THIS IS A READ ONLY SCRIPT, IF YOU'RE A PILOT, COMMANDER OR MISSION DIRECTOR, CHECK PATREON FOR THE LINK TO THE COMMENT VERSION. THIS IS MEANT FOR A READ THROUGH AND GENERAL OVER ALL COMMENTS (NOT WORRIED ABOUT GRAMMAR OR PHRASING). THANK YOU!

Imagine being strapped into a rocket, watching out the window as the Earth shrinks below you, seeing the blue sky turn black. And then when the engines shut down, suddenly feeling everything become weightless. You unlatch your restraints and you float up to the window.

You are living the reality many people have dreamt about. But just as soon as you are getting used to the sensation of weightlessness, you're instructed to buckle back up because you're already falling back to Earth and you're about to re-enter Earth's atmosphere.

So wait, you were in space. Why didn't you stay there? What made this spacecraft reach space, but not orbit? What's the difference? Why did you only feel weightlessness for a few minutes instead of hours or days? Was there still gravity?

I'm Tim Dodd the Everyday Astronaut and today, we're going to dive in deep between what's the differences between space and orbit, dive into orbital velocity and the Karman line, and how and when exactly astronauts experience zero g.

And just to clear things up, we're not doing this to diminish the idea of suborbital rides to space, we're really just intending to clear up some common questions and misconceptions about spaceflight.

I mean I don't think many people would want to strip the astronaut wings off of Alan Shepard and Gus Grissom from their first spaceflight missions that were suborbital. No doubt their experiences and those who ride suborbital flights today, are profound.

~~But it did get me thinking, is being in space for only a few minutes worth it? So to answer that question I figured we'd talk to Coby Cotton from Dude Perfect who has gone to space on Blue Origin's New Shepard to get a sense of what it was like.~~

So here's the timestamps for those sections which are also in the description, the YouTube timeline is broken up into these sections and of course, we have an article version of this video up at Everyday Astronaut .com

And while you're there, take a look at our awesome shop where you can find our incredibly detailed 1:100 scale Falcon 9 rocket model and lots of other cool stuff!

Ok, let's get started!

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INTRO

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Space VS Orbit

Ok, I think the best place to start this topic is to help make sure we have a good understanding of the differences between getting to space and getting into orbit. I have a saying, to get to space you go up, but to stay in space you have to go sideways really really fast.

Let's go back to imagining you're on a suborbital rocket such as Blue Origin's New Shepard. The booster burns for almost 2 and a half minutes, reaching a maximum velocity of just over 3,000 kmh.

After engine shut down it coasts up above the Karman line or 100 km, slowing down from the moment the engines shut down right up until it kisses its peak altitude known as its apogee about 4 minutes after lift off, and then it begins to fall right back down to Earth.

As soon as the engine cuts off, you will actually begin to experience weightless-ness, even though you're still traveling upwards and you're only about halfway to space.

You'll actually continue to experience weightlessness not just until you reach the highest point or apogee, but all the way through the highest point and even while you fall back down. It's not until the vehicle starts to be slowed down by the atmosphere would you "feel" gravity.

Well specifically you're feeling the deceleration. So the lack of feeling of gravity you experience isn't because you're in space, it's because you and everything around you is experiencing the exact same acceleration.

And with no air or ground or anything to slow you or the spacecraft down at different rates, you are for all intents and purposes floating around inside the spacecraft.

There's actually a decent chance you've experienced the feeling of zero G, if you've ever jumped on a trampoline, or one of those slingshot rides or ridden on a rollercoaster… that brief moment where your stomach feels like it's in your chest.

That's because you and everything inside you is experiencing the same acceleration, you're for a brief moment more or less weightless.

And this really is all a zero-G flight is, a parabolic flight where the jet shoots you up, and then it follows your ballistic trajectory so you are at first coasting up and then falling until the plane has to come out of its dive, giving you about 30 seconds of weightlessness.

Actually once the plane stops climbing and begins to level out and your body leaves the ground, you can actually imagine the plane disappearing, you've been tossed by the plane and you'd follow a nice big arc of a ballistic trajectory.

