

A 1977 Time Capsule, Voyager 1 runs on 69 KB of memory and an 8-track tape recorder

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Right now, more than **15 billion miles from Earth**, a 48-year-old spacecraft is hurtling through interstellar space at 38,000 miles per hour.

It is the farthest human-made object in the universe.

It is sending back scientific data that no other instrument in existence can collect.

And it is doing all of this on **69 kilobytes of memory and an 8-track tape recorder**.

The phone in your pocket has roughly **one million times more memory** than the computer running Voyager 1.

A single low-resolution photograph taken on that same phone contains more data than

Voyager 1's entire onboard storage.

And yet here it is, still functioning, still transmitting, still making discoveries in a region of space no spacecraft has ever reached before, almost half a century after it left Earth on a mission originally designed to last five years.

Voyager 1 is, by any measure, **the most improbable success story in the history of human exploration.**

How Voyager 1 Was Built and What It Was Designed to Do

Voyager 1 launched on **September 5, 1977**, from Cape Canaveral aboard a Titan-Centaur rocket.

Its twin, Voyager 2, had already left Earth two weeks earlier on a slightly different trajectory.

The primary mission was relatively modest by the standards of what would follow: conduct flybys of Jupiter and Saturn, photograph their moons, and measure the magnetic and particle environments around the outer planets.

Built by NASA's Jet Propulsion Laboratory (JPL) in California, each Voyager is equipped to conduct experiments using television cameras, infrared and ultraviolet sensors, magnetometers, plasma detectors, cosmic-ray and charged-particle sensors, and spacecraft radio.

The spacecraft was engineered with extreme conservatism.

Every system that could be made redundant was made redundant.

Every component was tested beyond its stated tolerance.

The engineers who built it, working with the technology of the mid-1970s, designed something that was never expected to still be operating in the 2020s, and yet here it is.

The computers aboard Voyager 1 are **programmed in assembly language** and are capable of executing approximately **81,000 instructions per second.**

The smart phone that is likely sitting in your pocket is probably about 7,500 times faster than that.

Voyager transmits its data back to Earth at **160 bits per second**.

A slow dial-up connection can deliver at least 20,000 bits per second.

And its transmitter, the antenna pointing back at Earth across 15 billion miles of void, **produces just 22.4 watts of power**, roughly equivalent to a refrigerator light bulb.

By the time that signal reaches Earth, it has spread across space so completely that its power is reduced to approximately **0.1 billion-billionths of a watt**.

Detecting it requires some of the most sensitive radio equipment ever built.

The 8-Track Tape Recorder That Actually Is Not What You Think

The detail that tends to generate the most astonishment, and the most misunderstanding, is the 8-track tape recorder.

When people hear “8-track,” they typically picture the clunky consumer cartridges that played Led Zeppelin in 1970s station wagons.

Voyager’s Digital Tape Recorder is not that.

The data tape recorder system was subcontracted to Lockheed and manufactured by Odetics Corp. The specs show that the machine was a belt-driven recorder that used a 1,076-foot-long reel of half-inch wide magnetic tape which recorded data on eight separate tracks.

Eight tracks of data recording on a half-inch tape reel is where the “8-track” comparison comes from.

But the engineering behind it was anything but consumer-grade.

Odetics, the manufacturer, claimed that the tape would travel through the mechanism a distance of 2,700 miles before discernible wear.

The tape's exact magnetic composition was engineered specifically for the harsh environment of deep space, where temperatures swing from extreme cold to radiation bombardment, and where no human hand will ever be available to replace a worn component.

The DTRs in both spacecraft performed flawlessly from their launch in 1977 and through the entire Grand Tour mission, as well as the extended mission that set both vehicles on a course out of the solar system.

In 2007, the DTR in Voyager 1 was shut down for good, not due to any issues with the unit, but because of the dwindling supply of power coming from the craft's radioisotope thermal generators.

The tape recorder did not fail.

The power supply simply could no longer spare the energy to run it.

That distinction matters.

