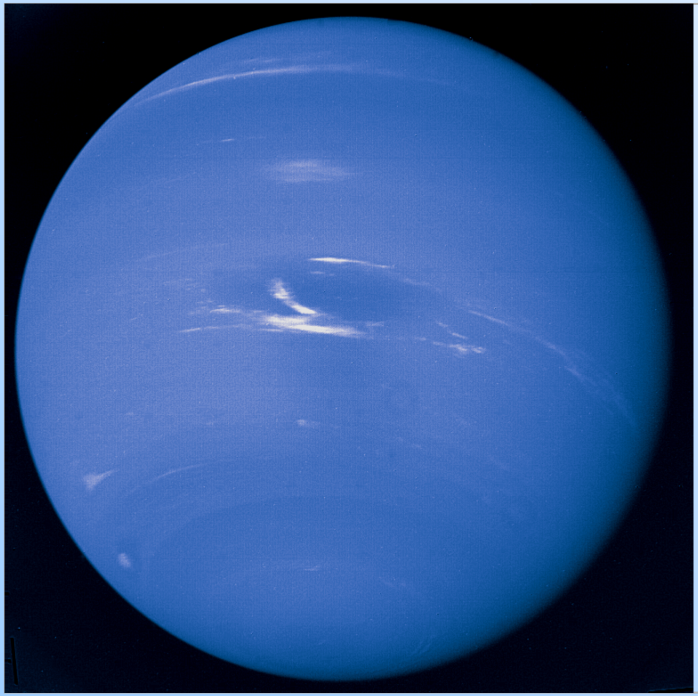
Aerocapture Implementation of NASA's "Neptune Orbiter With Probes" Vision Mission



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Outer Planets Assessment Group (OPAG)

Boulder, Colorado

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Technical Teams

–Science Team

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- Co-Investigators
  - Dr. Thomas R. Spilker, Study Lead
    - –Jet Propulsion Laboratory
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  - Dr. William D. Smythe
    - –Jet Propulsion Laboratory
  - Dr. Linda J. Spilker
    - –Jet Propulsion Laboratory
  - Dr. Richard E. Young
    - –NASA Ames Research Center

–Implementation Team

- Dr. Thomas R. Spilker
  - Study Lead, Mission Architect; JPL
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  - Systems Engineer
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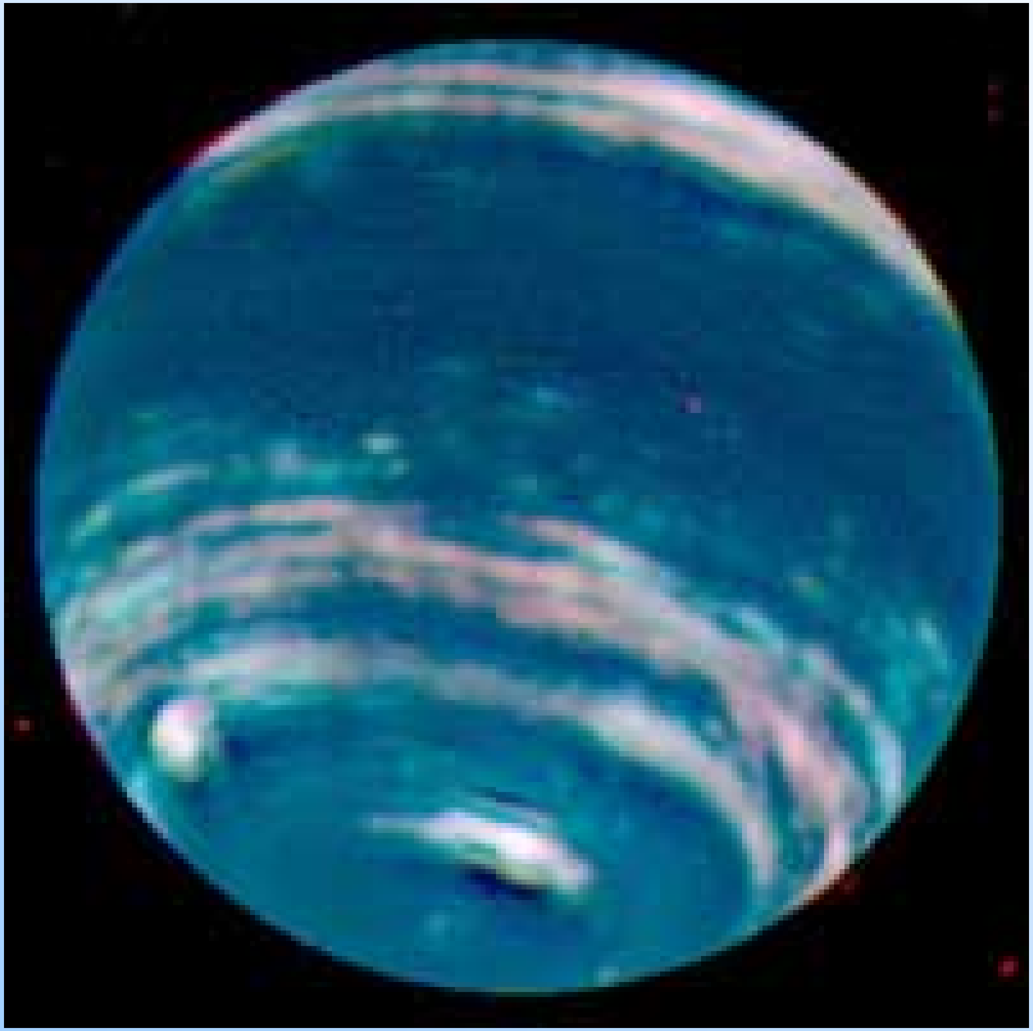
- Dr. Robert J. Haw
  - Transfer trajectory design
  - Jet Propulsion Laboratory
- Dr. Mary K. Lockwood
  - Aerocapture systems
  - NASA Langley Research center
- Dr. Bernard Laub
  - Aerocapture thermal protection
  - NASA Ames Research Center
- Dr. Robert N. Miyake
  - Spacecraft thermal systems
  - Jet Propulsion Laboratory
- Mr. Nathan J. Strange
  - Tour trajectory design
  - Jet Propulsion Laboratory
- Dr. Ethiraj Venkatapathy
  - Entry probe thermal protection
  - NASA Ames Research Center

