Vision and Voyages

For Planetary Science in the Decade 2013-2022

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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.

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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.

Committee Organization

Steering Group
Steve Squyres, Chair
Larry Soderblom, Vice Chair
Vice Chairs of Panels
9 others

Inner Planets Panel
Ellen Stofan, Chair
Steve Mackwell, Vice Chair
10 others

Outer Planets Panel
Heidi Hammel, Chair
Amy Simon-Miller, Vice Chair
9 others

Primitive Bodies Panel
Joe Veverka, Chair
Hap McSween, Vice Chair
10 others

Mars Panel
Phil Christensen, Chair
Wendy Calvin, Vice Chair
9 others

Outer Planet Satellites Panel
John Spencer, Chair
Dave Stevenson, Vice Chair
10 others

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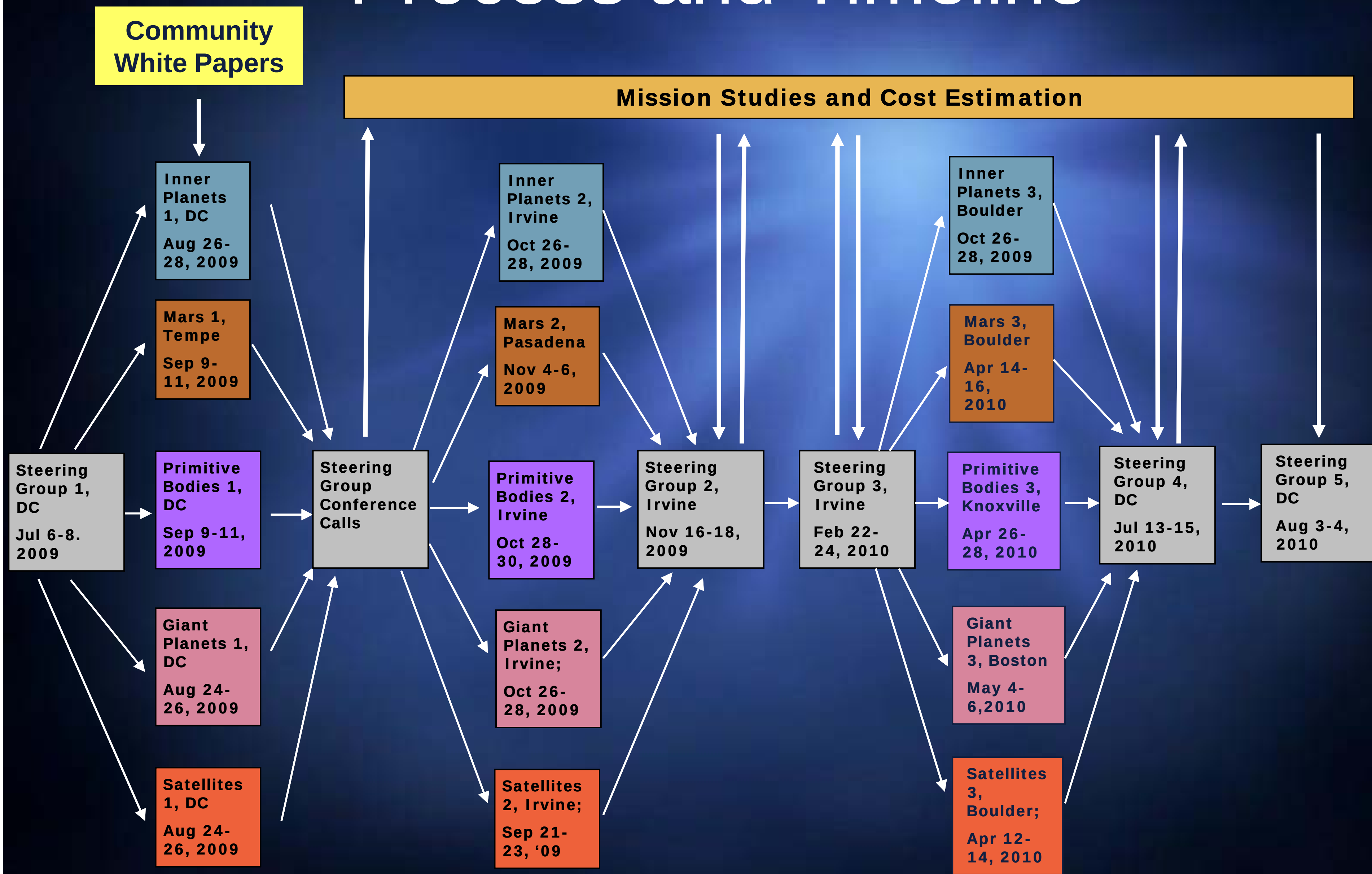
Inputs From The Community

- 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.

Process and Timeline



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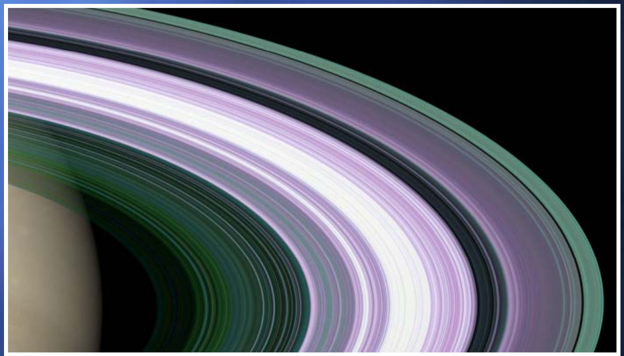
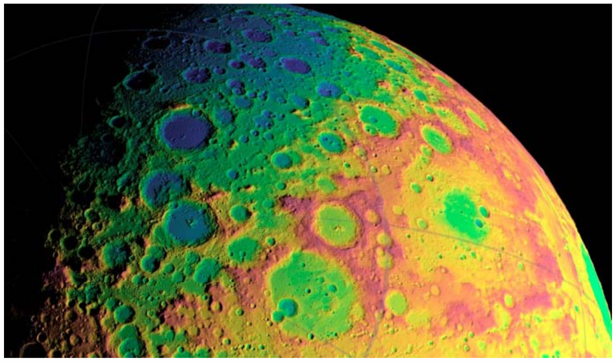
Crosscutting Themes

- 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?

