Planetary Probes and the Planetary Decadal Survey

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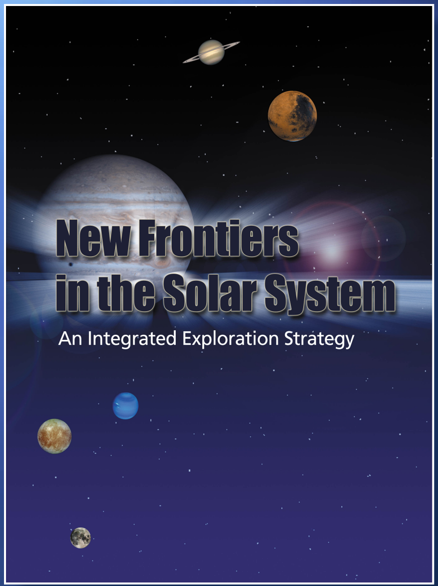
What Is A Decadal Survey?

- 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.

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

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

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

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

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

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.

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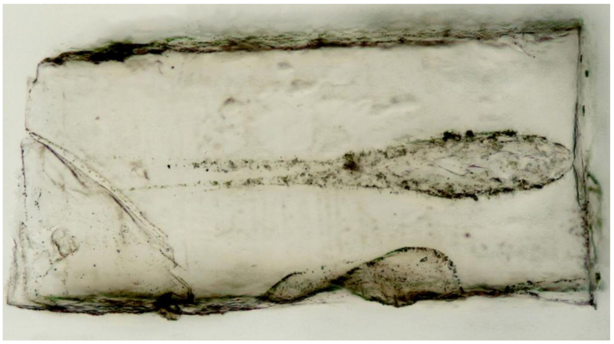
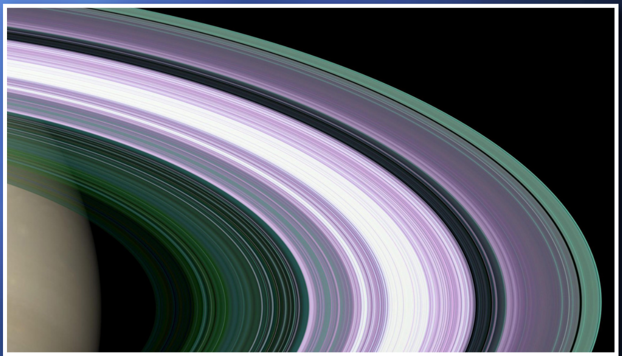
Crosscutting Themes

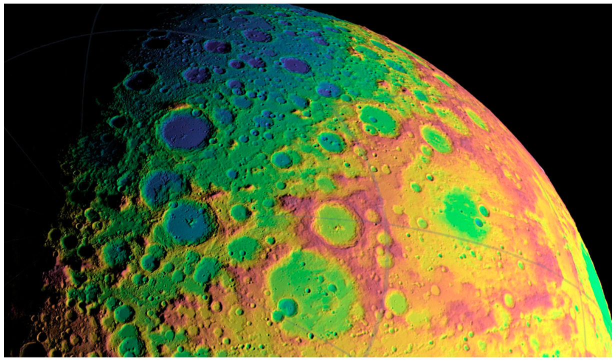
- The community inputs led to identification of three Crosscutting Themes for planetary science:
  - Building New Worlds: Understanding solar system beginnings
  - Planetary Habitats: Searching for the requirements for life
  - Workings of Solar Systems: Revealing planetary processes through time
- The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

Building New Worlds

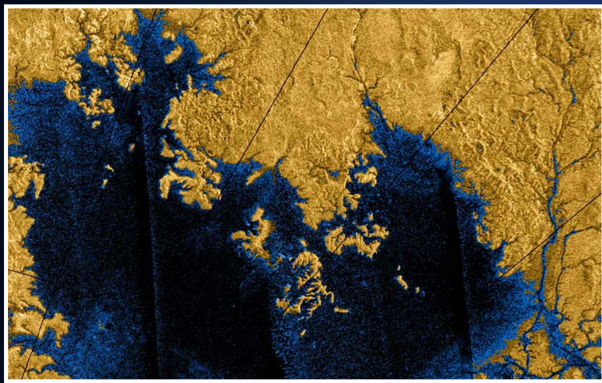
- What were the initial stages, conditions and processes of solar system formation and the nature of the interstellar matter that was incorporated?
- How did the giant planets and their satellite systems accrete, and is there evidence that they migrated to new orbital positions?
- What governed the accretion, 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?

