THE CASE FOR A NEPTUNE ORBITER/MULTI-PROBE MISSION. H. B. Hammel[1], C. C. Porco[2], and K. Rages[3] [1]Space Science Institute (CT Office, 72 Sarah Bishop Road, Ridgefield, CT, 06877, hbh@alum.mit.edu), [2]University of Arizona (LPL, Tucson, AZ, 85721, carolyn@raven.lpl.arizona.edu), [3]Space Physics Research Institute (NASA/Ames, MS 245-3, Moffett Field, CA, 94035-1000, krages@mail.arc.nasa.gov).

Introduction: We propose a mission to the Neptune system comprised of an orbiter with a Neptune atmospheric multi-probe. NASA's Solar System Exploration theme listed a Neptune mission as one of its top priorities for the mid-term (2008-2013) [1]. A recent NASA study also gave it top ranking for rich scientific return and connections to astrophysical problems outside the Solar System (atmospheric structure and dynamics; geology; ring systems/dynamics; magnetic fields/dynamos; pre-biotic chemistry on Triton; local extrasolar planet analog), calling it "almost Cassini-like in scope, near Discovery-like in cost" [2].

Neptune: In spite of (perhaps due to) Voyager's success at Neptune [3] and subsequent studies with HST [4], many questions about Neptune remain unanswered. *Atmospheric dynamics and structure.* What powers the winds, and why are the winds and thermal structure similar to those of Uranus, though the internal heat sources differ? How deep does the zonal structure go? Need: visible imaging and thermal mapping at various phase angles with scales down to 10 km; occultations of radio telemetry signals to probe atmosphere down to ~2 bar. *Atmospheric chemistry.* What is the composition of discrete features (bright and dark), and of the atmosphere as a function of altitude? Need: UV occultations to measure density, scale height, temperature and composition; compositional mapping at near-IR wavelengths. *Planetary interior and magnetic field environs.* Why are the magnetic fields much more asymmetric in ice giants than in gas giants? Need: measurements of magnetic field and magnetospheric particles at a variety of latitudes and longitudes.

Triton: Short of exploring Pluto, exploring Triton may provide our best opportunity to examine the surface and atmosphere of a Kuiper Belt Object analog. *Atmospheric structure and composition.* What is Triton's atmospheric composition and structure, and how has it changed since Voyager [5]? Need: radio occultations for atmospheric size/structure; high phase and high-res (100-300 m) limb imaging for hazes/plumes; UV occultations (density, scale height, temperature, composition); atmospheric sampling (fly-through). *Surface geology and composition.* Is there evidence for "recent" solid-state convective activity in an icy mantle? How does composition vary between/within surface features? What causes geologic structures on Triton's surface? Has the geyser distribution [3] changed since Voyager? Have atmospheric changes modified the surface? Need: UV to near-IR global imaging (<100 m); high-res imaging (10-30 m) of selected locales; thermal (50 and 100 μm) mapping; global 1-km imaging spectroscopy at 1-5 μm with $\lambda/\delta\lambda$=300.

Rings and small satellites: Are the ring arcs of Neptune a "major ring system waiting to happen"? Is a resonant model for arc stability correct? If not, how do arcs remain stable? Do Neptune's inner satellites show the effect of extreme tidal stress? Need: low-phase 100-m scale imaging of arcs to find embedded bodies; high-phase 1-km scale imaging to detect new rings/arcs and to characterize ring/arc morphology; spectroscopic capability to determine composition.

Neptune orbiter: The orbiter is the core of the mission, providing a remote sensing platform, *in situ* probes of the magnetic field and environs, and primary data links. A integrated imaging package would include: visible imager, IR imaging spectrometer, and UV imaging spectrometer. Other remote sensing devices are a thermal IR spectrometer and a microwave radiometer. Space physics detectors might include a magnetometer (and perhaps other instruments). Radio science instruments would also be necessary.

Atmospheric multi-probe: Multi-probes are an essential part of an investigation of the deep (~100 bar) atmospheric structure and chemistry on Neptune. However, significant technology advances would be required to enable high S/N transmission from depth in a cost-effective manner. An optimal probe package would include a main probe (GCMS; sensors for temperature, pressure, and acceleration; solar and IR radiometers; nephelometer) and at least three mini-probes (GCMS; temperature, pressure, and acceleration sensors) to sample diverse atmospheric regions.

Triton lander: A stretch goal would be a miniature surface lander to make *in situ* studies of the satellite's lower atmosphere and surface geology/composition.

Technological challenges: Recent studies indicate a Neptune mission with these capabilities is feasible given innovative technologies [2]: high-power lightweight SEP and solar sails; qualified aeroshells; aerocapture; autonomous spacecraft communications; advances in miniaturization; lightweight power generation systems; temperature-tolerant electronics (~50K); lightweight structures. These technology drivers are required for many outer planet missions; their solutions will be broadly applicable. The Neptune mission's unmatched diversity of science yield should place it at the top of the queue for outer planet exploration.

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. [3] Smith B. A. et al. (1989) *Science*, 246, 1422-1449. [4] Sromovsky L. A. et al. (2001) *Icarus*, in press. [5] Elliot J. L. et al. (1998) *Nature,* 393, 765-767.