

## SCIENCE &amp; TECHNOLOGY

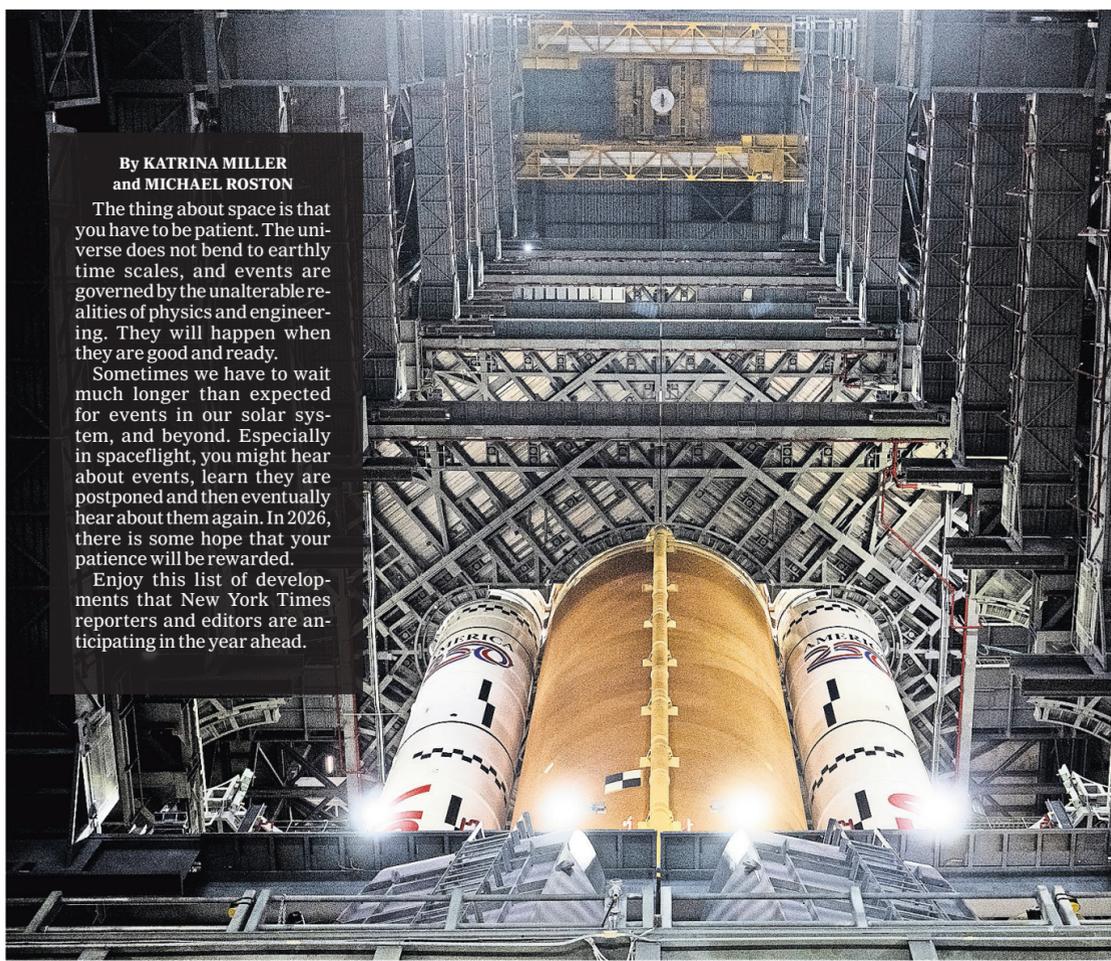
# Celestial Happenings That Are Worth the Wait

By **KATRINA MILLER**  
and **MICHAEL ROSTON**

The thing about space is that you have to be patient. The universe does not bend to earthly time scales, and events are governed by the unalterable realities of physics and engineering. They will happen when they are good and ready.

Sometimes we have to wait much longer than expected for events in our solar system, and beyond. Especially in spaceflight, you might hear about events, learn they are postponed and then eventually hear about them again. In 2026, there is some hope that your patience will be rewarded.

Enjoy this list of developments that New York Times reporters and editors are anticipating in the year ahead.



JOEL KOWSKY/NASA

## The Artemis II Mission

NASA is sending astronauts back toward the moon. No, for real this time.

It has been more than 50 years since humans exited low-Earth orbit and traveled around the moon. In the time since, space agencies have built space shuttles and space stations, but their crews have remained within our planet's close embrace.

Early this year, astronauts from NASA and the Canadian Space Agency will again travel around the moon and back. The crew of four is made up of (below, from left) Victor Glover, Jeremy Hansen, Reid Wiseman and Christina Koch. Mr. Glover will be the first Black person to go around the moon, and Ms. Koch the first woman. Mr. Hansen will be the first Canadian, and the first non-American, to ever do that.