Science Objectives: Why Study the Neptune System?

- Study the interior structure, composition, and atmospheric dynamics of an “ice giant,” with probes to 100 bars and orbiter remote sensing over 3-year orbital tour
- Investigate the surface, interior, and atmosphere of Triton, which may be a captured Kuiper Belt Object, with > 40 flybys (altitude < 1000 km) and possibly a Triton lander
- Observe the response of the magnetosphere to daily “pole on” orientation to the solar wind, with 3-year orbital tour
- Study Neptune’s unique ring arcs and associated moons over 3 year mission, with 3-year orbital tour

Neptune in 2003: Keck Telescope



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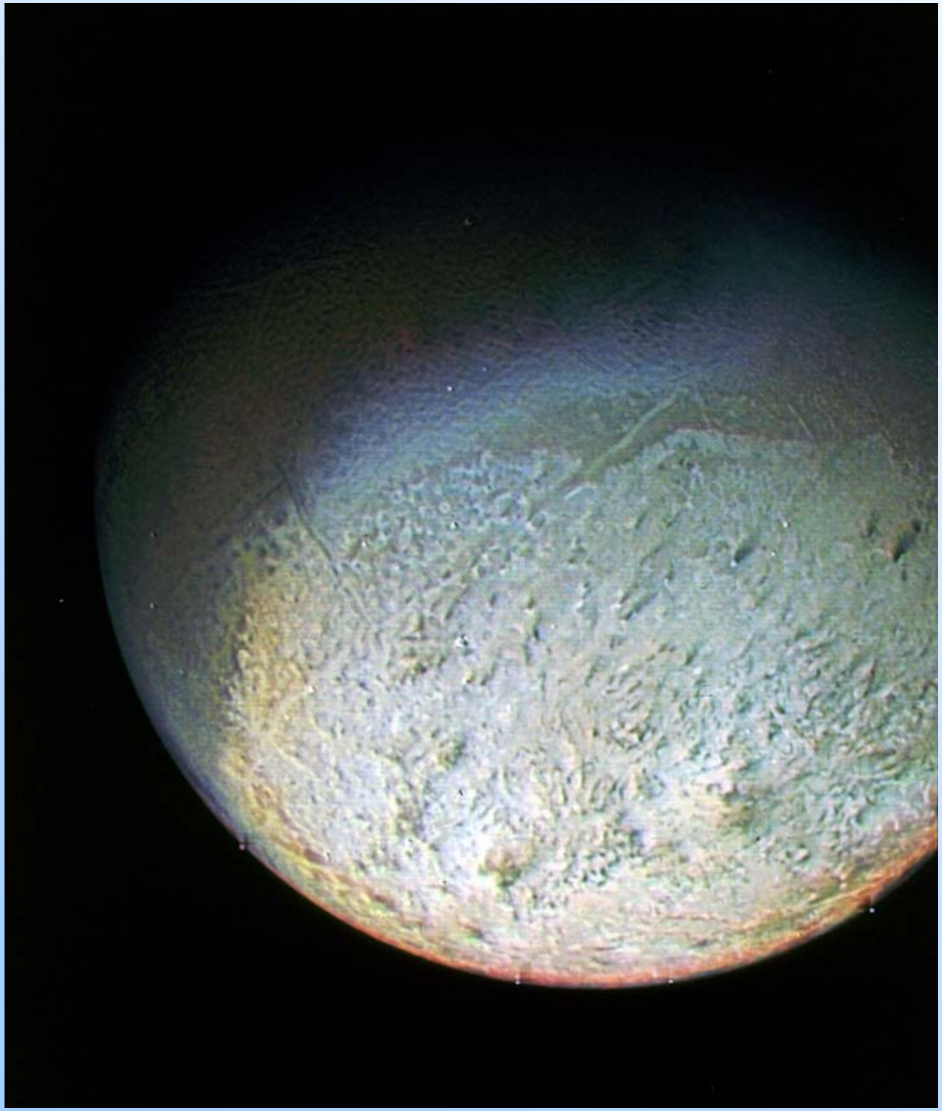
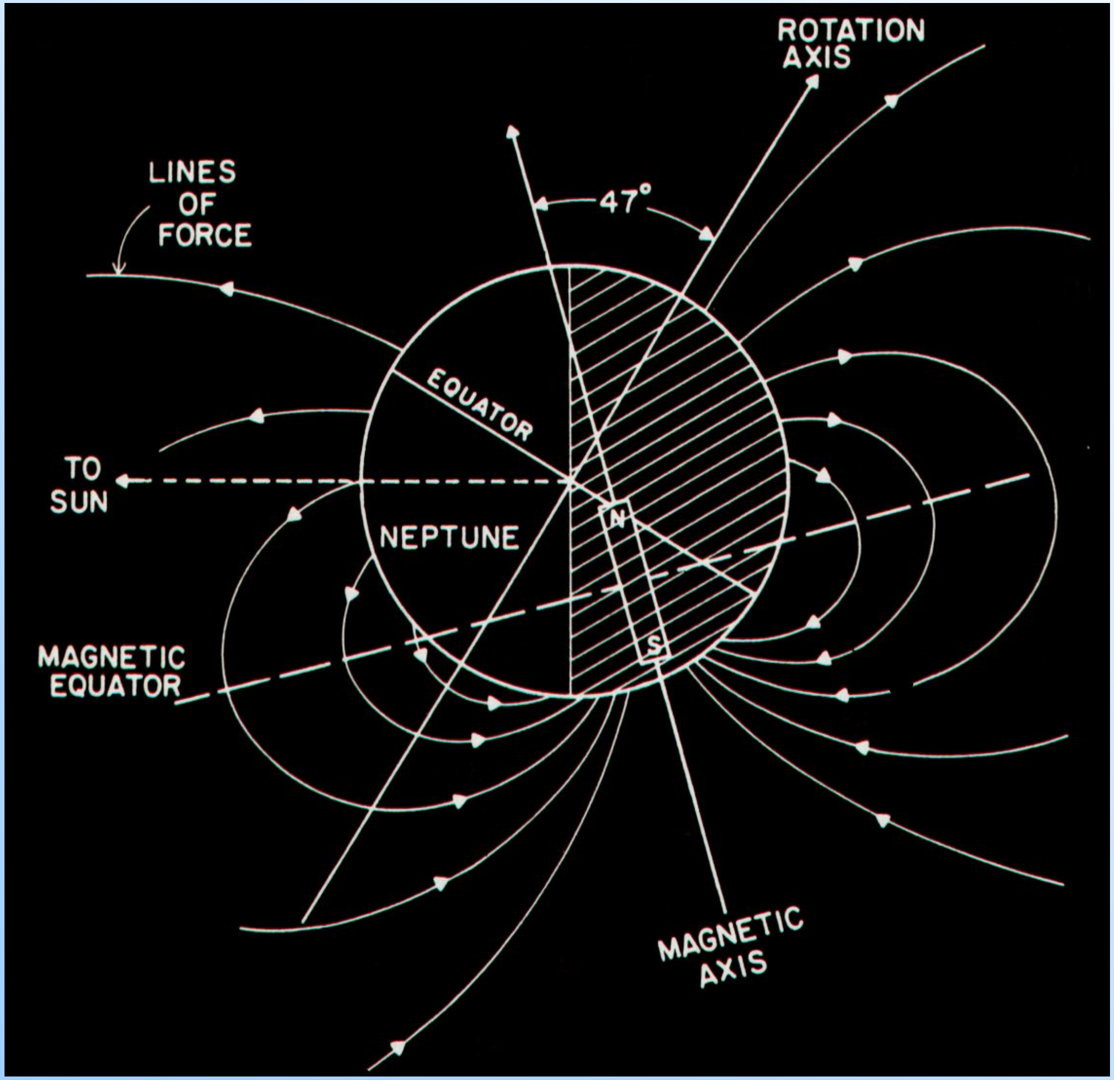
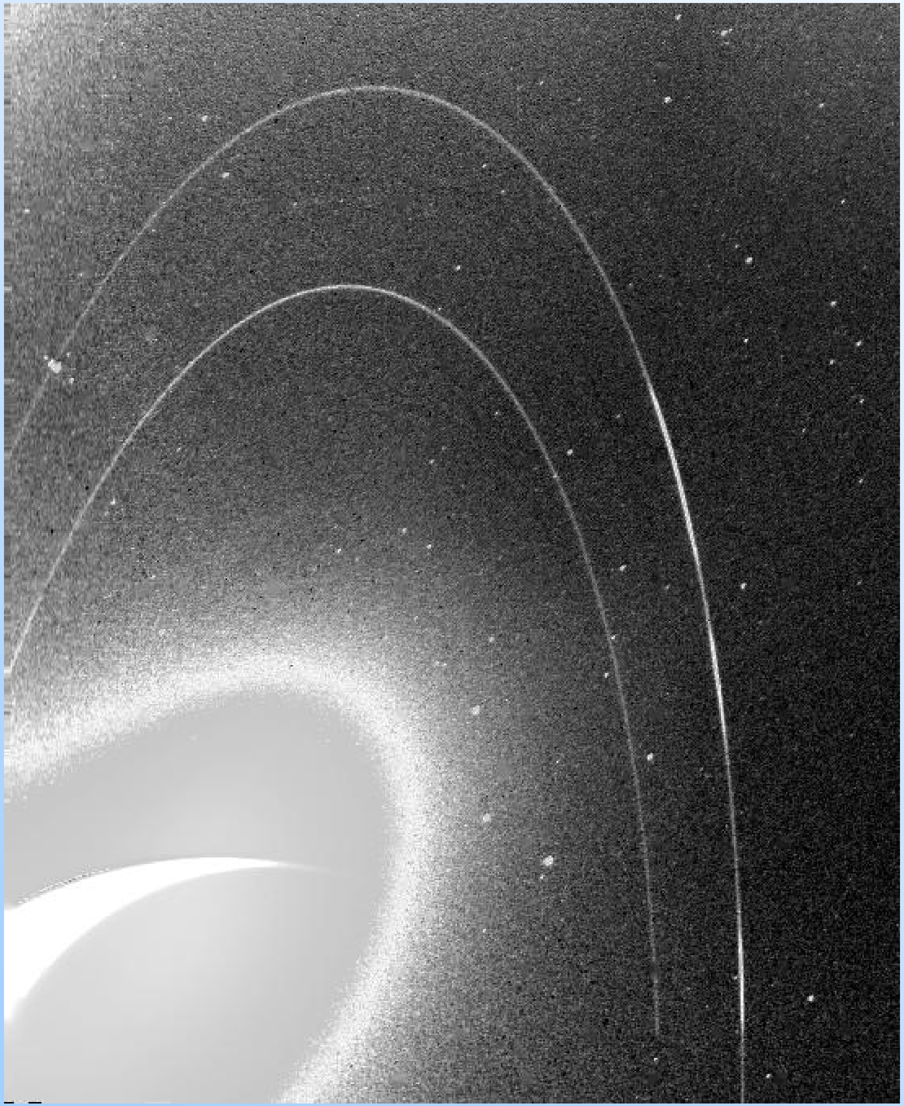
Voyager 2 View of Triton



