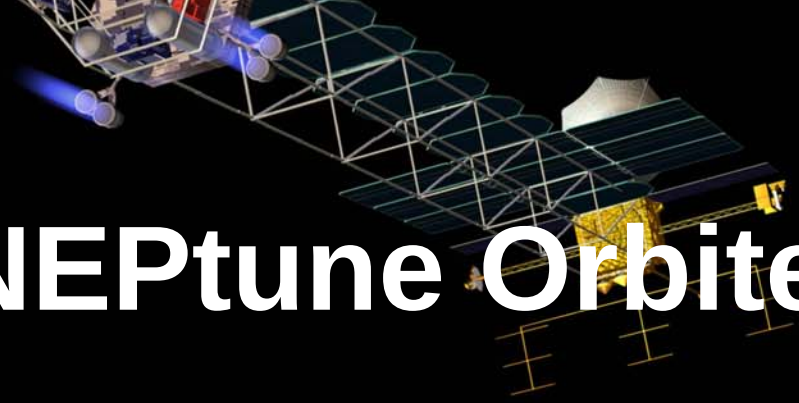
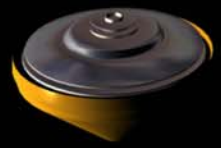


NEPtune Orbiter with Probes

10 June 2005



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Leora Peltz

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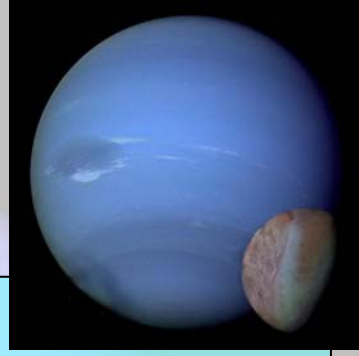
Harv Willenberg

Steve Sichi
Dave Smith

Why Explore the Giant Planets?



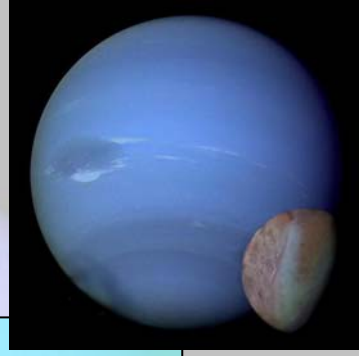
Solar System Studies

- The Giant Planets had significant influence on the early history, evolution, development of the solar system: Thought to have deflected icy planetesimals containing water and other volatiles to inner solar system from region of Neptune. Detailed comparisons of internal structures and compositions of gas giants with ice giants will yield valuable insights into processes that formed the solar system.

- Comparative planetology of deep well-mixed atmospheres of the Outer Planets is key to the origin and evolution of the solar system. (Atreya, Outer Planets Forum, Pasadena, June 2004)

- Comparison between Ice Giants and Gas Giants cannot proceed until our understanding of Ice Giant systems is at the level of Gas Giants.

Why Explore the Giant Planets?



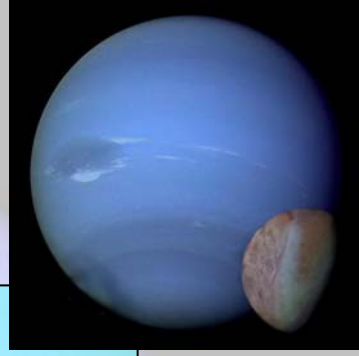
Extra Solar Planetary Studies

- **The Giant Planets provide context / initial point of comparison and understanding of extrasolar Giant Planets.**
- **Rings around the Giant Planets are the closest analog in our solar system to circumstellar disks from which planets form.**

References

1. Ingersoll, A.P., H.B. Hammel, T.R. Spilker, and R.E. Young, "Outer Planets: The Ice Giants", 2005
2. Hammel, H.B., A.P. Ingersoll, T.R. Spilker, and R.E. Young, "Interdisciplinary Program for Ice Giant Systems", 2004

Exploration of the Giant Planets
Gas Giants and Ice Giants

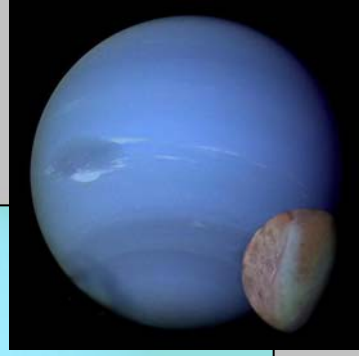


Background

Extensive studies of the two Gas Giants Jupiter and Saturn have been conducted, but only "snapshot studies" of the Ice Giants.