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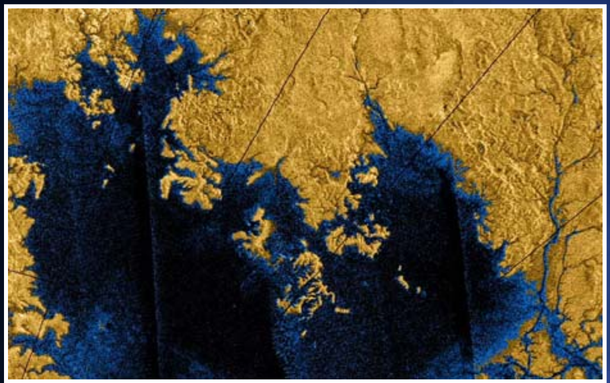
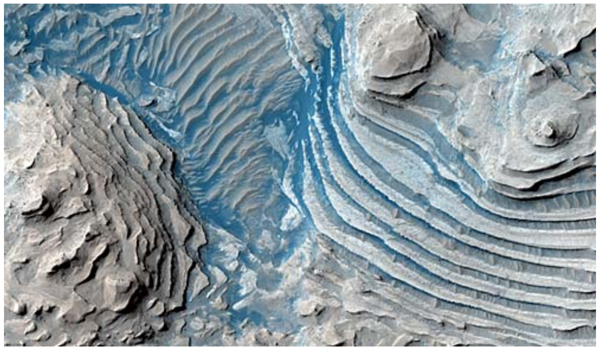
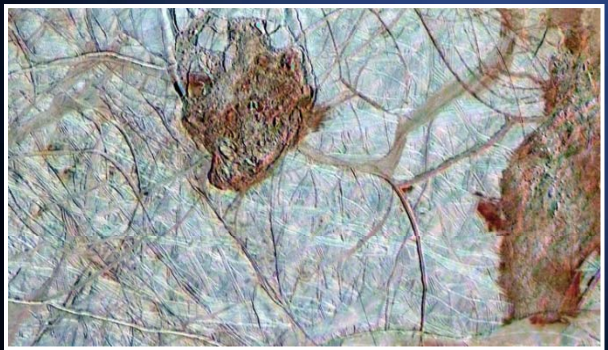
Planetary Habitats







- 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?

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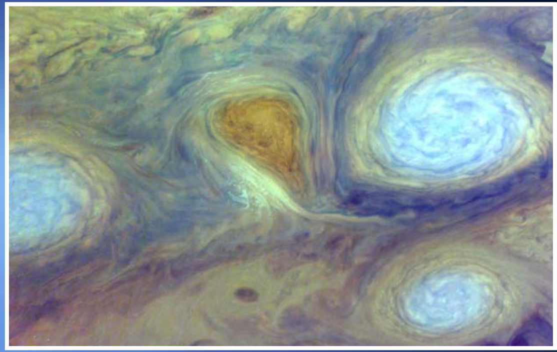
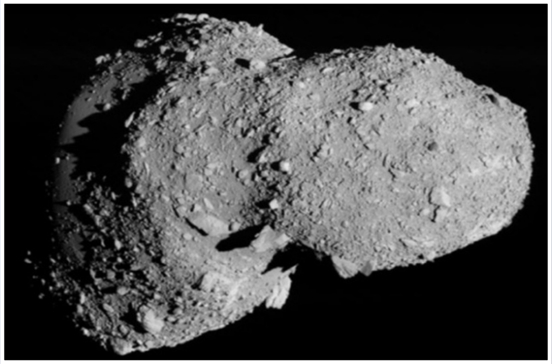
Workings of Solar Systems

- 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?





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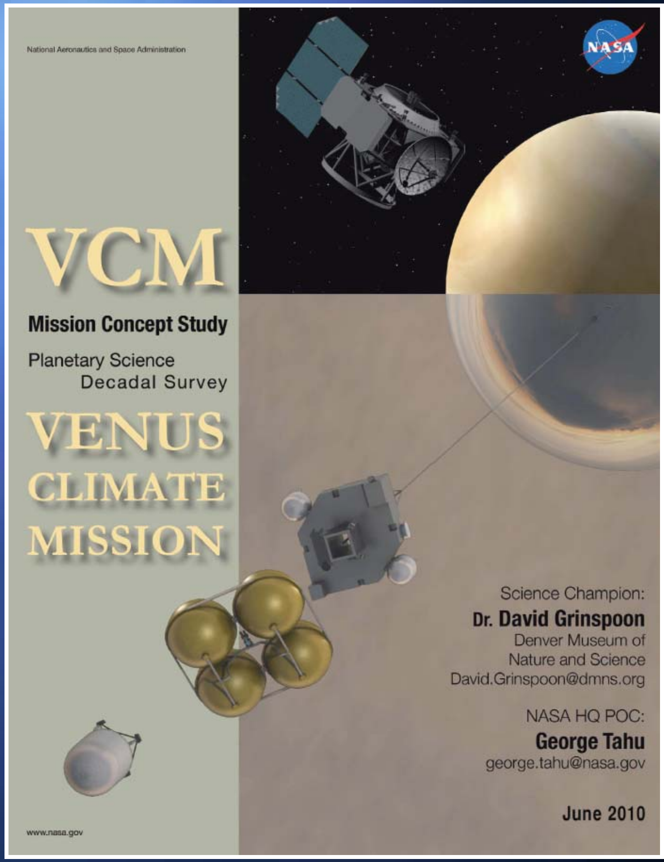
Mission Studies

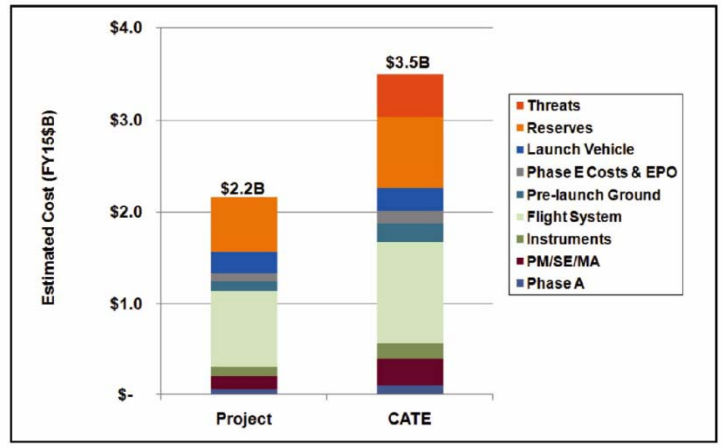
- Based on the science identified via white papers and other community inputs, 25 mission candidates were chosen for detailed study.
- Studies were performed by APL, GSFC, and JPL. Each study team included at least one science representative from the appropriate panel.
- The studies involved considerable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