Asymmetric Magnetic Field



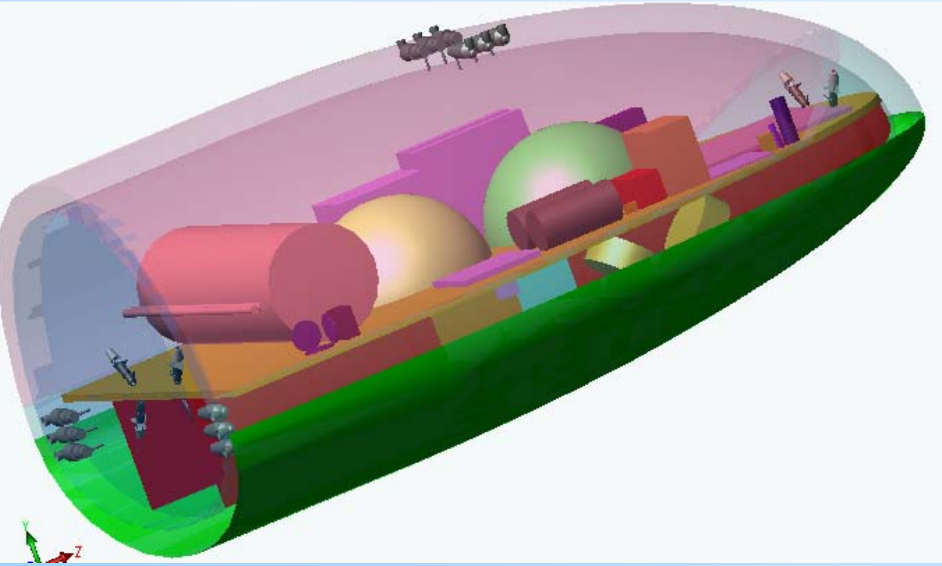
Rings and Ring Arcs

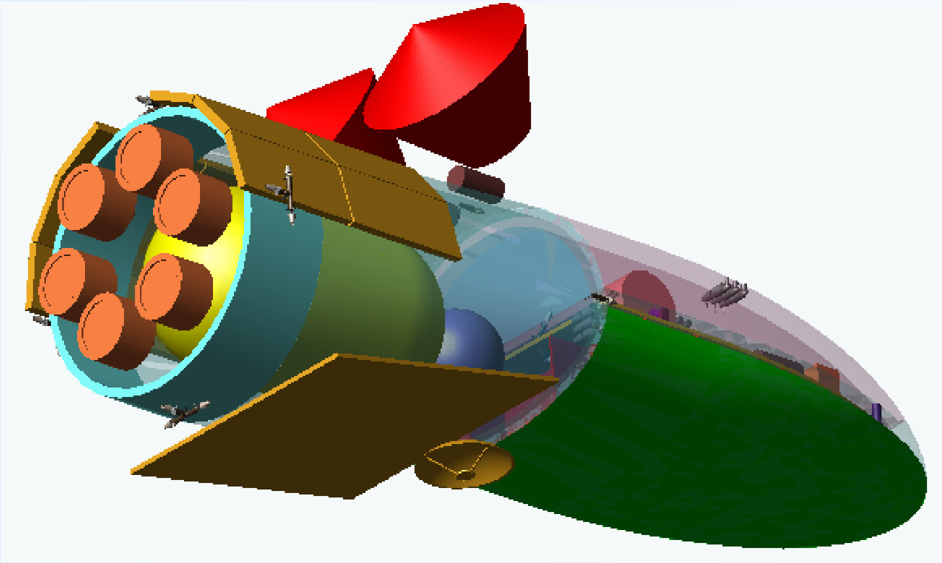


Mission Architecture

- Single launch with Delta IV-Heavy-class LV
- SEP or chemical propulsion, + gravity assists, to Jupiter; JGA to Neptune; total transfer time ~12 years or less
- Aerocapture insertion into Neptune orbit
  - Entry speeds from 23 to 32 km/s available
- At least 2 Neptune entry probes to at least 100 bar levels, deployed and supported (i.e., data relay) pre-aerocapture
- 3-year prime mission in Neptune orbit, powered by RTGs; extended mission possible
- At least 40 close (<1000 km) Triton flybys during prime mission for Triton science and orbit evolution; Triton lander is possible.
- Ka-band radio for primary downlink
  - 10 terabits data volume with Next Gen DSN

Flight System





Aerocapture System Analysis Team orbiter and "Ellipsled" design

Ellipsled and SEP stage, with cruise HGA, entry probes, and probe data relay antenna

Mission Design: Transfer to Neptune

- *Example* SEP launch option
  - Launch Feb 2017 on a Delta 4050H-19, $C_3 = 12.5$
  - S/C launch mass, 6250 kg, yields 800 kg launch margin
  - Arr Aug 2029; 1900 kg (dry) delivered to Neptune orbit
- *Example* Chem launch option
  - Launch Dec 2015 on a Delta 4050H-19, $C_3 = 28$
  - S/C launch mass, 4780 kg, yields 420 kg launch margin
  - Arr Aug 2029; 1900 kg (dry) delivered to Neptune orbit
- SEP system 30-40 kW, 5-6 NEXT thrusters
  - Dry mass slightly over 1300 kg
- Small (260 kg) carrier stage for chem option
  - 10 terabits data volume with Next Gen DSN