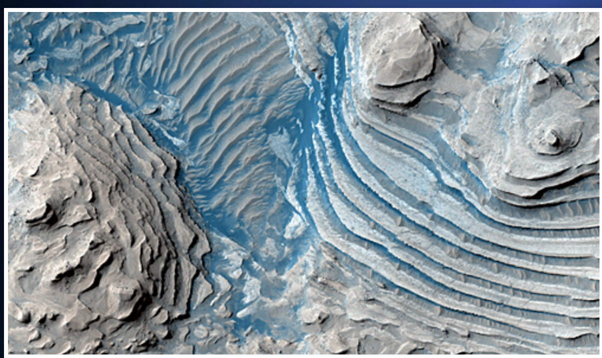


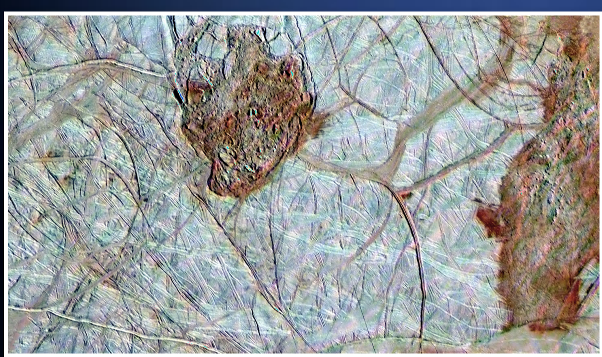




Planetary Habitats



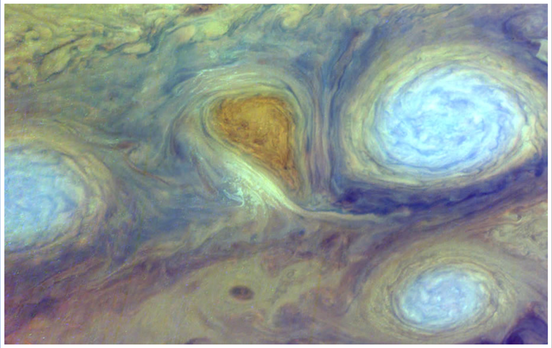


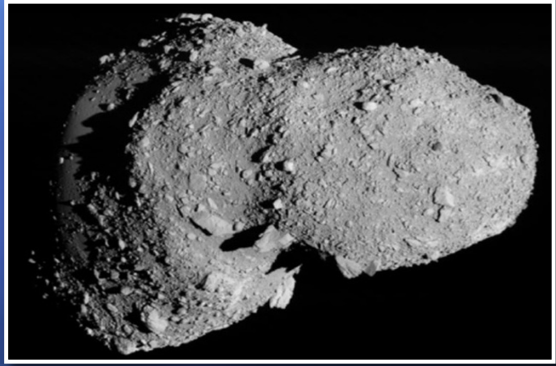


- What were the primordial sources of organic matter, and where does organic synthesis continue today?
- Did Mars or Venus host ancient aqueous environments conducive to early life, and is there evidence that life emerged?
- Beyond Earth, are there modern habitats elsewhere in the solar system with necessary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