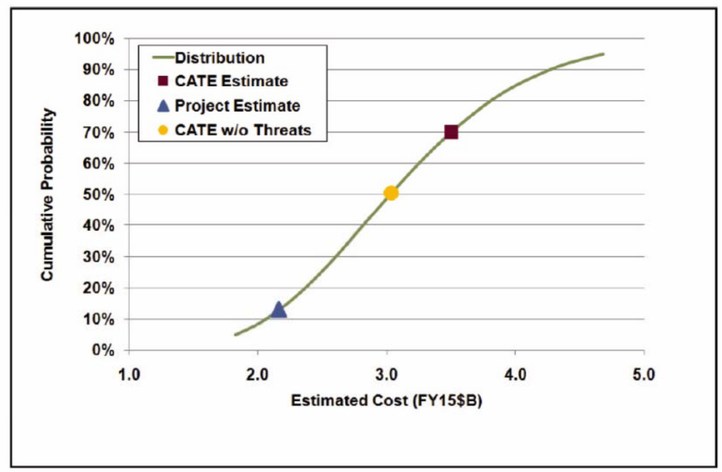
Cost and Technical Evaluations

- 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

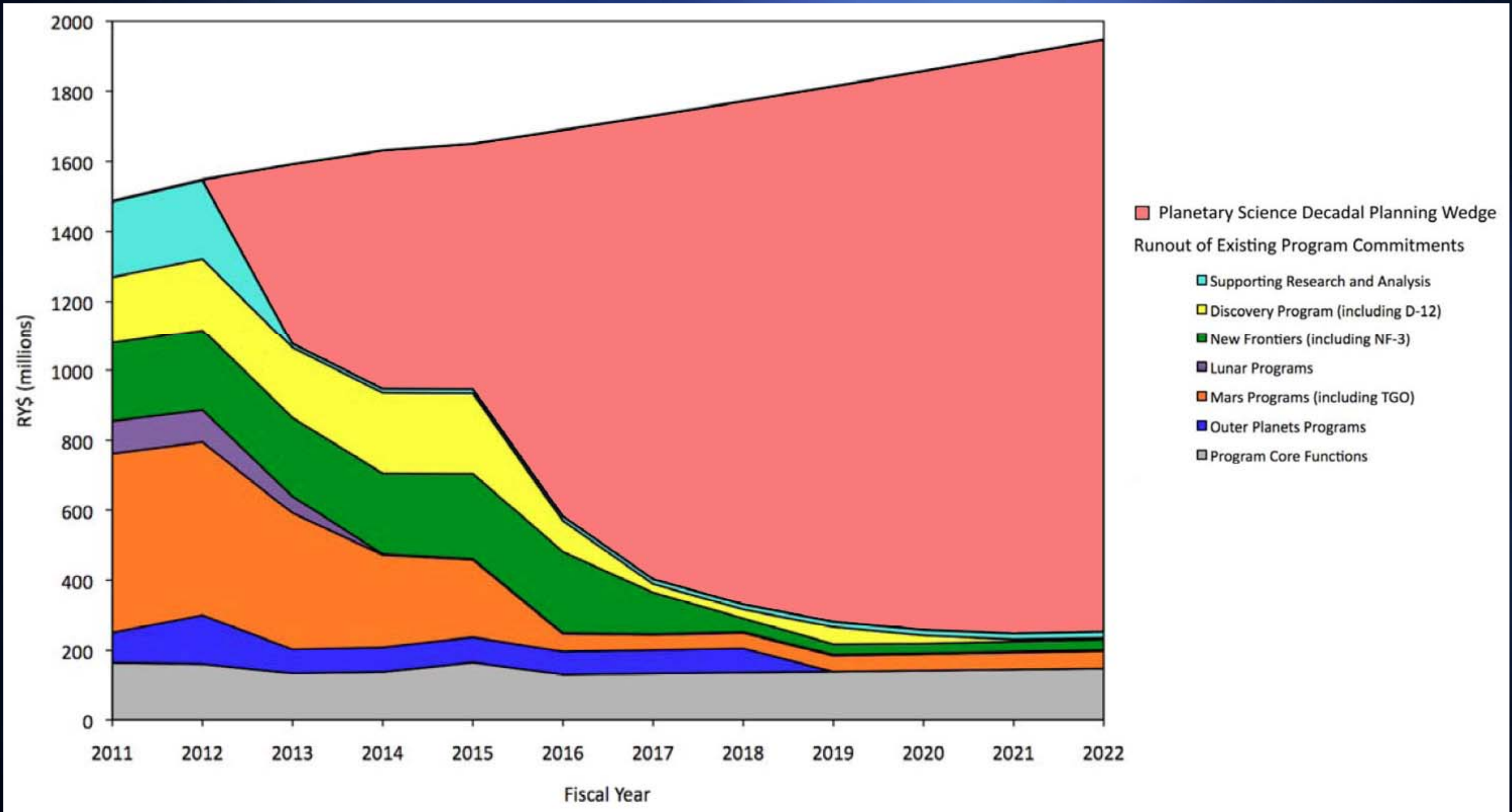


Mission Prioritization

- 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 <u>strong consensus</u>.