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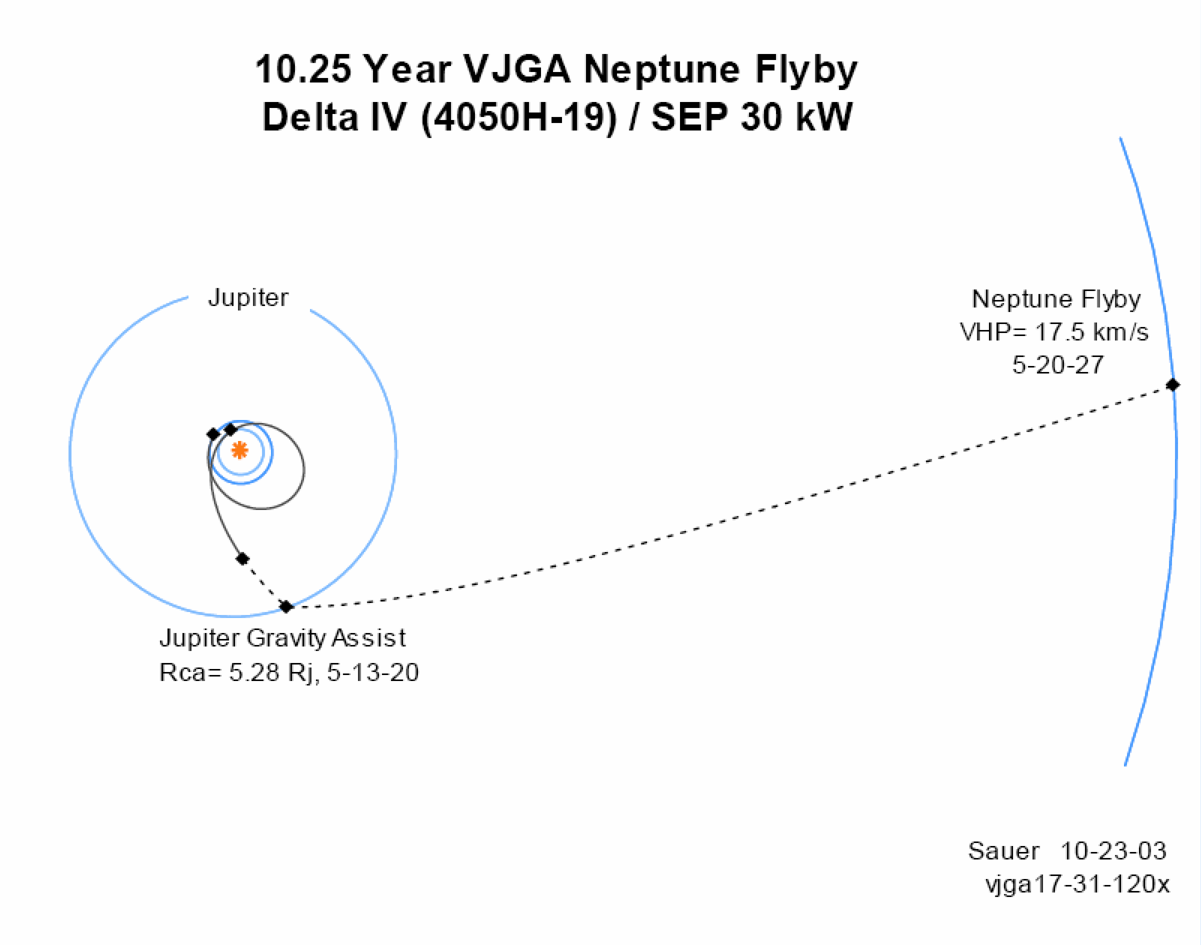
Example Transfer to Neptune