The plane just follows that ark so you and the plane are all in the same inertial reference frame.

So this is why it is incorrect when people say there is no gravity in space. It's simply not true, however, Earth's gravitational influence does decrease the further away you are from it, but it's not the decrease in Earth's gravitational influence that makes you feel weightless.

Gravity follows the inverse square law. This means if you were twice as far from a planetary body, its gravity wouldn't be half as strong, it'd actually be one quarter as strong.

So you can actually be in space at 100 km but still pulled by nearly the same amount of Earth's gravity as those on the ground. At 100 km in altitude, Earth's gravity is still pulling you down at 9.5 m/s2 of acceleration vs the 9.8 m/s2 on the surface.

So again, it's not the lack of gravity that would make you experience weightlessness, it's the fact that you and the vehicle you're inside are all experiencing the same inertial reference frame. So don't confuse zero g or weightlessness with a lack of gravity.

A similar thing is true of the Earth's atmosphere. It's a gradient, and the higher you get, the thinner the air becomes until at some point the atmosphere is so thin it's virtually non-existent. So similar to gravity, it's not like right at 100 km the Earth's atmosphere suddenly stops.

And really, isn't that all space is, just an absence of matter or the absence of an atmosphere? Well yeah, but where does that start?

How little of an atmosphere does there need to be before it's considered "no atmosphere" since there'll certainly be a rogue molecule or two even in the deepest depths of space.

This topic of where does space start is often up for debate, but here's why we often say 100 km is the start of space.

Earth's gravity pulls down on the molecules in the atmosphere, and those molecules in essence are stacked on top of eachother which ends up making the atmosphere thicker and thicker the lower you are.

By 100 km in altitude, the atmosphere is virtually non-existent. Sure, you're bound to run into a few molecules here and there, but to be pedantic at 100 km there's roughly 0.000001% the amount of air molecules as there are at sea level. So it's not like there's zero air, but real close to zero.

But this 100 km we keep mentioning is known as the karman line, and it isn't just a completely arbitrary number. I mean it is in some ways, yeah it actually is a touch arbitrary, because it was rounded up to the nice round number of 100 km. However it does have some technical considerations for being 100 km.

First consideration of why the Karman line is where it is, is because of flying an aircraft. An aircraft has to overcome gravity via its aerodynamic lift. The thinner the atmosphere, the faster the vehicle must travel to generate enough lift to overcome gravity.

At extremely high speeds, centrifugal force becomes a contributing factor in maintaining altitude, this is known as Kepler force. These two forces converge at a certain point in altitude where the aerodynamic lift is equal to the Kepler force.

Fly higher in altitude than that point and the velocity becomes so high to maintain lift that the Kepler force dominates over the lifting force and so at some point you're pretty much orbiting rather than flying.

Another consideration is the highest altitude where you can travel fast enough to generate enough lift to stay aloft, but not so fast that you overheat your vehicle.

The original calculation was done using the most state of the art aircraft at the time, the Bell X-2 which was made of stainless steel and a copper-nickel alloy to withstand high temperatures.

This chart showed that at an altitude above 83.82 km, the X-2 would have to fly so fast to maintain lift that the heat would be high enough to cause it to lose structural integrity. Assuming some future advances in aerodynamics and material science, the Karman line was raised to 100 km.

Of course both the lift vs kepler force and the maximum temperature vs velocity could vary from vehicle to vehicle, but roughly 100 km has become the agreed upon altitude that regardless of your vehicle's design, in order to stay above 100 km, you're orbiting rather than flying.

But this still brings up the question, what exactly is orbiting? How do you get into orbit? Why is it such a big deal vs going to space on a suborbital ride?

Orbit VS Sub-orbit

In order to understand the difference between orbit and sub-orbit, I think we actually have to learn something counterintuitive about orbits. So before we get into how you get into orbit, let's start off already in orbit.

So, you're in a spacecraft and you're orbiting the Earth. You're traveling at 28,000 km/h, orbiting the planet every 90 minutes at an altitude of 400 km. Awesome.