It All Has To Fit

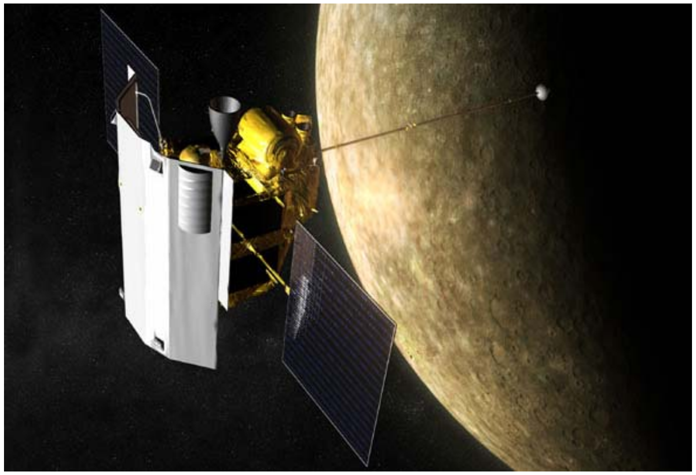


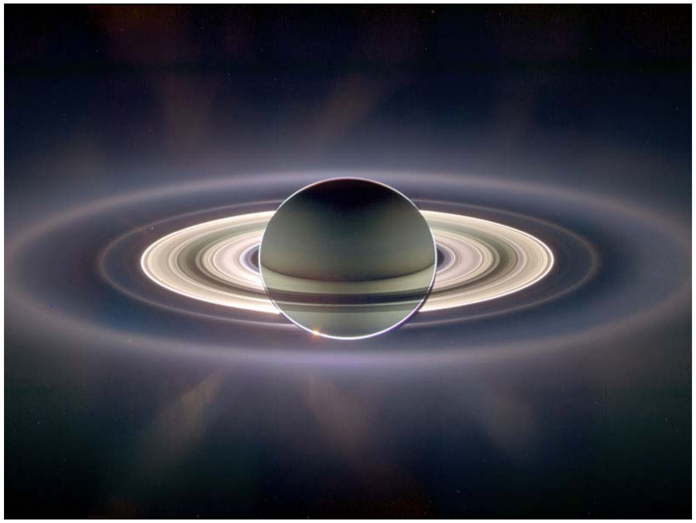
(Data and projections provided by NASA)

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.

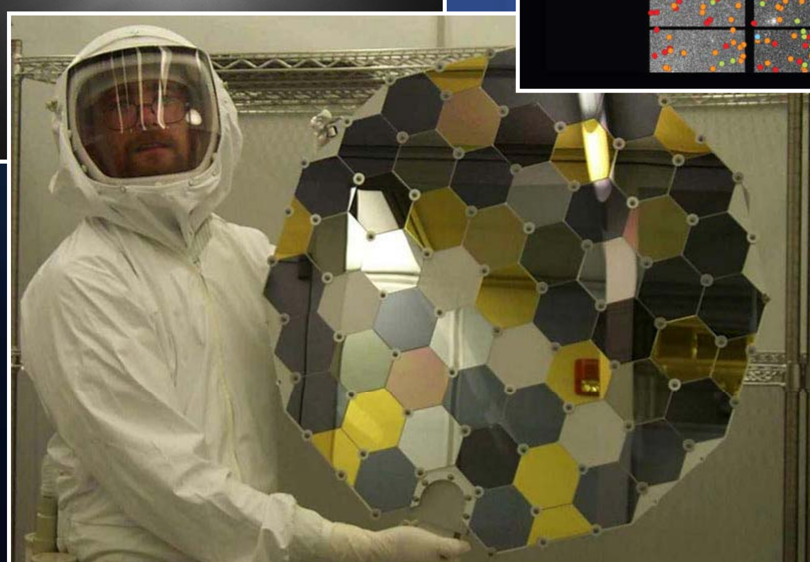
- *A planetary exploration technology development program should be established, and carefully protected from incursions on its resources.*

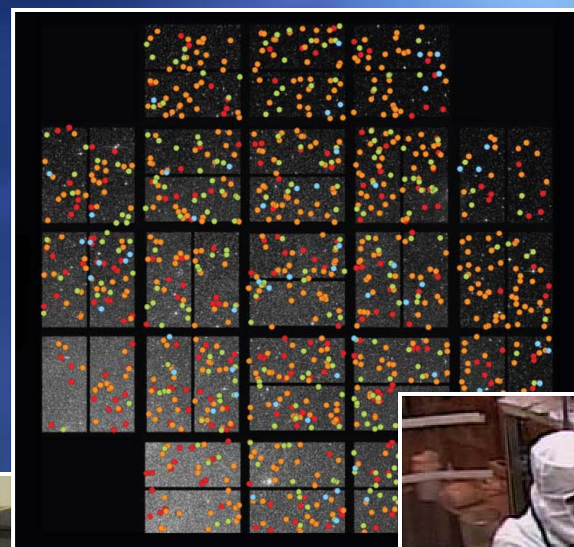
- *This program should be funded at 6-8% of the total NASA Planetary Science Division budget.*

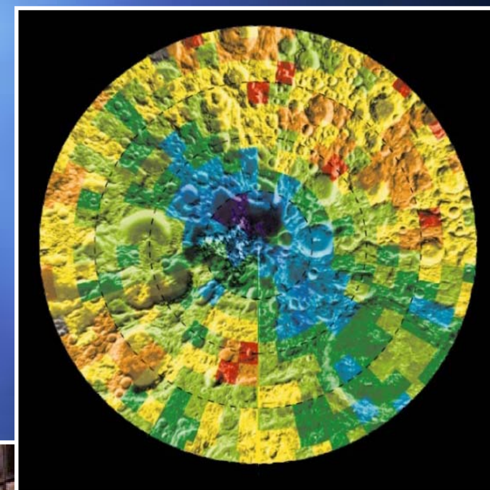
- All recommendations are consistent with this level of technology funding.