The 10-day journey will not greatly differ from that of Apollo 8, the first time NASA astronauts looped around the moon, in December 1968. But if the mission gets off the ground at Kennedy Space Center in Florida and splashes down in the Pacific Ocean, it will prove that the Orion capsule, a key vehicle in NASA's lunar infrastructure, is a safe ride for astronauts. It could happen as soon as next month.

Landing NASA astronauts on the moon is another story entirely.



JOE SKIPPER/REUTERS

## Infrared Eyes in Space

NASA is preparing to launch its next-generation space telescope, named after Nancy Grace Roman, its first chief astronomer, no later than May 2027. But the agency plans to move the telescope to Kennedy Space Center in Florida in the summer and to try to launch as early as the fall.

Astronomers will use the Roman telescope's infrared vision to map billions of galaxies, data that will help them learn more about dark energy. Construction of the telescope was completed just months after astronomers uncovered evidence that the nature of dark energy is more complex than previously understood.

The telescope will also help researchers hunt for exoplanets and study the swirling disks of cosmic matter in which they form, expanding our catalog of other worlds in the Milky Way. Some planets may be orbiting within a star's habitable zone or may have gone entirely rogue, existing in the galaxy unattached to a host star.

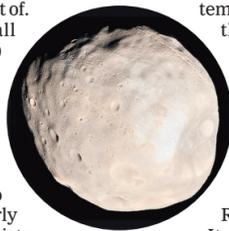
## A Japanese Journey to Mars

The United States and China both plan to send robotic spacecraft to collect pieces of Mars for study on Earth. But Japan might beat them at that game. Sort of.

Mars has two small moons, Phobos (inset) and Deimos, which have long fascinated scientists. Theories about their origins vary. One holds that they are pieces of the red planet ejected into space by a collision early in the solar system's history. Or they might be asteroids captured by Martian gravity.

Studying those moons up close, and bringing samples of them to

Earth, could help sort out that mystery. Japan's mission, called Martian Moons Exploration or MMX, intends to do that, reaching Mars to study the two moons, then attempting a brief landing on the larger one, Phobos, to collect samples.



NASA/JPL

Japan has completed similar missions twice with Hayabusa and Hayabusa2, with the second mission bringing material from the asteroid Ryugu to Earth in 2020.

It might try to launch MMX at the end of the year, although a recent failed flight of H3, a Japanese rocket, could affect the launch schedule.

## Rubin's Survey of the Stars

The Vera C. Rubin Observatory, which houses a telescope on a mountain in Chile, observed its first light last year and shared breathtaking images of the universe with the world in June. The observatory is set to begin its official survey of space and time early this year.

For the next 10 years, Rubin will capture about a thousand images of the southern sky almost every night in one of the darkest places on Earth, using the largest digital camera ever constructed. The wealth of data will elucidate how objects in the universe, like black holes and asteroids, evolve over time. It will also help astronomers better understand the nature of dark energy, a mysterious force pushing the cosmos to expand ever faster, and dark matter, the invisible substance that shapes our cosmos.

Already, Rubin has discovered more than 2,000 asteroids and spotted Comet 31/ATLAS, an interstellar visitor from beyond our solar system that has generated a lot of buzz online.



BLUE ORIGIN, VIA ASSOCIATED PRESS

## A New Moon Race

China has set a goal of landing astronauts on the moon before 2030. In August, it conducted the first test on Earth of Lanyue, its lunar lander for astronauts. It intends to use that vehicle for an Apollo-like mission.

NASA has planned a more complex mission, Artemis III. It relies on Starship, a next-generation spacecraft built by SpaceX, to land two astronauts near the moon's south pole. In 2024, the agency said it would achieve this feat

by mid-2027. But SpaceX, Elon Musk's company, struggled in its test campaign last year.

In November, NASA sought alternative proposals, and President Donald J. Trump signed an executive order in December that set a lunar landing in 2028 as the new goal. That date is ambitious, and two events this year could set the stage for whether China gets astronauts to the moon before Americans return.

First, SpaceX plans to test the latest version of its Starship vehicle. If early flights succeed

and it is able to relaunch a vehicle that fully orbits the Earth, its plans may be back on track, even if it cannot achieve a 2028 landing.

The second involves Blue Origin, the company owned by Jeff Bezos. It is planning a robotic lunar landing with a version of its Blue Moon vehicle this year (left, a rendering of the spacecraft on the moon's surface). If successful, NASA could consider Blue Origin's alternative lander proposal, which is simpler and might be ready sooner than Starship.

# All the Roads That Led to

By **FRANZ LIDZ**

The apostle Paul traveled widely across the Roman Empire to spread the Christian faith. One key segment of his second missionary journey, which began in A.D. 49 in Jerusalem, involved an overland trek across modern-day Turkey to Alexandria Troas, a city south of ancient Troy.

This route covered about 2,000 kilometers and would have taken some 524 hours to walk — or 466 hours if traveling by donkey.

We know this because a study published in November in the *Nature* journal *Scientific Data* significantly updated the estimated size of the Roman Empire's road system, increasing its total length to about 301,690 kilometers from approximately 193,100 kilometers. Rome probably achieved peak road sometime around A.D. 150, when the empire was at its most prosperous and extensive. But the database tallies all the roads presumed to have existed during Rome's life span, from roughly 312 B.C. to A.D. 400.