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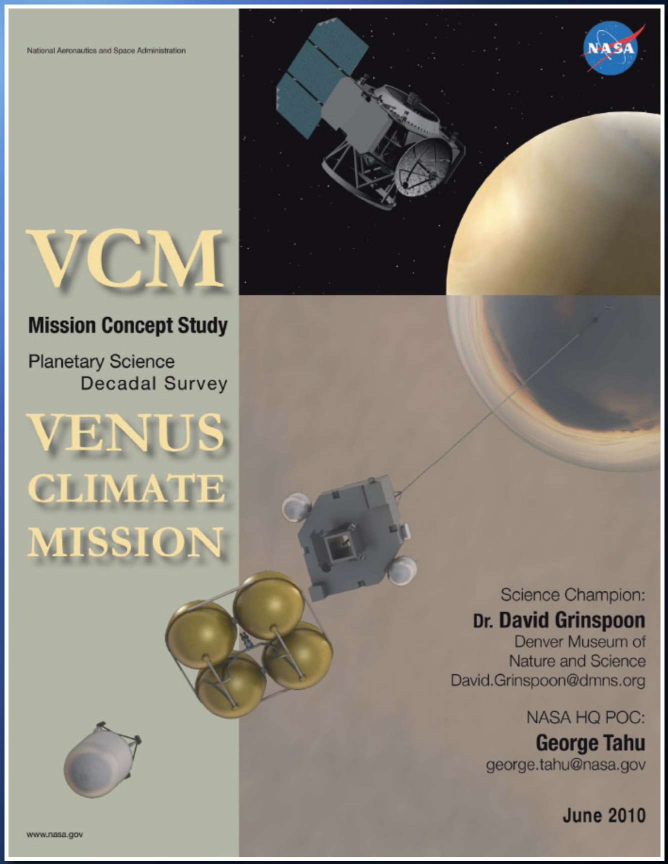
Mission Studies

- 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.
    - Selected subset went through detailed Cost and Technical Evaluation



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>.

