Will we ever go back to explore the ice giants? Yes, if we keep the missions simple and affordable

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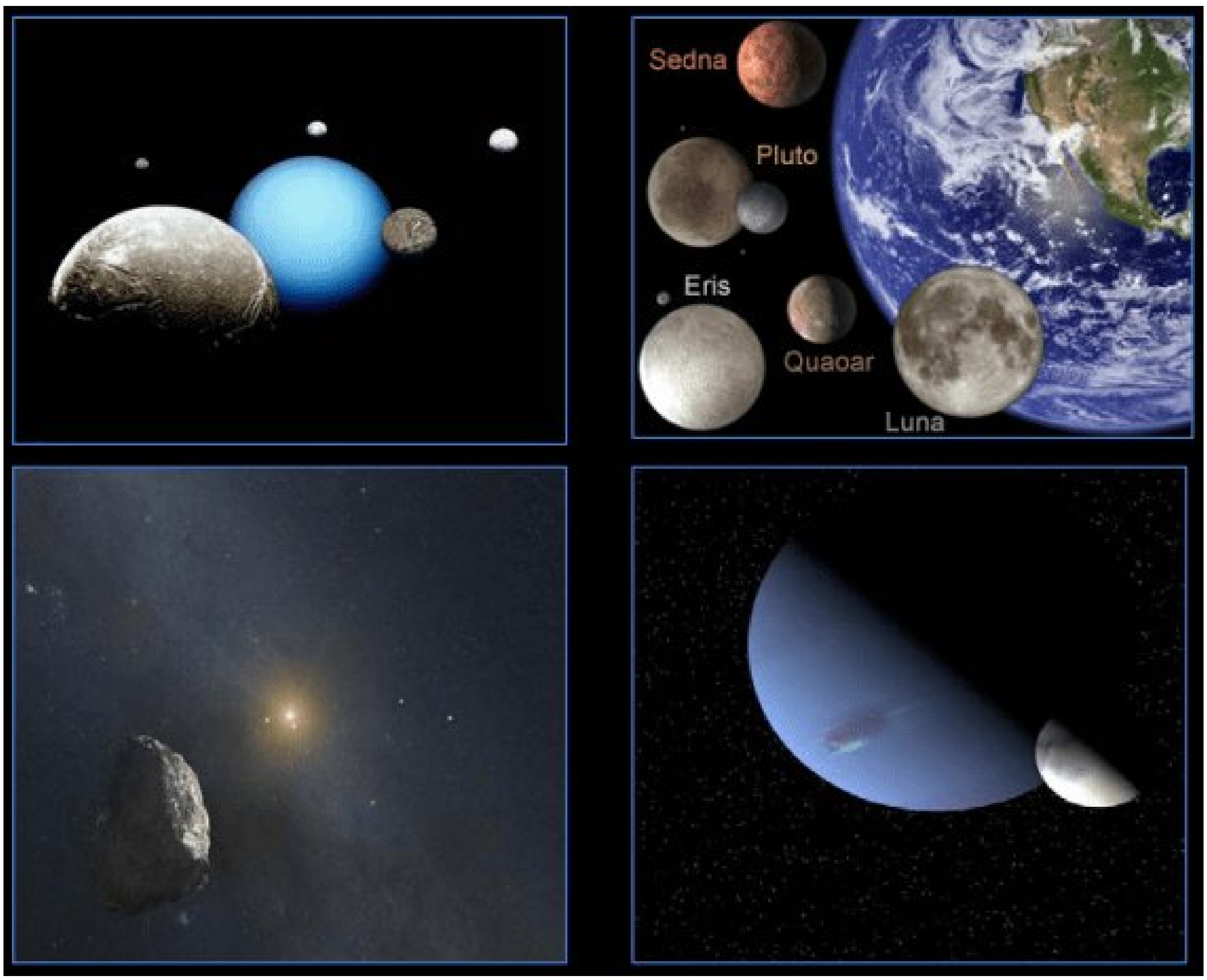

Other scientists have also urged the Decadal Survey to consider combining missions to the ice giants and KBOs. This image is from "Outer Solar System Exploration: A Compelling and Unified Dual Mission Decadal Strategy for

Exploring Uranus, Neptune, Triton, Dwarf Planets, and Small KBOs and Centaurs.." Credit: Simon, Stern, Hofstadte

It's been over 35 years since a spacecraft visited Uranus and Neptune. That was Voyager 2, and it only did flybys. Will we ever go back? There are discoveries waiting to be made on these fascinating ice giants and their moons.

But complex missions to Mars and the moon are eating up budgets and shoving other endeavors aside.

A new paper, available on the preprint server *arXiv*, shows how we can send spacecraft to Uranus and Neptune cheaply and quickly without cutting into Martian and Lunar missions.

