first year, and then by 1.5% above inflation each successive year.*

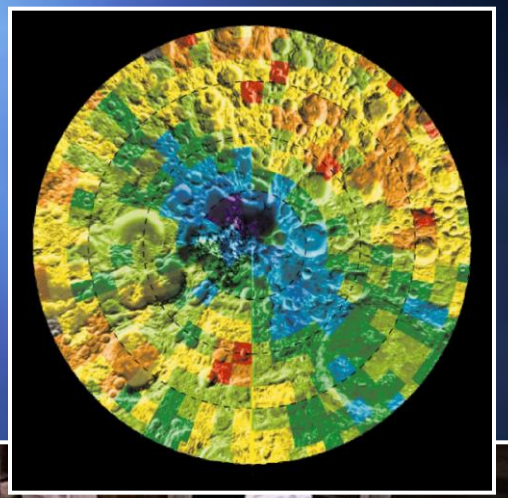
- All subsequent recommendations are consistent with this funding increase.

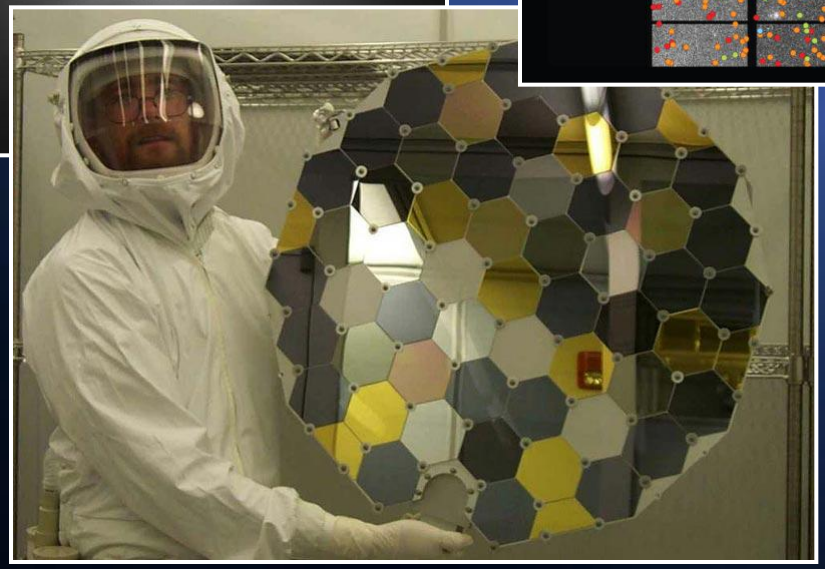
Technology Development

- Technology development is fundamental to a vigorous and sustainable program of planetary exploration.
- *A planetary exploration technology development program should be established, and carefully protected from incursions on its resources.*
- *This program should be funded at 6-8% of the total NASA Planetary Science Division budget.*
- All recommendations are consistent with this level of technology funding.

The Discovery Program

- The Discovery Program has produced spectacular and cost-effective science, and can continue to do so well into the future.





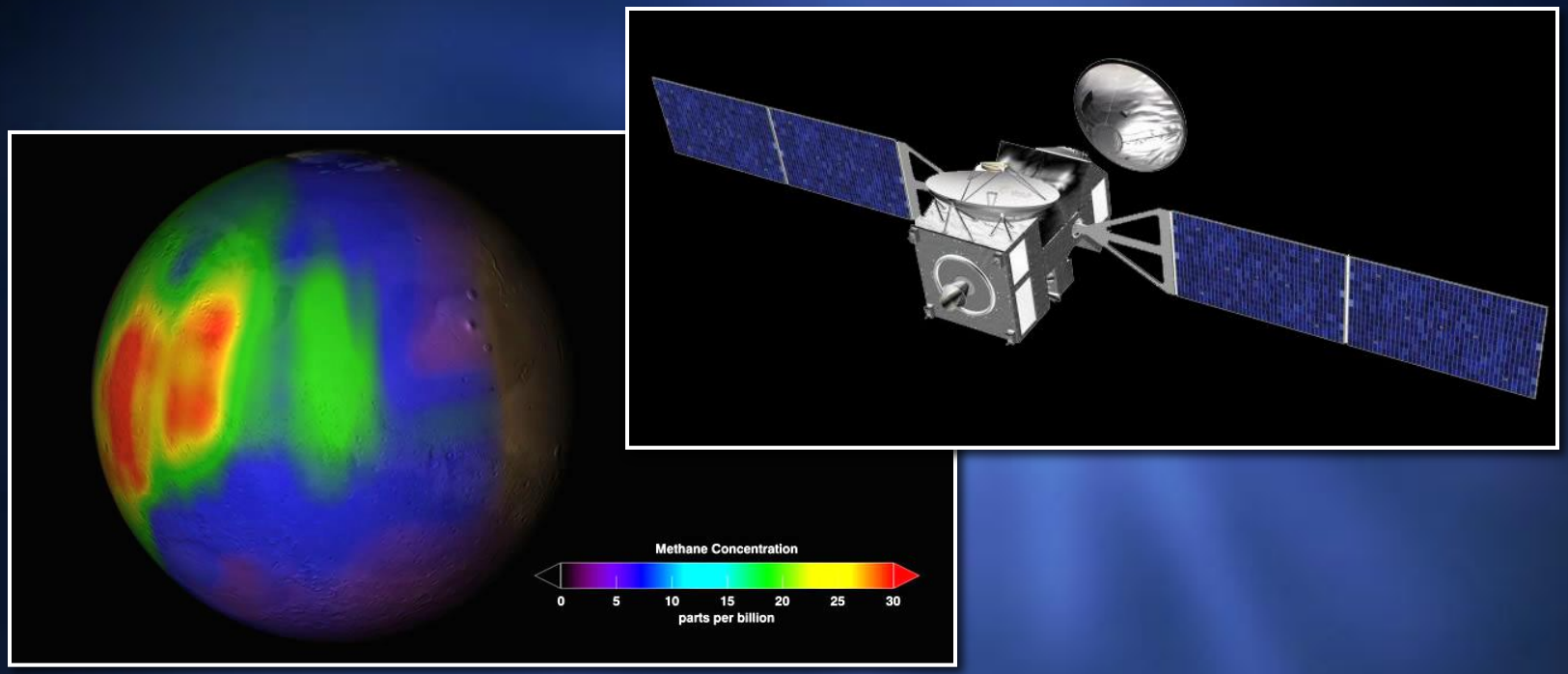
The Discovery Program

- *Continue the Discovery program at its current funding level, adjusted for inflation, with a cost cap per mission also adjusted for inflation (i.e., to $500 million FY'15).*

- *Assure a regular, predictable, and rapid (≤ 24-month) cadence of Discovery AOs and selections.*

- No recommendations are made for Discovery mission priorities; this is left to the AO and peer review process.

