How (and Why) SpaceX Will Colonize Mars

August 16, 2015 By Tim Urban

This is Part 3 of a four-part series on Elon Musk's companies. For an explanation of why this series is happening and how Musk is involved, start with Part 1.

Pre-Post Note: I started working on this post ten weeks ago. When I started, I never intended for it to become such an ordeal. But like the Tesla post, I decided as I researched that this was A) a supremely important topic that will only become more important in the years to come, and B) something most people don't know nearly enough about. My weeks of research and discussions with Musk and others built me an in-depth, tree-trunk understanding of what's happening in what I'm calling The Story of Humans and Space—one that has totally reframed my mental picture of the future (yet again). And as I planned out what to include in the post, I wanted to make sure every Wait But Why reader ended up with the same foundation moving forward—because with everything that's coming, we're gonna need it. So like the Tesla post, this post became a full situation. Even the progress updates leading up to its publication became a full situation.

Thanks for your patience. I know you'd prefer this not to be a site that updates every two months, and I would too. The Tesla and SpaceX posts were special cases, and you can expect a return to more normal-length WBW posts now that they're done.

About the post itself: There are three main parts. Part 1 provides the context and background, Part 2 explores the "Why" part of colonizing Mars, and Part 3 digs into the "How." To make reading this post as accessible as possible, it's broken into five pages, each about the length of a normal WBW post, and you can jump to any part of the post easily by clicking the links in the Table of Contents below. We're also trying two new things, both coming in the next couple days:

1) PDF and ebook options: We made a fancy PDF of this post for printing and offline viewing (see a preview here), and an ebook containing the whole four-part Elon Musk series:

Get the PDF

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udio version. You can find an unabridged audio version of the post, read by me, as well as a sion about the post between Andrew and me here.

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tents

2365 AD, Ganymede

One more day until departure. It was so surreal to picture actually *being* there that she still didn't really believe it would happen. All those things she had always heard about—buildings that were constructed hundreds of years before the first human set foot on Ganymede; animals the size of a house; oceans the size of her whole world; tropical beaches; the famous blue sky; the giant sun that's so close it can burn your skin; and the weirdest part—*no Jupiter hovering overhead*. Having seen it all in so many movies, she felt like she was going to visit a legendary movie set. It was too much to think about all at once. For now, she just had to focus on making sure she had everything she needed and saying goodbye to everyone—it would be a long time before she would see them again...

Part 1: The Story of Humans and Space

About six million years ago, a very important female great ape had two children. One of her children would go on to become the common ancestor of all chimpanzees. The other would give birth to a line that would one day include the entire human race. While the descendants of her first child would end up being pretty normal and monkey-ish, as time passed, strange things began to happen with the lineage of the other. [1] [1] ← click these

We're not quite sure why, but over the next six million years, our ancestral line started to do something no creatures on Earth had ever done before—they woke up.

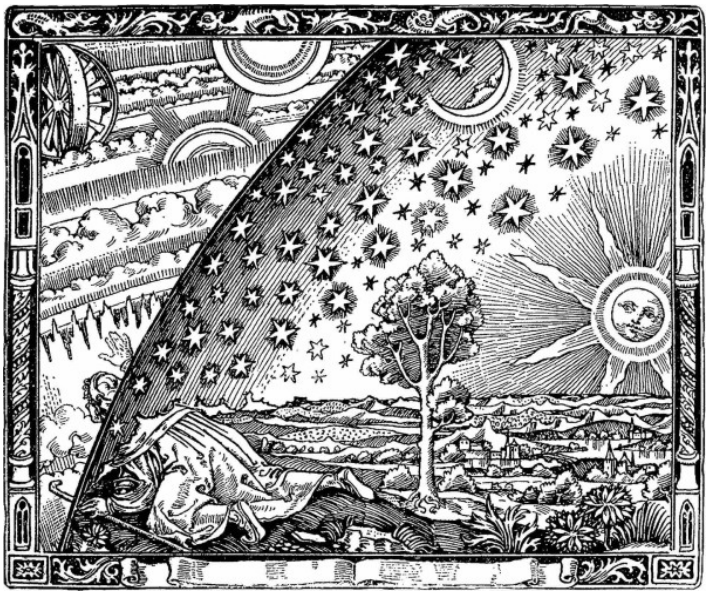
It happened slowly and gradually through the thousands of generations the same way your brain slowly comes to in the first few seconds after you rouse from sleep. But as the clarity increased, our ancestors started to look around and, for the very first time, *wonder*.

Emerging from a 3.6-billion-year dream, life on Earth had its first questions.

What is this big room we're in, and who put us here? What is that bright yellow circle on the ceiling and where does it go every night? Where does the ocean end and what happens when you get there? Where are all the dead people now that they're not here anymore?

We had discovered our species' great mystery novel—*Where Are We?*—and we wanted to learn how to read it.

As the light of human consciousness grew brighter and brighter, we began to arrive at answers that seemed to make sense. Maybe we were on top of a floating disk, and maybe that disk was on top of a huge turtle. Maybe the pinpricks of light above us at night are a glimpse into what lies beyond this big room—and maybe that's where we go when we die. Maybe if we can find the place where the ceiling meets the floor, we can poke our heads through and see all the super fun stuff on the other side. [2]



Around 10,000 years ago, isolated tribes of humans began to merge together and form the first cities. In larger communities, people were able to talk to each other about this mystery novel we had found,

comparing notes across tribes and through the generations. As the techniques for learning became more sophisticated and the clues piled up, new discoveries surfaced.

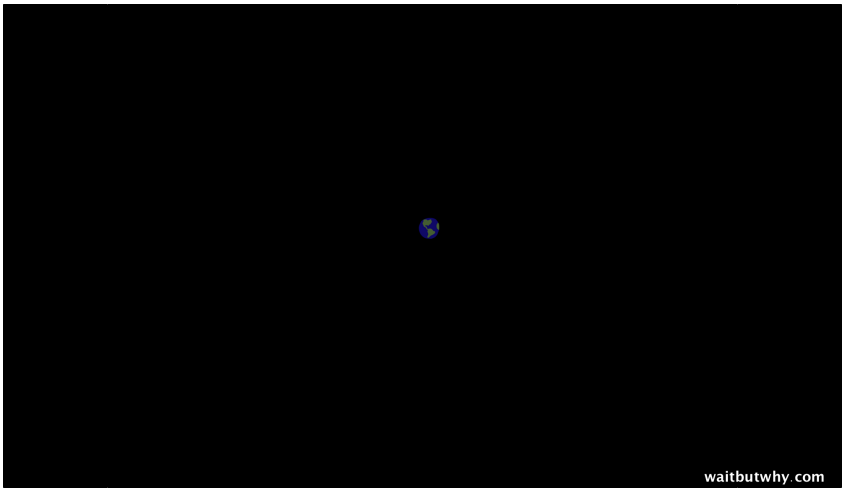
The world was apparently a ball, not a disk. Which meant that the ceiling was actually a larger sphere surrounding us. The sizes of the other objects floating out there in the sphere with us, and the distances between them, were vaster than we had ever imagined. And then, something upsetting:

The sun wasn't revolving around us. We were revolving around the sun.

This was a *super* unwarm, unfuzzy discovery. Why the *hell* weren't we in the center of things? What did that mean?

Where are we?

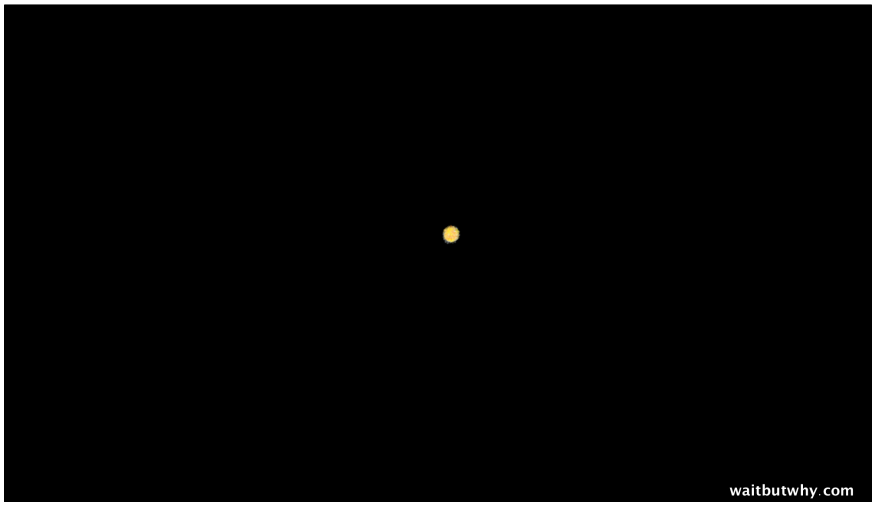
The sphere was already unpleasantly big—if we weren't in the center of it, were we just on a random ball inside of it, kind of for no apparent reason? Could this really be what was happening?



Scary.

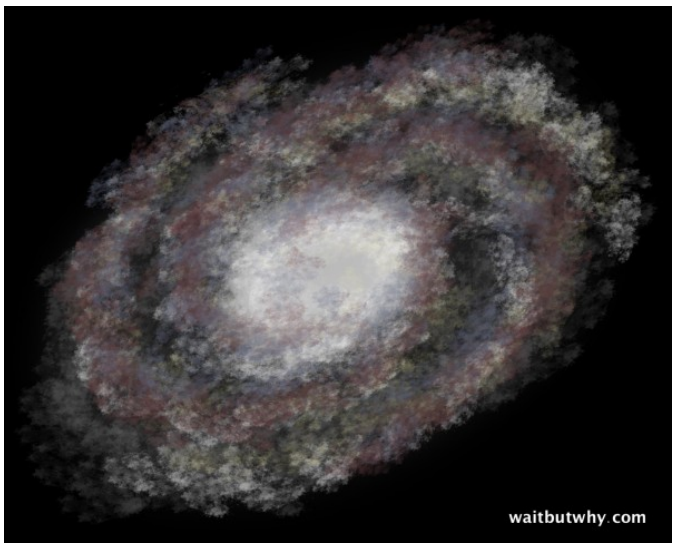
Then things got worse.

It seemed that the pinpricks of light on the edge of the sphere weren't what we thought they were—they were other suns like ours. And they were out there floating just like our sun—which means *we weren't inside of a sphere at all*. Not only was our planet not the center of things, even our *sun* was just a random dude out there, in the middle of nowhere, surrounded by nothingness.



Scary.

Our sun turned out to be a little piece of something much bigger. A beautiful, vast cloud of billions of suns. The everything of everything.



At least we had that. Until we realized that it wasn't everything, it was this:

Darkness.

The better our tools and understanding became, the more we could zoom out, and the more we zoomed out, the more things sucked. We were deciphering the pages of *Where Are We?* at our own peril, and we had deciphered our way right into the knowledge that we're unbelievably alone, living on a lonely island inside a lonely island inside a lonely island, buried in layers of isolation, with no one to talk to.

That's our situation.

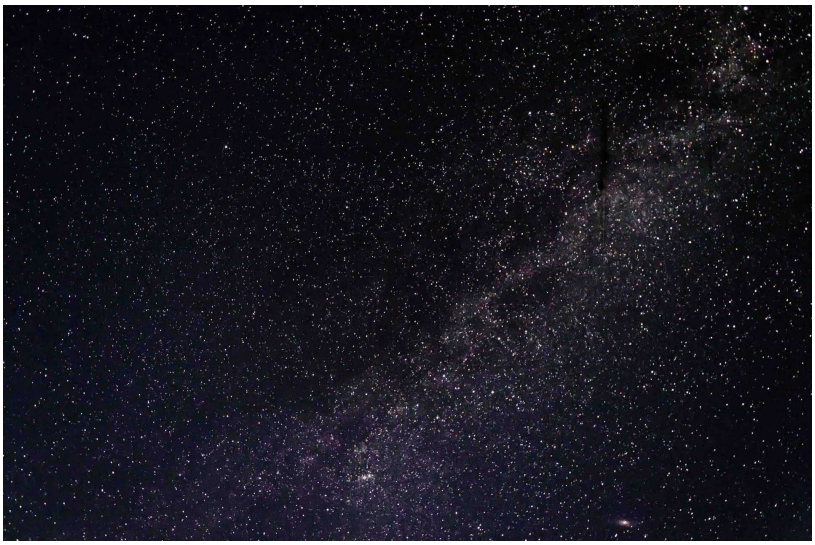
In the most recent 1% of our species' short existence, we have become the first life on Earth to know about the Situation—and we've been having a collective existential crisis ever since.