The Discovery Program

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







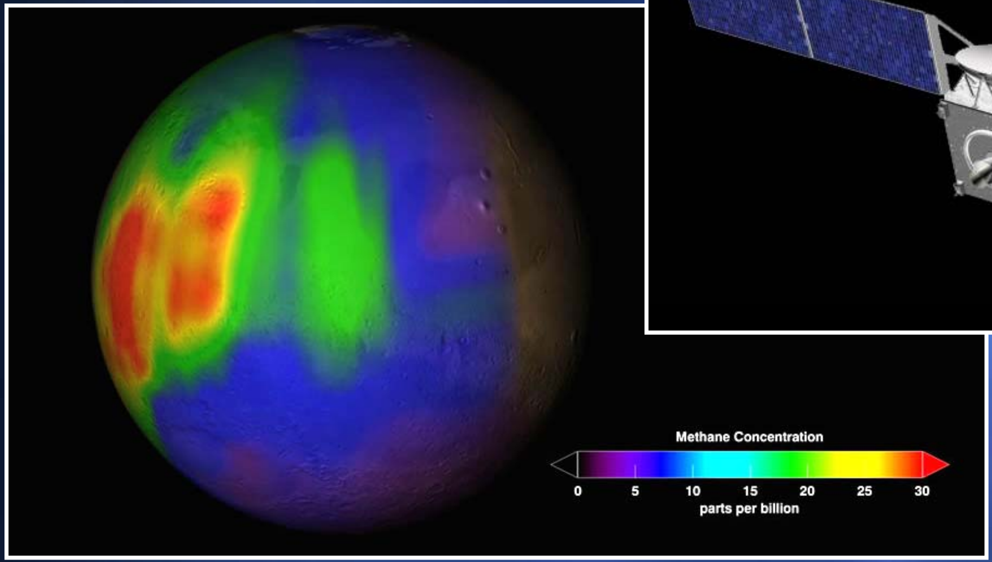
The Discovery Program

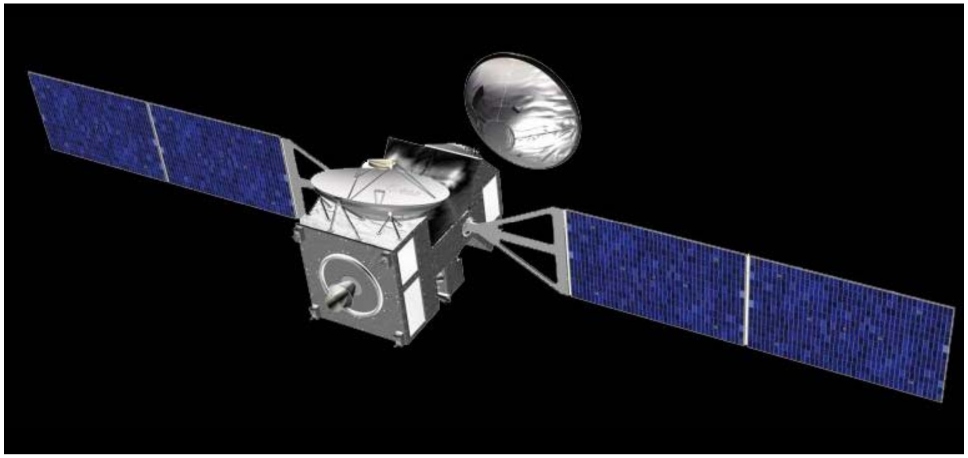
- *Continue the Discovery program at its current funding level, adjusted for inflation, with a cost cap per mission also adjusted for inflation (i.e., to $500 million FY'15).*

- *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.*

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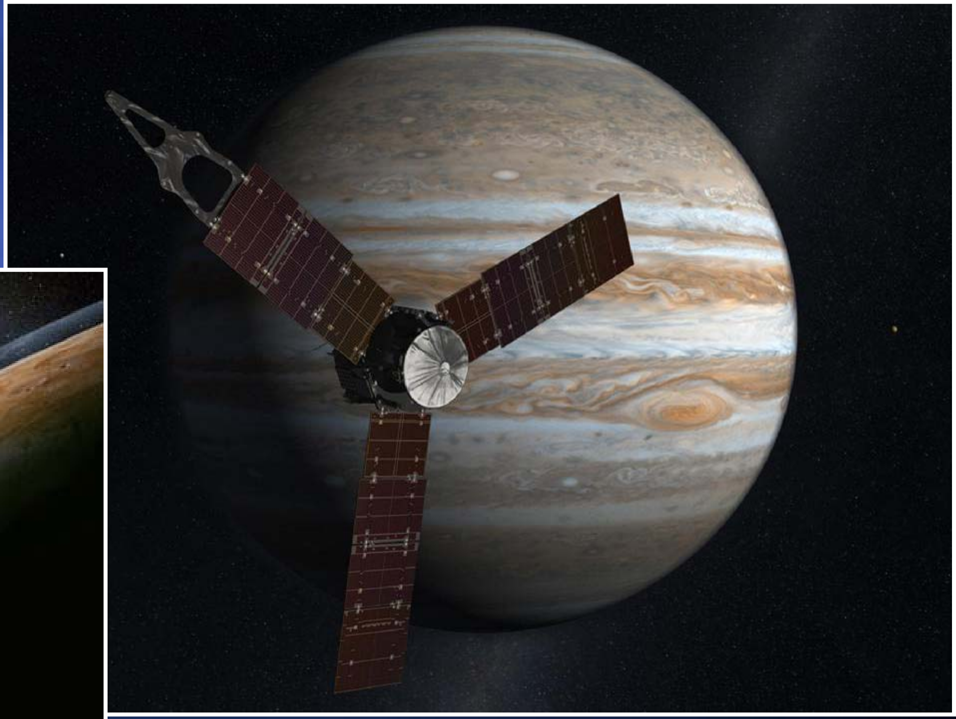
The New Frontiers Program

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



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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*

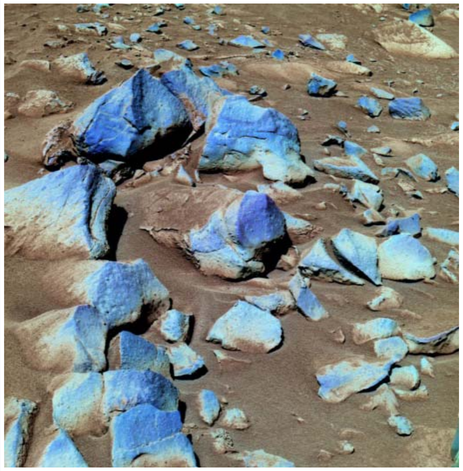
2. Detailed investigation of a probable ocean in the outer solar system: *Descoped Jupiter Europa Orbiter (JEO)*

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 <u>enabled</u> 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.



