Voyager

BULLETIN

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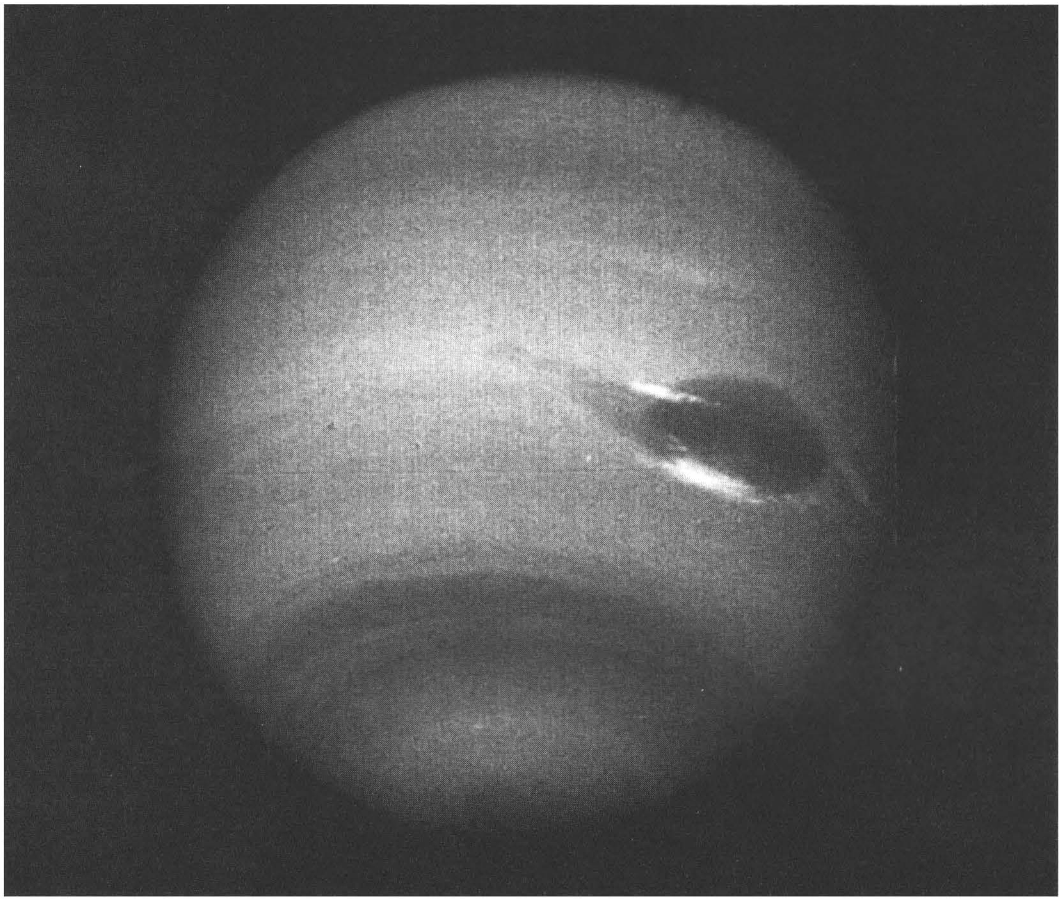


A dark feature extending westward and northward toward the equator from the Great Dark Spot (GDS) developed over a relatively short period (three rotations or about 54 hours), and continues to evolve with time.
(P-34594 BW)

Intriguing . . .

As Voyager 2 approaches Neptune, rapidly increasing image resolution is revealing striking new details in the planet's atmosphere, including features as small as a few hundred kilometers in extent. Bright, wispy "cirrus-type" clouds overlie the Great Dark Spot (GDS) at its southern margin and over its northwest boundary. This is the first evidence that the GDS lies lower in the atmosphere than these bright clouds, which have remained in its vicinity for several months. Increasing detail in global banding and in the south polar region can also be seen; a smaller dark spot at high southern latitudes is dimly visible.

Further study may reveal whether a dark feature seen extending north and west toward the equator from the Great Dark Spot represents an actual flow of dark cloud material from the GDS or is a result of atmospheric disturbances associated with the western boundary of the GDS.