You really can't blame us. Imagine not realizing that the universe is a thing and *then realizing the universe is a thing*. It's a *lot* to take in.

Most of us handle it by living in a pleasant delusion, pretending that the only place we live is in an endless land of colors and warmth. We're like this guy, who's doing everything he possibly can to ignore the Situation: [3]

And our best friend for this activity? The clear blue sky. The blue sky seems like it was *invented* to help humans pretend the Situation doesn't exist, serving as the perfect whimsical backdrop to shield us from reality.

Then nighttime happens, and there's the Situation, staring us right in the face.



Oh yeah...

This la-di-da → oh yeah... → la-di-da → oh yeah... merry-go-round of psychosis was, for most of recent history, the extent of our relationship with the Situation.

But in the last 60 years, that relationship has vaulted to a whole new level. During World War II, missile technology leapt forward, [2] and for the first time, a new, mind-blowing concept was possible—

Space travel.

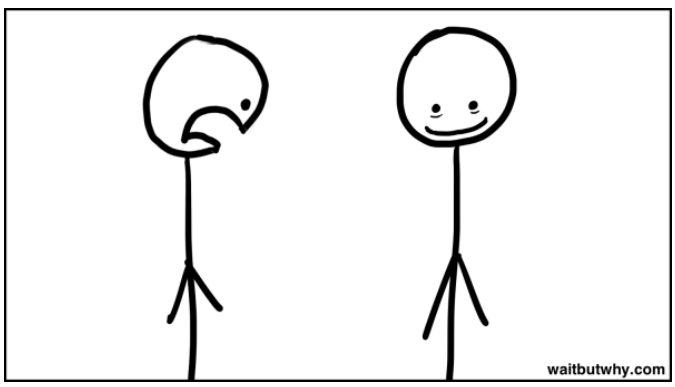
For thousands of years, The Story of Humans and Space had been the story of staring out and wondering. The possibility of people leaving our Earth island and *venturing out into space* burst open the human spirit of adventure.

I imagine a similar feeling in the people of the 15th century, during the Age of Discovery, when we were working our way through the world map chapter of *Where Are We?* and the notion of cross-ocean voyages dazzled people's imaginations. If you asked a child in 1495 what they wanted to be when they grew up, "an ocean explorer" would probably have been a common response.

In 1970, if you asked a child the same question, the answer would be, "an astronaut"—i.e. *a Situation explorer*.

WWII advanced the possibility of human space travel, but it was in late 1957, when the Soviets launched the first man-made object into orbit, the adorable Sputnik 1, that space travel became *the* defining quest of the world's great powers.

At the time, the Cold War was in full throttle, and the US and Soviets had their measuring sticks out for an internationally-televised penis-measuring contest. With the successful launch of Sputnik, the Soviet penis bolted out by a few centimeters, horrifying the Americans.

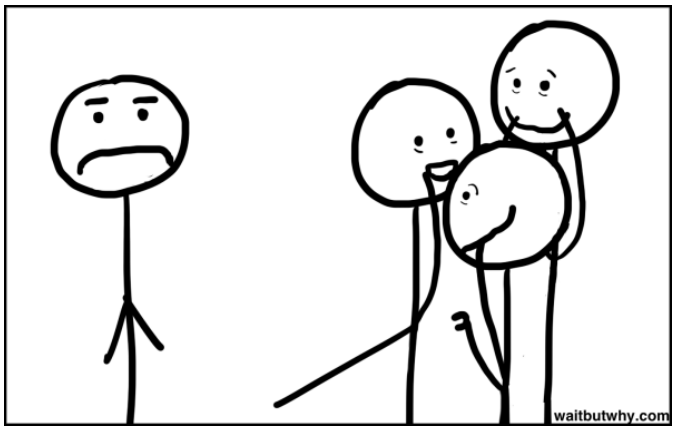


To the Soviets, putting a satellite into space before the US was proof that Soviet technology was superior to American technology, which in turn was put forward as proof, for all the world to see, that communism was a system superior to capitalism.

Eight months later, NASA was born.

The Space Race had begun, and NASA's first order of business would be to get a man into space, and then a man into full orbit, preferably both before the Soviets. The US was not to be shown up again.

In 1959, NASA launched Project Mercury to carry out the mission. They were on the verge of success when in April of 1961, the Soviets launched Yuri Gagarin into a full orbit around the Earth, making the first human in space *and* in orbit a Soviet.

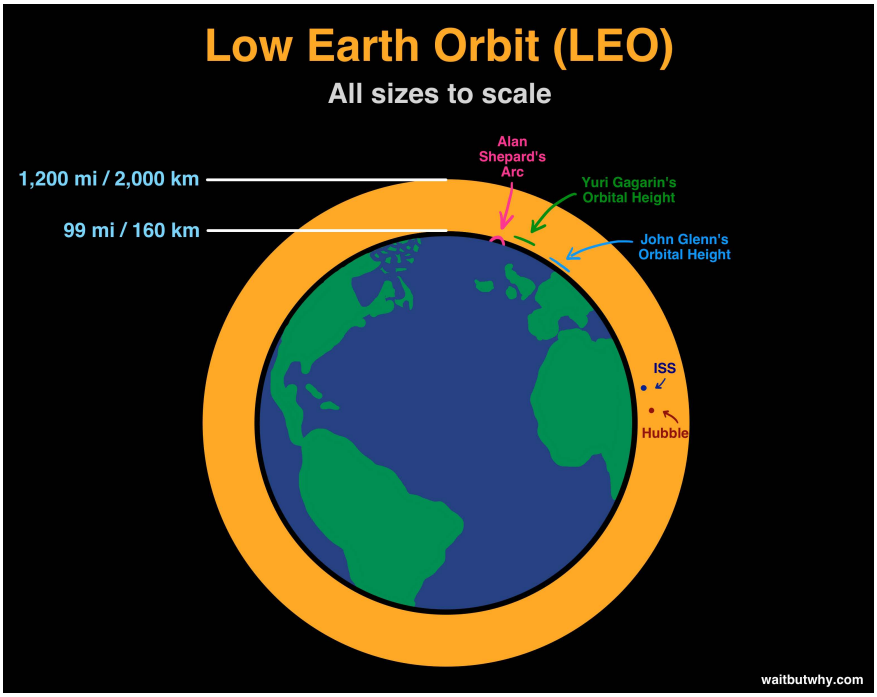


It was time for drastic measures. John F. Kennedy's advisors told him that the Soviets had too big a lead for the US to beat them at any near-term achievements—but that the prospect of a manned *moon* landing was far enough in the future that the US had a fighting chance to get *there* first. So Kennedy gave his famous "we choose to go to the moon, not because it is easy, but because it is hahhd" speech, and directed an outrageous amount of funding at the mission ($20 billion, or $205 billion in today's dollars).

The result was Project Apollo. Apollo's mission was to land an American on the moon—and to do it *first*. The Soviets answered with Soyuz, their own moon program, and the race was on.

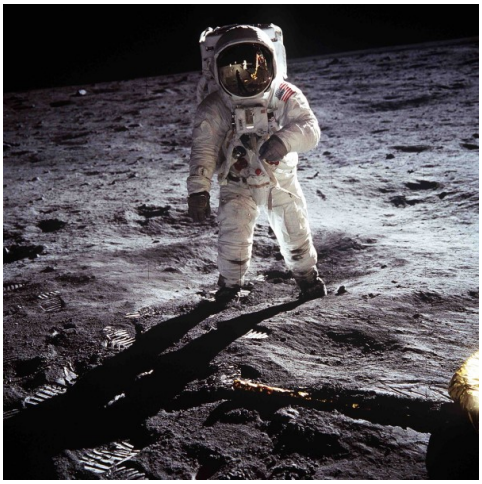
As the early phases of Apollo started coming together, Project Mercury finally hit its stride. Just a month after Yuri Gagarin became the first man in space, American astronaut Alan Shepard became the second man in space, completing a little arc that didn't put him in full orbit but allowed him to give space a high-five at the top of the arc. A few months later, in February of 1962, John Glenn became the first American to orbit the Earth.

The next seven years saw 22 US and Soviet manned launches as the superpowers honed their skills and technology. By late 1968, the furiously-sprinting US had more total launches under their belt (17) than the Soviets (10), and together, the two nations had mastered what we call Low Earth Orbit (LEO).



But LEO hadn't really excited anyone since the early '60s. Both powers had their sights firmly set on the moon. The Apollo program was making quick leaps, and in December of 1968, the US became the first nation to soar outside of LEO. Apollo 8 made it all the way to the moon's orbit and circled around 10 times before returning home safely. The crew, which included James Lovell (who a few months later played the role of Tom Hanks on the Apollo 13 mission), shattered the human altitude record and became the first people to see the moon up close, the first to see the "dark" side of the moon, and the first to see the Earth as a whole planet, snapping this iconic photo:[4]

Upon return, the crew became America's most celebrated heroes—which I hope they enjoyed for eight months. Three Apollo missions later, in July of 1969, Apollo 11 made Americans Neil Armstrong[3] and Buzz Aldrin the first humans on the moon, and Armstrong took this famous photo of Aldrin looking all puffy:[5]



It's hard to fully emphasize what a big deal this was. Ever since life on Earth began 3.6 billion years ago, no earthly creature had set foot on any celestial body other than the Earth. Suddenly, there are Armstrong and Aldrin, bouncing around *another* sphere, looking up in the sky where the moon is supposed to be and seeing the Earth instead. Insane.

Project Apollo proved to be a smashing success. Not only did Apollo get a man on the moon before the Soviets, the program sent 10 more men to the moon over the next 3.5 years on five other Apollo missions. There were six successful moon trips in seven tries, with the famous exception being Apollo 13, which was safely aborted after an explosion in the oxygen tank.[4]

The Soviet Soyuz program kept running into technical problems, and it never ended up putting someone on the moon.

The final Apollo moonwalk took place in late 1972. In only one decade, we had conquered nearby space, and progress was accelerating. If at that time you had asked any American, or any other human, what the coming decades of space travel would bring, they'd have made big, bold predictions. Many more people on the moon, a permanent moon base, people on Mars, and beyond.

So you can only imagine how surprised they'd be if you told them in 1972, after just watching 12 humans walk on the moon, that 43 years later, in the impossibly futuristic-sounding year 2015, the number of people to set foot on the moon *would still be 12*. Or that after leaving Low Earth Orbit in the dust years earlier and using it now as our pre-moon trip parking lot, 2015 would roll around and LEO would be the farthest out humans would ever go.

1972 people would be blown away by our smart phones and our internet, but they'd be just as shocked that we gave up on pushing our boundaries in space.