Mars Trace Gas Orbiter

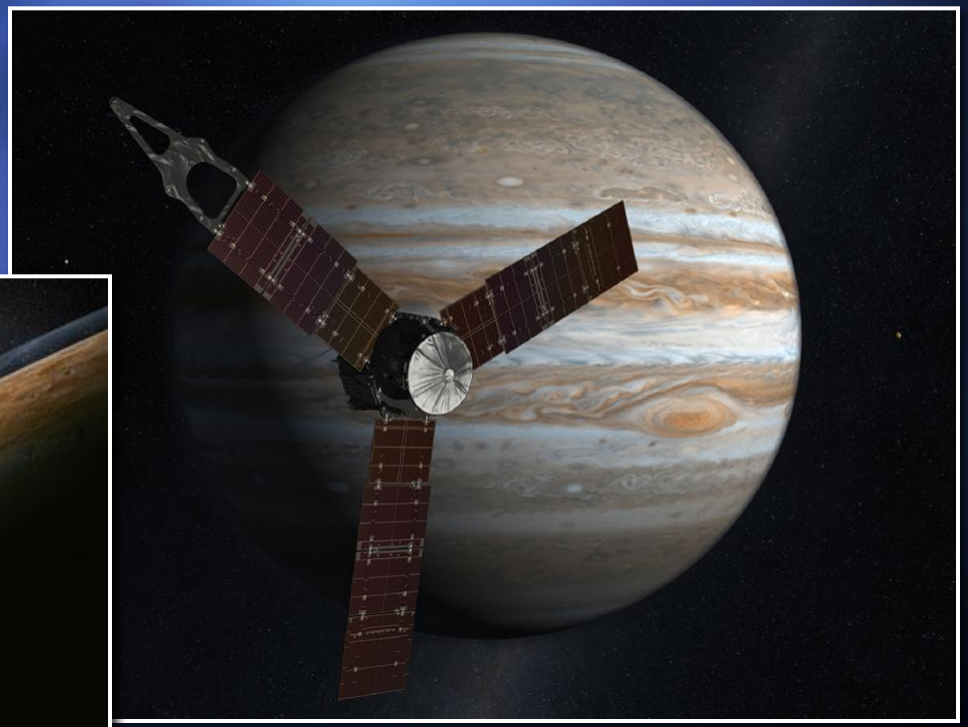


- Joint mission with ESA: NASA provides most of the science payload, and the launch.

- *Carry out this mission as long as this division of responsibilities with ESA is preserved.*

The New Frontiers Program

- New Frontiers missions can address high priority and technically complex science goals that are beyond the capabilities of Discovery missions.



The New Frontiers Program

- The New Frontiers program of PI-led strategic missions has been a success, and should continue.

- *Change the New Frontiers cost cap to $1.0 billion FY'15, excluding launch vehicle costs.*

- *Select New Frontiers missions NF-4 and NF-5 in the decade 2013-2022.*

New Frontiers 4 Selection

- Select NF-4 from among:
  - *Comet Surface Sample Return*
  - *Lunar South Pole-Aitken Basin Sample Return*
  - *Saturn Probe*
  - *Trojan Tour and Rendezvous*
  - *Venus In Situ Explorer*
- No relative priorities among these are assigned.
- If the selected NF-3 mission addresses the goals of one of these, remove that one from the list.

New Frontiers 5 Selection

- For NF-5:
  - *The remaining candidates from NF-4*
  - *Io Observer*
  - *Lunar Geophysical Network*

- Again, no relative priorities are assigned.

Flagship Missions
(in priority order)

1. Begin NASA/ESA Mars Sample Return campaign: *Descoped Mars Astrobiology Explorer-Cacher (MAX-C)/ExoMars*

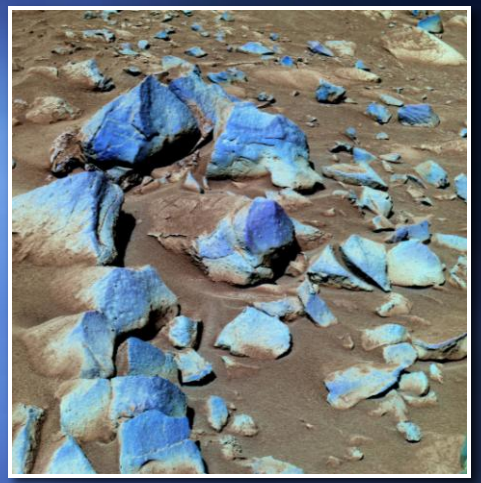
2. Detailed investigation of a probable ocean in the outer solar system: *Descoped Jupiter Europa Orbiter (JEO)*

3. First in-depth exploration of an Ice Giant planet: *Uranus Orbiter and Probe*

4. Either *Enceladus Orbiter* or *Venus Climate Mission* (no relative priorities assigned)

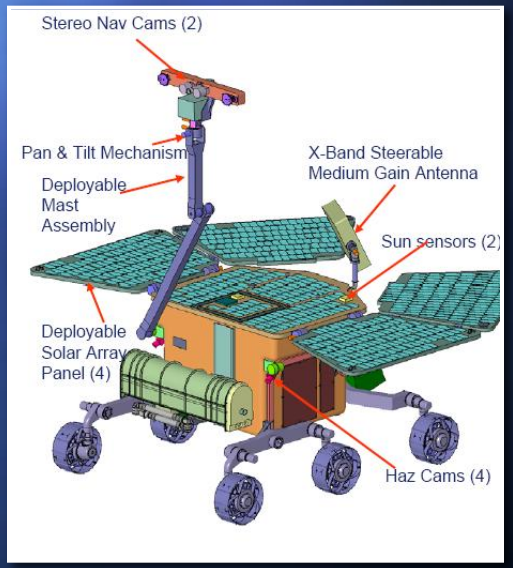
Flagship Priority 1: MAX-C/ExoMars

- The view expressed by the Mars community is that Mars science has reached a point where the most fundamental advances will come from study of returned samples.
- MAX-C/ExoMars will perform *in situ* science and collect and cache samples, beginning a three-mission campaign to return samples from Mars.
- Mars Sample Return is enabled by ESA participation throughout the campaign.
- Of the three missions in the campaign, only MAX-C/ExoMars is recommended for 2013-2022.
- The campaign is multi-decadal, and its priority is based on its anticipated total science return and total cost.