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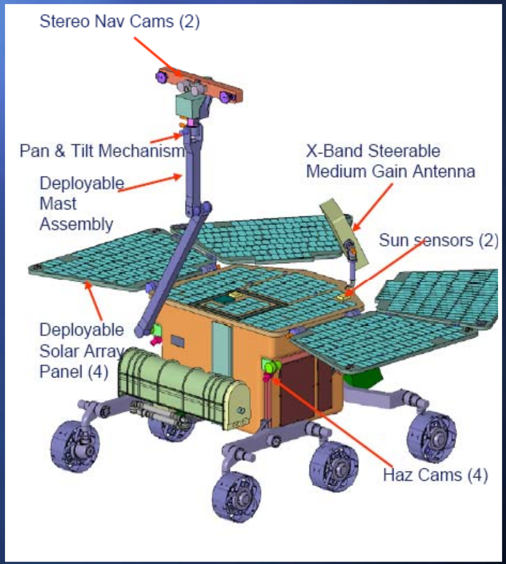
The Need For A Descope

- 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.

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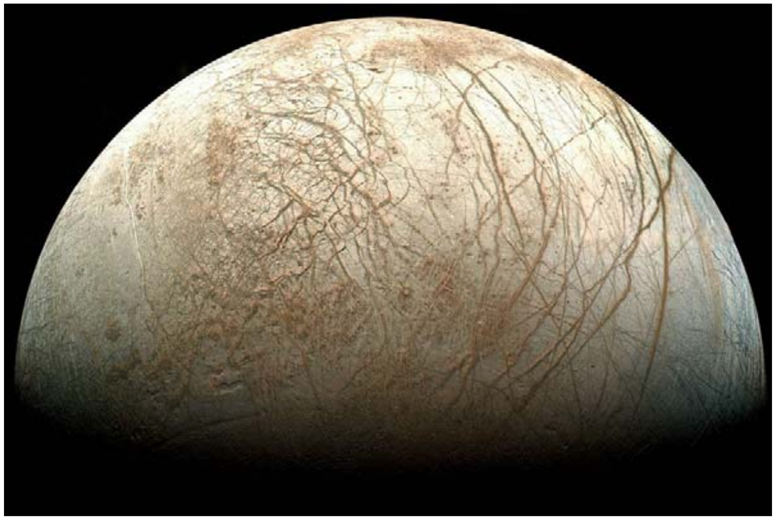
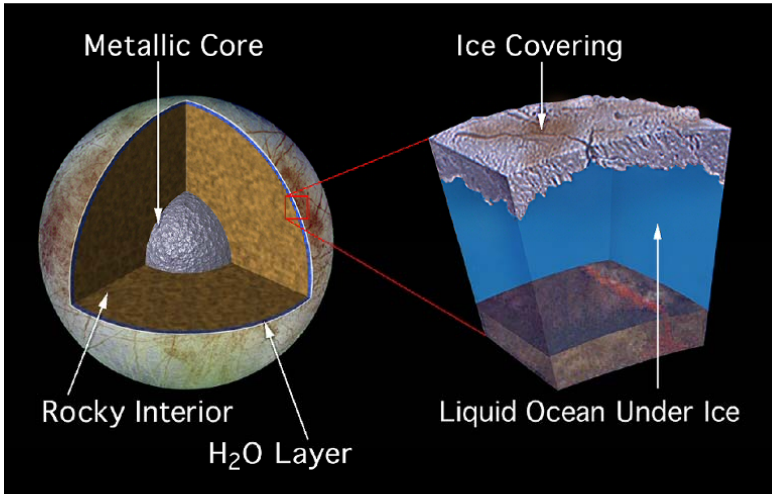
Flagship Priority 2: JEO

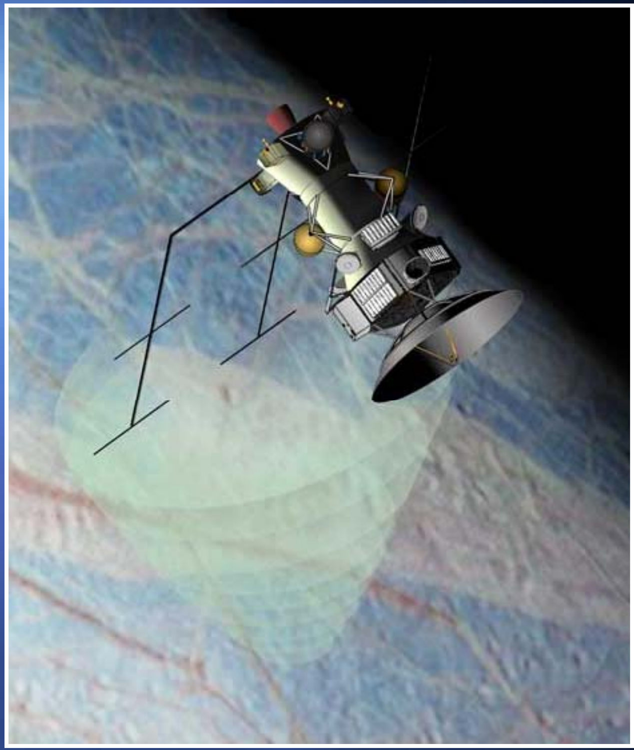
- Europa's probable ocean may be the best candidate in the solar system beyond Earth for a presently habitable environment.
- Orbital tour of Jupiter system, followed by 100-200 km Europa orbit
- Instrumentation to characterize Europa's tidal flexure, the thickness of the ice shell, and the character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





The Need For A Descope

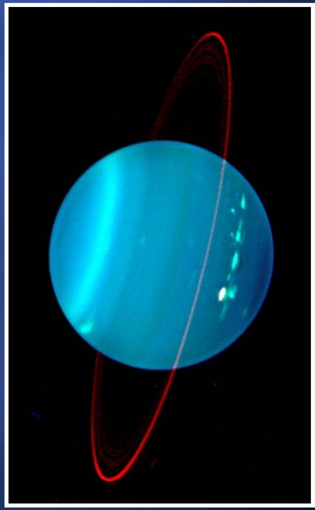
- The CATE estimate for the cost of JEO is $4.7 billion. This is too large a fraction of the planetary budget.
- *Fly JEO only if changes to both the mission and the NASA planetary budget make it affordable without eliminating other recommended missions:*
  - This will require a reduction in the mission's scope and cost
  - JEO will probably also require a new start that increases the overall budget of NASA's Planetary Science Division



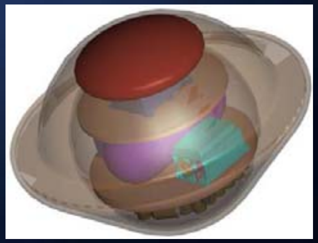
- *Immediately begin an effort to find major cost reductions in JEO, with the goal of minimizing the necessary planetary science budget increase.*
- JEO science would be enhanced by conducting the mission jointly with ESA's proposed Ganymede Orbiter mission.