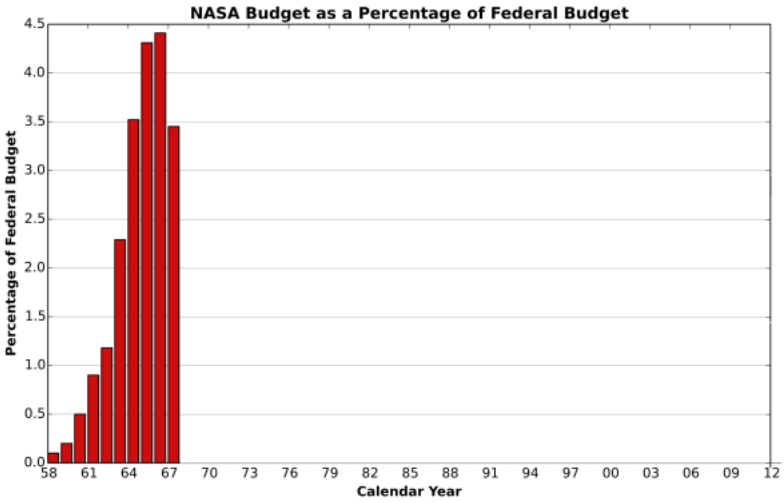
So what happened? After such a wildly exciting decade of human space adventure, why did we just *stop?*

Well, like we found in the Tesla post, "Why did we stop?" is the wrong question. Instead, we should ask:

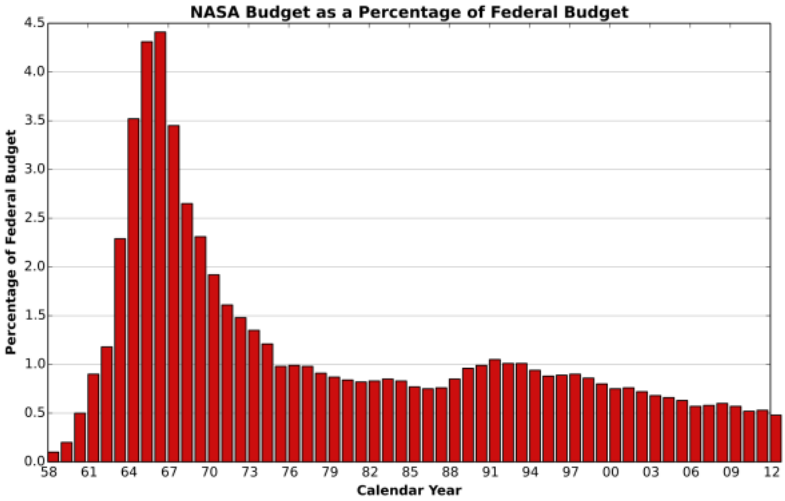
Why were we ever adventurous about sending humans into space in the first place?

Space travel is unbelievably expensive. National budgets are incredibly tight. The fact is, it's kind of surprising that a nation *ever* ponied up a sizable chunk of its budget for the sake of adventure and inspiration and pushing our boundaries.

And that's actually because no nation *did* blow their budget for the sake of adventure and inspiration and pushing our boundaries—two nations blew their budgets because of a *penis–length* contest. In the face of international embarrassment at a time when everyone was trying to figure out whose economic system was better, the US government agreed to drop the usual rules for a few years to pour whatever resources were necessary on the problem to make sure they won that argument—



And once they won it, the contest was over and so were the special rules. And the US went back to spending money like a normal person.[6]



Instead of continuing to push the limits at all costs, the US and the Soviets got a grip, put their pants back on, shook hands, and started working together like adults on far more practical projects, like setting up a joint space station in LEO.

In the four decades since then, the Story of Humans and Space has again become confined to Earth, where we find ourselves with two primary reasons to interact with space (Note: the next whole chunk of the post is a slight diversion for an overview on satellites, space probes, and space telescopes. If that doesn't excite you, I won't be hurt if you skip down to the International Space Station section):

1) Support for Earth Industries

The first and primary reason humans have interacted with space since the Apollo program isn't about human interest in space. It's about using space for practical purposes in support of industries on Earth —mostly in the form of satellites. The bulk of today's rocket launches into space are simply putting things into LEO whose purpose is to look back down at Earth, not to the great expanses in the other direction.

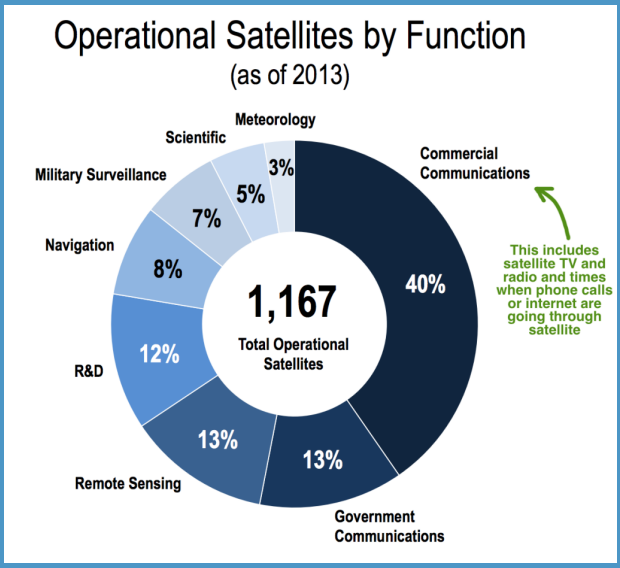
Here's a little satellite overview:

Satellites Blue Box

We don't think about them that often, but above us are hundreds of flying robots that play a large part in our lives on Earth. In 1957, lonely Sputnik circled the Earth by itself, but today, the worlds of communication, weather forecasting, television, navigation, and aerial photography all rely heavily on satellites, as do many national militaries and government intelligence agencies.

The total market for satellite manufacturing, the launches that carry them to space, and related equipment and services has ballooned from $60 billion in 2004 to over $200 billion in 2015. Satellite industry revenue today makes up only 4% of the global telecommunications industry but accounts for over 60% of space industry revenue.[7]

Here's how the world's satellites break down by role (in 2013):[8]

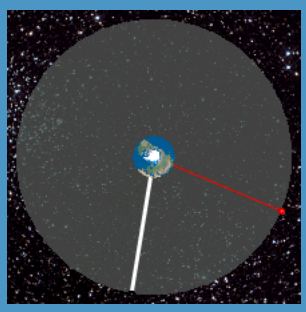


Of the 1,265 active satellites in orbit at the beginning of 2015, the US owns by far the largest number at 528—over 40% of the total—but over 50 countries own at least one orbiting satellite.

As for *where* all of these satellites are, most of them fall into two distinct "layers" of space:

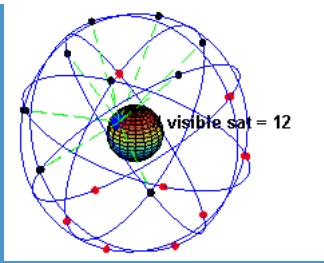
About two-thirds of active satellites are in Low Earth Orbit. LEO starts up at 99 miles (160 km) above the Earth, the lowest altitude at which an object can orbit without atmospheric drag messing things up. The top of LEO is 1,240 miles (2,000 km) up. Typically, the lowest satellites are at around 220 miles (350 km) up or higher.

Most of the rest (about one-third) of the satellites are much farther out, in a place called geostationary orbit (GEO). It's right at 22,236 miles (35,786 km) above the Earth, and it's called geostationary because something orbiting in it rotates at the exact speed that the Earth turns, making its position in the sky stationary relative to a point on the Earth. It'll seem to be motionless to an observer on the ground.[9]



GEO is ideal for something like a TV satellite because a dish on the Earth can aim at the same fixed spot all the time.

A small percentage of other satellites are in medium Earth orbit (MEO), which is everything in between LEO and GEO. One notable resident of MEO is the GPS system that most Americans, and people from many other countries, use every day. I never realized that the entire GPS system, a US Department of Defense project that went live in 1995, only uses 32 satellites total. And until 2012, the number was only 24—six orbits, each with four satellites. But you can see in the GIF below that even with 24, a given point on the Earth can be seen by at least six of the satellites at any given time, and usually it's nine or higher (in the GIF, the blue dot on the Earth is a hypothetical person on the ground, and whichever satellites can see him at a given time are blue, with the green lines showing their line of sight to the person):[10]

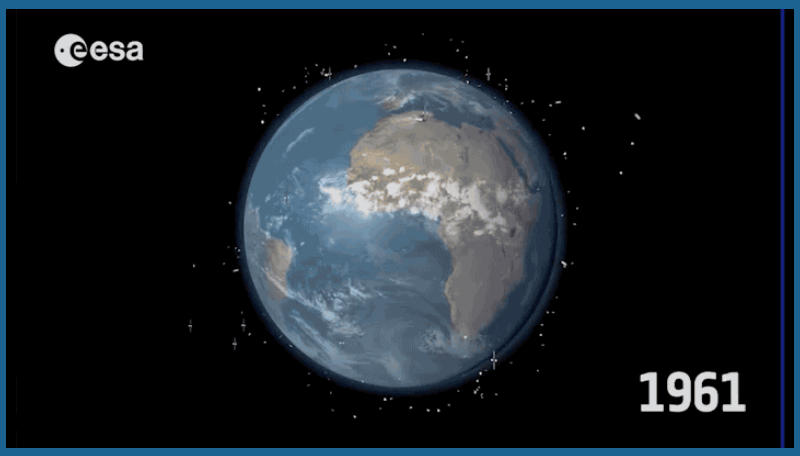


This is why your phone's map can still show your location even when you're somewhere with no cellular service—because it has nothing to do with cellular service. The system is also set up to be redundant—only four satellites need to simultaneously see you in order for the system to pinpoint your location. GPS satellites have an orbital period of about 12 hours, making two full rotations of the Earth each day.[5]

You can see satellite locations using Google Earth (here's a cool video of Google Earth showing the satellites).

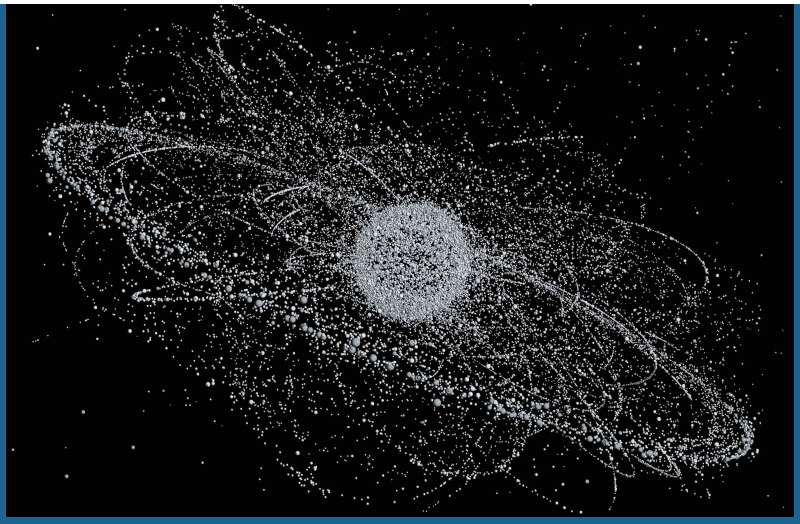
Space Debris Bluer Box

There's a big problem happening in the world of satellites. In addition to the 1,265 active satellites up in orbit, there are thousands more inactive satellites, as well as a bunch of spent rockets from previous missions. And once in a while, one of them explodes, or two of them collide, creating a ton of tiny fragments called space debris. The number of objects in space has risen quickly over recent decades, as a GIF[6] made by the ESA shows (with exaggerated-sized objects relative to the Earth's size):[11]



The majority of satellites and debris are bunched around the Earth in LEO, and the outer ring of objects is what's located in GEO.