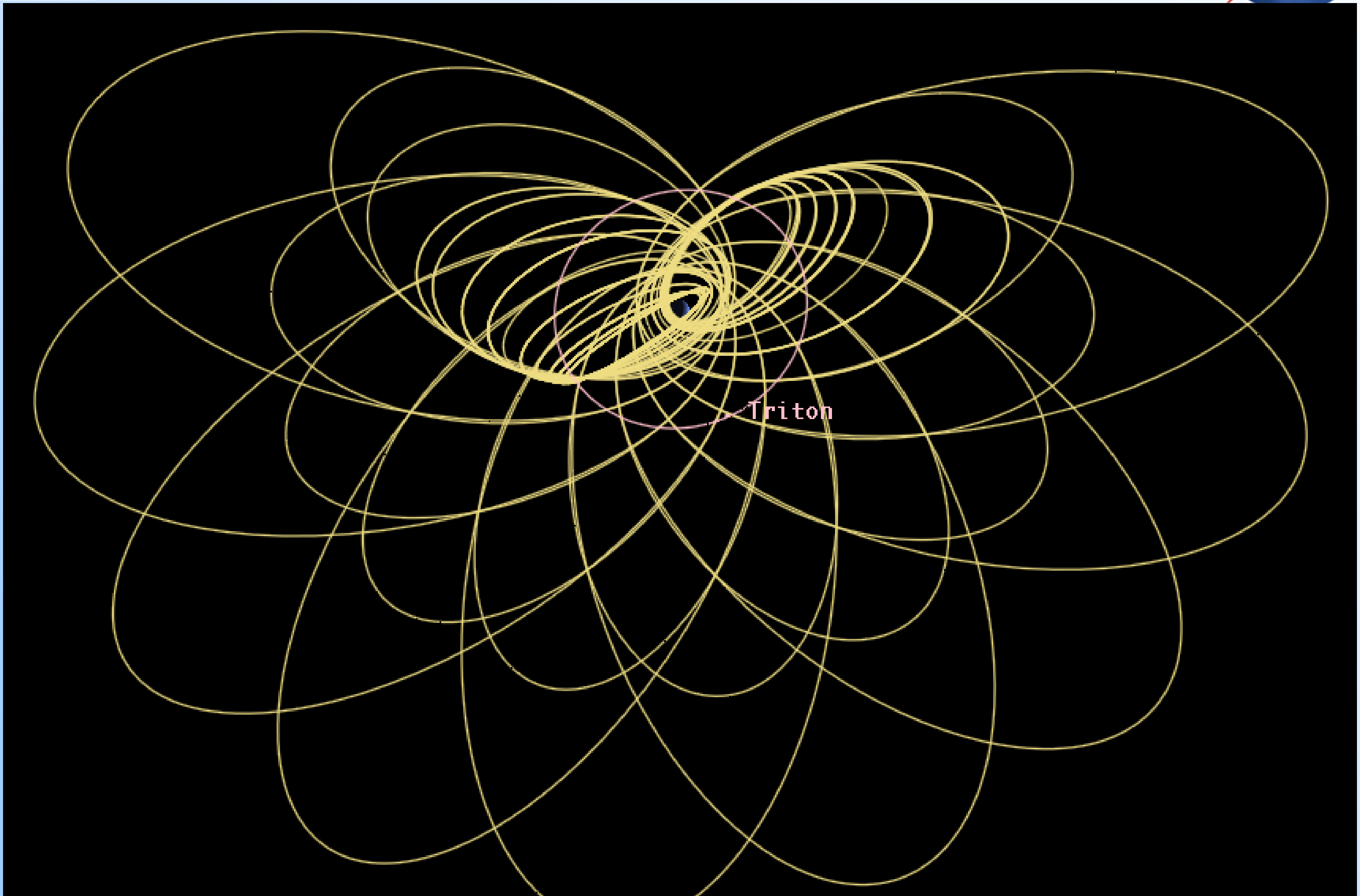


- 10.25-year transfer uses SEP and a Venus gravity assist
- Entry speed 26.7 km/s prograde, 31.7 km/s retrograde

Mission Design: Neptune System Tour

- Tour begins after aerocapture exit cleanup maneuver
- Science investigations require observing Neptune, its rings, and its magnetosphere from a wide range of radial distances, solar phase angles, longitudes, latitudes, and inclinations
- Close flybys (<1000 km altitude) of Triton to study atmosphere, surface, interior (magnetic field and moment of inertia); flybys provide gravity assists to alter the spacecraft's orbit around Neptune
- *Fully integrated* example tour design demonstrates ability to fulfill science requirements within 2 years
- 3-year prime mission yields flexibility in the tour design
- Cassini mission is demonstrating the operations processes needed (e.g., quick post-flyby nav solutions and maneuver design)

Mission Design: Neptune System Tour (Sun is to the right)



Enabling Technologies

- Aerocapture systems and software: thermal protection system (TPS) materials; autonomous guidance, navigation, and control; aeroshell simulation and ground test facilities; sensors and actuators
- Aerocapture flight demonstration - next opportunity is New Millennium Program's ST-9
- Entry probe TPS, pressure vessels, and thermal insulation
- Advanced radioisotope thermoelectric generators (RTG)

Greatly Enhancing Technologies

- Large, multi-engine solar electric propulsion (SEP) systems
- Advanced DSN ground stations for high data volumes

SSE Decadal Survey 2003: Primary Recommendations on Infrastructure (1)

- We recommend that NASA commit to significant new investment in **advanced technology** in order that future high-priority flight missions can succeed..