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

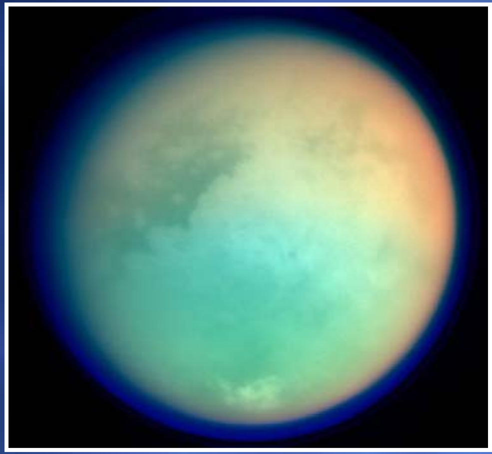


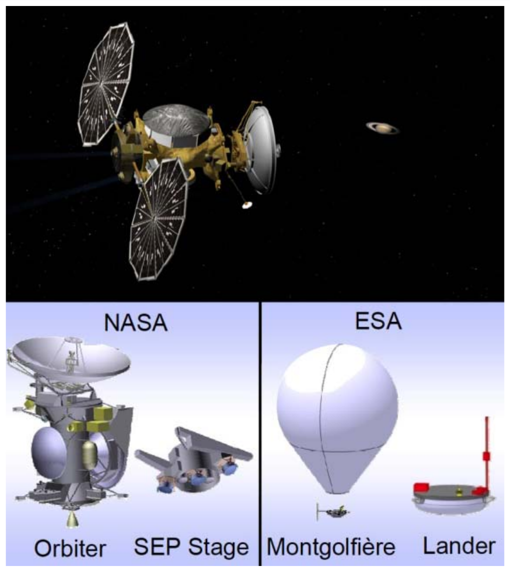
- Orbiter to perform remote sensing of planet's atmosphere, magnetic field, rings, and satellites.
- Atmospheric entry probe.
- Potential for new discoveries comparable to Galileo at Jupiter and Cassini at Saturn.
- *Uranus is preferred over Neptune for 2013-2022 for practical reasons involving available trajectories, flight times, and cost.*

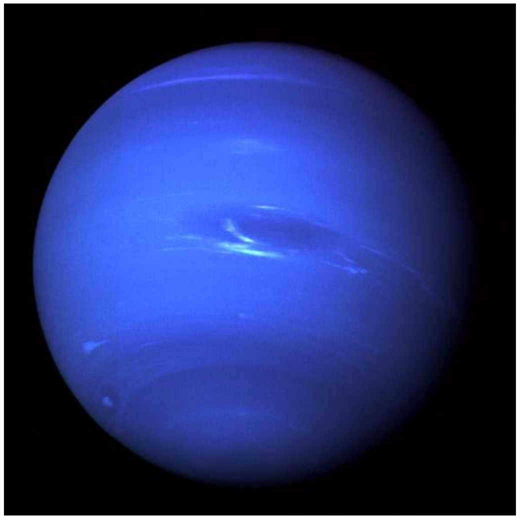


Technology Development Priorities

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







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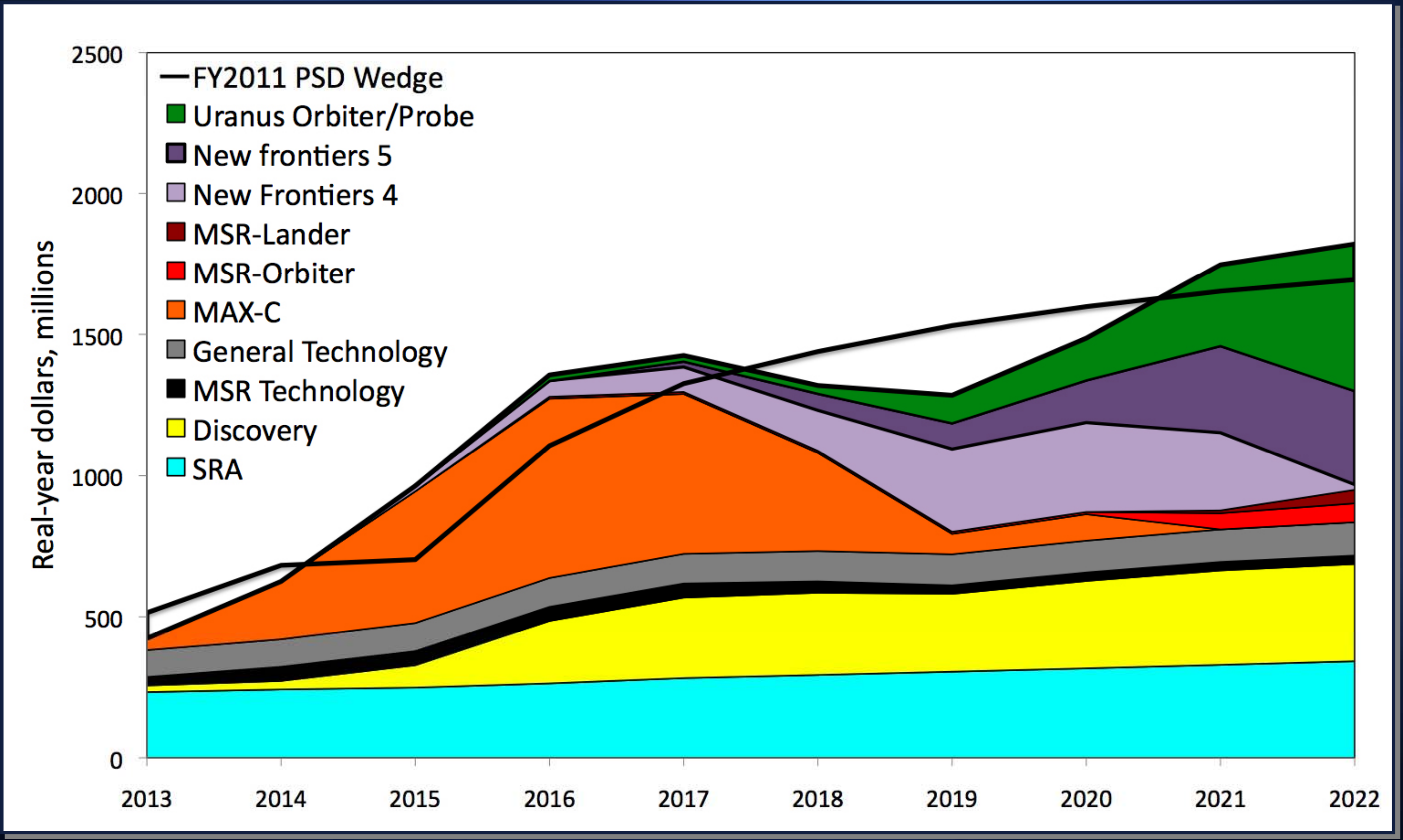
The Cost-Constrained Program