Earth space agencies track about 17,000 objects in space, only 7% of which are active satellites. Here's a map showing every known object in space today.[12]

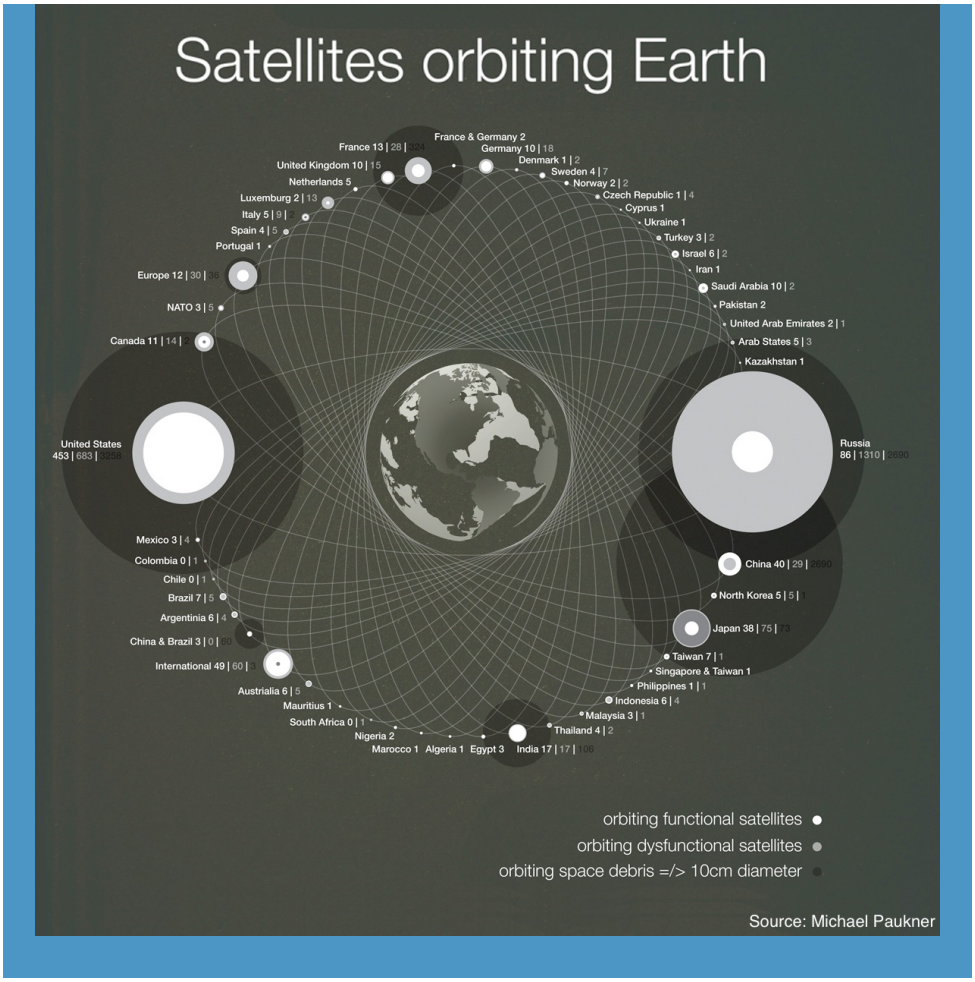


But the crazy thing is they only track the large objects, and that's what we're seeing in that image. Estimates for the number of smaller debris objects (1 – 10 cm) range from 150,000 to 500,000, and there are over a million total pieces of debris larger than 2 mm.[13]

The issue is that at the incredible speeds at which space objects move (most LEO objects zip along at over 17,000 mph), a collision with even a tiny object can cause devastating damage to an active satellite or spacecraft. An object of only 1 cm at those speeds will cause the same damage in a collision as a small *hand grenade*.[7][14]

Over a third of all space debris originated from just two events: China's 2007 anti-satellite test, when China shat on the world's face by intentionally blowing up one of its own satellites, creating *3,000* new pieces of debris large enough to be trackable, and a 2009 collision between two satellites that exploded into 2,000 debris chunks.[15] Each collision increases the amount of debris, which in turn increases the likelihood of more collisions, and there's danger of a domino effect situation, which scientists call the Kessler Syndrome. A bunch of parties are proposing ways to mitigate the amount of debris in LEO—everything from harpooning the debris to laser blasting it to intercepting it with a cloud of gas.

Here's a chart that sums up each nation's "space footprint," showing the quantity of active satellites, inactive satellites, and space debris caused by each country:[16]



There are a few other space activities in the "Support for Earth Industries" category of human/space interaction—like space mining, space burial, and space tourism—but at least for now, satellites account for almost the entire category.

2) Looking and Learning

The second reason humans have interacted with space in the last four decades proves that while we may have stopped sending people into The Situation, we never lost our hunger to learn about what's out there. As society moved on from space and turned its attention elsewhere, astronomers have kept busy at work deciphering their way through page after page of the old mystery novel, *Where Are We?*

Astronomers learn best with their eyes, and a side effect of the Space Race was the development of far better technology for seeing what's out there. There are two high-tech ways modern astronomers see things:

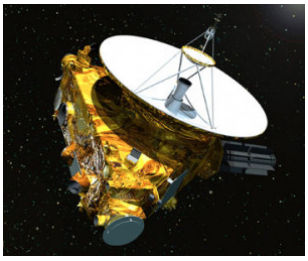
Looking and Learning Tool #1: Sending probes around the Solar System

Basically, scientists fire a fancy robot toward some distant planet, moon, or asteroid, and the robot spends months or years flying through space, bored, until it finally arrives. Then, depending on the plan, it either just flies by the object, taking some pictures on the way, orbits the object to get more detailed information, or lands on the object for a full inspection. Everything it learns, it sends back to us, and one day, when its job is done, we either kill the probe by crashing it into the object or let it just fly out into deep space to be depressed.

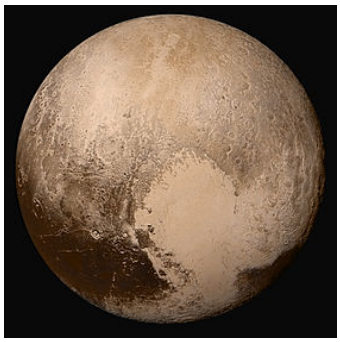
I often use myself as a litmus test for what the public probably knows about or doesn't know about. As I've mentioned before on this blog, I've been seriously dating astronomy ever since I was three years old—so if I don't know something going on in the world of space, I assume that most people don't. And when it comes to space probes, I've felt pretty disoriented. Are there 200 of them flying around out there? 50? 9? Why are they out there, who sent them, and what are they doing? All I'd know is that sometimes there would be a random story about some probe sending back stunning pictures—I'd open the cnn.com gallery, click through them, be thrilled for a second, send the link to the three friends of mine who are also dating astronomy, and then try to close the page but instead see some trashy CNN clickbait headline on the side of the page, click that, and ruin my life for the next three hateful hours. That's my relationship with humanity's space probes.

But in researching this post, I quickly realized there's not that much to know, and it doesn't take too big an effort to get fully oriented. Here are what I consider the eight key space robots to know about right now:[17]

1) New Horizons (Pluto, NASA)



New Horizons goes first because its big moment just happened. Launched in 2006 on a decade-long trip to Pluto (sped up on its way by a Jupiter fly-by in 2007 that gravity-zinged it to a much faster speed), New Horizons *finally* reached Pluto on July 14th, 2015. It didn't land on Pluto, but it flew very near to it and showed us Pluto for the first time:[8][18]



Next, New Horizons will be on its way further outwards into the Kuiper belt to send back images of comets and dwarf planets. You can track New Horizons' location here.

Awkwardly, Pluto was still a planet when New Horizons launched, and everyone spent the years following Pluto's demotion avoiding making eye contact with the New Horizons team. While I agree with the common sentiment that it's sad that Pluto's sad about its demotion,[9] the truth is, Pluto should probably appreciate that it got away with 76 illegitimate years as a planet celebrity, pulling in a ton of Kuiper belt ass in the process, given that fellow Kuiper belt dwarf planet Eris spent that whole time living its life in total obscurity, only discovered in 2005.

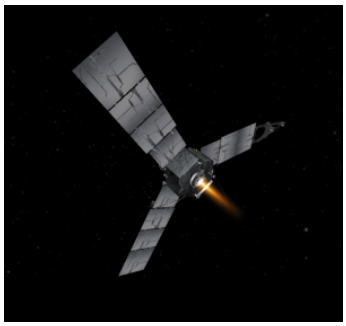
2) Curiosity (Mars, NASA)

Curiosity is a now-famous rover. A car-sized lovable lander robot dropped down on Mars's surface in 2012, Curiosity is studying a bunch of things inside a large crater, with its primary objective being to figure out if there's ever been life on Mars. The last two Mars rovers, Opportunity and Spirit, landed in 2004 with a planned mission of 90 days. Both lasted way past their expiry date, and Opportunity is *still* active. Such a good boy.

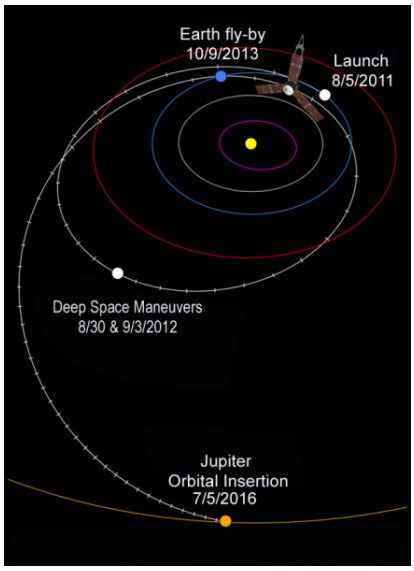
There are a bunch of other probes orbiting around Mars as well, but Curiosity is the main event there.

In my research, I came across this video from an IMAX movie about getting the rover Spirit from Earth to the surface of Mars and thought it was the coolest video ever. Until I found this video about getting Curiosity on Mars, which was even cooler.

3) Juno (Jupiter, NASA)

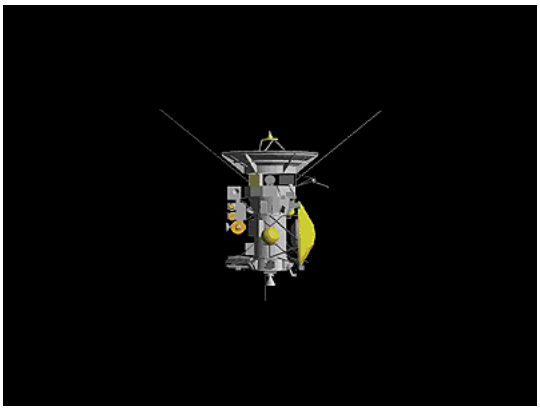


Juno left Earth in 2011, made a big loop and came back to Earth in 2013 to get a gravity zing (during which it captured a cool video of the moon circling the Earth), and is now on its way to Jupiter, where it'll arrive in July of 2016.[19]

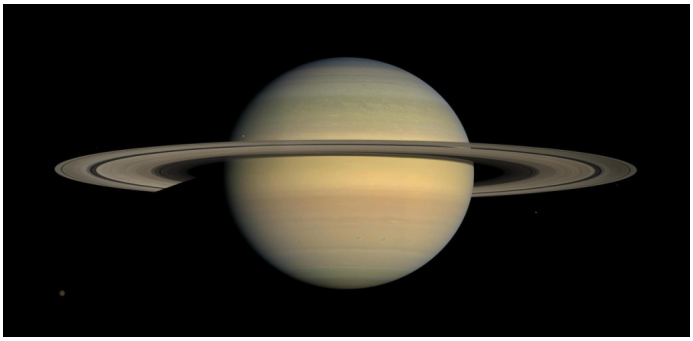


Once it arrives, Juno will orbit Jupiter, taking pictures and using sensors to try to figure out what's going on in there underneath all the succulent-looking cloud tops. It'll die by falling into Jupiter, hopefully snapping and relaying some quick photos of what it looks like inside Jupiter's atmosphere before burning up so that someone can make a virtual reality video that lets you descend into Jupiter's surface.