The Need For A Descope

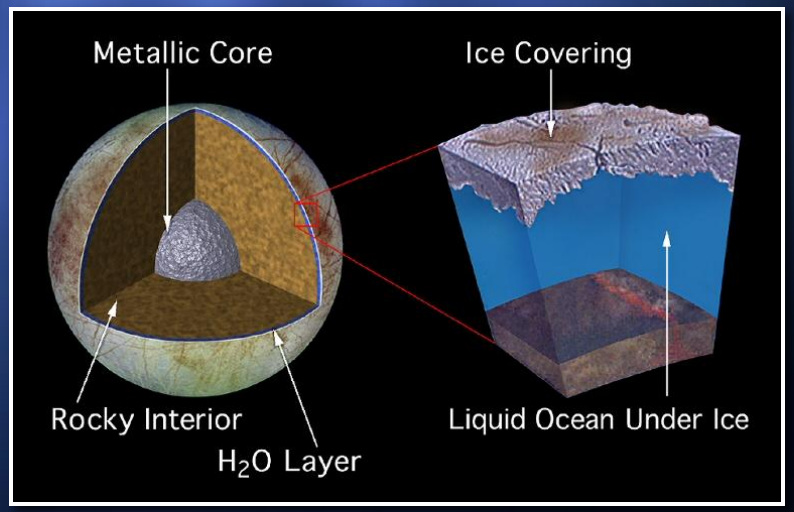
- The CATE estimate for the cost to NASA of MAX-C/ ExoMars is $3.5 billion. This is too large a fraction of the planetary budget.
- *Fly MAX-C/ExoMars only if it can be conducted at a cost to NASA of ≤ $2.5 billion FY'15.*
- Descopes must be equitable between NASA and ESA. *It is critical that the partnership with ESA be preserved.*
- If the goal of $2.5 billion cannot be achieved, MAX-C/ExoMars should be deferred to a subsequent decade or cancelled.



- No alternate plan for Mars exploration is recommended. If MAX-C/ExoMars cannot be carried out for a cost to NASA of ≤ $2.5 billion then other Flagship missions take precedence.

Flagship Priority 2: JEO

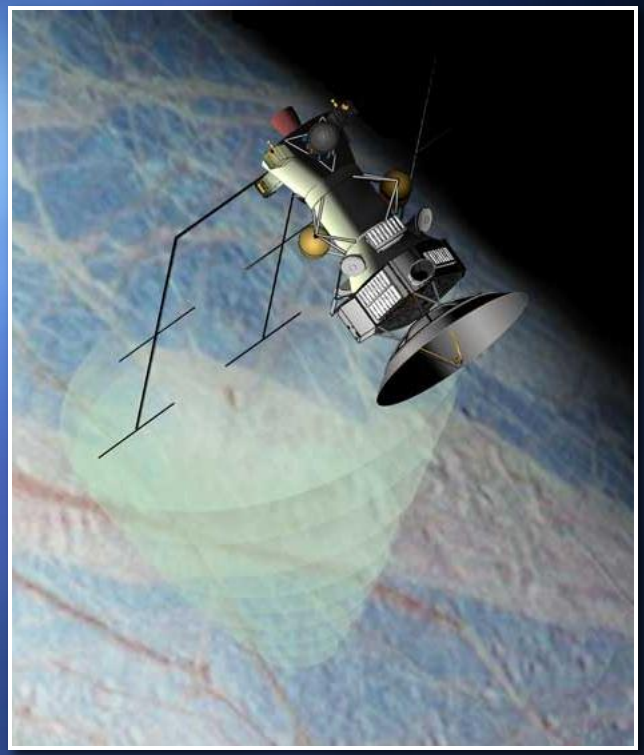
- Europa's probable ocean may be the best candidate in the solar system beyond Earth for a presently habitable environment.
- Orbital tour of Jupiter system, followed by 100-200 km Europa orbit
- Instrumentation to characterize Europa's tidal flexure, the thickness of the ice shell, and the character of the surface and subsurface.



The Need For A Descope

- The CATE estimate for the cost of JEO is $4.7 billion. This is too large a fraction of the planetary budget.

- *Fly JEO only if changes to both the mission and the NASA planetary budget make it affordable without eliminating other recommended missions:*
  - This will require a reduction in the mission's scope and cost
  - JEO will probably also require a new start that increases the overall budget of NASA's Planetary Science Division

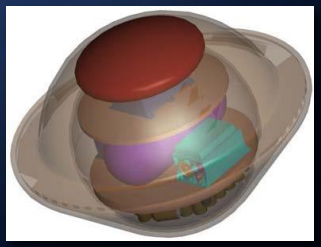


- *Immediately begin an effort to find major cost reductions in JEO, with the goal of minimizing the necessary planetary science budget increase.*

- JEO science would be enhanced by conducting the mission jointly with ESA's proposed Ganymede Orbiter mission.

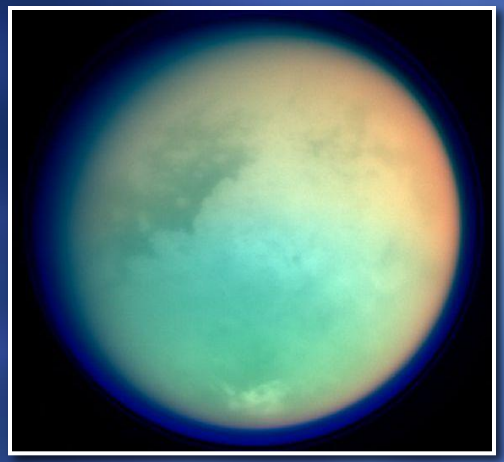
Flagship Priority 3: Uranus Orbiter and Probe