Look for Voyager 2 near Sagittarius

Obviously, we can't see anything as small as the Voyager spacecraft four and a half billion kilometers away, but we *can* locate Neptune in the night sky, and thus imagine Voyager 2's position. Looking low on the western horizon just after sunset, one can see Saturn, just above the constellation Sagittarius. To the left and above Saturn will be Neptune. For readers familiar with astronomy, Neptune's coordinates on August 24 will be right ascension 18 hours 42 minutes, declination -22 degrees 11 minutes, and its magnitude will be 7.9.

Highlights of the Near-Encounter Phase

Most of the high-value science Voyager 2 will gather during the entire four-month encounter period will come during a 53-hour period spanning August 24, 25, and 26.

By then, Neptune will completely fill the wide-angle (WA) camera's field of view (55.6 x 55.6 milliradians), which looks at fifty times more viewing area than the narrow-angle (NA) camera (7.5 x 7.5 mrads). Triton, for so long just a few pixels across even in the narrow-angle camera, will fill half the narrow-angle camera's field of view.

Near the start of the near-encounter sequence, on August 24, the 70-m antenna in Canberra, Australia, will transmit to the spacecraft a precise tone at the X-band frequency (about 8400 megahertz). The tracking stations near Madrid, Spain, will then carefully listen to Voyager's return signal more than eight hours later (the signals, traveling at the speed of light, will take more than four hours each way to travel the 4.5 billion kilometers between the spacecraft and Earth). With Neptune tugging on Voyager, there will be a measurable Doppler shift, which can then be used to deduce the strength of Neptune's gravity.

Every six minutes, the low-energy charged particle detectors will collect high-rate samples of the flow directions of charged particles in Neptune's (expected) magnetosphere.

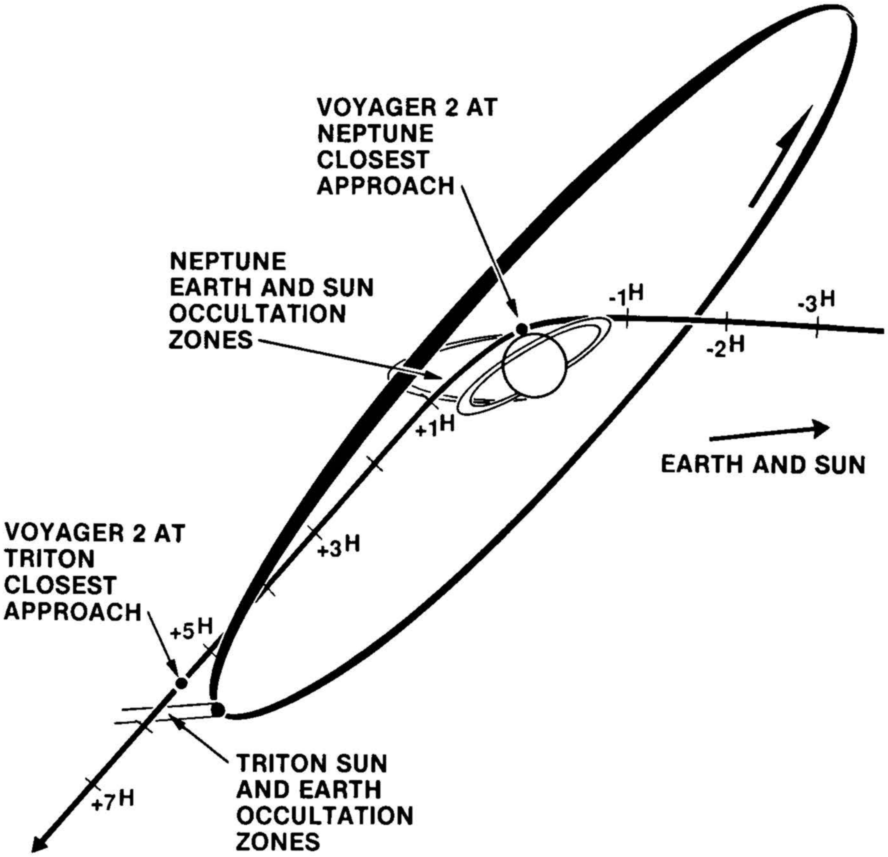
About eleven hours before Neptune closest approach (N-11h), Voyager 2 will take its best picture of the small moon Nereid, which will span less than 20 pixels in the narrow-angle frame (Neptune was this size in January 1989).