Now if you were to change your velocity, things might not do what you'd think. If you were to speed up, your orbit would change, but not right at the place where you sped up. The change happens on the opposite side of the planet where your orbit would raise.

And when you slow down the opposite happens, your orbit on the exact other side of the planet would lower! And assuming your orbit is anything but circular, it's called elliptical, because the orbit is an ellipse or an oval.

And if you're in an elliptical orbit, when you're at the highest point or apogee, you'll be going the slowest, and then you actually fall down to the lowest point of the orbit, or perigee, and that's the fastest point in your orbit! Just like going up and down hills on a rollercoaster!

So if you're in a circular orbit and you want to raise your altitude, you have to speed up, this will put you into an elliptical orbit, you're now at the perigee and your apogee will be on the opposite side of the planet.

Then you just have to coast up to apogee and speed up again so your perigee matches your apogee and you're in a circular orbit at a new higher altitude.

The opposite is true if you wanted to be in a lower orbit. You have to slow down first, that will put you into an elliptical orbit and you'll now be at apogee with a perigee on the opposite side of the planet.

Then when you get to perigee you slow down again and it'll lower your apogee until it matches your perigee and you'll be in a new circular orbit at a lower altitude.

If you've ever played Kerbal Space Program, this concept is likely very familiar to you, which is why I love that game. It's taught me so much about orbital mechanics and rocket science.

And quick little side note, you might notice that Kerbal Space Program calls it apoapsis and periapsis. That's because that is actually the generic term for the high and low point of an orbit.

Apogee and perigee are specific when orbiting the Earth, apolune and perilune are the terms for orbiting the moon, and aphelion and perihelion are the terms when orbiting the sun. But apoapsis and periapsis can describe any orbit regardless of what it's orbiting.

Ok, now that we understand all of those things, let's go back to riding on a suborbital ride on New Shepard. What if, right when you hit apogee, you tossed a ball out the hatch at 15 m/s…

Well, it'll fly sideways relative to you, but in the grand scheme of things it will mostly end up just falling, landing pretty darn close to where you took off from.

Similar to that classic demonstration where you flick a ball off a counter and drop a ball off a counter at the same time and they'll both hit the ground together, one will just be further away from you then the other.

But the way you can think about it is the ball's trajectory basically makes an orbit around the center of the Earth, it just runs into the surface of the Earth and its perigee is barely beyond the Earth's center point because the ball wasn't traveling very fast at apogee.

And as we learned before, the faster you're traveling at apogee, the higher your perigee will be. And obviously the ball is going VERY slow at apogee, so our perigee will be VERY VERY low, like deep within the Earth, only a tiny bit above the center of the Earth.

So to get into orbit we need to raise the lowest point in our "orbit" so that we miss the Earth entirely… and how do we do that? We need to speed up. A LOT.

Now let's shoot a bullet out of a pistol horizontally at 350 m/s when we're at apogee. The bullet will go much further than the ball you threw, but it will still collide with the Earth, just much further away from the launch pad.

And again, its trajectory basically follows a path as if it were orbiting the center of the Earth, so if we look at its trajectory vs the ball we threw, you can see its perigee near the center of the Earth is actually higher up from the center of the Earth than the ball's perigee.

In other words, its perigee is higher because it was traveling faster at apogee. See where this is going?

Let's step it up even more, let's fire a sniper rifle horizontally that can shoot a round at 1,400 m/s. Again, the bullet flies a lot further yet, but gravity still pulls the bullets down so it too will hit the atmosphere and eventually, the ground. And again, its perigee is quite a lot higher than the other objects.

So in order to stay in space we need to reach a velocity of roughly 7.8 km/s, which is 28,000 kph or about 17,500 mph. At this velocity, our arc will go beyond the horizon and it'll miss the atmosphere and the Earth entirely!

As you can imagine, it's probably quite difficult to get anything large up to orbital velocities by shooting them out of a really large gun, especially if it's something fragile and squishy like a human.

So instead of accelerating up to those velocities virtually in an instant, an orbital rocket will continually accelerate for about 8 minutes so it can reach orbital velocities. And since it gets above pretty much all the atmosphere that would slow it down, it will now stay orbiting the Earth until it de-orbits.