The demands of deeper, scientifically fulfilling missions to Mars and the moon are squeezing the budgets of NASA, the ESA, and other agencies. But there are fascinating worlds further out in the solar system that are begging to be explored. Especially the ice giants Uranus and Neptune.

NASA has a strong focus on Mars and the moon right now. The eventual Mars Sample Return mission will be resource intensive, as will the Artemis program. But the ice giants demand attention, too, even though we can never land there or gather samples from them. They played a role in the evolution of the solar system, they're similar to many exoplanets we find in distant solar systems, and our brief encounters with them gave us only tantalizing glimpses.

The last spacecraft to fly past Uranus was Voyager 2 in 1986, and it was the only one. It got to within 81,500 kilometers (50,600 miles) of the planet's cloud tops. Voyager 2 was also the last and only spacecraft to fly past Neptune, coming to within 4,800 kilometers (2,983 miles) above the planet's north pole in 1989. Imagine what dedicated orbiters could discover with modern technology.

The Hubble space telescope has tried to fill in the gaps in our understanding of the solar system's pair of ice giants. But it struggles to reveal details from a distance. The James Webb Space Telescope has shown its ability to study our solar system's planets with its fascinating images of Jupiter, but it has other jobs to do. Observations from a distance will always have their limitations and can never replace purpose-built missions.

Philip Horzempa, from LeMoyne College at Syracuse University, says that we can explore both Uranus and Neptune if we're guided by two simple words: simple and affordable. In a white paper submitted to the National Academies of Sciences, Horzempa outlines the case for building a pair of orbiters to visit Uranus and Neptune. He explains how they needn't be ground-breaking designs, and they needn't be flagship missions.

Instead, NASA could rapidly develop missions to both ice giants that could gather important scientific data without breaking their budget. Launch windows are approaching for missions to both planets, and rather than propose elaborate missions that may never get approved, NASA should develop reasonable missions that can advance our understanding of both worlds.

Horzempa points out that there's a historical precedent for this. Some of NASA's best missions were only launched as more streamlined, cheaper versions of their original proposals. The Viking Mars landers were eventually launched as more streamlined versions of an initial mission proposal. NASA's Grand Tour program in the 1970s called for four probes: two would've visited Jupiter, Saturn, and Pluto. Two more would've visited Jupiter, Uranus, and Neptune. But the program was enormously expensive and was canceled. Instead, NASA launched Voyager 1 and 2. The New Horizons mission and the Parker Solar Probe have similar backstories.

Timing is critical. Later this decade, there are two launch windows that can take advantage of Jupiter gravity-assist maneuvers. "In order to take advantage of the first Jupiter assist, it is imperative that Phase A should begin for a Neptune Orbiter in 2022," Horzempa writes, so time is running out. "This abbreviated timeline dictates the use of a simple craft with no atmosphere Probe."

Ideal missions to both planets would include orbiters and atmospheric probes. Both planets likely have solid cores, but the rest of their compositions are very strange and might include regions where methane decomposes into diamond crystals that rain downward like hailstones into oceans of liquid carbon. We've got a lot to learn about Uranus and Neptune and their atmospheres, but more detailed studies with probes will have to wait.

Sacrificing an atmosphere probe is a trade-off worth making if it means that a mission can be launched to take advantage of gravity-assist maneuvers, according to Horzempa. "Key to affordability is the separation of the probe missions from the orbiters," he writes. This makes the orbiters more simple and cheap, which increases the likelihood that they will be approved.

Probes could still come later, Horzempa says, which can be an advantage for future atmospheric probe missions to both ice giants. "The orbiters will be given 1st priority in the launch queue. Since the Probe program will be untethered from the Orbiter effort, its mission cadence will be determined by factors unique to the study of giant planet atmospheres."

All spacecraft are high-tech endeavors, but orbiters themselves are the most well-understood design. Rovers are enormously complex, and sample-return missions ratchet the complexity up even further, though neither of those is explicitly relevant to the ice giants. Restricting ice giant missions to orbiters only makes the missions feasible. "The ice giant Orbiters will build on the experience of previous such missions. By now, industry has 'figured out' how to construct such craft," writes Horzempa.

For NASA, the 2020s is a decade of stiff competition for resources. Their budget will be stretched thin by Artemis, Mars Sample Return, and other programs like the Lunar Discovery program. But since missions to the ice giants can take so long, we run the risk of getting no new data from either planet for up to 40 years unless NASA acts now. "A radically new approach is called for if we are to obtain any new data in the coming 20–40 years," Horzempa says.

One of the critical pieces for simple and affordable missions concerns the power source. Solar power is in short supply in the ice giants' neighborhood. Spacecraft traveling that far are designed around radioisotope thermoelectric generators. They contain radioactive isotopes that decay and release heat, which is then converted into electricity. This is the type of system that the New Horizons mission to Pluto uses.