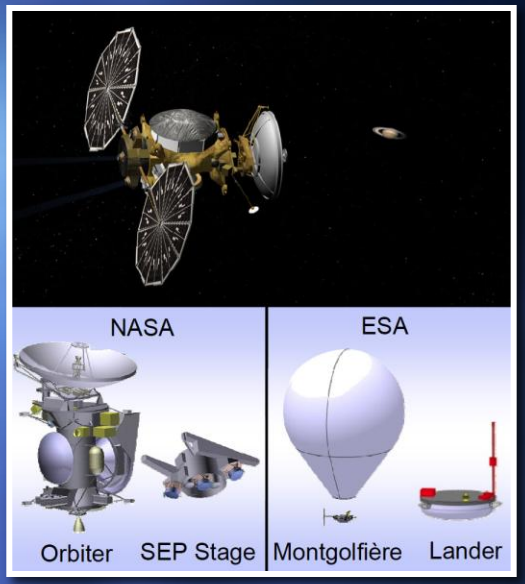
- Uranus and Neptune belong to a distinct class of planet: the Ice Giants
  - Small hydrogen envelopes
  - Dominated by heavier elements
  - The only class of planet that has never been explored in detail
- Orbiter to perform remote sensing of planet's atmosphere, magnetic field, rings, and satellites.
- Atmospheric entry probe.
- Potential for new discoveries comparable to Galileo at Jupiter and Cassini at Saturn.
- *Uranus is preferred over Neptune for 2013-2022 for practical reasons involving available trajectories, flight times, and cost.*

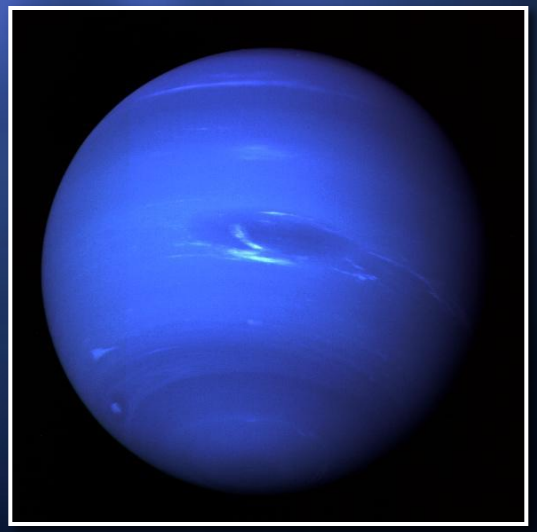


Technology Development Priorities

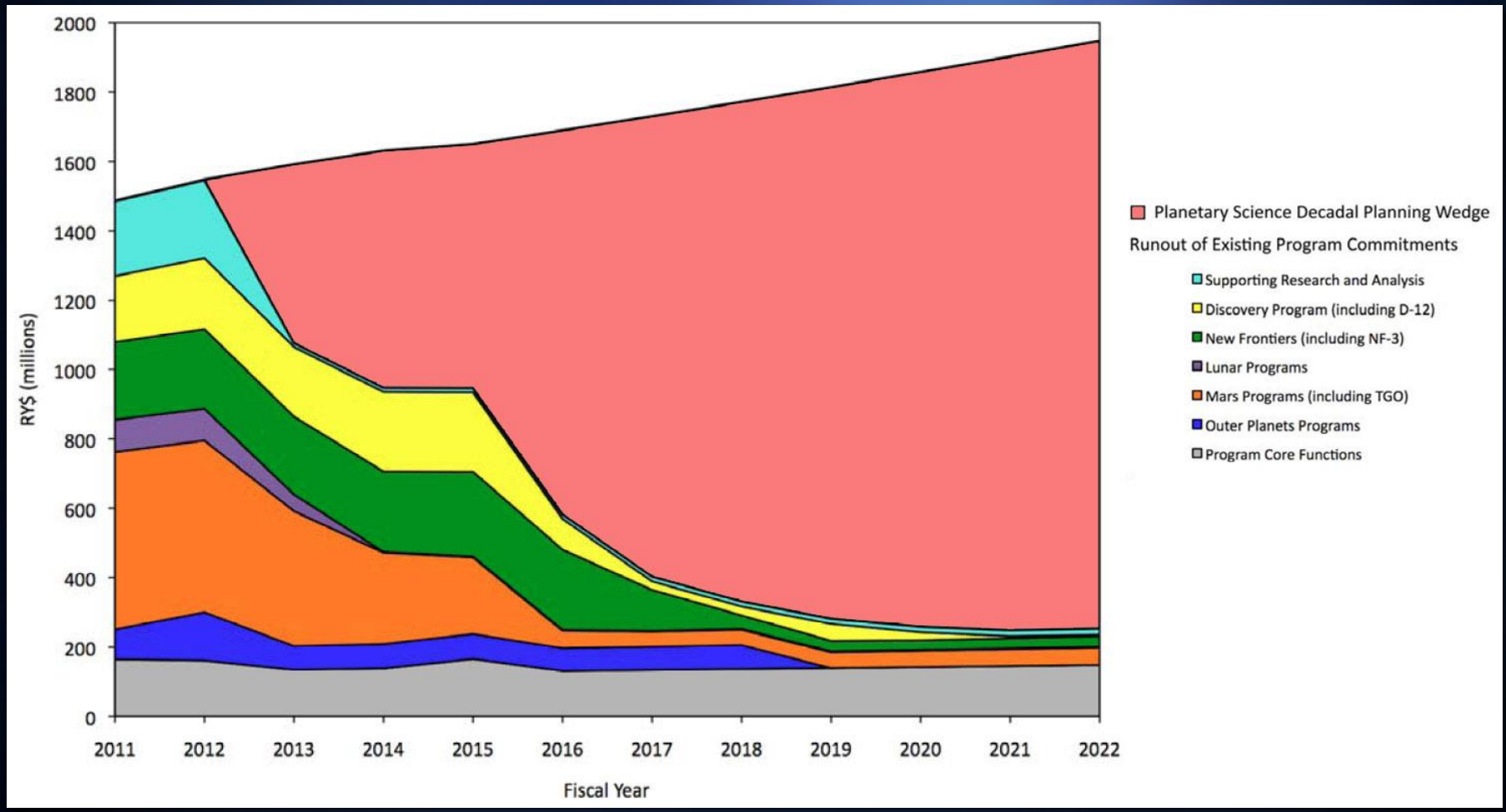
- High priority missions for future study and technology development:
  - *Titan Saturn System Mission*
  - *Neptune Orbiter and Probe*
  - *Mars Sample Return Lander and Orbiter*