From N-10h to N-8h, the infrared instrument will be trained on a spot in Neptune's atmosphere at -40.4 degrees south latitude. This is the latitude Voyager's radio signal will pass through as the spacecraft reappears from behind the planet at the end of its Neptune Earth-occultation experiment, 55 minutes after Neptune closest approach. Using the data collected from this infrared observation, scientists can later determine the helium abundance at this occultation egress point, as it is called. These data will provide pieces of the puzzle needed to determine the overall atmospheric structure and composition.

After imaging, infrared, and photopolarimetric observations of Neptune's sunlit limb (edge), Voyager will next train its cameras on the ring-arc region. Between N-7h 17m and N-6h 22m, two retargetable ring-arc observations will employ for the first time a clever technique called Nodding Image Motion Compensation (NIMC) to "freeze" the motion of selected clumps of orbiting ring-arc material. (NIMC "nods" the spacecraft just enough to track the target but not enough to break the antenna's line of sight to Earth, thus allowing the data to be returned to Earth as it is taken, rather than recorded onboard the spacecraft for later playback to Earth.) Between the two ring observations, Voyager has been reprogrammed to shutter four images of the recently discovered moon 1989N2.

By N-5h 18m, a photopolarimetric and ultraviolet scan of Neptune's bright limb will be completed. Ring observations will continue for almost two more hours. Between N-4h 55m and N-3h 3m, the sensitive detectors in the photopolarimeter and ultraviolet spectrometer will gaze at the star Sigma Sagittarii (also known as Nunki) as it appears to drift behind the right-hand half of the ring-arc system as a result of Voyager's motion. This stellar occultation may provide detailed ring-arc region structural and orbital data.

While the bright limb scans and stellar occultations are taking place, Voyager 2 will be receiving updated instructions from Earth. All of the science observations between about N-3.5h and N+9h are sequenced in three separate movable blocks that can be shifted in time. The Neptune Movable Block (NMB) contains the spacecraft's instructions for all activities around Neptune closest approach from N-3h 20m to N+1h 46m; the Triton



Voyager 2's closest approach to Neptune on August 25 (GMT) will be about 3000 miles above the planet's cloudtops. Five hours later, the spacecraft will fly within about 23,900 miles of the moon Triton.

Movable Block (TMB) contains the observations around Triton closest approach from N+1h 50m to N+8h 38m; and the Vernier Movable Block (VMB) encompasses the critical sequence for controlling the Neptune radio science occultation from N-5m to N+56m. The Vernier Movable Block overlies the Neptune Movable Block.

By allowing the entire block of activities in each block to shift, timing updates can be applied to the whole set in one simple step, instead of changing individual timing parameters in each observation. Shifts in multiples of 48 seconds are possible for the NMB and TMB; for the VMB, a special technique will allow shifts in radio science occultation events of as little as one second, independent of how much the NMB is shifted. The success of the radio science measurements is dependent upon the Navigation Team's ability to estimate the time of closest approach to within one second. For everything except the critical radio science occultation, 48 seconds would be good enough.

Other updates in these instructions will also control scan-platform pointing to several high-value targets, spacecraft rates for the radio science occultation maneuver, and rates for a critical Triton Image Motion Compensation (IMC) maneuver.

By N-3h, another retargetable ring-arc observation will be finished. The best image of Triton before Neptune closest approach will be taken: Triton will subsequently be eclipsed by Neptune's southern limb, and won't be visible again until the spacecraft arcs over Neptune's pole. The scan platform will shift back to Neptune for some imaging, infrared, and photometry measurements. The Low-Energy Charged Particle (LECP) instrument will switch into a higher-energy sampling mode as Voyager 2 penetrates the deepest part of Neptune's magnetic field and radiation belts. The other fields and particles instruments will also add to the flood of data.

