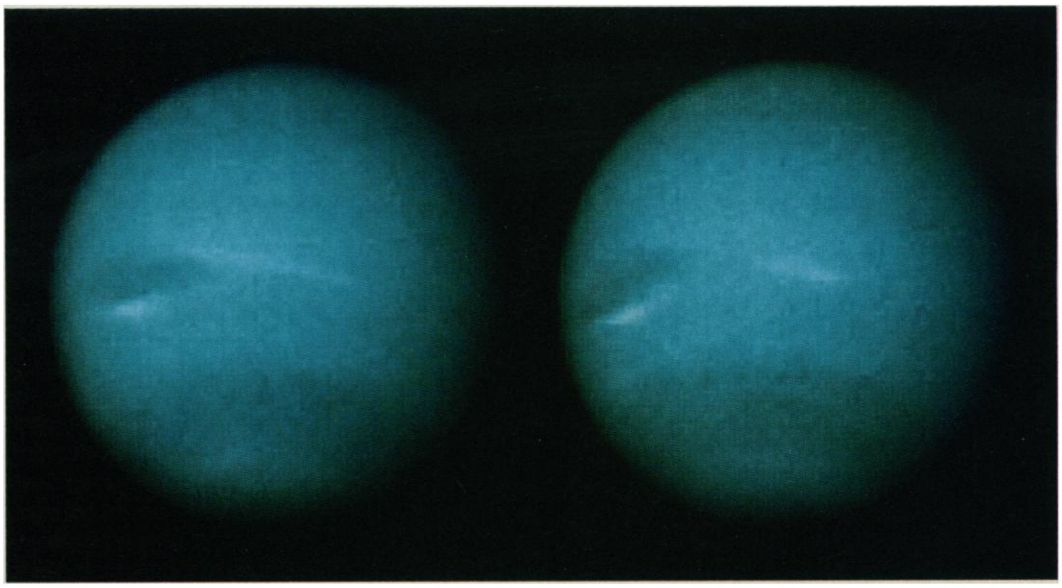
News & Comment

Facing a Final Exam at Neptune

Jupiter, Saturn, and Uranus have taught many lessons about the outer planets; but will they apply to Voyager 2's last port-of-call, the still mysterious planet Neptune?



NASA/JPL

A changeable planet. *In July, Voyager 2 caught this dark spot, which has been stable for 6 months, and an adjacent bright cloud that changed during the 3 days between these images made with various filters.*

FOR SPACE PHYSICISTS MICHAEL DESCH and Michael Kaiser, the first test is over. They failed. The Voyager 2 spacecraft had picked up natural radio emissions well before its previous close encounters with the gas giants Jupiter, Saturn, and Uranus. When would it pick up radio noise as it homed in on Neptune? Desch and Kaiser had predicted that it would be no later than 7 July. But as of 6 August, Neptune was silent.

A portion of their exam is over and they have flunked, but Desch and Kaiser have no reason to be ashamed. The guessing game is going on throughout the world of planetary science as Voyager 2 nears its rendezvous with Neptune on 24 August before heading out of the solar system. Indeed, speculation based on what Voyager found during its last three flybys is running rampant, fueled in part by a geophysics journal's call for formal Neptune predictions. The game—in which wrong guesses can be as instructive as right ones—was formalized by *Geophysical Research Letters* Editor Alexander Dessler. It has proved very popular, encouraging an unprecedented number of researchers to go on record with forecasts that might otherwise have remained hallway banter.

Predictions of everything from the frequency of Neptunian lightning to what Neptune's large moon Triton will look like are now in print. By the end of the month, most of the rest of the grades on the Voyager Neptune test will be in, assuming Voyager 2 is still in one piece then. It has to safely negotiate an as yet invisible system of rings surrounding the planet. So with luck, over the days of the encounter, Voyager 2 will assign a pass/fail grade to many predictions.

"Most predictions in the past have been wrong," says Dessler, the space physicist at Rice University who put planetary scientists to the test. "But I think the scientific community benefits. It increases the number of people interested in the encounter. It focuses on where the theories are weak and need work. And it makes the encounter even more wonderful when you have preconceived ideas so different from reality."

Desch, who still listens for some whisper from Neptune, agrees. "I'm one who will be eating his words. There will be a lot of us, but it's all fun."