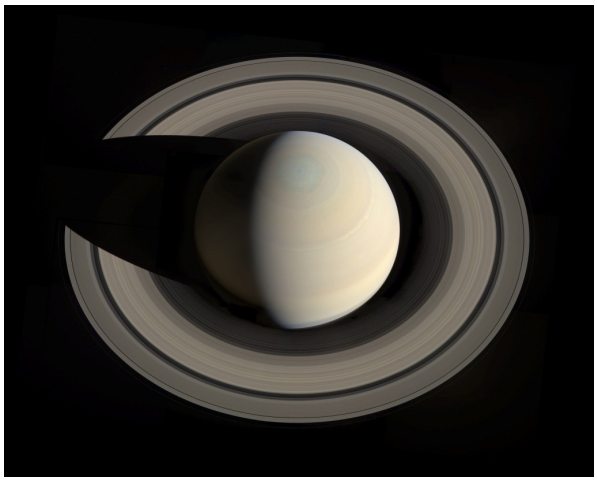
4) Cassini (Saturn, NASA / European Space Agency / Italian Space Agency collaboration)



Launched in 1997, Cassini set off towards Saturn, the only planet in the Solar System who decided it was okay to wear a tutu. Reaching Saturn in 2004, Cassini became the first probe in history to orbit the planet, sending back some jaw-dropping pictures, like this one:[20]

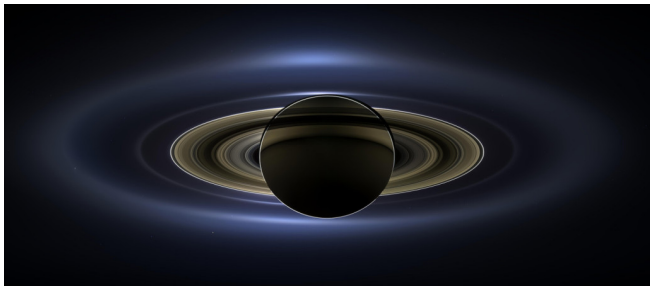


And this one:



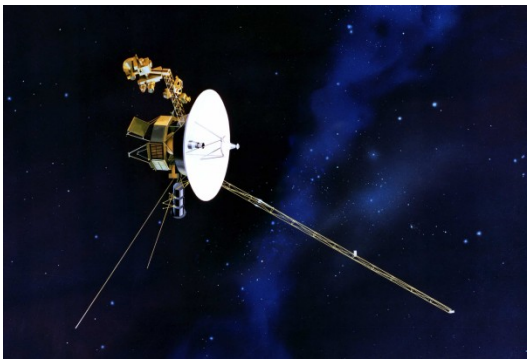
And this close-up of the rings:

And this absurdly cool picture of Saturn with the sun behind it:

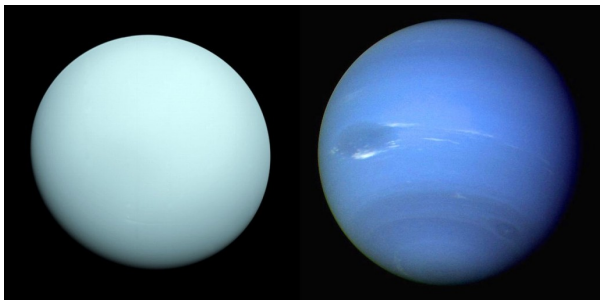


In 2005, Cassini dropped its attached lander, the upsettingly-named Huygens, down onto the largest of Saturn's moons, Titan. Here's a real image of the surface of Titan, taken by Huygens (it's creepily fascinating seeing the actual surface of something as far away and mysterious as a Saturn moon): [21]

5 and 6) **Voyager 1 and 2** (Jupiter, Saturn, Uranus, Neptune; NASA)



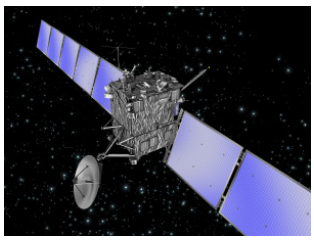
Launched in 1977, the two Voyager probes were the first probes to collect images of the four outer giants of the Solar System. Voyager 2 is still the only probe to visit Uranus and Neptune, taking these eerie photos of the two, respectively:[22]



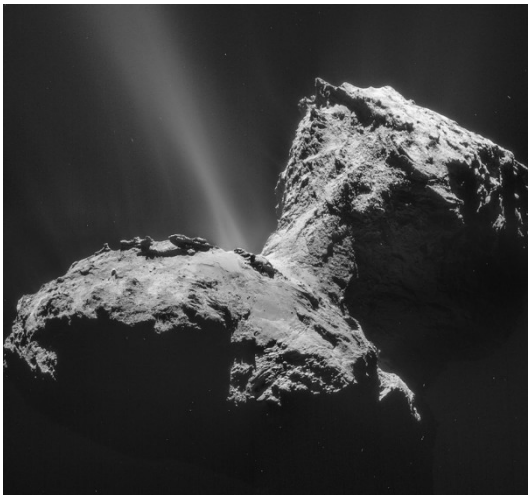
The cool thing about the Voyagers is that even though their original missions are now long over, they're still zooming outward. They're both ridiculously far away now and going super fast. Voyager 1 is the faster of the two, going 38,000 mph (61,000 km/h)—so fast that it would cross the Atlantic Ocean in five minutes—and it's the farthest man-made object from Earth, currently 131 AU[10] away from Earth. It was also the first man-made object to leave the Solar System. At this rate, Voyager 1 will reach Proxima Centauri, the closest star to us, in about 73,000 years.

Another cool thing about the Voyagers is that before they launched, a NASA committee, led by Carl Sagan, loaded them each up with a time capsule, full of symbols, sounds, and images of Earth (and symbol instructions about how to play and view the media), so the probes can one day tell aliens what our deal is. Probably a waste of everyone's time, but who knows.

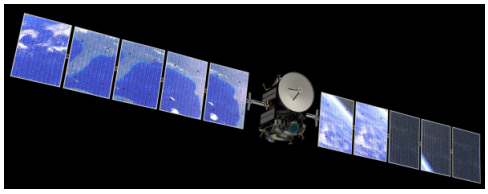
7) **Rosetta** (comet, ESA)



Launched in 2004, Rosetta got a lot of attention last year when it reached comet 67P in August 2014 and successfully dropped its little lander, Philae, onto the comet a couple months later. Comet 67P turned out to kind of just be a big rock (2.7 mi/4.3 km long), but the images taken by Rosetta were cool:

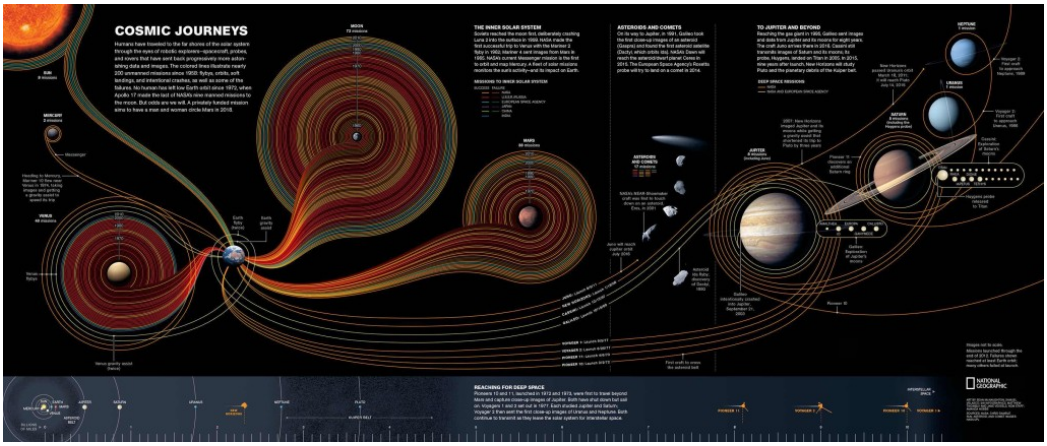


8) Dawn (Vesta and Ceres, NASA)



Dawn can't believe it made the cut on this list. The reason I included it is that I'm not sure people realize that there are huge, almost planet-size objects in the asteroid belt. The asteroid belt, a huge ring of millions of asteroids, including over 750,000 that are at least 1 km in diameter,[23] lies between the orbits of Mars and Jupiter (not to be confused with the much larger Kuiper belt that surrounds the outer Solar System). Among the many asteroids in the asteroid belt is Ceres, a dwarf planet 27% the diameter of the moon that makes up one-third of the asteroid belt's total mass, and Vesta, the second largest object in the belt after Ceres and the brightest belt object in our night sky.[11] I didn't really know Ceres and Vesta were things. Anyway, Dawn, which was launched in 2007, spent nine months orbiting Vesta in 2011 before heading off to Ceres, where it arrived in March 2015 (making it the first probe to orbit two different bodies).

There's another handful of probes out there as well. Like Messenger, which orbited Mercury for seven years until intentionally crashing into it in April 2015; Akatsuki, a Japanese probe that was supposed to start orbiting Venus in 2010 but botched it, and will try again this year; a bunch of probes uneventfully circling the moon, including China's Chang'e 3, which dropped the first lander on the moon since 1976; and a group of others taking measurements from the sun. Here's an exhaustive list of all past and present probes, and an awesome National Geographic visualization that sums it all up (click the graphic for a larger view):[24]



Looking and Learning Tool #2: Telescopes

Telescopes have been around since the early 17th century, and as they got more and more powerful over the next 400 years, they became humanity's primary tool for turning the pages of *Where Are We?*

But there came a point when ground telescopes ran into a limit on what they'd be able to see, no matter how advanced they became. You know when you look at a light through a glass of water and the light is all bendy and silly? That's what's happening when stars twinkle, except instead of water, we're looking at them through the Earth's atmosphere. The atmosphere doesn't distort light as much as water does, but stars and galaxies are *tiny* pinpricks of light in our sky, so any level of blur is a big problem—it's like being underwater in a swimming pool and looking upwards, trying to examine a bunch of birds flying in the sky above.

In the 1960s, humans gained the ability to put telescopes in *space,* where they'd show us the first crystal-clear view of the stars in history. In 1990, NASA launched the first truly badass space telescope, the Hubble. [12] [25]

The 13-ton, school bus-length Hubble Space Telescope's 7.9 foot (2.4 m) lens is accurate enough to shine a laser beam on a dime 200 miles away and powerful enough to see a pair of fireflies in Tokyo from your home in Boston (if the Earth were flat). And in its position in orbit 340 miles above Earth, where there's no atmosphere or light pollution in the way, the Hubble is on what NASA calls "the ultimate mountaintop." [26] All of this gives the Hubble an unprecedented view of the universe, allowing it to spend the last 25 years sending us the most astounding photographs of things I can't really believe are real. Like this epic galaxy: [27]

Or these two galaxies, which are in the slow process of merging:

Or the inconceivably huge Pillars of Creation (the left finger is so big, at four light years from top to bottom, that if you started at the knuckle and flew in an airplane upwards, it would take 4.5 *million* years to get to the fingertip):

Or the time Hubble aimed its lens at a tiny, seemingly empty square of the sky (seen here next to the moon to show the size of the square):

And found thousands of galaxies:

What Hubble and other space telescopes[13] have shown us has revealed worlds of new information about where we are and how we got here, expanding our knowledge about everything from dark energy to the origin and age and size of the universe to the number of planets out there like ours that might have life on them.

