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What was the trajectory of the Artemis capsul on return, and
splash down?

The **Artemis program** has completed two Orion capsule returns so far: the uncrewed **Artemis I** i
2022 and the crewed **Artemis II** on April 10, 2026 (splashdown at approximately 8:07 p.m. EDT /
or early April 11 UTC). nasa.gov

Artemis I (Uncrewed, 2022)

- **Trajectory**: Orion followed a **skip reentry** profile after its lunar mission. It entered Earth's atmosphe
speed, briefly "skipped" off the upper atmosphere to manage energy and heating, then descended fully
produced a glowing plasma trail visible in onboard and ground footage. The capsule decelerated from
mph, experienced peak heating, and relied on its heat shield before parachute deployment (drogues fo
three main parachutes).
- **Splashdown**: Pacific Ocean, about 100 miles (160 km) off the west coast of Mexico's **Baja Californi**
near **Guadalupe Island**. It occurred on December 11, 2022, at 12:40 p.m. EST (9:40 a.m. PST). Recc
from NASA and the U.S. Navy retrieved the capsule. space.com

Artemis II (Crewed, 2026)

- **Trajectory**: NASA used a **more direct reentry** path than Artemis I to reduce stress on the heat shield
more charring than expected on the uncrewed test flight). The capsule separated from its European Se
oriented heat-shield-forward, and hit the atmosphere southeast of Hawaii at Mach 33 (24,000 mph / ~
It flew roughly 2,000–3,000+ miles (3,200+ km) through the atmosphere while decelerating under int
heating (up to ~5,000°F / ~2,760°C on the shield). A final trajectory correction burn fine-tuned the pa
Communication blackout occurred during peak heating. Parachutes deployed in sequence (drogues at
mains at lower altitude), slowing it to ~17–20 mph for water impact. The crew experienced up to ~3.9
scrippsnews.com
- **Splashdown**: Pacific Ocean off the coast of **San Diego, California** (southern California coast). It wa
"perfect bull's eye" landing under partly cloudy skies, with the capsule upright after splashdown. Rec
extracted the four astronauts (Reid Wiseman, Victor Glover, Christina Koch, and Jeremy Hansen) for
checks. theguardian.com

Both missions targeted the Pacific for safety (vast open ocean away from populated areas and sh
and favorable recovery conditions. The reentry corridor was tightly controlled to ensure debris ris
minimal. Artemis I's skip trajectory helped validate the heat shield; Artemis II refined it for crewed

If you're asking about a specific mission (e.g., I vs. II) or want more details like exact coordinates,
performance data, or visuals from the reentry, let me know!

36 web pages

Heat shield performance details

Artemis III lunar landing

Why can't the "burn" occur in space to slow the descent, and
fall" to occur, and eliminate all this heat and speed stuff? Hov

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reach 24K miles per hour coming from the moon? Wouldn't t
mere ~10 hour trip instead of days?

Thought for 27s

The short answer: Braking with a big rocket burn *in space* before re-entry is possible in theory b
impractical—it would require carrying *enormous* amounts of extra fuel (far more than the spacecr
store), thanks to the rocket equation. The high re-entry speed (~24,000 mph / ~11 km/s for lunar
the natural result of "falling" back into Earth's gravity well from the Moon's distance. You *can't* eli
heat and speed without that fuel penalty. And no, the trip isn't ~10 hours because the capsule isn
24,000 mph the whole way—it coasts on a long, curved orbital path where its *average* speed is m

Here's the physics, step by step, without jargon where possible.

1. How the capsule reaches ~24,000 mph on the way back from the Mo

The Moon is ~238,000–250,000 miles away on average. After the crew module separates from the
module (or after the trans-Earth injection burn while in lunar orbit), the spacecraft is basically *falli*
Earth along an elliptical orbit.