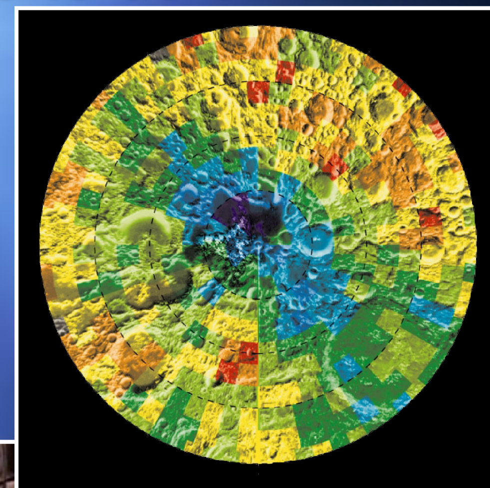
Recommendations of the Decadal Survey

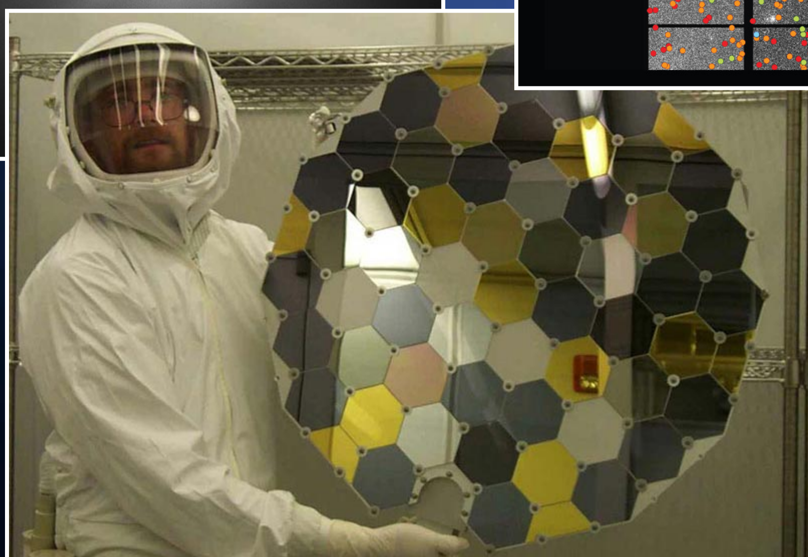
Technology Development

- 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

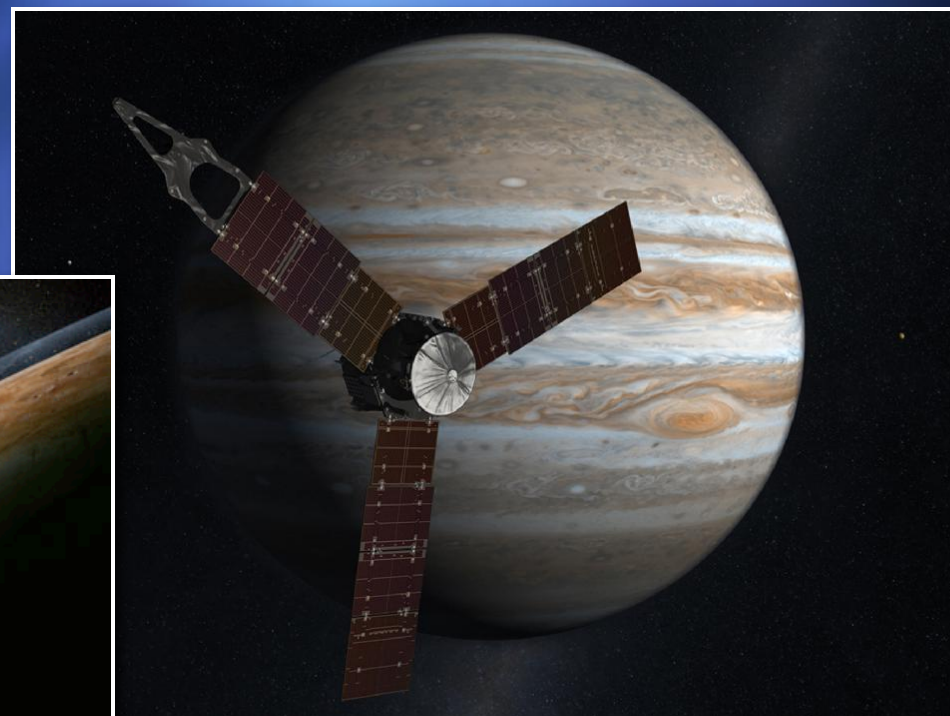
- The Discovery Program has produced spectacular and cost-effective science, and can continue to do so well into the future

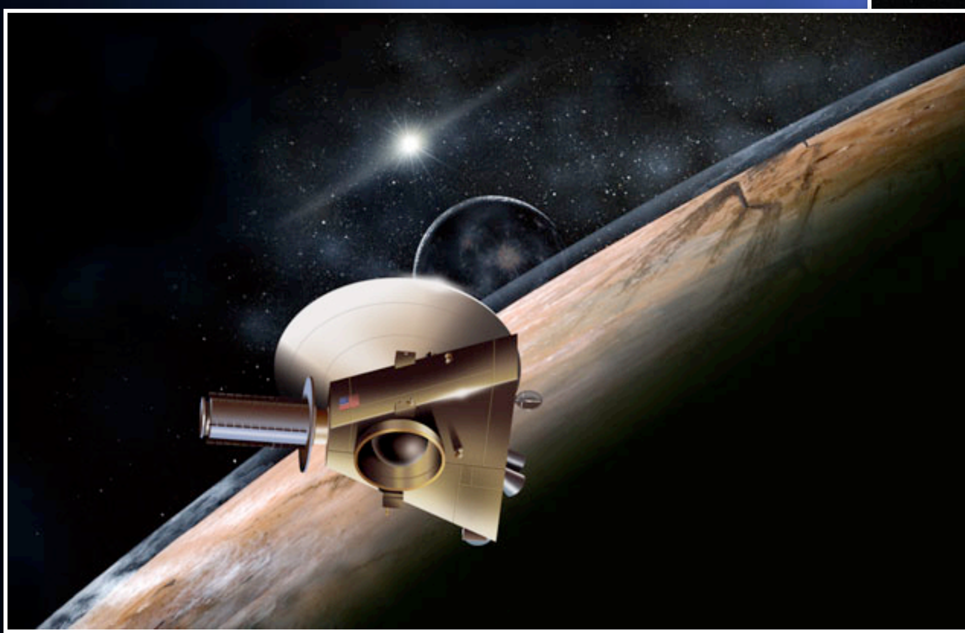




The New Frontiers Program

- 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

- 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
  - Left to PI to fit cost cap, and to define exact mission concept that addresses the science goals

- For NF5, add *Io Observer* and *Lunar Geophysical Network*

Saturn Probe

Saturn Atmospheric Entry Probe

Key Challenges:

- Entry Probe
  - *Mass Spectrometer and time past since heritage mission*
  - *High tempo operations after long hibernation period*
  - *Reproduction of heritage TPS manufacturing process*
- Payload Requirements Growth
  - *Concept study indicates multiple probes is a consideration though baseline design has a single probe*
  - *Instrument suite is minimal and possible future design iterations may consider enhanced payloads*

Scientific Objectives:

- Determine noble gas abundances and isotopic ratios of hydrogen, carbon, nitrogen, and oxygen in Saturn's atmosphere
- Determine the atmospheric structure at the probe descent location
- Key science themes cited:
  - *Constrain models of solar system formation and the origin and evolution of atmospheres*
  - *Provide a basis for comparative studies of the gas and ice giants*
  - *Provide a link to extrasolar planetary systems*

Key Parameters:

- Entry Probe Payload (2 instruments)
  - *Mass Spectrometer*
  - *Atmospheric Structure Instrument*
- Carrier-Relay Spacecraft Bus
- 2 Advanced Stirling Radioisotope Generators (ASRGs)
- Launch Mass: 957 kg
- Launch Date: 2027 (on Atlas V 401)
- Probe: Direct Entry to Saturn, Carrier-Relay: Saturn Flyby

Flagship Missions

(in priority order)

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

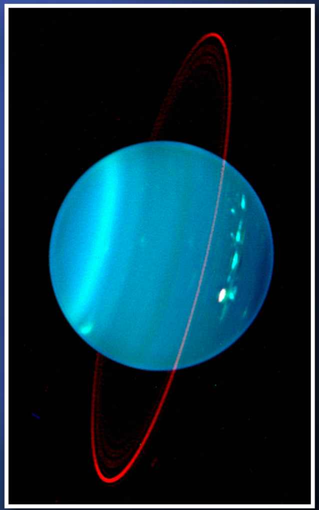
2. Detailed investigation of a probable ocean in the outer solar system: *Descoped Jupiter Europa Orbiter (JEO)*

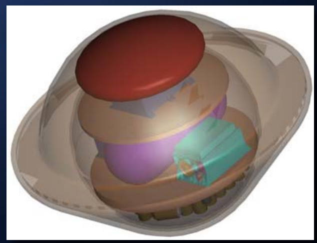
3. First in-depth exploration of an Ice Giant planet: *Uranus Orbiter and Probe*

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

Flagship Priority 3: Uranus Orbiter and Probe

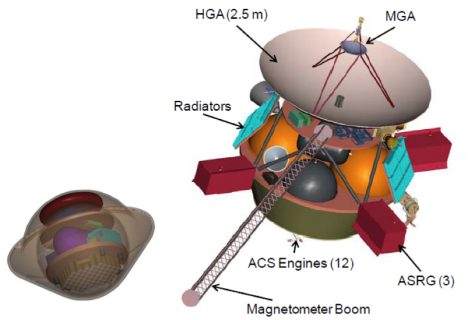
- Uranus and Neptune belong to a distinct class of planet: the Ice Giants
  - Small hydrogen envelopes
  - Dominated by heavier elements
  - The only class of planet that has never been explored in detail
- Orbiter to perform remote sensing of planet's atmosphere, magnetic field, rings, and satellites
- 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*





Uranus Orbiter/Probe No SEP

Uranus Orbiter with Entry Probe



Key Challenges:

- Demanding Entry Probe Mission
  - *High tempo operations just prior to UOI*
  - *Probe mass spectrometer*
  - *High probe deceleration environment at entry*
- Long Life for Orbiter
  - *Ensuring reliability and performance of ASRGs*
- System Power
  - *Low power margins for this phase*
- Mass Sensitivity to Trajectory Opportunities
- High Magnetic Cleanliness for Orbiter
  - *Demanding requirement to reduce SC noise to 0.1 nT background*

Scientific Objectives:

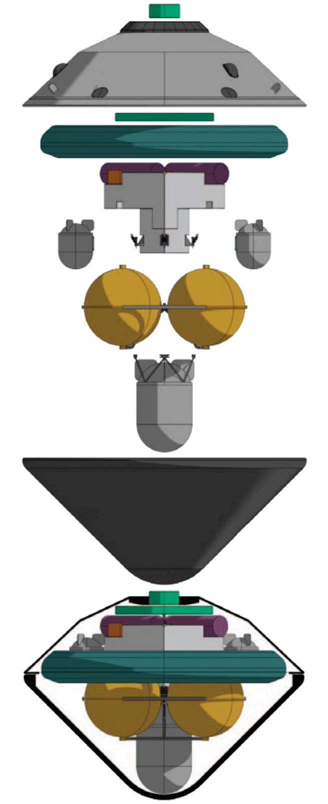
- Investigate the interior structure, atmosphere, and composition of Uranus
- Observe the Uranus satellite and ring systems
- Key science themes cited:
  - *Determine atmospheric zonal winds and structure*
  - *Understand Uranus' magnetosphere and interior dynamo*
  - *Determine noble gas abundances and isotopic ratios of H, C, N, and O within Uranus' atmosphere*
  - *Determine the internal mass distribution of Uranus*
  - *Determine horizontal distribution of atmospheric thermal emission*
  - *Observe Uranus' satellites*

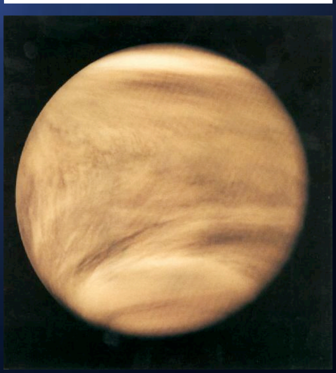
Key Parameters:

- Orbiter Payload (9 instruments)
  - *Wide and Narrow Angle Cameras*
  - *Vis/NIR Mapping Spectrometer, UV Imaging Spectrograph*
  - *Mid-Infrared Thermal Detector*
  - *Plasma Instruments(2), Magnetometer, Ultra-stable Oscillator*
- Entry Probe Payload (4 instruments)
  - *Mass Spectrometer*
  - *Atmospheric Structure Instrument, Nephelometer*
  - *Ultra-stable Oscillator*
- 3 Advanced Stirling Radioisotope Generators (ASRGs)
- Launch Mass: 2245 kg
- Launch Date: 2019 (on Atlas V 551)
- Orbit: 1.3 Ru x 51.3 Ru, 97.7 deg inclined orbit + Satellite tour

Flagship Priority 4/5: Venus Climate Mission

- Venus is distinctly different than Mars or Earth
  - Understand evolution of dense CO_2 atmosphere
  - Understand global climate of terrestrial planets
- Characterize the atmosphere
- 4 elements: Orbiter, balloon/gondola, mini-probe, sondes
- 21-day balloon life, delivers 45-min probe/sonde
- Detailed atmospheric structure





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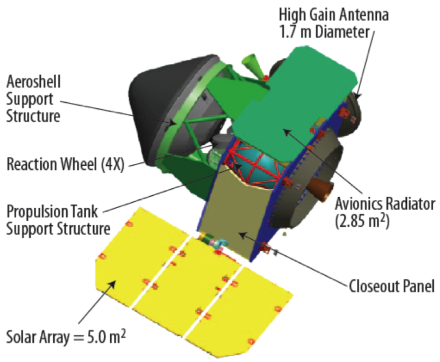
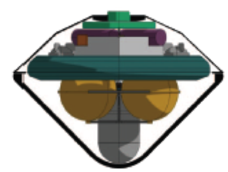
Venus Climate Mission (VCM)

VCM Carrier Spacecraft and Entry Flight System



Carrier Spacecraft


Entry Flight System (EFS)

Key Challenges:

- Multiple Element Communications Architecture
  - *Critical Mini-Probe/Dropsonde science data is relayed through Gondola/Balloon to Carrier to Earth*
  - *Mini-Probe must communicate with Balloon/Gondola during inflation process*
  - *Challenge to predict Gondola/Balloon location for reacquisition*
- High Tempo Operations Near VOI
  - *EFS entry 2 hrs post-VOI, Probe jettisoned minutes after entry*
- Time Elapsed Since Heritage System Development
  - *Study uses Pioneer Venus and Galileo Probe as basis for several estimates*
- Potential for Carrier Spacecraft Instrument Growth

Scientific Objectives:

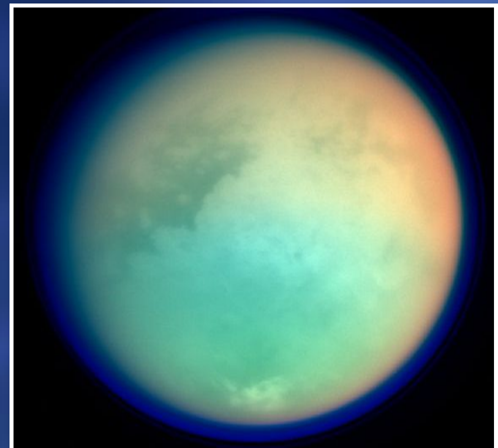
- Examine the Venus atmosphere
  - *Improve understanding of the current state and evolution of the strong CO_2 greenhouse climate*
- Improve our ability to model climate and global change on Earth-like planets
- Key science themes cited:
  - *Characterize the CO2 greenhouse atmosphere of Venus*
  - *Characterize the dynamics of Venus' superrotating atmosphere*
  - *Constrain surface/atmosphere chemical exchange*
  - *Determine origin of Venus' atmosphere*
  - *Understand implications for climate evolution of Earth*

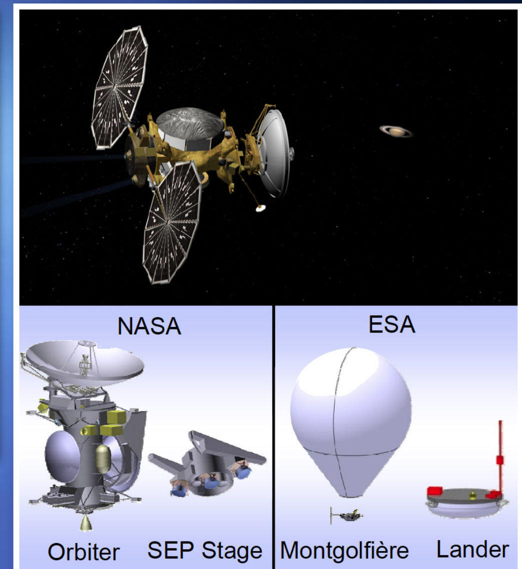
Key Parameters:

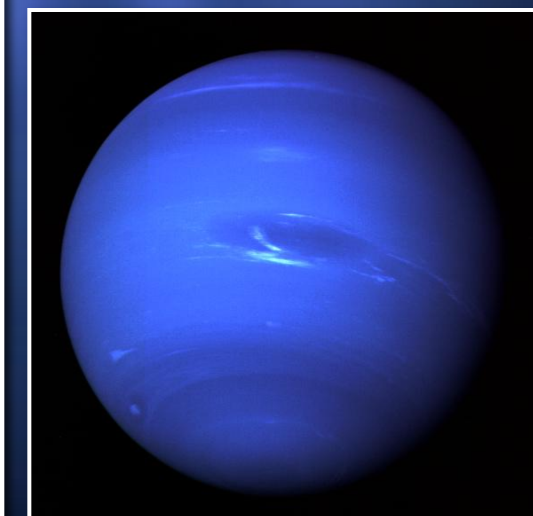
- Carrier Spacecraft
  - *Vis/IR Camera*
- Gondola/Balloon
  - *Atmospheric Structure Investigation, Nephelometer*
  - *Neutral Mass Spectrometer, Tunable Laser Spectrometer*
  - *Net Flux Radiometer*
- Mini-Probe (1) and Dropsondes (2)
  - *Atmospheric Structure Investigation, Net Flux Radiometer (All)*
  - *Neutral Mass Spectrometer (Mini-Probe only)*
- 5 m^2 gimbaled solar array on Carrier, batteries on probes
- Launch Mass: 3984 kg
- Launch Date: 2021 (on Atlas V 551)
- Carrier Orbit: 500 km x 66,300 km, Balloon Alt.: 55.5 km