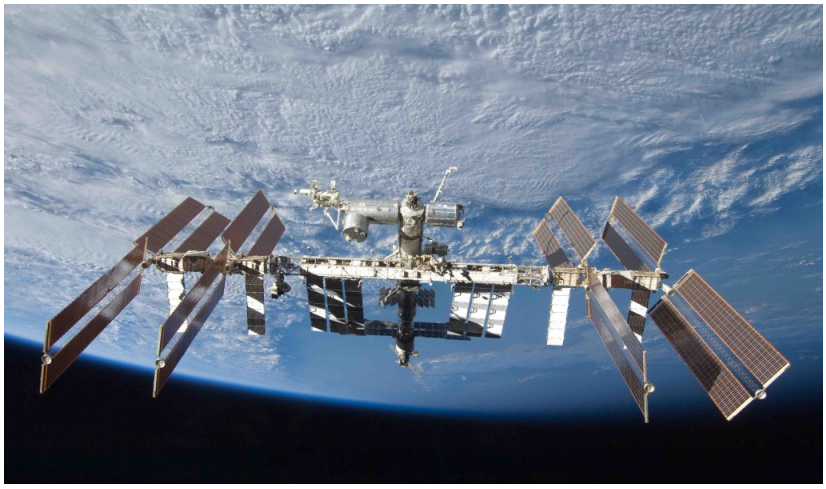
For over 40 years now, those two objectives—supporting Earth industries and continuing to learn and discover—have been the extent of our relationship with space.

And because those two goals are both best accomplished by *machine* space travelers, the most recent chapter of The Story of Humans and Space has been all about space faring machines, with the human role taking place on or very near Earth, controlling things with joysticks.

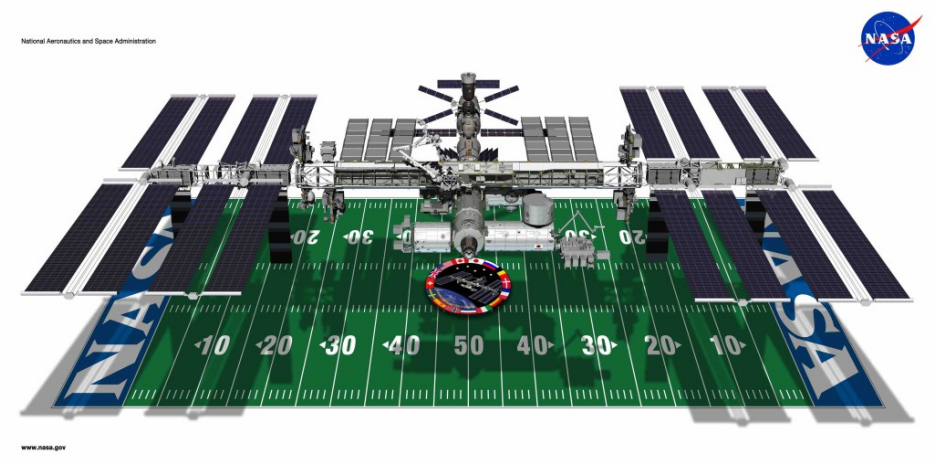
The only reason any humans have gone to space since Apollo 17 returned to Earth in 1972 is that sometimes, the machines aren't yet advanced enough to do a certain task, so we need to send a human up to do it instead. Of the roughly 550 people who have ever been in space, over 400 of them have gone there in the post-Space Race era. But since Apollo, the reasons have been practical—scientists and technicians going to space to do a job. That's why each and every manned mission of the past four decades has kept within the thin blanket of space surrounding the Earth—Low Earth Orbit.

The International Space Station

Today, the purpose of almost every manned space mission is to take astronauts to and from the International Space Station (ISS).[28]



The ISS is an international collaboration among 16 countries, started in 1998 and constructed over the span of a decade. The space station orbits the Earth in the lowest strip of LEO at an altitude of between 205 and 255 miles (330–410 km[14]), about the distance across Iceland—close enough to the ground that you can easily see it at night with your naked eye.[15] And it's bigger than people realize, weighing as much as 320 cars and spanning the full length of an American football field:[29]



What the Hell Does Anyone Do in the ISS? Blue Box

As I began working on this post, I realized I didn't really know what the ISS was for or what anyone did while they were there. Every time I see a video of what goes on inside the space station, it's just some adult floating around having playtime.

Conveniently, there's such a thing as an ISS *conference*, and it happened to take place last month, in Boston. So I went. The conference was run by the Center for the Advancement of Science in Space (CASIS), which manages the US portion of the ISS. Here's what I learned at the conference:

- The ISS is a science laboratory. It's kind of like other labs, except with the party trick that it's soaring through space, so it's the one lab where you can test things in zero gravity (it's not actually zero gravity—it's *micro*gravity—something I'll explain later in the post).

- What most ISS experiments have in common is that they're there for the gravity situation, but beyond that, they span a wide range of purposes—everything from learning about osteoporosis as astronauts' bones atrophy (because they don't have to fight against gravity), to testing how equipment holds up in space, to analyzing how fluids behave and interact without the influence of any other forces, to using the change in gravity to trick bacteria into revealing which genes make them immune to certain medicines.

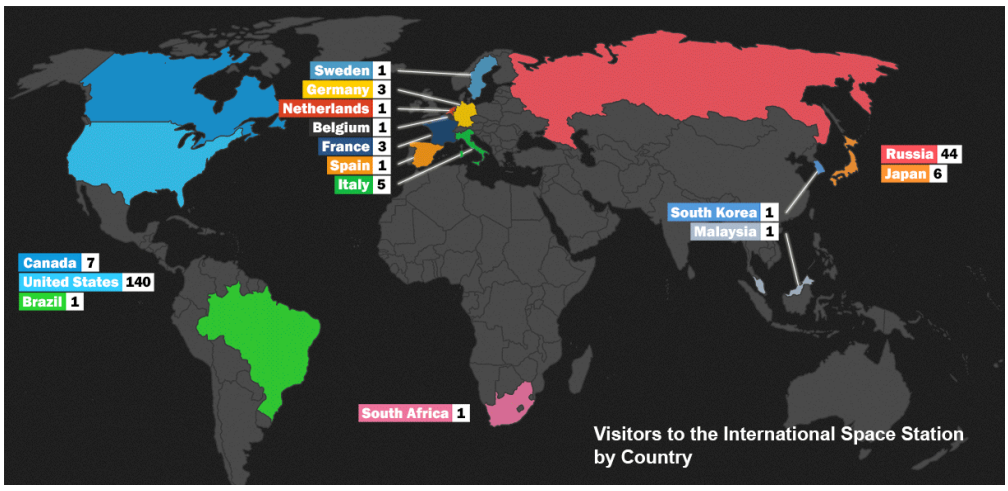
- Astronauts in the ISS have a tight and controlled schedule during the week. At all times, they're either sleeping (8.5 hours), eating (1.5 hours for breakfast/dinner, 1 hour for lunch) exercising (mandatory 2.5 hours a day), or working on experiments

(9 hours a day)—I took this photo of the current schedule of the three astronauts on the ISS.[16] Weekends are off, which could not possibly sound more fun—you get to spend the whole time floating around and looking out the window.

- I'm not the only one who badly wants to play on the ISS—there's a furiously competitive process to be selected by NASA to go. Thousands apply, 100 are picked for a final round interview and physical examination, and only one or two end up getting the nod. On rare occasion, a private company or individual can buy a spot on the station for a few days, but it costs around $60 million.

If you want to get a better feel for what it's like to live on the ISS, here's a video tour of the space station by a floaty astronaut.

So far, 216 people have gotten to play on the ISS, from 15 countries:[30]



How Stuff Gets to Space

We've gone over what's in space, but how does all that stuff *get* to space? Have you ever asked yourself how something like the GPS satellite gets up there in the first place? The answer is that there are nine countries that have the ability to launch something into orbit: Russia, the US, France, Japan, China, India, Israel, Iran and, um, North Korea—along with one non-national entity, the European Space Agency (ESA). If a satellite goes up into space, it's because someone paid one of those ten entities to bring it there atop a massive, expensive rocket (or because a country is putting one up there for its own uses).

As for launching *humans* into space, only three countries in history have done it—Russia, the US, and China (who is a fast-growing newcomer to the space industry). Since the 60s, Russia has used its Soyuz rockets to launch people into space, and the US, after wrapping up the Apollo program in 1972, regained the ability to put people in orbit in 1981 with the Space Shuttle program.[31]

Over the next 30 years, the US launched 135 Space Shuttles into LEO, with 133 successes. The two exceptions are fairly traumatizing parts of American history—*Challenger* in 1986 and *Columbia* in 2003.

The Space Shuttle Program retired in 2011. Today, only two countries can launch a human into orbit—Russia and China. With no capability themselves, the US—the country that once triumphantly put a man on the moon while the world watched—now has to launch their astronauts on Russian rockets, at Russia's whim.

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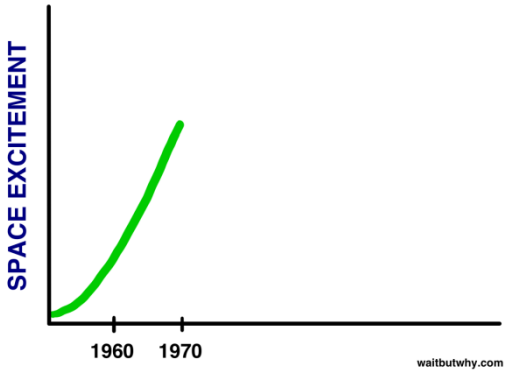
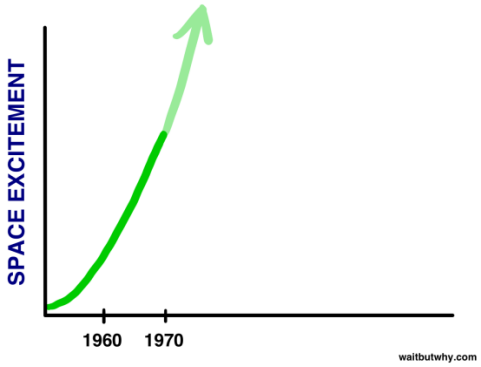
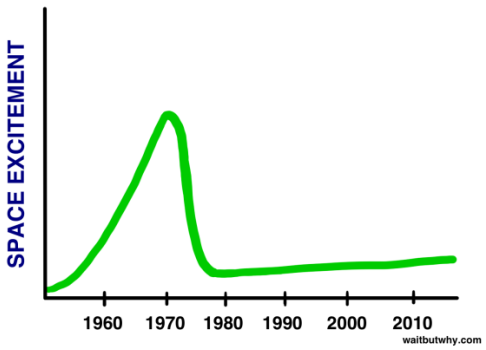
So what are we to make of The Story of Humans and Space? It's a bit of an odd tale. In 1970, the story looked like this:



So the assumption about where the story was headed was this:



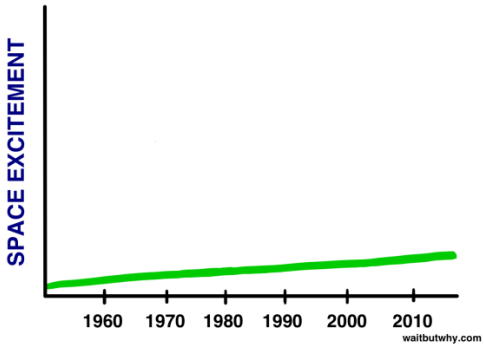
But now it's 2015, and it turns out that this is what was happening:



When I look at what's going on with humans and space today, I should think it's incredible. Just 58 years after the Soviets put the first man-made object into orbit, we now have a swarm of high-tech equipment soaring around our planet, giving humans magical capabilities in vision and communication. There's a team of flying robot messengers spread out through the Solar System, reporting back to us with their findings. There's a *huge flying telescope* high above Earth, showing us exactly what the observable universe looks like. There's a football field-sized *science lab* 250 miles above our heads with *people* in it.