- Earth's gravity pulls it faster and faster the closer it gets (converting gravitational potential energy int
energy).
- At lunar distance the relative speed is modest (the Moon itself orbits Earth at only 2,200 mph). But by
screams into the upper atmosphere, it's hitting **lunar-return velocity**: roughly 24,000–25,000 mph (1
is similar to Earth's escape velocity scaled for the distance.
- Artemis II (and Apollo before it) uses a "free-return" or near-free-return trajectory: after a small burn
orbit, gravity alone swings it home. No constant thrusting at max speed—just coasting while accelera
in Earth's gravity well. scientificamerican.com +1

That peak speed only happens right at the end, near Earth. Earlier in the trip the capsule is movin

2. Why the trip takes days, not ~10 hours

Your 10-hour calculation assumes constant 24,000 mph straight-line travel the whole distance. Th
orbits work:

- The spacecraft follows a long, looping elliptical path around Earth (a transfer orbit). It doesn't point s
and floor it.
- Most of the journey is spent at much lower average speeds. The 24,000 mph is only the *final* speed af
gradual acceleration.
- Real transit times: Artemis I took 10 days total (out and back); Artemis II was similar—4 days each w
lunar returns were ~2.5–3 days. Missions optimize for safety, fuel efficiency, and the right re-entry co
speed. reddit.com +1

If you tried a straight, powered dash it would need *way* more fuel and wouldn't be safer.

3. Why not just do a huge braking burn in space and "free-fall" the rest way?

This is the key part of your question. Slowing down *before* hitting the atmosphere sounds logical
the speed out there!"), but:

- **The rocket equation makes it brutal.** Every extra pound of fuel you need to slow down also has to l
from Earth, which requires *even more* fuel to carry *that* fuel. For lunar-return speeds (~11 km/s to kill
rocket so massive that the spacecraft becomes impractically heavy. Real numbers from orbital mecha
propulsive deceleration would require propellant mass many times the spacecraft's dry mass.
space.stackexchange.com +1

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- **Atmospheric drag (aerobraking) is "free" delta-v.** The atmosphere does the slowing for you—no e needed. The heat shield turns kinetic energy into plasma and heat instead of burning propellant. This crewed lunar return (Apollo, Artemis) and most Earth-orbit re-entries use it. Using rockets alone for t slowdown is "extremely expensive" and, for practical spacecraft, impossible with current mass budge reddit.com +1
- Orion's service module *does* have thrusters, but they're for small course corrections, lunar orbit insert the initial trans-Earth injection burn—not for killing 24,000 mph. Carrying enough extra propellant fo braking would have made the whole mission unlaunchable with SLS.

In short: the heat and speed are the *price* of using Earth's gravity and atmosphere efficiently. The engineered to handle ~5,000 °F plasma; it's lighter and more reliable than hauling the fuel for a r slowdown. scientificamerican.com

Bottom line

Re-entry isn't a design flaw—it's the smartest, lightest way to get home. Every gram counts in spa aerobraking saves enormous mass (and therefore cost and risk). The "free fall" you're picturing *is* already happening; the high speed is just gravity doing its job over hundreds of thousands of mil

If you want the exact delta-v numbers, a diagram of the free-return trajectory, or why future Mars use even more aggressive aerobraking, just ask!

9 web pages

Explain rocket equation details

Compare Apollo reentry methods

OK, so why aren't the near earth comets and such also affecte same draw and create issues with an actual hit?

They **are** affected by exactly the same gravitational "draw" from Earth. Any object falling toward E Moon's distance (or similar) gains roughly the same speed due to Earth's gravity well—peaking n (~24,500 mph) at the top of the atmosphere. That's why lunar-return spacecraft and some natura objects (NEOs) experience comparable high-speed atmospheric entries. The physics is identical: g converts potential energy into kinetic energy as the object "falls" inward.