•Power: Advanced RTGs
•Power: In–space Nuclear power source
•Propulsion: Nuclear--powered electric propulsion
•Propulsion: Advanced electric engines
•Propulsion: Aerocapture
•Communications: Ka band
•Communications: Optical
•Architecture: Autonomy
•Avionics: Advanced packaging and miniaturization
•Instrumentation: Miniaturization
•Entry to landing: Autonomous entry, precision landing
•In-situ ops: Sample gathering, handling and analysis
•In-situ ops: Instrumentation
•Mobility: Autonomy
•Contamination: Forward-contamination avoidance
•Earth return: Ascent vehicles

Backup Slides

API's Opinions on Broader Issues

Agree on a message - the SSE Decadal Survey

If you repeat it, they will come

Support Discovery, New Frontiers, consensus-building toward Flagships - the Great Observatories model

Beware of entitlements, creeping science requirements, special deals on spacecraft, lobbying, earmarking

If Congress thinks we are pork, we will be eaten

SSE Decadal Survey: Mission Priority by Panel

Panel	Mission Concept Name	Cost Class
Inner Planets		
	Venus In-Situ Explorer	Medium
	South Pole-Aitken Basin Sample Return	Medium
	Terrestrial Planet Geophysical Network	Medium
	Venus Sample Return	Large
	Mercury Sample Return	Large
	Discovery Missions	Small
Primitive Bodies		
	Kuiper Belt-Pluto Explorer	Medium
	Comet Surface Sample Return	Medium
	Trojan/Centaur Reconaissance Flyby	Medium
	Asteroid Rover/Sample Return	Medium
	Comet Cryogenic Sample Return	Large
	Discovery Missions	Small
Giant Planets		
	Cassini Extended Mission	Small
	Jupiter Polar Orbiter with Probes	Medium
	Neptune Orbiter with Probes	Large
	Saturn Ring Observer	Large
	Uranus Orbiter with Probes	Large
	Discovery Missions	Small
Large Satellites		
	Europa Geophysical Explorer	Large
	Europa Lander	Large
	Titan Explorer	Large
	Neptune Orbiter/Triton Explorer	Large
	Io Observer	Medium
	Ganymede Orbiter	Medium
	Discovery Missions	Small
Mars		
	Mars Sample Return	Large
	Mars Smart Lander	Medium
	Mars Long-Lived Lander Network	Medium
	Mars Upper Atmosphere Orbiter	Small
	Mars Scouts	Small

- Missions listed in Priority Order
- Missions in bold face were selected by the Steering Group for overall prioritization

SRM 3 - The SSE Strategic Roadmap

Roadmap Requirements - Technology

Note: Protection systems includes thermal protection systems during hypervelocity entry

Technology and Advanced Development Area
Deep Space Power Generation
Radioisotope Power (thermoelectric)
Radioisotope Power (Stirling, SRG)
Solar Power Generation
Deep Space Transportation
Solar Electric Propulsion -
Aerocapture
Advanced Chemical
Deep Space Telecommunications
Direct to Earth
Proximity (Relay) Communications
Extreme Environments
Protection Systems
Component hardening
Operational Resilience
Planetary Protection
Forward Protection
Backward Protection
Systems Analysis
Science Instruments
Remote Sensing
In situ Sensing

SSE Decadal Survey 2003: Mission Priorities

- *Small Class (<$325M)*

  1. Discovery missions at one launch every 18 months
  2. Cassini Extended mission (CASx)

- *Medium Class (<$650M) – New Frontiers*

  1. Kuiper Belt/Pluto (KBP)
  2. South Pole Aitken Basin Sample Return (SPA-SR)
  3. Jupiter Polar Orbiter with Probes (JPOP)
  4. Venus In-situ Explorer (VISE)
  5. Comet Surface Sample Return (CSSR)

- *Large Class (>$650M)*

  1. Europa Geophysical Explorer (EGE)

Priorities for New Ground-Based Activities

Enter an equal partnership with NSF to build and operate a

- Large-aperture Synoptic Survey Telescope (LSST)