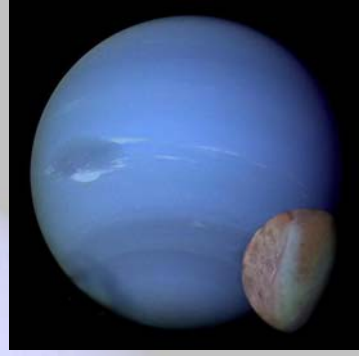
- **Jupiter**
  - **Galileo: 8 years: Dec 1995 --> Sept 2003**
  - **Flybys: Pioneer, Voyager, Ulysses and Cassini**
- **Saturn**
  - **Cassini: 1 year, continuing for many years**
  - **Flybys: Pioneer, Voyager**
- **Uranus**
  - **Voyager 2 flyby on 24 Jan 1986**
- **Neptune**
  - **Voyager 2 flyby on 25 Aug 1989**

Ice Giants: Key Scientific Questions



- Atmospheric Dynamics and Structure
  - Energy source
  - Depth of zonal structure, latitudinal variations
  - Similarities / differences between Ice Giants and Gas Giants; between Uranus and Neptune
- Atmospheric Chemistry
  - Composition as function of altitude
  - Composition of bright and dark features
- Planetary Interiors and Magnetic Fields
  - Asymmetry of magnetic fields (relative to Gas Giants)
  - Source and stability of magnetic fields
- Rings and Icy Satellites
  - Stability of ring arcs; resonant model
  - Composition
  - Triton's N2 atmosphere, origin, structure, stability, evolution
  - Similarities with KBOs

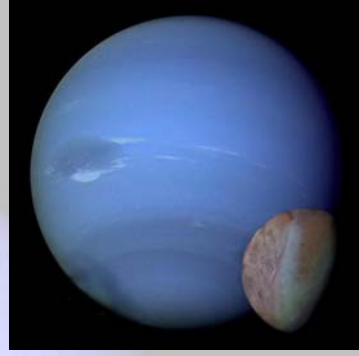
Why Neptune?
- General Science -



Rich scientific return and connections to astrophysical problems beyond the solar system, including

- Atmospheric structure & dynamics (e.g., atmospheric dynamics of distant, rapidly spinning planets with a “bottomless atmosphere”)
- Triton as KBO / “icy time capsule” of dynamical and chemical processes in early solar system
- Ring arcs - unique among rings in solar system (comparative ringology); rings are best analog for initiation of solar system formation from circumstellar disk
- Orientation of magnetic field provides opportunity to study diurnal forcing of magnetosphere (once per day)

Why Neptune?
-Triton-

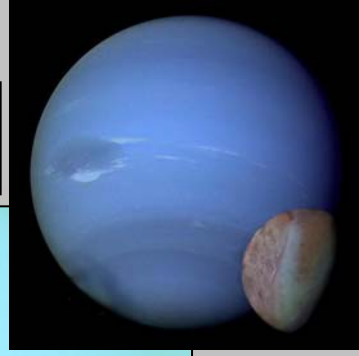


- Triton as captured KBO - low altitude flybys and lander(s) possibly provide best means for long term studies of a KBO
- Pluto - Triton comparative planetology
- Triton - Titan comparative planetology
- Origin of N2 atmospheres (Triton at 35 °K vs. Titan)
- Dynamics and structure of tenuous atmospheres
- Geysers / solid state greenhouse
- Possible prebiotic chemistries
- Other icy and irregular satellites as possible captured KBOs

References

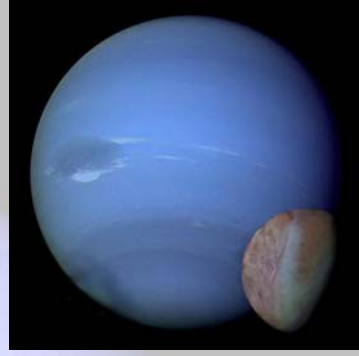
1. NASA (1999) Exploration of the Solar System: Science and Mission Strategy
2. Porco, C. C. (1998) Report of the NASA SSES Astrophysical Analogs Campaign Strategy Working Group

NEPtune Science Goals and Objectives



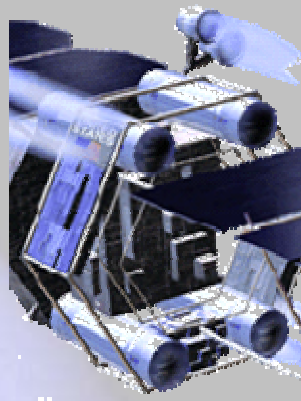
- **Origin and Evolution of Ice Giants** Neptune atmospheric elemental ratios relative to hydrogen (C, S, He, Ne, Ar, Kr, Xe) and key isotopic ratios (e.g., D/H, $^{15}N/^{14}N$), gravity and magnetic fields. [Probes, Orbiter]
- **Planetary Processes** Global circulation, dynamics, meteorology, and chemistry. Winds (Doppler and cloud track), trace gas profiles (e.g., PH_3, CO, ortho / para hydrogen); cloud structure, microphysics, and evolution; photochemistry and tracers of thermochemistry (e.g., disequillibirum species). [Probes, Orbiter]
- **Triton** Origin, plumes, atmospheric composition and structure, surface composition, internal structure, and geological processes [Orbiter, Lander]
- **Rings** Origin / evolution, structure (waves, microphysical, composition, etc.) [Orbiter]
- **Magnetospheric and Plasma Processes** [Orbiter]
- **Icy Satellites** Origin, evolution, surface composition and geology [Orbiter]