Why the same effect applies to comets and asteroids

- **Earth's escape velocity sets the floor**: Any object arriving from far away (like the Moon or beyond) atmosphere at *at least* ~11.2 km/s if it's on a trajectory that intersects Earth. Slower than that, and it w enough energy to reach us from lunar distances in the first place. en.wikipedia.org
- **Near-Earth asteroids (mostly from the asteroid belt)**: These are in orbits around the Sun that cross Their relative speed to Earth is typically lower because they're bound to the inner Solar System. Aver speeds are around **17–20 km/s** (~38,000–45,000 mph). Many hit at speeds close to lunar-return veloc en.wikipedia.org
- **Comets (especially long-period ones from the outer Solar System or Oort Cloud)**: These can com more eccentric (stretched) orbits with higher speeds relative to Earth—often **30–60+ km/s** (up to ~72 maximum for bound Solar System objects). They fall from much farther out, so they gain even more Sun's gravity well *plus* Earth's. Short-period comets are slower, closer to asteroid speeds. impact.ese.ic.a

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In short: the "draw" is the same, but starting conditions (orbital energy and direction) determine t speed. A spacecraft on a deliberate free-return from the Moon is engineered to arrive at ~11 km/ objects arrive at whatever speed their Solar System orbit dictates—sometimes similar, sometimes

Do they "create issues" with actual hits?

Yes—they absolutely do when trajectories align for a direct hit. That's exactly what meteors, fireb impact craters are:

- Small objects (pebbles to car-sized) burn up as bright meteors due to the same atmospheric compressi that Orion experiences, just on a faster, steeper scale.
- Larger ones can survive to the ground (meteorites) or explode in the air (like Chelyabinsk in 2013).
- Really big ones in the past created massive craters (e.g., Chicxulub that helped end the dinosaurs) bec kinetic energy is enormous—far more destructive than any spacecraft re-entry.

The reason we don't see constant catastrophic hits today:

- **Space is mostly empty**. Even with thousands of known NEOs, the odds of a precise trajectory interse Earth are extremely low. Most "near-Earth" objects pass by at safe distances (millions of miles).
- **Jupiter acts as a shield**. Its massive gravity deflects or ejects many comets and asteroids before they Solar System.
- **Most potential impactors have already hit** over billions of years, or their orbits have been cleared/s
- Large dangerous objects (km-sized) hit on timescales of tens to hundreds of thousands of years or lon ones are more frequent but cause less damage. dw.com

NASA and others actively track NEOs precisely because high-speed impacts *are* a real (though lo risk. Missions like DART have even tested ways to nudge them off course if needed.

Key difference from the Artemis capsule

The Orion capsule is on a *controlled, shallow* trajectory designed to graze the atmosphere just rig from its shape to manage deceleration and avoid skipping out or burning up too intensely. Most objects come in at random angles and speeds, so their "re-entries" are uncontrolled and often m per unit mass.

The gravity well works the same for everything. The high speed isn't unique to human spacecraft- fundamental consequence of falling deep into Earth's gravitational potential from lunar (or greate Natural objects just don't get the benefit of a heat shield, parachutes, or precise navigation.

If you'd like numbers for a specific asteroid/comet example, a comparison of energy released, or calculate these velocities, let me know!

53 web pages

Explain escape velocity calculation

Discuss DART mission details

OK, so back to the Arte3mis II return, at 24,000 MPH, wouldn' sound barrier issues with everyone hearing them break it acro entire trajectory?

No, there wouldn't be a loud **sonic boom** heard continuously "across the entire trajectory" by ev the path. Here's why, with the specifics for **Artemis II**'s return.

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Sonic Booms Basics in This Context

A sonic boom occurs when an object travels **faster than the speed of sound** (~767 mph at sea l varies with altitude and temperature) and pushes air molecules faster than they can get out of th creates a shock wave (like a pressure cone trailing behind the object) that reaches the ground as "boom" or rumble, sometimes rattling windows.