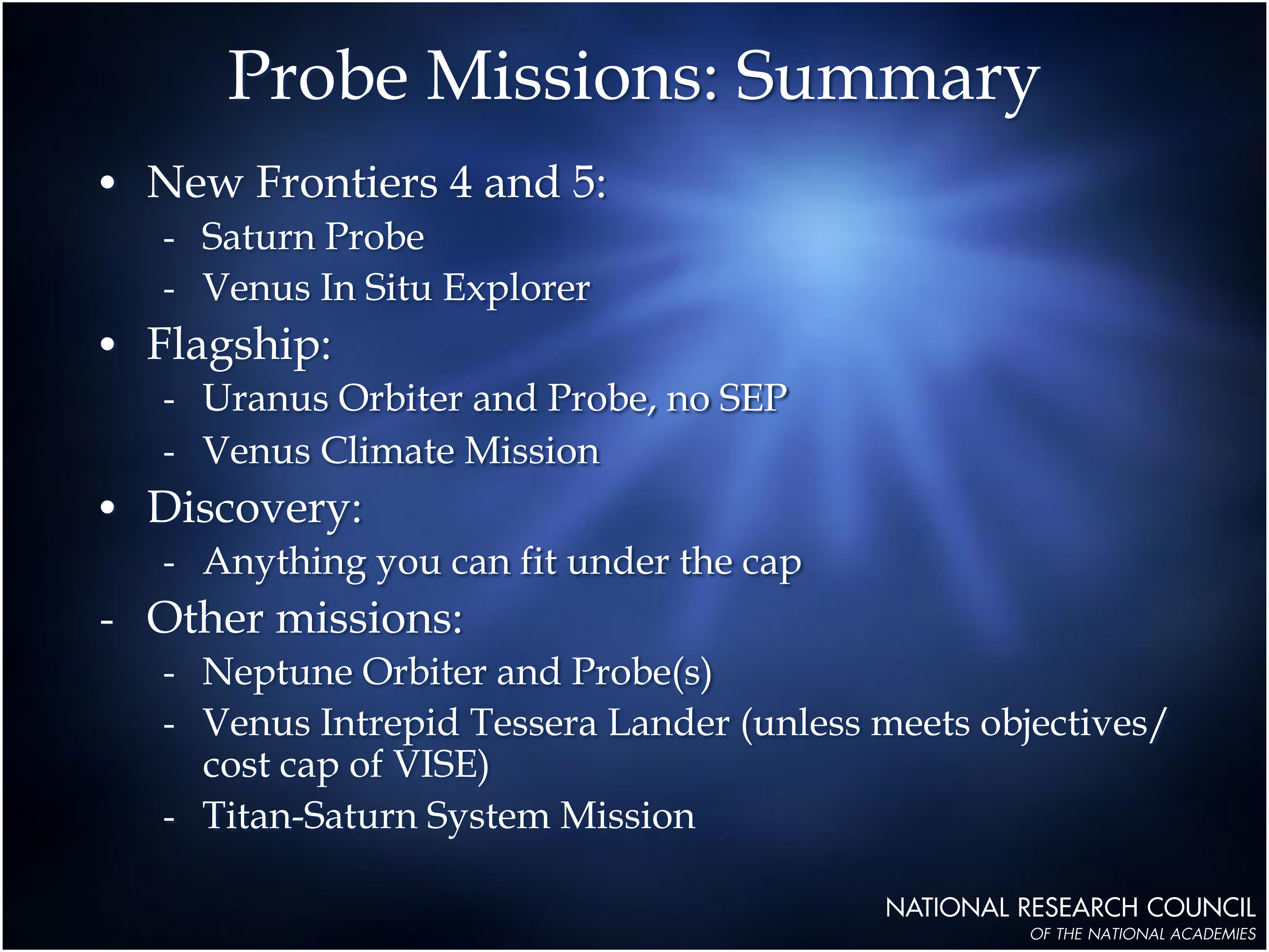
Technology Development Priorities

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








Probe Missions: Summary
• New Frontiers 4 and 5:
- Saturn Probe
- Venus In Situ Explorer
• Flagship:
- Uranus Orbiter and Probe, no SEP
- Venus Climate Mission
• Discovery:
- Anything you can fit under the cap
- Other missions:
- Neptune Orbiter and Probe(s)
- Venus Intrepid Tessera Lander (unless meets objectives/ cost cap of VISE)
- Titan-Saturn System Mission
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