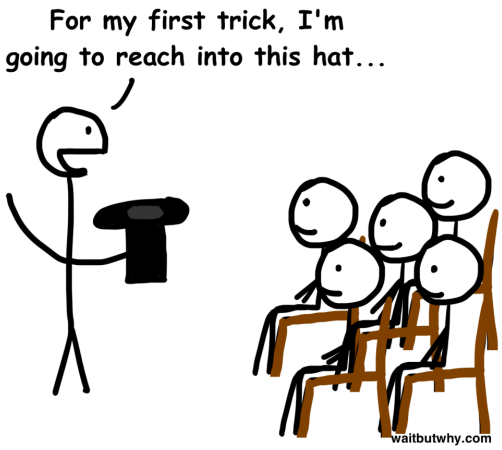
Everything I just said is *amazing*.

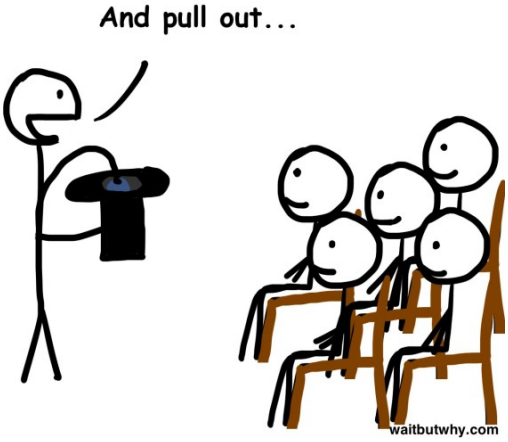
And if only The Story of Humans and Space looked like this—

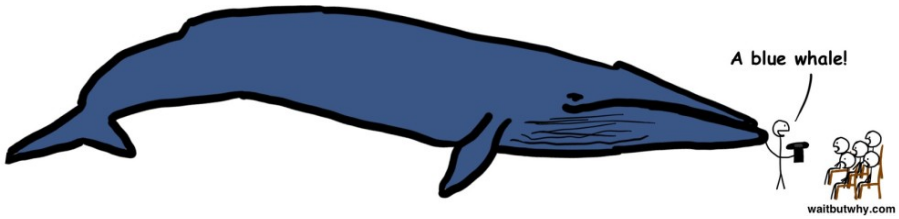


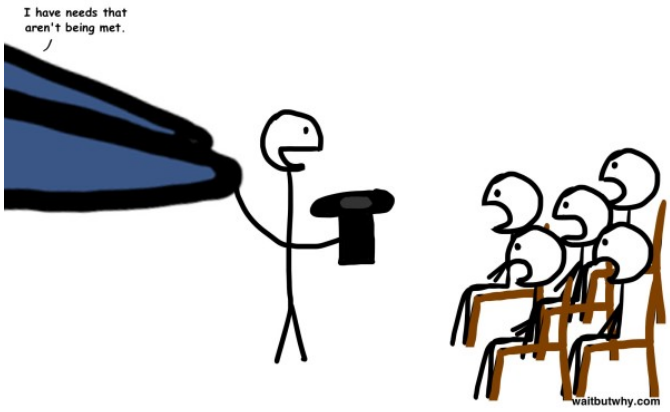
—I would be *marveling* at the things we're currently doing out in The Situation.

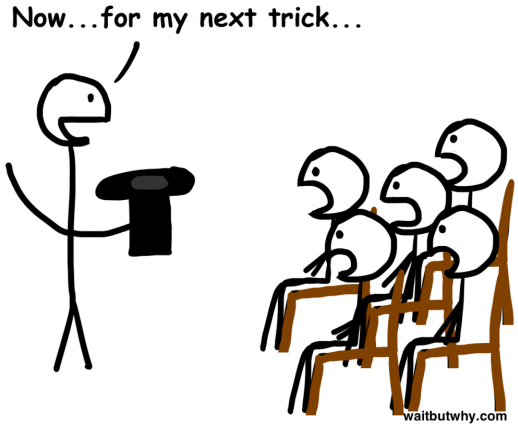
But unfortunately, the 60s happened. So instead, it's like this:



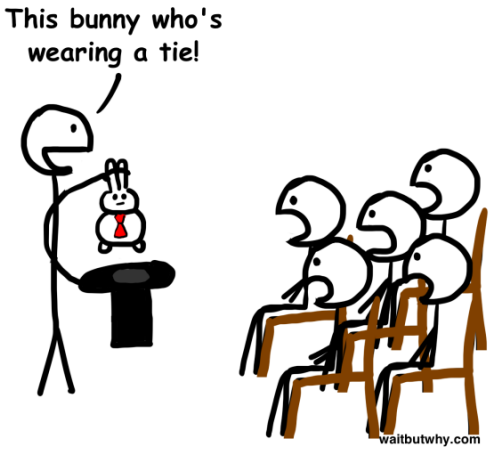


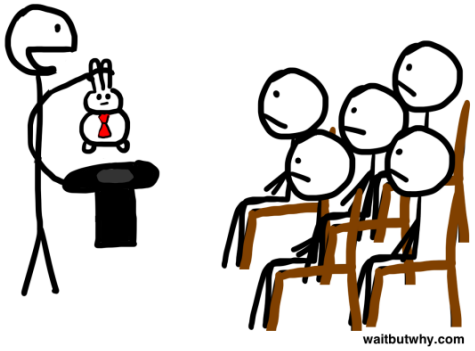


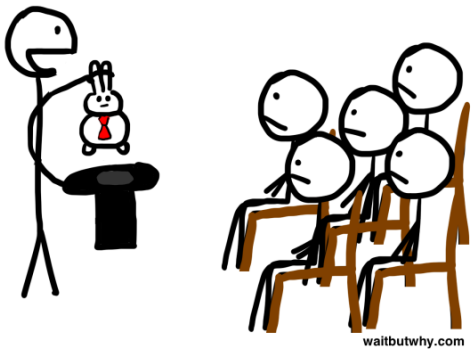

I have needs that aren't being met.
waitbutwhy.com

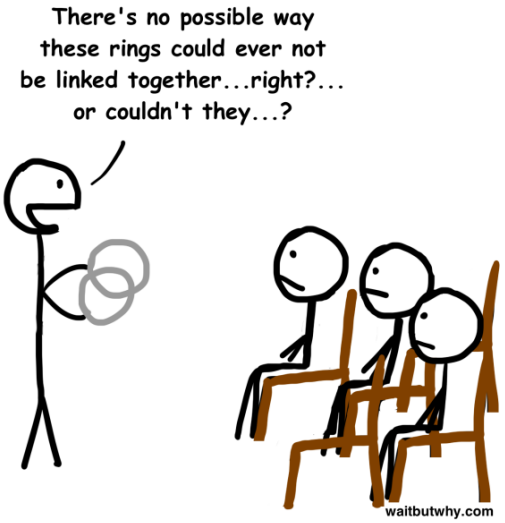

Now...for my next trick...
waitbutwhy.com

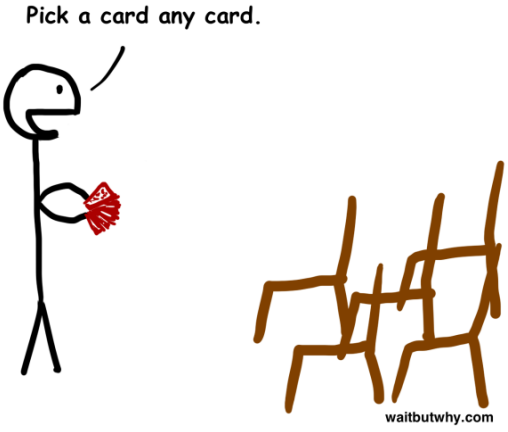

I'm going to reach in here...
and pull out...
waitbutwhy.com


This bunny who's wearing a tie!
waitbutwhy.com









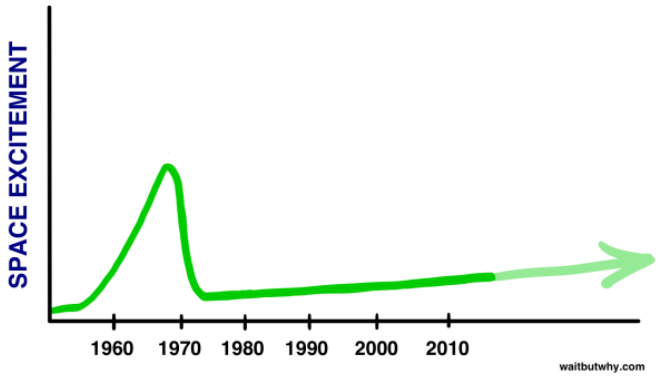
A good magic show follows a simple rule—make the act get better as it goes along. If you can't continue to stay a step ahead of the increasingly-jaded crowd, they'll quickly tune you out.

In some areas, the Humans and Space magic show has continued steadily upward. In our quest for knowledge and understanding, for example, we continue to outdo ourselves, learning significantly

more about the universe every decade. The human spirit of *discovery* is alive and well, having thrived in space in the years since Apollo.

But as fascinated as we are by discovery—as much as we yearn to know all the secrets hidden in the pages of *Where Are We?*—when it comes to filling us with true excitement and inspiration and getting our *adrenaline* pumping, discovery doesn't hold a candle to *adventure.* Probes and telescopes may fill us with wonder and light up our curiosity, but nothing gets us in our *animal core* like watching our species go *where no man has gone before.* And in that arena, the last four decades have left us feeling empty. After watching people land on the moon, following manned missions to and from the ISS is, as Ross Andersen said, "about as thrilling as watching Columbus sail to Ibiza."

And that's why, in today's world, The Story of Humans and Space has drifted off the front page of our consciousness. The topic that should drop all of us to our knees has become a geeky sideshow. Ask 10 well-educated people you know about what's going on with Solar System probes or the ISS or NASA or SpaceX and most won't be able to tell you very much. Some won't even know that people ever go to space anymore. People don't know because people don't care. Because of the way it played out, The Story of Humans and Space feels like a disappointment. And looking at the world around us today, it's intuitive to predict that future chapters of the space story will continue to putter along as they do today:



Many people don't think this is a bad thing. "Why spend exorbitant amounts of money sending people to the far reaches of space when we have so many problems right here on Earth?" they ask. Massachusetts Congressman Barney Frank, who spent three decades playing a key role in US budget decision-making, calls ambitious manned space travel "at best a luxury that the country ought not to be indulging in" and "a complete and total waste of money" and "pure boondoggle."[32] And the dramatic slashes to NASA's budget since the Space Race ended suggest that Frank isn't the only US politician to hold this view.

Upon first assessment, Frank is being perfectly rational—after all, in the face of concerns like healthcare, national security, education, and poverty, should we really make room for an "adventure budget"? And in that light, the graph projection above for The Future of Humans and Space seems all the more likely to continue on its current course.

I've spent the last couple months reading, talking, and thinking almost non-stop about what the coming chapters of this story will look like—and my assumptions about the future have now changed dramatically.

I think we're all in for a big surprise.

Part 2: Musk's Mission →

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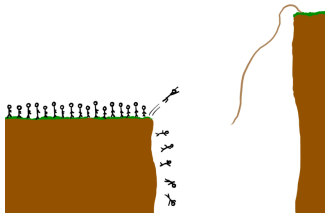

[Why Cryonics Makes Sense]

maria juchkov • 23 days ago

Absolutely love the series! But I have a few questions...
If Mars is to be the Plan B for Earth, why send people back to Earth? And when the time does come that Earth will become uninhabitable will SpaceX & Mars be able to cope with a mass exodus?

And further more, does Elon have any plans for what type of economic system will be on Mars? After all, what's the point colonising Mars, only to live unsustainability & trash it too...

Reply • Share ›

stephenshenfield • 2 months ago

The author neglects the medical effects of switching between different gravity environments. Even with well-designed exercise routines, astronauts who spend any length of time in space suffer serious physical disabilities on return to earth. Among other things, this will deter people from returning to each after even a couple of years on Mars (plus 6--12 months in space).