The Orion capsule entered the atmosphere at ~**24,000–25,000 mph** — that's roughly **30–33 tim** of sound (hypersonic). It absolutely created shock waves and a plasma sheath from compression/ several factors prevent a dramatic, widespread audible boom the whole way:

- **The "boom carpet" is narrow and localized**: Sonic booms from high-speed objects are heard prima limited area directly beneath (or near) the flight path, called the boom carpet. For Artemis II, the reen was over the Pacific Ocean, starting southeast of Hawaii and curving toward the splashdown point ~5 San Diego. Much of the high-supersonic/hypersonic phase happened far offshore, so the shock waves weakened before reaching populated land. wjhl.com
- **High altitude weakens the sound**: The strongest shock waves form early in reentry (when the capsul high—tens to hundreds of miles up). By the time the pressure waves propagate down to the ground, tl greatly attenuated by distance, atmospheric refraction (bending due to temperature/wind layers), and a This is why many people on the ground hear little or nothing, even if a boom is theoretically possible
- **The trajectory is shallow and over water**: Orion used a controlled, lifting reentry (not a steep dive). path through the upper atmosphere while decelerating. The portion where it was supersonic over or n minimal and mostly coastal/offshore. NASA designed it this way partly for safety and recovery.

What Actually Happened with Artemis II

Pre-splashdown predictions from NASA and the USGS indicated a possible sonic boom (or felt pr in parts of **Southern California** around 5–5:15 p.m. PST on April 10, 2026, potentially rattling win coastal areas near San Diego. They even asked the public to report it via the USGS "Did You Feel (normally used for earthquakes). latimes.com

In reality:

- Some coastal residents may have heard a brief boom or felt a rumble/thump.
- Many others (even in San Diego or farther inland) reported hearing nothing, leading to some disappoi online.
- The boom was **not** heard across the entire West Coast or the full trajectory—only potentially in a limi under the final approach.

This matches historical crewed lunar returns (Apollo missions) and other high-speed reentries like Crew Dragon: occasional localized booms or window rattles near the landing zone, but not a con audible event for hundreds or thousands of miles.

Why It Doesn't Sound Like a Jet Breaking the Sound Barrier Repeatedly

- Fighter jets or the Space Shuttle (on certain paths) produce clearer booms because they fly lower and over land at lower supersonic speeds.
- Reentry vehicles are much higher and faster initially, with the shock wave behaving differently due tc hypersonic regime and plasma effects.
- The capsule slows rapidly once deep in the atmosphere (via drag and the heat shield), so the time spei supersonic" speeds near the ground is very short.

The astronauts inside don't hear a boom either—the shock wave trails behind them, and they're a of it.

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In short, the physics does produce shock waves at 24,000 mph, but the combination of altitude, c and atmospheric effects means it doesn't translate to everyone along the route hearing dramatic It was more of a potential localized event for Southern California coastal areas.

If you watched any live coverage or have reports from specific locations, or want details on how t w .efacts with the plasma, feel free to share!

42 web pages

Hypersonic shock wave physics

Apollo sonic boom experiences

If the moon tugs our oceans, wouldn't the earth's "gravity" be the Orion capsule from the beginning as the moon is tugging toward it? With no resistence, wouldn't that 24K mph speed h achieved rather quickly? Also, you stated "Orion's service mo have thrusters, but they're for small course corrections, lunar insertion/exit, and the initial trans-Earth injection burn—not f 24,000 mph," and "rection burn fine-tuned the path." How ca small thrusters alter the course of something traveling at 25K "curve" it's trajectory as it is re-entering our atmosphere? Wo need to be constant "course corrections" from the moment it entry for it to arrive where they expected it?

Thought for 17s

No, the Moon isn't constantly "tugging back" hard enough to cancel Earth's pull or make t mph speed happen instantly. And the small thrusters **don't** need to fight 25,000 mph constantl the path in real time during re-entry. Everything happens because of how orbits and free-fall wor no air resistance, no roads, just gravity and precise, infrequent nudges.