At N-1h 41m, the sensitive optics of the instruments on the scan platform will be pointed away from Neptune—towards deep space—to protect them from possible pitting during the inbound ring-plane crossing. Then, one hour from its aiming point, Voyager 2 will configure its radio transmitter for the ring-arc system and Neptune occultations, calibrate its antenna, and gather baseline pre-occultation data until N-20m.

For about ten minutes centered around N-56m, the spacecraft will cross the ring plane just outside the ring-arc region. The plasma wave instrument should pick up the sounds of microscopic (harmless) ring particles vaporizing as they hit the spacecraft.

Immediately after the ring-plane crossing, the spacecraft will roll 61 degrees from the lock star Canopus to orient the fields and particles instruments for measurements of the charged particles that should be raining into Neptune's north pole along the magnetic field lines, perhaps causing auroral activity ("northern lights"). At the end of this roll, the spacecraft's attitude will be under

Neptune Encounter Events Summary

EVENT	DATE	EARTH RECEIVED TIME*
Neptune—encounter period begins	*June 5, 1989*	
Nereid—closest approach (4,655,000 km)	*August 24, 1989*	*9:02 p.m.*
Inbound ring-plane crossing	*August 25, 1989*	*12:01 a.m.*
Neptune—closest approach (4,900 km)		*1:03 a.m.*
Neptune—Earth occultation		*1:09–1:58 a.m.*
Neptune—Sun occultation		*1:09–1:59 a.m.*
Outbound ring-plane crossing		*2:24 a.m.*
Triton—closest approach (38,360 km)		*6:17 a.m.*
Neptune—encounter period ends	*October 2, 1989*	

**Time signal will be received at JPL, Pacific Daylight Time (PDT).*

the control of the onboard gyroscopes.

Last-minute "shoehorning" has enabled the flight team to insert an instruction to Voyager 2 to shutter a high-resolution image of the recently discovered moon 1989N1 about 45 minutes before the closest approach to Neptune. By a stroke of luck, the image can be taken during a radio science antenna pointing calibration maneuver, which provides almost perfect image motion compensation. Details as small as 2.5 kilometers across should be visible on this small moon's disk.

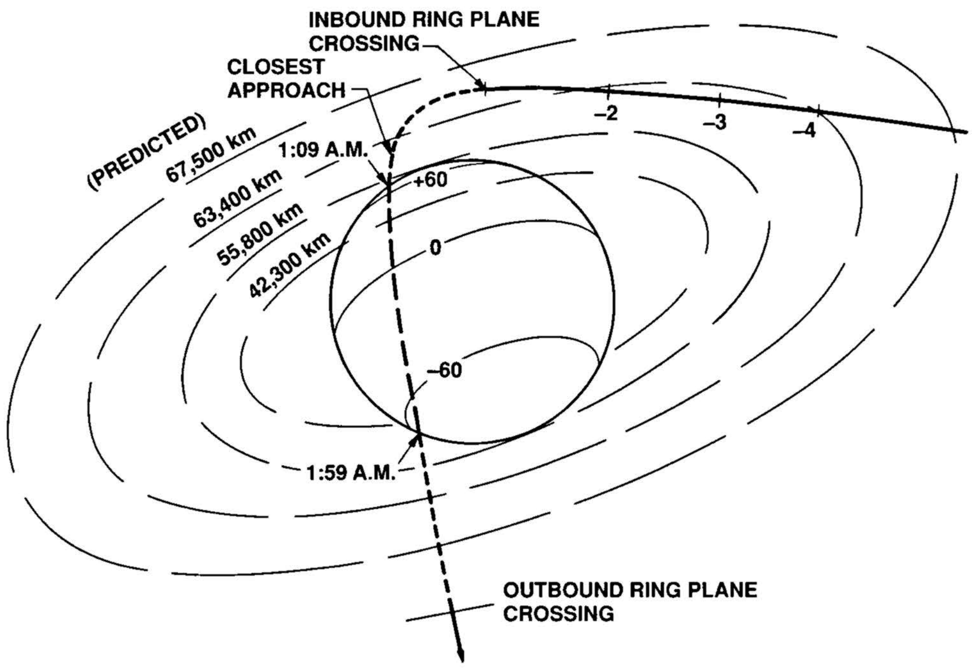
With pure X- and S-band tones emanating from Voyager 2, the radio science ring occultation will begin at about N-60m and extend until about N+5m. Back on Earth, the spacecraft will rise above the horizon over the Deep Space Network sites in Australia. The Australian government's Parkes Radio Telescope will join the DSN's tracking coverage about two hours later. A bit more than four hours after the closest approach to Neptune, Voyager 2's signals will arrive at the arrayed antennas, distorted in meaningful ways by their passage through Neptune's ionosphere, ring-arc system, and atmosphere.