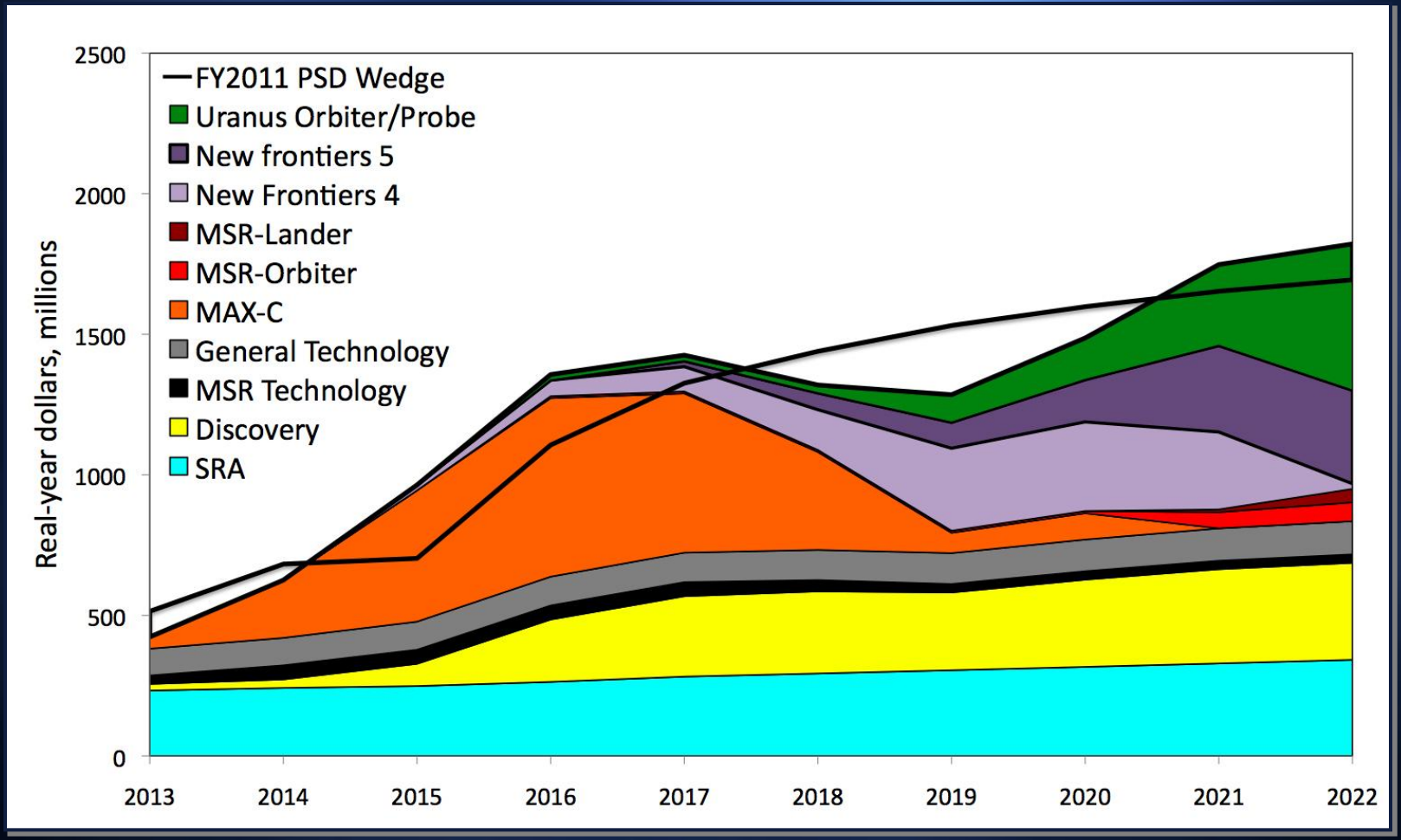


It All Has To Fit

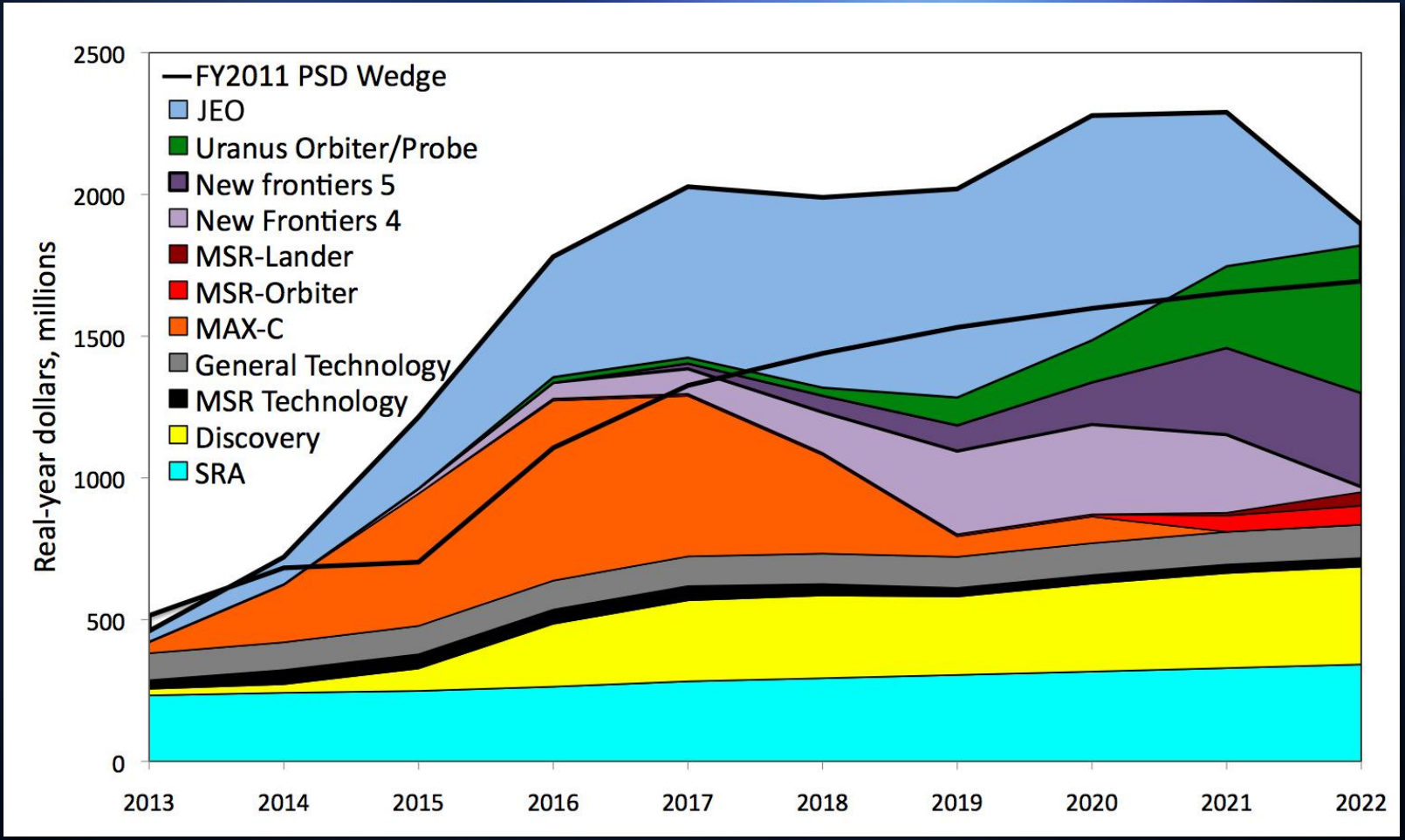


(Data and projections provided by NASA)