1. The gravity "tug-of-war" and why speed builds gradually (not quickly

You're right that the Moon tugs on the oceans (causing tides) and technically on the Orion capsu the whole Earth-Moon-spacecraft system is orbiting their common center of mass (the barycente Earth). Once the trans-Earth injection (TEI) burn commits Orion to the return, it's on a **free-return** designed so Earth's gravity naturally pulls it home while the Moon's gravity is already factored in.

svs.gsfc.nasa.gov

- **It's not a straight-line tug-of-war.** The capsule isn't "fighting" the Moon the whole way. The path is elliptical orbit around Earth that grazes the Moon's influence just right. Gravity from both bodies is c acting, but the net effect is that the capsule simply **coasts and falls** deeper into Earth's gravity well ov
- **Speed doesn't ramp up instantly.** Near the Moon (~238,000 miles out), its relative speed is low (sin Moon's orbital speed around Earth, ~2,200 mph). As it falls closer to Earth, gravity accelerates it—lik something from a tall building, but on a cosmic scale. It takes ~4 days for Artemis II because most of spent at much lower average speeds; the 24,000 mph peak only happens right at the end, when it's dee gravity well. No resistance in vacuum means it keeps whatever velocity it has, but the acceleration is spread out. nasa.gov
- **Why tides don't "cancel" this:** Tides happen because oceans are fluid and deformable over short dis capsule is in true free-fall with the spacecraft—everything (crew, ship, Moon's pull) is accelerating to the same gravity. The Moon's tug is tiny compared to Earth's at return distances and is accounted for i math.

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In short: the capsule is already "falling" toward Earth the moment it leaves lunar orbit. The free-re uses both gravities like a slingshot in reverse—no fuel needed after the initial TEI burn.

2. How small thrusters fine-tune the path (even at high speeds) without corrections

The thrusters you're asking about are **not** trying to fight 25,000 mph drag or constantly steer like the exact sequence for Artemis II:

- **Big picture:** Most of the return is pure coasting on the free-return path. Small **return trajectory cor burns** happen days earlier (e.g., Flight Day 7 and 9): 9–15 seconds long, changing velocity by just 1. second. These are done with the service module still attached (it has the main propulsion). nasa.gov +1
- **Final tweak:** After the crew module separates from the service module (~20–37 minutes before splas southeast of Hawaii), the **capsule itself** fires its own onboard thrusters (reaction control system, or RC last short burn. This happens in vacuum, before hitting the atmosphere, and puts it on the perfect entry the capsule orients heat-shield-forward and starts rolling maneuvers for stability. youtube.com +2

of miles (or at least many thousands) from the entry point, that tiny nudge gets magnified over time a like a tiny steering wheel turn on a highway that changes your lane miles later. Orbital mechanics me ft/s can shift the entry angle by the fraction of a degree needed (the corridor is tight, less than 1° marg constant firing required once the path is set—gravity does the rest. nasa.gov

During actual atmospheric re-entry (the "24k mph heat and speed stuff"):
The service module is already gone (it burns up separately). The crew module has no big engine l small RCS jets for **attitude control** (pointing the capsule correctly). It doesn't "curve" the trajecto thrusters anymore. Instead:

- It uses its shape to generate a little **lift** (like a wing) while rolling/banking to steer slightly left/right w corridor.
- The atmosphere does the heavy braking (drag + heat shield). The path was locked in by those earlier l is essentially ballistic with minor lift guidance. abcnews.com

No constant corrections needed mid-plasma because the entry interface (where it first hits the at was already perfect. The whole system is engineered so one final pre-entry nudge is enough.

This is exactly how Apollo did it too—precise burns early, then coast and let physics take over. Th thrusters are efficient because space is vacuum and distances are huge.

If you want the exact delta-v numbers, a diagram of the free-return path, or what the final burn lo the live stream, just say the word!

7 web pages

Explain free-return trajectory details

Compare Apollo reentry techniques

Quick Answer

Ask anything

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