At N-5m, the duration of each of Voyager's thruster pulses will be increased from four-thousandths of a second to ten-thousandths, just in case Neptune's atmosphere applies some unexpected drag on the vehicle, and also to provide quicker response to maneuver commands needed for the occultation experiment. This special provision will remain in place for the next hour. The shift of the Vernier Movable Block will precisely control the timing for all occultation activities for the next hour. Since the telemetry stream will have been turned off an hour earlier to concentrate power in the pure radio signal, all spacecraft telemetry during this time will be routed to the tape recorder for later playback.

Voyager 2's speed relative to Neptune is expected to peak at an impressive 98,350 km/h (60,980 mi/h) as it silently and effortlessly sails through its aiming point—right on target—a mere 4400 km (2730 mi) above Neptune's sensible atmosphere, and only 4900 km (3000 mi) above the methane cloudtops below. This is by far the closest Voyager 2 will come to any body since it left Earth twelve years ago. As it arcs over 77 degrees north latitude, the spacecraft will start to slow down, and begin its permanent journey down and out of the ecliptic plane.

As Voyager 2 approaches the dark side of the planet, Neptune's sunrise terminator will pass beneath, and within about six minutes after closest approach, Voyager will watch with a special ultraviolet Sun-viewing port as the distant Sun disappears into Neptune's ever-thickening atmosphere.

With its pure-tone transmissions still turned on—and while completely out of view from the Earth—the automated spacecraft will perform an amazing string of 24 maneuvers, collectively known as the "limbtrack" maneuver, to precisely point the boresight of the spacecraft's high-gain antenna along Neptune's limb, starting with the ingress point in Neptune's northern hemisphere, then around the left limb (as viewed from Earth), and ending with the egress point at -40.4 degrees south. The limbtrack maneuver will take about 48 minutes. The radio signals will be bent (refracted) as they pass through Neptune's atmosphere, and the limbtrack maneuver will control the pointing of the antenna to ensure that these



Voyager 2 will disappear behind Neptune for about 48 minutes and the spacecraft's radio signals will be refracted through the atmosphere along the planet's left limb.

signals are bent so they hit the Earth and, thus, the waiting antennas in Australia and Usuda, Japan. We will learn a great deal about Neptune's atmosphere, size, and shape from this experiment.

While Voyager 2 orchestrates its limbtrack maneuver, it will also collect fields and particles data, take infrared and ultraviolet data from Neptune's polar region, and also take a series of three wide-angle images of the ring-arc system in forward-scattered sunlight. The last of these observations will employ a new image smear reduction ploy called Maneuverless IMC (MIMC). Instead of moving the entire spacecraft smoothly to track the target, only the scan platform will be moved. Although the platform's motion is somewhat jerky, this technique will still afford clearer images than if no attempt were made to track the target.

As the spacecraft emerges from behind Neptune at N+55m 8s—again watching with the ultraviolet instrument—it will see the Earth first, followed by the Sun 49 seconds later. Voyager 2 will continue to point its antenna at Earth for the outbound ring occultation, and will take an edge-on shot of the ring-arc system as the spacecraft descends across the ring-plane at N+1.5h. For the next 20 minutes, Voyager will observe the planet's crescent limb in Neptune's southern hemisphere.

Once past Neptune and out of the planet's shadow, the spacecraft will focus more of its attention on Triton, while the high-paced routine of fields and particles data-taking continues.

About two hours past Neptune, the spacecraft will roll to a new lockstar, Alkaid, primarily to orient the charged-particle instruments for magnetospheric measurements between Neptune and Triton while, at the same time, preserving good viewing of Triton for the long-awaited upcoming observations.