The Cost-Constrained Program



The Recommended Program



(JEO costs shown do not include descope)

Recent Developments

Mission Directorate: Science
Theme: Planetary Science

FY 2012 Budget Request

Budget Authority ($ millions)	FY 2010	Ann CR. FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
FY 2012 President's Budget Request	1,364.4	-	1,488.9	1,365.7	1,326.4	1,271.0	1,188.9
Planetary Science Research	161.6	-	183.9	196.0	208.6	208.4	210.5
Lunar Quest Program	94.5	-	114.5	81.2	48.9	28.1	19.5
Discovery	184.5	-	175.6	205.1	245.7	265.5	242.8
New Frontiers	279.6	-	176.9	265.8	245.5	291.1	296.3
Mars Exploration	438.2	-	594.4	433.1	408.7	309.0	245.9
Outer Planets	100.6	-	120.8	80.5	82.2	84.1	88.5
Technology	105.5	-	122.9	104.1	86.6	84.9	85.4

Note: The new Planetary Science Decadal survey, developed by the National Academy of Sciences, will be released in March 2011. The decadal survey is designed to broadly canvas the field of planetary science to determine the current state of knowledge and then identify and prioritize the most important scientific questions and associated missions during the 2013-2022. NASA will re-examine all elements of the Planetary Science program and may modify future budget and content to better align with the findings and recommendations of the report.

The FY 2011 appropriation for NASA was not enacted at the time that the FY 2012 Request was prepared; therefore, NASA is operating under a Continuing Resolution (P.L. 111-242, as amended). Amounts in the "Ann. CR FY 2011" column reflect the annualized level provided by the Continuing Resolution.

In accordance with the President's proposal to implement a five-year non-security discretionary spending freeze, budget figures shown for years after FY 2012 are notional and do not represent policy. Funding decisions will be made on a year-by-year basis.

If Less Funding Is Available…

- Descope or delay Flagship missions.
- Slip New Frontiers and/or Discovery missions only if adjustments to Flagship missions cannot solve the problem.
- Place high priority on preserving R&A and technology development funding.

Implications

- Protect R&A, Technology, Discovery and New Frontiers.
- Fly MAX-C/ExoMars only if:
  - The cost to NASA is no more than $2.5 billion.
  - It leads realistically to sample return.
- If MAX-C/ExoMars does not meet these criteria, second priority is JEO. (There is no recommended “Plan B” for Mars.)
- If JEO is not affordable, third priority is Uranus Orbiter and Probe ($2.7 billion).
- If UOP is not affordable, fourth priority is Venus Climate Mission ($2.4 billion) or Enceladus Orbiter ($1.9 billion).

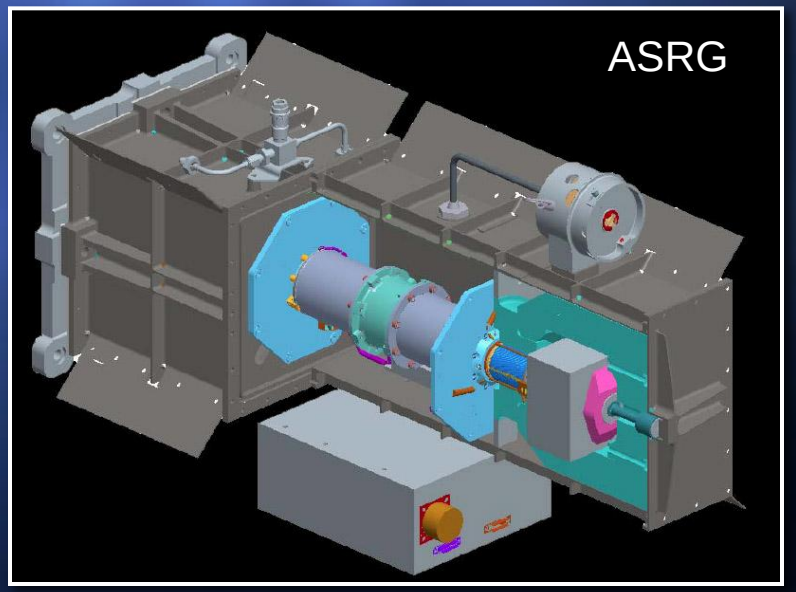
Launch Vehicle Costs

- Launch vehicle costs are rising, and tend to be a larger fraction of mission costs than they once were.

- Steps can be considered to reduce launch costs:
  - Use dual manifesting (two missions on a single launch).
  - Make block buys across NASA, or with other agencies (*e.g.*, DoD).
  - Exploit technolgies that reduce flight system mass, allowing use of smaller launch vehicles.

Plutonium-238

- The amount of plutonium-238 available for spacecraft power systems is shrinking alarmingly.
- *Without a restart of plutonium-238 production, it will be impossible for NASA to carry out important planetary missions, particularly in the outer solar system.*
- JEO should switch to Advanced Stirling Radioisotope Generators (which require substantially less plutonium) for power production.
- ASRG development should receive attention comparable to a flight project.



Interaction With Human Exploration

- Some solar system bodies are likely targets of future human exploration:
  - The Moon
  - Asteroids
  - Mars and its moons

- *It is vital to maintain the science focus of peer-reviewed NASA missions to these bodies.*

- Both the Space Science program and the human exploration program can benefit from carefully crafted intra-agency partnerships (LRO is a good recent example).