I think this is pretty intuitive when playing Kerbal Space Program. When you launch a rocket, hop over to map view by pressing M. You'll notice it's constantly plotting its ballistic trajectory. As we ascend, we see a trajectory line beginning to form ahead of our rocket.

If we cut our engines at any point, we'd more or less coast up and follow that ballistic arc. The faster we go, the further that arc gets in front of the rocket because of the rocket's inertia.

So the trick is to start to aim that trajectory over the horizon, so after an initial ascent, the rocket needs to start pitching over to gain more and more horizontal velocity. This way our trajectory will continue out over the atmosphere.

And remember that whole speeding up raises the opposite side of our orbit? That's basically what we're doing during ascent after we've pitched over.

Assuming the rocket has enough inertia to get it above the atmosphere, the most important thing to do is to accelerate horizontally to raise our perigee.

And you can imagine it takes a much larger, more complicated and more powerful vehicle to go from 3,000 kph on a suborbital ride compared to the 28,000 kph it takes to get into orbit. We can see this difference just by looking at a scale comparison of New Shepard to SpaceX's Falcon 9.

And this doesn't even go into all the other considerations like long term life support, reentry velocities and logistics, orbital communications etc etc. Again, this isn't meant to be putting suborbital spaceflight down, but just simply trying to show the differences between them.

Ok, I think that's about it, it's time for just a few more thoughts.

Summary

Getting to space and going into orbit are two very different things. You can't orbit without the airless environment of space, but you can be in space without being in orbit, albeit for a brief moment in time.

Getting above the atmosphere is vital so the atmosphere doesn't slow the object down. If an object's orbit bites into the atmosphere too much, it will slow it down, which lowers the orbit, which means there's more atmosphere to slow it down and lower the orbit until it de-orbits.

This is even a consideration on a larger time scale for EVERYTHING in low Earth orbit, but the atmosphere at say 300 km is just so nearly non-existent, it can take years for something to deorbit due to atmospheric drag.

This really is the only reason rockets even go up in the first place. If Earth had no atmosphere, you could simply launch from a high point, fly ever so slightly up to avoid terrain and you could orbit at a very low altitude. In fact, this is true on the moon.

But the other thing to remember is that just because you're in space, it doesn't mean there's no gravity. The amount of gravity you experience in low Earth orbit is nearly the same as the amount of gravity down on Earth.

The reason you feel weightlessness is because you and the spacecraft you're inside are all basically falling at the same rate. The reason you don't hit the ground is because you have so much velocity forward, you're constantly missing the ground.

At the end of the day, I know it can be easy to say suborbital as if it's some kind of snide comment, or be cynical that it's just some meaningless joy ride for billionaires. And of course, there is some truth to some of that, but that doesn't mean it's pointless.

At 90 years old WIlliam Shatner viewed Earth from space on Blue Origin's New Shepard and he was utterly speechless and emotional when he landed. In fact he felt immense grief at the fragility of our planet and had a strong reaction often known as the overview effect.

The perspective of seeing our Earth from space is often eye opening and enlightening for people, helps people understand the borderless nature of our species, how we're all neighbors just sharing this one fragile little blue ball.

But that's not all suborbital rides are good for. They actually do serve a purpose scientifically. The ability to have 4 full minutes of weightlessness if often plenty of time to perform vital and significant experiments.

In fact, did you know NASA has a 132 meter deep vacuum chamber that allows experiments the opportunity to experience 5.18 seconds of free fall. If that's worth it to have a 132 meter deep vacuum tunnel for 5.18 seconds for scientists, imagine what 4 minutes of clean zero g would be worth!

But that's pretty much it! Hopefully this video helps you understand the differences between going to space and getting into orbit, between zero g and no gravity and gained a little perspective on how orbits work.

Let me know if you have any other thoughts or questions in the comments below!

Our own definitions of space // poetic // mcdowell // karman

Gus Grissam // Alan Shepard of original astronaut wings?

Scientific value on suborbital vehicles

Apoapsis and periapsis

SOURCES
Karman line - https://hal.science/hal-03420278v1/file/DTIS21210pu.pdf