NEPtune Mission Overview



- Use of NEP (nuclear electric propulsion) to support a large payload mass and provide adequate power for high-data rate return and simultaneous operation of all orbiter instruments
- Jupiter flyby 4 years after launch reduces total transit time to 12.9 years
- First probe separated at 62 days prior to entry, followed by orbiter deflection maneuver
- Second deflection maneuver required to release second probe
- 5 hour descent missions for both probes
- Transfer to Triton lander release orbit and long duration Triton observation period

NEPtune Orbiter
Candidate Science Payload



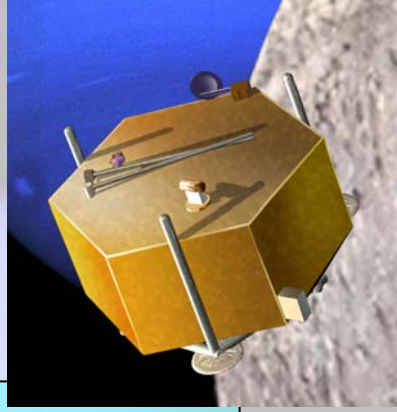
- High resolution UV spectrometer
- High resolution IR spectrometer
- IR spectral imager
- High resolution camera
- Ion/neutral mass spectrometer
- Ka/X/S-band radio science
- Plasma wave instrument

- Magnetometer
- Bolometer array
- Microwave radiometer
- Uplink radio science
- Laser altimeter
- Bistatic radar
- Penetrating radar

NEPtune Probe
Candidate Science Payload

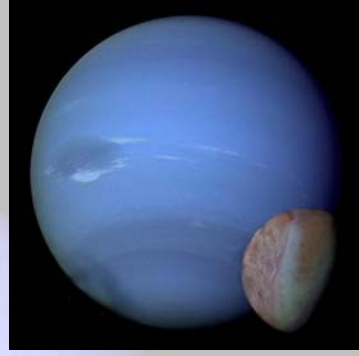
- Gas Chromatograph / Mass Spectrometer (GCMS)
  - Composition profiles, noble gases, isotopic ratios, hydrocarbons
- Atmospheric Structure Instrument (ASI)
  - P / T profiles; acceleration measurements in upper atmosphere → density
- Net Flux Radiometer (NFR)
  - Radiative balance
- Nephelometer
  - Cloud particle size, density, microphysics
- Helium Abundance Detector
- Doppler Wind Experiment (DWE)
- Analog Resistance Ablation Detector (ARAD)
- Ortho / Para H_2 detector
- Lightning detector

NEPtune Triton Lander Candidate Science Instruments



- Surface Science Package including
  - Physical properties instrument (density, electrical & thermal properties)
  - Color panoramic camera
  - Surface sampling device
  - Seismometer
  - Near IR Spectrometer
- Gas Chromatograph / Mass Spectrometer (atmosphere and surface composition)
- Atmospheric Structure Instrument (pressure and temperature during descent and on surface)

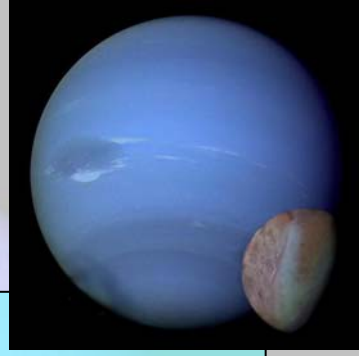
NEPtune Mass Summary



Mission Element	Mass (kg)
Orbiter	
Science	171.1
Spacecraft	N/A*
Probe #1	300.0
Science	19.4
Other	280.6
Probe #2	300.0
Science	19.4
Other	280.6
Lander	500.0
Science	23.2
Other	476.8
Summary	
Total Payload Mass Available	1500.0
Total Payload Mass (CBE)	1271.1
Margin (kg)	228.9
Margin (%)	15.3%
Total Science Mass	233.1