It means a piece of 1970s magnetic tape technology **survived nearly three decades in interstellar space without a single mechanical failure.**

What Voyager 1 Has Actually Discovered

The technology specifications are remarkable in themselves.

But what Voyager 1 has done with that technology is more remarkable still.

During its Jupiter flyby in 1979, the spacecraft discovered **active volcanoes on Io**, one of Jupiter's moons, the first time volcanic activity had ever been observed on another world beyond Earth.

It revealed the complexity and structure of Jupiter's atmosphere, confirmed the existence of Jupiter's rings, and captured images of Europa that first hinted at the possibility of a liquid water ocean beneath its icy surface.

At Saturn in 1980, Voyager 1 made its closest approach to Titan, Saturn's largest moon, discovering that it has a thick nitrogen atmosphere, making it the only moon in the solar system with a substantial atmosphere, and hinting at the hydrocarbon chemistry that

would later be confirmed by the Cassini-Huygens mission.

Then it kept going.

In **August 2012**, Voyager 1 crossed the heliopause, the boundary where the Sun's solar wind can no longer push back against the interstellar medium, **becoming the first human-made object to enter interstellar space.**

That moment was not just a milestone in mission terms.

It was a fundamental scientific event.

For the first time in the history of the universe, as far as we know, **an object built by a living species had left the protective bubble of its home star system** and begun sampling the plasma, magnetic fields, and cosmic ray environment of the space between the stars.

The data Voyager 1 is sending back from interstellar space is unique and irreplaceable.

No other spacecraft is there.

No other instrument can collect it.

And it is arriving at Earth, 23 hours after transmission, at 160 bits per second, encoded on a system built when Jimmy Carter was about to become President of the United States.

The Thruster Crisis That Almost Ended Everything in 2025

The story of Voyager 1 in 2025 was nearly a very different kind of story.

Earlier this year, NASA engineers at the Jet Propulsion Laboratory faced a crisis that could have ended the mission entirely, not with a dramatic failure, but with a quiet, irreversible drift.

Voyager 1 uses roll thrusters to keep its antenna pointed precisely at Earth.

Even a tiny misalignment, a fraction of a degree, is enough to lose the signal entirely.

As Voyager program scientist Patrick Koehn explained to [NPR](#), “even just a very small tip away, a fraction of a degree, can swing the beam away from the Earth. Something like a half a degree results in the beam missing the Earth by the distance between the Earth and the Sun.”

The primary roll thrusters had been dead since 2004.

The backup thrusters had been running ever since, but they were slowly clogging with silicon dioxide residue that had accumulated over nearly five decades, as a rubber diaphragm inside the fuel tank gradually degraded.

“Think of it as the nozzle getting smaller and smaller with debris,” Voyager Mission Manager Kareem Badaruddin explained. “The thruster gets weaker and weaker and allows less propulsion.”

The situation was made critical by a separate, unrelated event: the only ground-based antenna powerful enough to send commands to Voyager 1, **Deep Space Station 43 in Canberra, Australia**, was scheduled to go offline for major upgrades from May 4, 2025, through February 2026.

Engineers at NASA’s Jet Propulsion Laboratory revived a set of thrusters aboard Voyager 1 that had been considered inoperable since 2004.

The fix required an idea that, on paper, sounded elegant but in practice was terrifying.

Engineers suspected that the primary thrusters’ heaters had not permanently failed in 2004, but had simply had their power switches flipped to the wrong position by an electronics glitch.

If that theory was correct, flipping them back might restart the heaters and revive the thrusters entirely.

If it was wrong, and the thrusters fired without the heaters running, the pressure buildup could cause **a catastrophic explosion**, destroying the spacecraft instantly.

And there was one more complication.

Any command sent from Earth takes **23 hours to reach Voyager 1**.

The team would send the command, wait 23 hours for it to arrive, then wait another 23 hours for confirmation to return.

No intervention was possible once the sequence began.

On March 20, 2025, they sent the command.

The heaters responded.

The thrusters fired.