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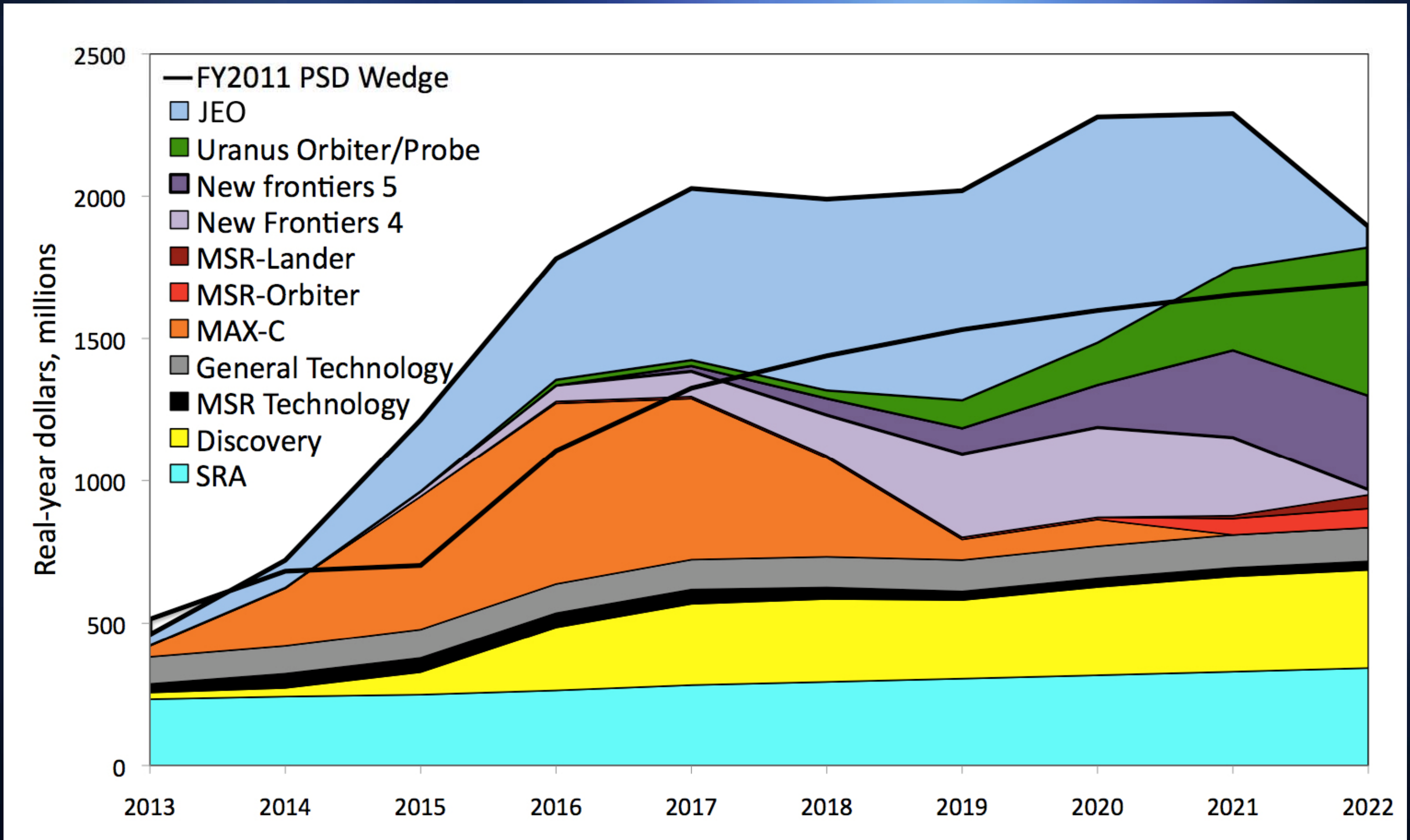
The Recommended Program



(JEO costs shown do not include descope)

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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 <u>only</u> 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).

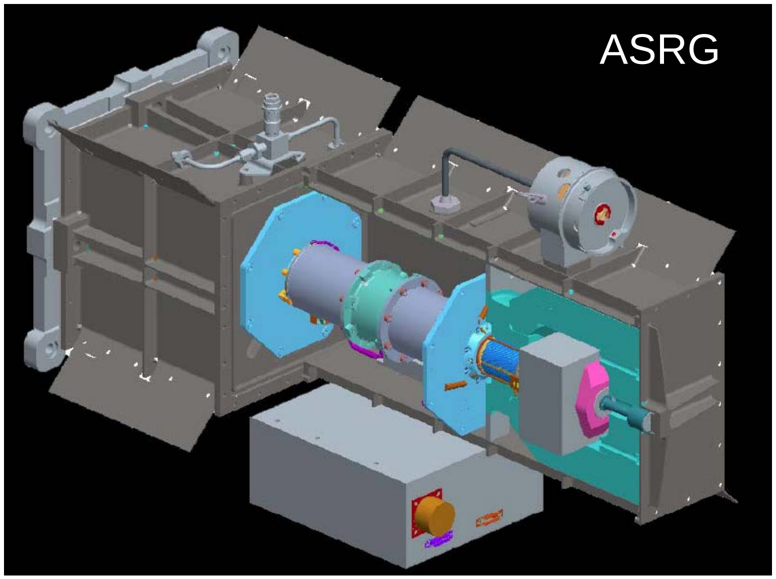
Launch Vehicle Costs

- 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.



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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.*

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