Supporting NASA Activities

- Data distribution and archiving:
  - *Maintain and upgrade Planetary Data System capabilities.*
- Education and outreach:
  - *Set aside ~1% of each flight project budget for education and outreach activities.*
- Telescope facilities:
  - *Continue NASA support for IRTF, Keck, Goldstone, Arecibo, and VLBA.*
- The Deep Space Network:
  - *Expand capabilities to meet requirements of recommended missions.*
  - *Maintain high-power X and Ka band uplink, and S, X, and Ka band downlink at all three complexes.*
- Sample curation and laboratory facilities:
  - *Consider the full costs to NASA of receiving and curating samples when planning sample return missions.*
  - *Before samples return, establish a program to develop instruments and facilities for sample analysis.*

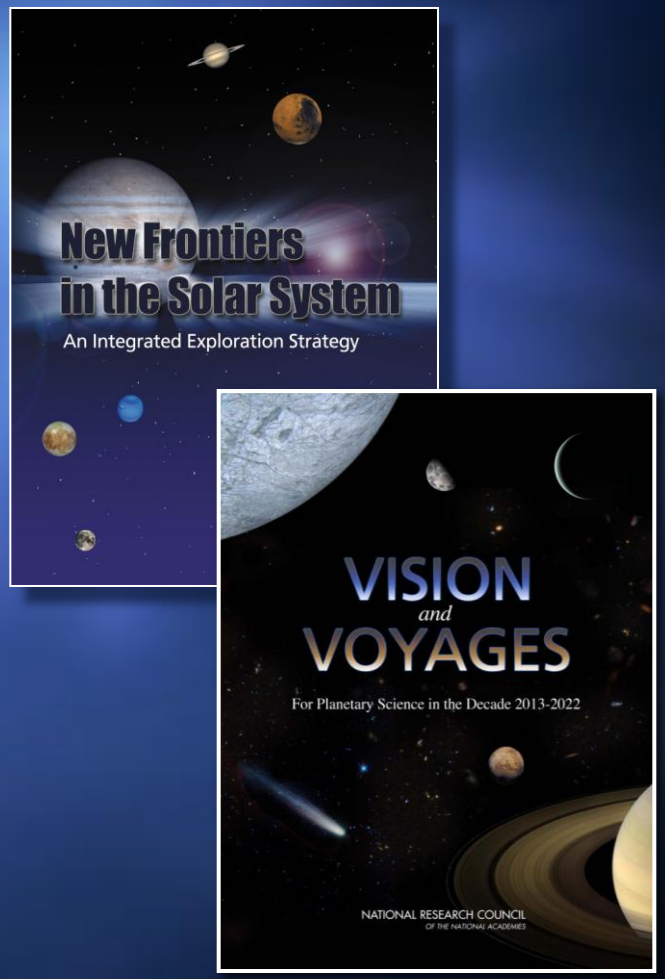
National Science Foundation

- Ground-based observatories supported by NSF are essential to planetary astronomy. *Continued NSF support for ground-based observatories is crucial.*
- NSF's Office of Polar Program supports important meteorite collection and planetary analog studies in Antarctica. *This support should continue.*
- NSF also funds laboratory research that is important to planetary science. *Expanded NSF funding of laboratory research in planetary science is recommended.*
- The Large Synoptic Survey Telescope (LSST) has the potential to make major contributions to planetary science, particularly for studies related to the origin, evolution, and dynamics of primitive bodies. *Timely completion of LSST, and its use for planetary science, are strongly encouraged.*

Backup Materials

What Is A Decadal Survey?

- Once every ten years, at the request of NASA and NSF, the National Research Council carries out a “decadal survey” for planetary science.
- The decadal survey involves broad participation from the planetary science community.
- It is the primary scientific input that NASA and NSF use to design their programs of planetary science and exploration.



- This decadal survey applies to the decade from 2013 to 2022.

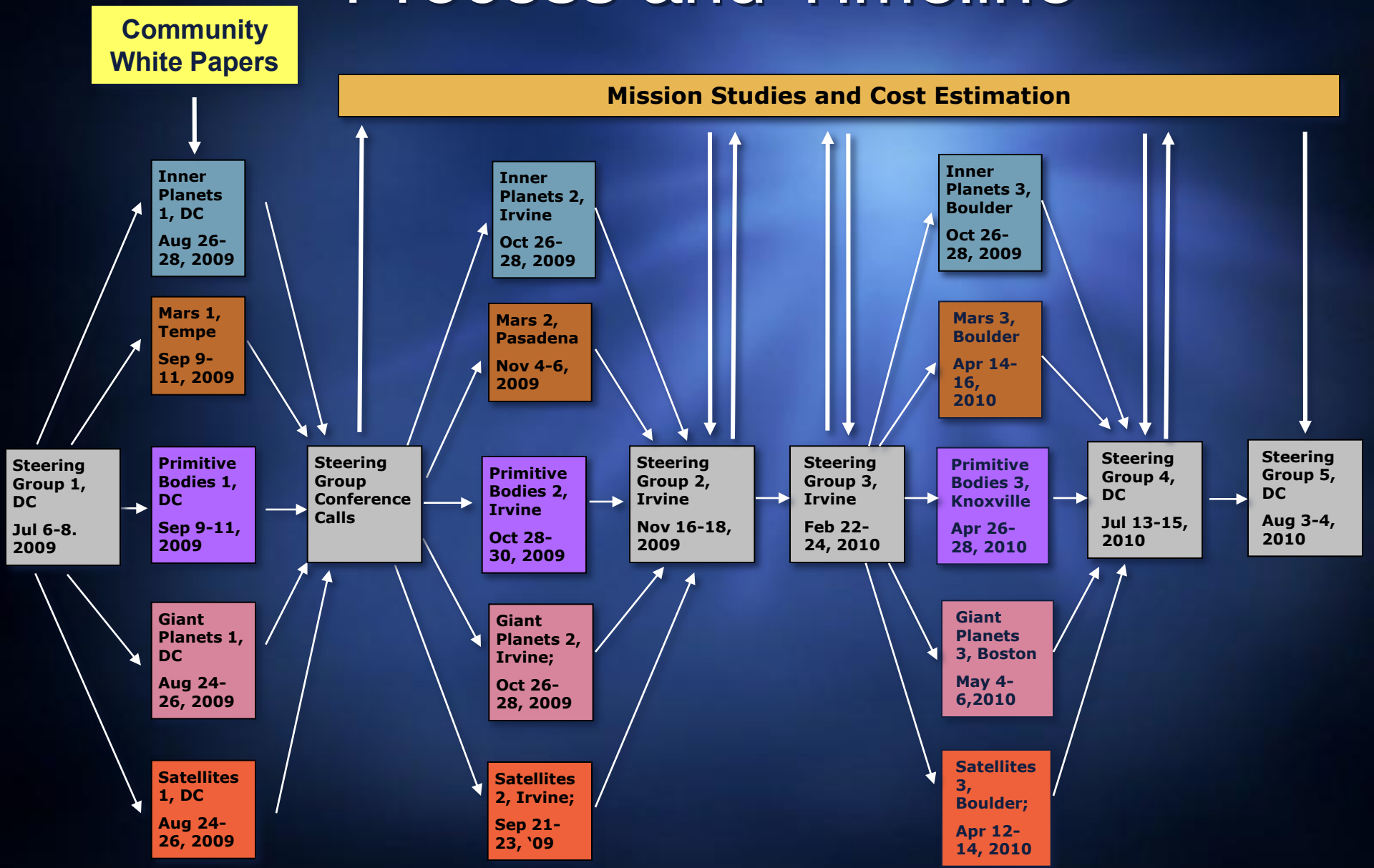
Guiding Principles

- Science Comes First: All recommendations must be first and foremost science-driven.
- Community Involvement: Solicit community input throughout the process.
- Transparency and Openness: Make the process as open and visible to all interested members of the community as possible.