"It was such a glorious moment," said Todd Barber, the mission's propulsion lead at JPL. "Team morale was very high that day.

These thrusters were considered dead. And that was a legitimate conclusion. It's just that one of our engineers had this insight that maybe there was this other possible cause and it was fixable. It was yet another miracle save for Voyager."

Where Voyager 1 Is Going and What Happens Next

Voyager 1 is currently travelling at approximately **38,000 miles per hour**, or about 17 kilometers per second, relative to the Sun.

At that speed, it covers roughly 900 million miles per year.

It will take approximately **300 years to reach the inner edge of the Oort Cloud**, the distant shell of icy objects that marks the outermost gravitational boundary of the solar system.

Leaving the Oort Cloud entirely will take **approximately 30,000 years**.

In around 40,000 years, Voyager 1 will pass within 1.6 light-years of a star called Gliese 445, before continuing its endless voyage through the Milky Way.

As for the mission itself, its radioisotope thermoelectric generators may supply enough electric power to return engineering data until 2036.

The team has been managing the power budget with increasing precision for years, turning off heaters, instruments, and systems one by one as the available power from the

plutonium-powered generators diminishes by approximately four watts per year.

The fields and particles instruments, the ones sending back irreplaceable data about the interstellar medium, have been prioritised.

Every year that Voyager 1 continues to function is a year of scientific data that could not be obtained any other way.

The Golden Record: A Message in a Bottle to the Cosmos

Voyager 1 carries one more thing worth mentioning.

Attached to its exterior is a **gold-plated copper disc**, 12 inches in diameter, containing 116 images encoded in analog form, greetings spoken in 55 human languages, an hour and a half of music from around the world, and a range of sounds of Earth, including ocean waves, wind, thunder, a cricket, a frog, a dog, a baby crying, and a human heartbeat.

The **Golden Record** was assembled under the direction of astronomer Carl Sagan and a small committee, with the explicit intention of communicating something of who we are to any intelligent life that might one day encounter the spacecraft.

The record includes instructions for how to play it, encoded as diagrams on its cover, along with a pulsar map that identifies the location of our solar system relative to 14 known pulsars, a kind of cosmic address.

Sagan described it as a message in a bottle cast into the cosmic ocean.

Whether it will ever be found, and whether anything capable of understanding it will ever exist to find it, are questions that cannot be answered.

But the record will drift through the galaxy for billions of years after the Sun has died and the Earth has been consumed, carrying the sounds of our world encoded in gold.

That is not a small thought.

What Voyager 1 Tells Us About Human Ingenuity

The story of Voyager 1 is, at its core, a story about what happens when engineering is

done with exceptional care and exceptional ambition.

The engineers who built it in the early 1970s did not know it would still be functioning in 2025.

They built it as if it might, anyway.

They over-engineered every system they could, redundantly backed up every critical function, and wrote software flexible enough to be updated from Earth decades after launch.

The result is a spacecraft that has survived thruster failures, computer glitches, power shortfalls, communications blackouts, and the complete absence of any human intervention for nearly half a century, and kept going.

It crosses approximately a million miles of space every 16 hours.

It communicates with Earth using the power of a refrigerator light bulb.

It stores its data on a system that predates the personal computer.

And it remains, **48 years after launch, the most distant human-made object in the universe**, still doing its job, still sending back data, still adding to the sum of human knowledge from a place no human being has ever been and may never go.

If that is not worth pausing to appreciate, it is hard to know what is.

Sources: [NASA, Voyager Mission](#) | [NASA JPL, Voyager Mission Page](#) | [NASA JPL, Thruster Revival, May 2025](#) | [NASA Science Blog, May 14, 2025](#) | [Smithsonian Magazine, May 2025](#) | [NPR, May 20, 2025](#) | [CNN, May 2025](#) | [Live Science, May 2025](#) | [Hackaday, Voyager DTR analysis](#) | [Northern Wilds Magazine, November 2025](#) | [Wikipedia, Voyager 1](#)