Unfortunately, the development of the next generation of RTGs was canceled. It was called the enhanced-MMRTG and would've delivered more power than previous RTGs. NASA has plans for a Next Generation RTG, but there are no firm dates attached to it and no guarantees it will be built.

This means that the standard MMRTG (Multi-Mission Radioisotope Thermal Generator) and solar power are the only available options. The orbiter missions are still doable, according to Horzempa. "This limitation means that the ice giant craft will need to be very frugal with their power demands." It also means that the Uranus orbiter could be forced to get by on solar power because RTGs take time to build and may be needed for other applications. (MSL Curiosity and the Perseverance rover both use MMRTGs.) For distant Neptune, an RTG is the only option.

"Two fast, simple, affordable (FSA) orbiters can be launched if one of those crafts is solar-powered," Horzempa explains. "Physics dictates that the single MMRTG be used for the Neptune Orbiter."

Thanks to continued technological progress, solar power is now a feasible power source for a Uranus orbiter, as long as power consumption is managed rigorously. New designs are 20% lighter and one-quarter the volume of previous panels while delivering the same power output. "The ROSA (Roll-Out Solar Array) and Mega-ROSA panels can provide 200–400 W at 20 A.U.," writes Horzempa. "The first ROSA array was launched to the ISS in 2017 and demonstrated its capability."

With less power available, decisions will need to be made about science payloads. The words simple and affordable are still the guiding ideas, and Horzempa outlines how science payloads can adapt. The obvious first step is to limit the number of science devices.

As a flagship mission, the Juno mission to Jupiter holds nine scientific instruments. One of them, the JunoCam, was included solely to provide optical light images for the rest of us to enjoy and isn't truly a science instrument. Simple and affordable orbiters to the ice giants won't have the same payload capabilities as Juno.

But, perhaps ironically, a high-resolution camera is probably the primary instrument for missions to Uranus and Neptune.

"With a limited payload, first priority goes to imaging," Horzempa writes. "The satellites of Uranus and Neptune are in dire need of complete, detailed photographic coverage." Horzempa points out that creating charts is the first step in exploration, "… a tradition that is thousands of years old," he explains.

"High-resolution and context cameras will produce those base maps," he says, and by adding near-IR imagers, the orbiters can probe the atmospheres and the ring systems.

Decoupling probe missions from orbiter missions is one way to develop missions that are fast and affordable. But probe missions are too important to ignore completely.

Horzempa explains that while orbiter technology is well-established and can be employed more readily, probe technology has fallen behind. Proposals for a Saturn probe have been rejected, leaving that technology to languish. Before we can ever send atmospheric probes to the ice giants, we should send one to Saturn.

"The initial mission would be a Saturn Probe. That would satisfy a long-standing objective and develop the technology required for almost-identical Probes for Uranus and Neptune," he writes. He also says that the Decadal Survey should "…advocate for combined KBO-Ice Giant Probe missions."

In his white paper, Horzempa keeps coming back to the idea that flagship missions that try to accomplish too much at once are likely to be rejected. While flagship missions including probes are not the priority in ice giant missions, neither should probes be forgotten. The idea for orbiter-only missions to Uranus and Neptune makes more sense if there are also plans for future atmospheric probes.

"Flagship missions are wonderful, but they are useless if they are so complex that they never
get funded and never fly," he writes. He refers to this as the "complexity trap." "Less ambitious missions will deliver less science, but they have a better chance of achieving a coveted new start."

NASA is considering a concept for a mission to Uranus and its moons. It's called the Uranus Orbiter and Probe, and it's a flagship mission that could be launched in 2031. It was being considered alongside a similar mission to Neptune called Neptune Odyssey. A flagship mission to Uranus makes logical sense because it follows similar missions to Jupiter and Saturn (Juno and Cassini.) But its potential expense means it may not be approved or developed in time. Horzempa's argument is that we can visit both ice giants cheaply and rapidly if we trim down the missions.

Ultimately, it's up to the Decadal Survey team to find the right mix. "This paper does not put forward a specific design but, rather, asks the Decadal team to endorse a competitive approach to the exploration of the ice giant systems," Horzempa states in his conclusion. He says that NASA should set the cost, outline the objectives, and let the commercial sector tackle it. That will engender healthy competition.

There is never a shortage of worthwhile missions. Successful missions to destinations throughout the solar system have only made us hungry for more. It's been over 35 years since Voyager 2 performed its brief flybys of the ice giants. That spacecraft's cameras were essentially TV cameras from the 1970s. Think of how much technology has advanced since then and how much we can learn from modern orbiters.

Horzempa makes a strong case for fast, simple, affordable missions that can take advantage of rapidly-approaching launch windows. Should NASA seize the opportunity?

More information: Philip Horzempa, Ice Giant Exploration Philosophy: Simple, Affordable, *arXiv* (2022). DOI: 10.48550/arxiv.2212.00803

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