Statement of Task

- The decadal survey was governed by a "Statement of Task".
- The Statement of Task was provided by NASA and NSF, with input from OMB.
- The Statement of Task emphasized that all recommendations should be science-driven.
- It also placed a strong emphasis on recommending a plan that can be carried out in full using funding projected to be available.

Process and Timeline

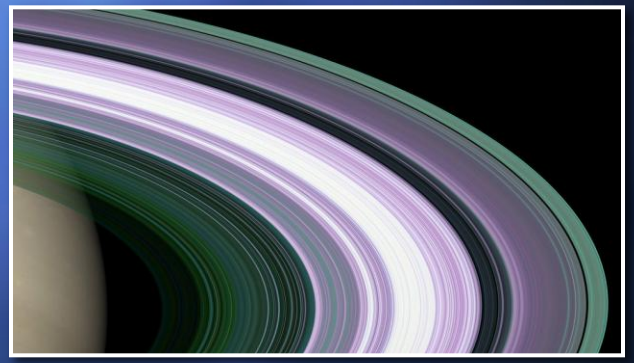


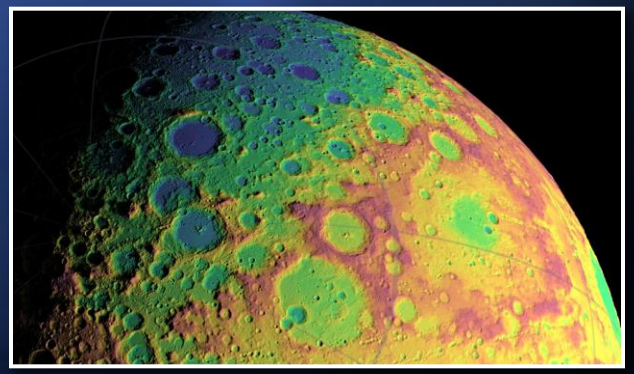
Crosscutting Themes

- The community inputs led to identification of three Crosscutting Themes for planetary science:
  - Building New Worlds: Understanding solar system beginnings
  - Planetary Habitats: Searching for the requirements for life
  - Workings of Solar Systems: Revealing planetary processes through time
- The report expands on these themes, identifying key scientific questions for each.

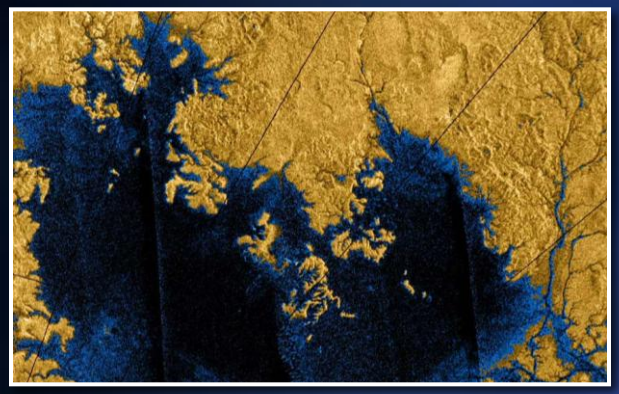
Building New Worlds

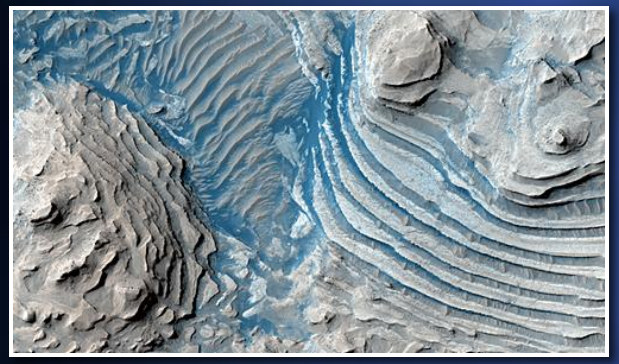
- What were the initial stages, conditions and processes of solar system formation and the nature of the interstellar matter that was incorporated?
- How did the giant planets and their satellite systems accrete, and is there evidence that they migrated to new orbital positions?
- What governed the accretion, supply of water, chemistry, and internal differentiation of the inner planets and the evolution of their atmospheres, and what roles did bombardment by large projectiles play?

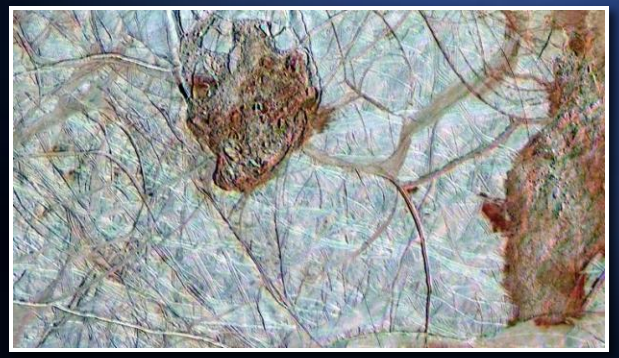




Planetary Habitats







- What were the primordial sources of organic matter, and where does organic synthesis continue today?
- Did Mars or Venus host ancient aqueous environments conducive to early life, and is there evidence that life emerged?
- Beyond Earth, are there modern habitats elsewhere in the solar system with necessary conditions, organic matter, water, energy, and nutrients to sustain life, and do organisms live there now?

Workings of Solar Systems

- How do the giant planets serve as laboratories to understand the Earth, the solar system and extrasolar planetary systems?
- What solar system bodies endanger and what mechanisms shield the Earth's biosphere?
- Can understanding the roles of physics, chemistry, geology, and dynamics in driving planetary atmospheres and climates lead to a better understanding of climate change on Earth?
- How have the myriad chemical and physical processes that shaped the solar system operated, interacted, and evolved over time?