Planetary meteorologists have been having fun for months now as images returned by Voyager 2 lend increasing support to the consensus prediction that Neptune's atmosphere will be more active, and far more interesting, than Uranus's. Voyager 2 and its companion Voyager 1, which parted ways with Voyager 2 at Saturn, had been finding progressively less active, more bland atmospheres as they traversed the solar system. Jupiter has its vibrantly colored cloud bands, dark and white eddies of all sizes, and its swirling Great Red Spot, but Saturn's wind-driven cloud bands are quiet and bland by comparison, and Uranus resembles nothing so much as a plain, aqua-blue billiard ball.

Neptune, however, was going to reverse the trend toward blandness, most researchers thought. It is the most distant from the sun of the four major outer planets and therefore receives the least warmth to drive its weather. And yet, unlike Uranus, it is clearly leaking heat from inside. This heat left over from its formation, meteorologists wagered, might drive the sorts of weather seen on Jupiter and Saturn.

The planetary meteorologists were right. Neptune, as it appeared to Voyager early this month, bears "a striking resemblance to Jupiter," says planetary meteorologist Andrew Ingersoll of the California Institute of Technology and the Voyager imaging team. "It's only a qualitative impression right now," he adds, "but it's uncanny because Neptune is so far out in the solar system. There is a dark shape with a bright central spot; it looks like a lot of the 'donuts' the Voyagers saw on Jupiter."

There is even what appears to be the Neptunian equivalent of the Jovian Great Red Spot. "It is the same shape as the Great Red Spot, they're at almost the same latitude and have about the same size relative to the planet," says Ingersoll. There is one difference, though—this one is dark blue.

Neptune weather has offered other pleasant surprises as well. The speed of Neptune's east-west winds varies from latitude to latitude by 100 meters per second, much as happens on Jupiter. "The amazing part of it," says Ingersoll, "is that almost every planet in the solar system has winds around

100 meters per second, despite the energy inputs varying by a factor of 1000." How does a planet receiving very little energy from the sun, and not much more from its interior, pump up its winds to the speeds found on planets with large energy sources? That is "the big unanswered question about the outer planets," says astronomer Reta Beebe of New Mexico State University.

Neptune is no twin of Jupiter, however. Beebe and the imaging team have compared Voyager images of the two at the same 40-million-kilometer distance. "You see a real difference," she says. Jupiter shows much stronger east-west banding and much more convective activity, the churning of the atmosphere that carries heat from the interior to drive the visible weather. "We see deep enough in Jupiter's atmosphere to see the top of the convection. At Neptune, we're looking through a stratospheric cloud deck modified by convection. The whole morphology is softer."

The biggest unanswered question about the Neptune system may be the nature of Triton, Neptune's lone major satellite. To astronomers, it has been only a star-like point of light. In that light, they have seen clear signs of methane, the only characteristic known for sure about Triton. It has not even been known for certain whether it was born into the Neptune family or was an intruder captured somehow by the planet, as suggested by Triton's tilted orbit.

So, with things that wide open, just about everybody is making guesses about Triton. In fact, there were more than 20 Triton predictions scattered through abstracts and papers published before the *Geophysical Research Letters* special August issue, which added six more.

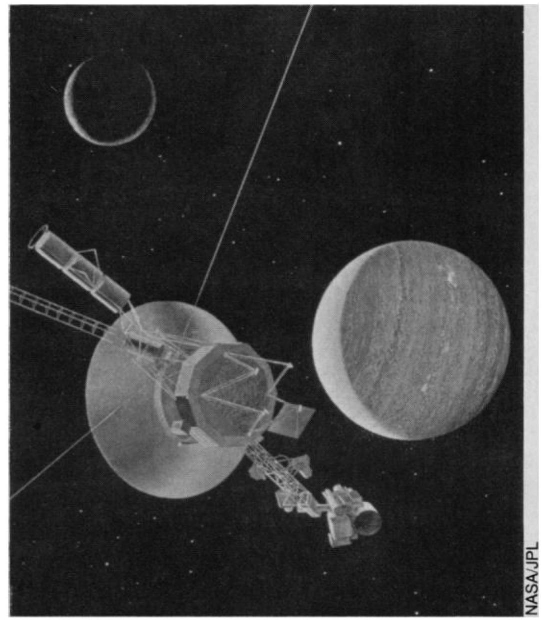
There is still time to make a Triton prediction yourself. You would start with the proven presence of methane. Add the possible existence of nitrogen. Include the certainty that Triton is extremely cold—its surface is no warmer than 63 K and very likely colder than that. Then you can build your own moon within the constraints of physics and chemistry, as you see them.