"The data set does not reflect one particular year or even century because, sadly, for the entire empire, we cannot confidently say how the road system changed within the entire Roman period," Tom Brughmans, an archaeologist at Aarhus University in Denmark who collaborated on the paper, wrote in an email. "We definitely have chronological information for some roads, but this is a minority."

Previous estimates focused on the main thoroughfares ra-

diating from Rome across Italy and the Empire, including the Via Appia (Appian Way) to the south; the Via Flaminia to the north, and major arteries like the Via Egnatia, across the Balkans, and the Via Domitia, across southern Gaul.

The paper's revised estimates incorporate major highways, strategic routes and local roads. The accompanying digital atlas, *Itiner-e*, leverages historical records alongside satellite and topographic data to model travel times accurately.

Dr. Brughmans proposed that while Roman expansion

## A digital atlas reveals an extensive network of routes.

was clearly aided by an advanced system for moving troops and goods, previous definitions of a "Roman road" have been too narrow, concentrating solely on the grand, engineered thoroughfares. He and his colleagues defined Roman roads more broadly to include any walkable path and used a practical, terrain-following mapping technique, rather than imposing unrealistic straight lines. The change substantially increased mapped networks in North Africa, Greece and the Iberian Peninsula.

Because many Roman roads are now gone, their exact posi-

tions were hard to determine; researchers used aerial analysis of the terrain, looking for faint signs in the plant life or subtle changes in height, to find these lost byways.

According to Dr. Brughmans, the precise course of most of the roads is unknown, with less than 3 percent of their locations confirmed. The paths are generally inferred from sparse evidence like scattered milestones.

Roads in desert areas are largely hypothetical. Instead of constructing single surfaced roads across the sand, the Romans built a system of parallel tracks to mark wide travel corridors. These routes are represented on the new online atlas by one illustrative line.

Mapping ancient transport paths provides a case study on the centuries-long societal impact of pandemics, Dr. Brughmans said. This strategy aids in comprehending events such as the Antonine Plague of A.D. 165, which is estimated to have killed one-quarter of the Roman Empire's populace, by connecting its spread to the Roman road system.

Daisy Dunn, a classicist and author of "The Missing Thread: A Women's History of the Ancient World," said that despite the Romans' reputation as master road builders, their old routes are often unmarked and easily missed today.

"Architectural enthusiasts are always reminding us to look up and appreciate the edifices towering over us," Dr. Dunn said. "Perhaps now, digital map in hand, we'll be tempted to look down again."



GONZALO IGNAZI

Conservation efforts have restored puma numbers in Argentine Patagonia, where Magellanic penguins had in the interim established large breeding colonies.

# Penguins Become Pumas' Prey

By **ALEXA ROBLES-GIL**

Penguins throughout the southern seas have to worry about being hunted by seals or orcas. On land, they can find safety in numbers. But in the Patagonia region of Argentina, the flightless seabirds are becoming snacks for an unexpected land predator: pumas.

In the early 20th century, widespread sheep ranching vanquished pumas from Patagonia. With those predators gone, Magellanic penguins, which had mostly lived on oceanic islands, established large breeding colonies on Argentina's coast. Conservation efforts have brought pumas back to the landscape.

Mitchell Serota, an ecologist and lead author of a new study published in the journal *Proceedings of the Royal Society B*, was interested in how Magellanic penguins, as a new food source, were altering the behavior of pumas. Dr. Serota and colleagues put GPS collars on 14 pumas in Monte León National Park

and collected information from 2019 to 2023.

Because penguins are migratory and are present at the breeding colony in the park for just over half the year, the scientists tracked how the pumas moved and interacted across seasons. The researchers found that pumas that hunted penguins had smaller territories than pumas that did not, and the big cats interacted with one another more frequently around the penguin colony.

By integrating GPS tracking with camera trap data, the team found what might be the highest density of pumas ever documented at a specific site, Dr. Serota said. Although pumas are typically solitary, their population density in this area was roughly double that observed elsewhere, leading to increased interactions among the felines.

Dr. Serota likened their presence to that of grizzly bears tolerating one another during the salmon run. "Food can bring predators togeth-

er," he said.

Changes to ecosystems can affect when, where and how predators obtain their food, leading to broader ecological effects. For pumas in the region, which typically feed on guanacos, a llama-like herbivore, those ecological effects are still unknown. The effects are also uncertain for the defenseless penguins, an easy catch for pumas.

"Will we see a situation in the future where the penguins go back to living mostly on oceanic islands?" asked Jake Goheen, a wildlife ecologist at Iowa State University not involved in the research.

A common assumption in scientific literature is that reintroducing large carnivores can revert an ecosystem to what it once was. But over the period of time that carnivores were absent, other things have changed too.

Restoring wildlife, Dr. Serota said, "can create these entirely new interactions that reshape animal behavior and populations in really unex-