* Orbiter mass is out of scope for this study

NEPtune Mission Description



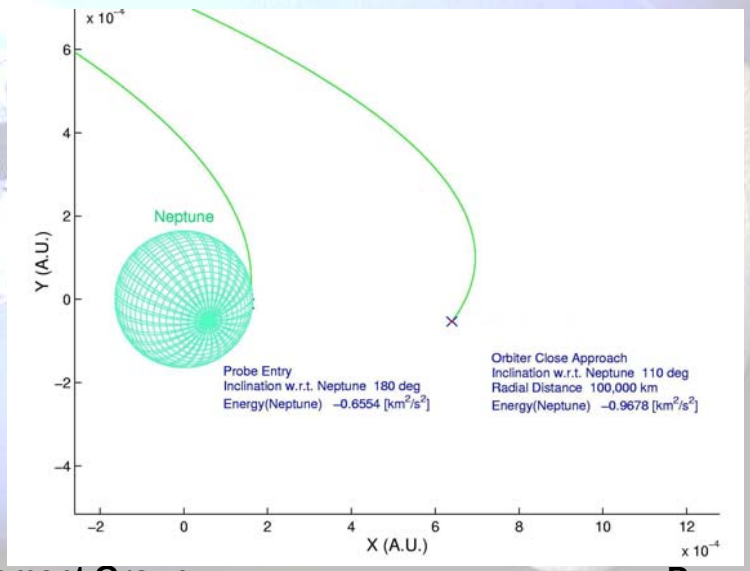
Orbiter Mission Summary

Trajectory Type	Jupiter Gravity Assist to Neptune Capture
Power (kW)	200
Isp (sec)	7500
Efficiency	75%
Initial C_3 (km^2/s^2)	10
Initial Mass (kg)	36,000
Minimum Jupiter Flyby Radius	$5R_j$

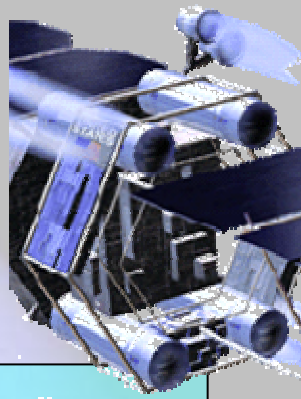
- **Launch in Jan 2016**
- **Jupiter flyby in 2020**
- **Probe Entries in Jan & July 2029**
- **Probe #1 on prograde entry**
- **Probe #2 on retrograde entry**
- **Probe data return for 5 hours after entry**
- **Triton Orbit in Oct 2033**
- **Lander released following Triton orbit**

Probes Mission Summary

Parameter	Probe #1	Probe #2
Altitude at Entry (km)	1000	1000
Entry Flight Path Angle	- 40°	- 45°
Probe-Orbiter Aspect Angle at Entry	10°	32°
Aspect Angle at Entry + 5 hrs	17°	35°
Maximum Aspect Angle	36°	44°
Max Range to Orbiter (km)	355,000	500,000
Latitude at Entry	1.3°	70°



NEPtune Orbiter Technology Development Needs

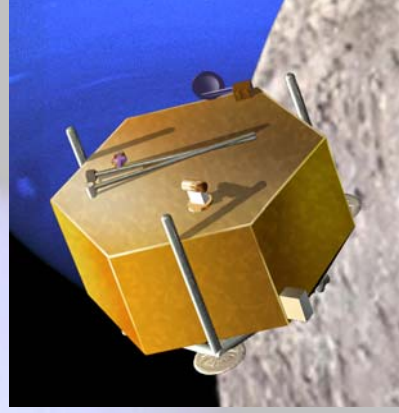


- Electric propulsion capability for continuous, long duration thrusting
- Mission design to support Orbiter science, multiple Probe / Lander targeting, separation, and telemetry links
- Launch vehicle strategy for heavy lift or on-orbit spacecraft assembly
- Development of lunar ISRU capability for launch from lunar base
- Shielding techniques to protect sensitive electronics from high radiation levels of nuclear reactor

NEPtune Probe Technology Development Needs

- Thermal protection system (TPS) and test facilities for 25 km/s Neptune entry condition
- Staging system to separate pressure vessel from deceleration module
- Pressure vessel design to maintain internal environment over 20+ year mission duration
- Probe penetration design for multiple windows and inlets
- High power / high efficiency transmitter and communications strategy for transmission through absorbing Neptune atmosphere
- Probe antenna for low frequency relay link from deep atmosphere
- High density battery design for operation after long transit period during 5 hour descent period
- Thermal design to maintain internal environment to acceptance limits for all electronics and mechanical systems

NEPtune Lander Technology Development Needs



- Thermal design to maintain internal lander temperatures within acceptance limits on the 35 °K Triton surface
- Active, propulsion and landing systems to target specific landing site
- Lander antenna to maintain link with Orbiter
- Surface sampling system to access uncontaminated Triton surface
- Drill to access subsurface material