The moon that emerges from publicly made predictions has a significant atmosphere—a feature that would set it apart from most satellites. The predicted atmospheric pressure ranges from a few millibars, like the atmosphere of Mars, to an upper limit of 100 millibars, one-tenth the surface pressure on Earth.

And what will be floating in this atmosphere? Saturn's satellite Titan sports a thick, haze-laden atmosphere that cut off Voyager's view of the surface. Professional forecasters, however, have favored an organic haze for Triton thin enough that it should not obscure the surface. They hope.

The latest data from Voyager are beginning to reassure scientists on at least this one prediction. They show Triton to be smaller—about 1400 to 1800 kilometers in radius, more reflective, and therefore colder than once thought. Colder should mean a thinner, clearer atmosphere.

With some reassurance that Triton will be more than a ball of haze, researchers are bracing themselves for the inevitable surprises. Indeed, Voyager has to prove some of the experts wrong because the theories advanced so far are at times incompatible. According to one model, there will be white organic compounds sifting down from the stratospheric haze and draping the landscape like snow. Another creates a banded Triton on which the changing seasons, depending on the latitude, cover red-orange organic goo with fresh frost or expose it to view. Several predictions call for bright polar caps. Taking a cue from Voyager discoveries on other satellites, icy volcanoes and their "lava" flows might still linger from Triton's early, warmer days.



Voyager approaches its targets. *A 1981 rendering of Neptune and its moon Triton.*

Those warmer days could possibly make for a disappointingly bland Triton. Planetary physicist David Stevenson of Caltech points out that the internal heating of Triton following its presumed capture must have driven volatile compounds such as methane and nitrogen from its interior to its surface. How much methane ice remains on the surface would determine Triton's topography. If there were a 10-kilometer-deep layer of methane ice, which flows like a water-ice glacier on Earth, any mountains, valleys, or meteorite craters in the underlying water ice would be drowned in a frozen ocean of methane. If there were much less methane, such features in the "bedrock" of water ice could emerge. "It's hard to make a prediction," says Stevenson, "but it's possible that Triton is as smooth as a billiard ball."

Right or wrong, predictions about a swirling atmosphere or an icy moon are of purely academic interest. But predictions about the rings of Neptune, on the other hand, are a matter of life and death. In order to have Neptune's gravity swing it near Triton, Voyager must sweep through the planet's equatorial plane, where there are at least three partial rings or ring arcs of billions of orbiting bits of debris. A collision could spell an early end to the mission.

The ring arcs, which were detected from Earth when stars blinked out behind them, fall between about 50,000 kilometers and 70,000 kilometers from the center of the planet. Voyager's most recent discoveries—three small moons 100 to 200 kilometers in diameter—orbit among the arcs and probably shape them. Voyager, by latest calculation, must pass through the ring plane at 84,000 kilometers, more than 10,000 kilometers outside what, with a closer look, may come to resemble an asteroid belt around Neptune.

"Eighty-four thousand kilometers places us at a very safe distance," says astronomer Carolyn Porco of the University of Arizona and the Voyager team. "Going through the equatorial plane is always a bit risky. It's just that the probabilities [of a damaging collision] are reasonably low." Porco bases her confidence on the observation that none of the four main ring systems around the major outer planets extend much beyond the Roche limit, a theoretical distance that is dependent on the mass of the planet. Neptune's Roche limit is 71,000 kilometers, well inside Voyager's ring plane passage.

Porco's empirical inference "is reasonably safe on theoretical grounds," says ring specialist Philip Nicholson of Cornell University. "On the other hand, we have the evidence of the G ring that says we're gambling a little." Voyager 2 brushed the dusty edge of Saturn's faint G ring, missing its core by only 2500 kilometers. It is an outrider to the main ring system, lying well beyond the Roche limit. "There is absolutely no theory for the origin of the G ring," notes Nicholson. "It's quite embarrassing; it shouldn't be there. So we're not certain there isn't a version of the G ring waiting for us at Neptune." Thus, the opportunity to test many of the Neptune and Triton predictions will depend on one ring prediction. Wish Voyager luck. ■ RICHARD A. KERR