For the next eight hours, Voyager will train its infrared, photopolarimetric, ultraviolet, and imaging instruments on Triton. The three highest-value imaging observations from this period promise to be among the sharpest set of pictures Voyager 2 has ever returned. Features as small as one kilometer (0.62 mile) across are expected to be resolved near the time of closest approach to Triton (N-5h15m).

By this time, Triton's small gravitational tug will be felt by Voyager, allowing scientists on Earth to measure the gravitational effects by observing changes in the radio signal. Voyager will next train its photopolarimetric and ultraviolet sensors on the star Beta Canis Majoris for about 20 minutes, watching its brightness change as it passes first through Triton's wispy atmosphere, then behind the moon, and back out again.

The ultraviolet instrument's Sun port will be pointed toward the Sun, and the spacecraft will configure its radio science equipment for another brief Earth and Sun occultation period. For nearly forty minutes, Voyager will hold its attitude steady as it watches the two orbs of light, which wink out behind Triton for about three minutes. All of this data will be recorded onboard the spacecraft for later playback to Earth.

About 17 minutes after the Triton occultations, the spacecraft will roll back to Canopus lock, to permit unobscured viewing back towards Triton and Neptune. A thin bright sliver of sunlight will gild the limb of an otherwise dark face of Triton. The next two hours will be filled with infrared, photopolarimetric, and ultraviolet observations of Triton's disk and atmosphere. By this time, Voyager 2's tape recorder will be nearly full.

The scan platform instruments will gaze back at the Neptunian system for 31 more hours, taking more observations with its various sensors before a new set of instructions from Earth assumes control of the spacecraft. Frequent sampling of fields and particles data will continue as Voyager passes through Neptune's magnetotail.

By N+1d, the collection of data on low-energy charged particles and flow direction will slow considerably. By then the spacecraft will already be over 1.5 million km (930,000 mi) from Neptune and its velocity will have slowed to about 61,200 km/h (38,000 mi/h), only sixty percent of the speed it had just a day earlier, and only five percent faster than the speed of its eventual solar system departure.

Between N+21h and N+1d 16h, the infrared and ultraviolet instruments will scan from north to south across Neptune's unlit disk in a repetitive sequence, gathering data complementary to the inbound set of observations.

One of the big priorities following the intensive 53-hour near-encounter period will be to unload the high-value data stored in Voyager's tape recorder and send it to Earth. This will be achieved with a series of long playbacks. By four days after closest approach, two playbacks of all high-value science should be completed.

Two mosaics of the ring-arc system that will come down from Voyager 2 in these playbacks may be quite revealing, having captured the ring particles in forward-scattered sunlight. A movie of the ring arcs, much like those "filmed" during Neptune approach, will be acquired on August 28.

Various infrared, photopolarimetric, and ultraviolet maps and scans will be completed during this load as well. About midway through, visual evidence of aurorae or lightning at Triton will be sought. For about 11 hours starting at N+3d 6h, the ultraviolet instrument will search for ultraviolet emissions around Neptune's disk, to help determine the composition of escaping gases.

On August 28, the spacecraft will briefly change its lock star to Spica to allow the LECP instrument to get a better sample of the charged-particle flows in the downstream solar wind and their interaction with particles in Neptune's nearby magnetic tail. About this time, Voyager 2 should be leaving Neptune's bubble-like magnetosphere and the surrounding bowshock, heading about 40 to 45 degrees south of the ecliptic plane.

Post-encounter observations and calibrations will continue until October 2.

Update

Voyager 2's navigators cancelled the course correction planned for August 15, believing that they have already placed the spacecraft so closely on target toward Neptune that the maneuver was not needed. The final tweak to the flight path, which will occur on August 21, will place the spacecraft at its closest approach target area. The aimpoint at Neptune will determine the spacecraft's flight path past the moon Triton five hours later. Navigators are targeting for a narrow cone of space behind Triton where the Earth and Sun will be temporarily blocked from the spacecraft's view. Passage through these occultation zones is necessary for critical observations of Triton's atmosphere by the ultraviolet spectrometer and the spacecraft's radio signals.

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