Another problem is the selection of colonists by ability to pay initially very high fares rather than by possession of needed skills, good physical and mental health, age, etc. If selection is based on criteria such as these most of those selected will not be able to afford the fare, so a lot of money will have to be raised from wealthy people who will not themselves be able to go to Mars.

The technical aspects of development of extraterrestrial colonies are outlined, but there is hardly any discussion of political and economic systems. The assumption seems to be that these will resemble those on earth, which is likely to be impracticable, especially at the early stages, and would also be undesirable, seeing what a mess these systems have made of earth. If two or more space powers set up their own colonies on the same planet what will the relations between them be?

Reply • Share ›

Summer of Love (bob) • 5 months ago

Tim, I'm afraid Musk sold you a load of manure on Mars. It is unlivable for humans and always will be. Reference the failure of the earthdome projects and you'll quickly realize domed cities don't work even on Earth, muc

1 Reply • Share ›

2ndGenSunRoad • 5 months ago

We on Earth are not in Energy paradise to sustain life on other planet, but actually in Energy prison;

"No device can generate energy in excess of the total energy put into constructing it".

https://the-fifth-law.com/p...

1 Reply • Share ›

GregWA • 6 months ago

"measuring contest"...have you actually read the history of Nazism or Communism? They weren't measuring anything...they were and are evil totalitarians hell bent on killing those who disagreed or would not submit (like radical Islam). And if you think this level of evil is restricted to modern times, read some more history. Musk and his family colonizing Mars as a modern day Ark story would not result in evil being excluded. I like science and I like science fiction, speculation, the rest, but please keep religion and politics out of it. Scientists, myself included, are typically no more qualified to expound on these things than anyone else. So I offer this post in that spirit: just one guy's opinion based on a little knowledge and much less wisdom.

p.s. Americans weren't horrified by the Soviets larger penis (first satellite/human in orbit), they were horrified

p.s., Americans weren't horrified by the Soviets larger penis (first satellite/human in orbit), they were horrified that the Soviets could now deliver nuclear weapons to America, with no warning or protection possible. Did you miss that bit of history or does that just boil down to a "penis measuring contest" for you? Sorry for the attitude, but I'm an old guy losing patience with how little people have learned from all of humanities mistakes.

2 ^ | v • Reply • Share ›

The_Unknown • 8 months ago

What about the reduced gravity on Mars? It's 38% of the gravity on earth if I recall correctly. Research has shown that microgravity in the ISS has a detrimental effect on muscle mass and bone density and even on organ function. Sure the first two can probably be solved by exercise but the organ function can't. And even if there's a big difference between almost no gravity and 38% of earth's gravity, there's no telling what the effect of long term (years or decades) exposure to this reduced gravity will be on human organs.

Reading these series of posts I do believe in the colonization of Mars but this reduced gravity has gotten me wondering about the long term feasibility of all this.

1 ^ | v • Reply • Share ›

Ante Renic • 9 months ago

Tim, take note. Your "what is an orbit" blue box gets several things wrong.

1) You said ponds have no high and low tides due to their lower mass than that of oceans. Their mass is completely irrelevant as acceleration is always the same, regardless of mass. Ponds don't experience high tides because there is no water that comes over from the back of the planet. Similarly there's no low tides because the water has no route to take to the other side of the planet.

2) The trajectory of a ball being fired at too high a speed would not look like that. It's not like it would circle for a bit and then start moving straight through space. The Earth is still acting on it, regardless of distance. As it moves further away, the curvature of the trajectory will become lower and lower, but it will always curve a little bit, it will certainly never become straight, not in the manner depicted, anyway.

3) Thrown objects would only fly in a circle if the source of gravity was in the center of the circle. This means that the trajectory of thrown objects isn't a circle even before they hit the ground. If the ground was a straight line (which it is if we zoom in enough, as in most physics problems) and gravity acted exactly downwards all the time, the trajectory would be a parabola (no air resistance). If the direction of gravity changed such that it's always perpendicular to the velocity, the trajectory would be a circle, as I've explained above. If the gravity, however, does change direction but is not always perpendicular to the trajectory, as is the actual, realistic (and drawn) case here, the trajectory would be something between a parabola and a circle.
Note that trajectories can also be ellipses; in fact, a circle is mathematically merely a special case of an ellipse (just as a square is a special case of a rectangle).

For the third note you can just add a blue square thing which says that the trajectory isn't exactly circular, but whatever.

Also note: Tesla started with 30 million, not 70 million. Elon's share of Paypal's sale was 130 million, so 100 went to SpaceX.

^ | v • Reply • Share ›

Ralph Fischer • 9 months ago

Main reason for bad wind and temerature on Venus is the fact that it got almost no rotation.

In order to colonize Venus i assume first it needs to be hit by some pretty big Asteroid to start a rotation.

Might even need a mass close to the moon.

2 ^ | v • Reply • Share ›

Ralph Fischer • 9 months ago

I think you got that one wrong: "Humans have never experienced a mass extinction event, and if one happened, there's a reasonable chance it would end the human race"

Humans faced black death and that took quite a bite into population.
Not to mention that we WITNESS a mass extinction event right now while reading. It is caused by many many humans totally ignorant to the fact that their actions are about to kill loads of liveforms, including bees. High chance that the mass extinction event for humans is just waiting for new years day.

^ | v • Reply • Share ›

Nicole Song ↗ Ralph Fischer • 9 months ago

Right, but the bubonic plague only killed about a third of Europe's population. It didn't even spread to any other continents. I'd say we're fine, it was not a huge event in humanity, unless you're strongly Euro-centric.

3 ^ | v • Reply • Share ›

Brandon • a year ago

I'm wondering whether the Martian calendar will start at year 0 from the day the first human set foot on the planet. That would be so huge. Finally not a religious calendar, but a true scientific calendar celebrating every 669 martian days the moment the first humans set foot on the planet.

5 ^ | v • Reply • Share ›

Hans Nelson • a year ago

Have you seen the "Economics of Airline Class" video by Wendover Productions on YouTube? I just happened to have seen this the other day, and it seems like it would be an interesting idea to toy with on the Mars Colonial Transporter. Thoughts?

Reply • Share ›

Michele • a year ago

How much space debris was added when the United States shit on the world's collective face in 1985 by destroying a satellite in orbit, and again in 2008?

4 Reply • Share ›

Isabella Pintor • a year ago

great article it took me an hour to read it but.. it was worth it

1 Reply • Share ›

Nicolas Stabilini • a year ago

I'm really concerned about horoscope... how would astrologyts get an astro-chart for a human born in Mars? (btw: I think horoscope is big big ball of bullshit)

Reply • Share ›

ImmortalWind • a year ago

Hey Tim, I was researching a little bit about Voyager's destination and it's actually NOT heading to Proxima Centauri as you seem to imply (unwillingly) in the Voyager section above. You might want to change this sentence.

3 Reply • Share ›

Blaine • a year ago

One thing I haven't yet seen anyone address is how the 38% Earth-gravity on Mars will affect humans that live there for long periods of time. Would a Martian-born-and-raised person who traveled to Earth be weak and unable to walk (or walk with great difficulty, bearing three times their normal weight) under the influence of the heavier gravity? If their muscles had only experienced the lighter gravity of Mars, wouldn't living on Earth be incredibly difficult for them? I feel like Martians would be at a physical disadvantage if they ever left their home planet. Am I wrong here?

8 Reply • Share ›

Michael Pang ↗ Blaine • a year ago

Yes I'd imagine that to be the case - although they're genetically the same so it's nothing a few months of working out shouldn't be able to fix.

Reply • Share ›

IamGrimalkin ↗ Blaine • a year ago

How 38% gravity will affect humans is unknown, because no-one has ever been in 38% gravity for long periods. However, research in the ISS and other space stations does give an idea of what zero gravity is like. Bone density and muscle mass does increase after long periods in zero-g, but it is possible to mitigate that by using the right exercise machines for 2 hours a day (if I remember correctly).

Reply • Share ›

Drabes ↗ IamGrimalkin • a month ago

I think you mean muscle mass and bone density decrease...

Reply • Share ›

IamGrimalkin ↗ Drabes • a month ago

Yes, I did mean that, thanks for the correction.

Reply • Share ›

Babette • a year ago

You said : "The spacecraft provided the rest of the boost after the rockets dropped away, using fuel from the big, for-some-reason-orange fuel tank."
At first they wanted to paint it white, until they found out that it saved 3000 kilo's not to. That's the reason why the thing was orange. Funny I remembered that detail but pleased to fill you in :-)

5 Reply • Share ›

iykcvth • a year ago

good article ;)

Reply • Share ›

guest • 2 years ago

The article talks about a lot of awful people in positions of power who weren't using space technology for positive things like Musk wants to, but for "measuring contests" like America vs. the Soviet Union, and other destructive military applications that continue the international measuring contest and line the pockets of politicians like Mr. Shelby. Now the US only wants to improve their space tech because another measuring contest is on the horizon -- and it's with some very scary people who are mixing mythology in with their measuring contest.

The Middle East is a mess enough to begin with, but now we've got Iran to deal with, firing off rockets for their moon god? As if that wasn't bad enough, there's the perpetual Iran-Saudi (Shia-Sunni) divide in Islam, vs. the Jewish government in Israel and whatever's left of millennialist Christianity in the United States government (not millennials as in teenagers with smartphones, but a sect of Christianity that believes in ushering in the Revelation through a massive, population-culling war in the Holy Land).

Imagine a sequel to the US-Soviet space race that boils down to a holy war, using cutting-edge technology to fulfill the prophecies of Bronze Age storybooks. 100 million people already died as a result of the global US vs communist "measuring contest." 100 million more died before that because Adolf, Tojo and Benito had a measuring contest with Franklin, Winston and Josef. On the micro level, a young man, the nephew of a local legislator, was brutally murdered in Chicago over the weekend because of a "measuring contest" over who had the better pair of sneakers. People have been assaulting each other over having the opposing US presidential candidate's bumper sticker on their car. This is what you call intelligent life?

Why the $#&% does Elon want to save a species of $%&#-flinging monkeys who are hard-wired to pursue these immature, but globally destructive, "measuring contests," whether in the name of money or ego or the claims of their gods? Why doesn't he focus on making the Martian mission a real-life Noah's ark instead? Just him and his family taking the animals and plants on a trip to get away from the god-botherers and their "measuring contests."

Reply • Share ›

Ed Jagger ↗ guest • a year ago

It's because Elon Musk is a very astute businessman. The radiation and low gravity environment will not allow long-term human survival on Mars, even with an artificial atmosphere, hydroponics, underground shelters. Human physiology and development did not evolve to exist in such an environment. Musk secretly knows this. It's the reason there are no plans for practice colonies on the Moon (which is much nearer). I agree that his modernised space-freighter system will make him more money than God - and he is doing a very good job of advertising Space X using this 'Mars mission to save humanity' But I'm afraid in the end it boils down to profit and share-holders, like everything else.

Reply • Share ›

Steve ↗ Ed Jagger • a year ago

Read more about Musk. This is an easy story to tell about him, but it's not supported by evidence. The evidence is very good that he is actually hell-bent on colonizing Mars.

Also, the radiation concern, while nonzero, is way overblown. Here's some info:
https://www.reddit.com/r/sp...

1 Reply • Share ›

Jonas Friedmann ↗ Steve • a year ago

You are hopefully right. There is a German physicist named Harald Lesch who says it makes no sense to colonize the mars. He says more or less it is not possible to create an atmosphere because the Mars has no magnetic field. We are not able to increase the mass. And solar winds will shave off any atmosphere we could build up. And even if it would be possible to create a stable atmosphere, the two moons Phobos and Deimos will rub at the atmosphere. Following they lose their energy and crash into the Mars. Than everything is destroyed again and for 100 thousand years no living will be possible again. What do you think?

Reply • Share ›

Steve ↗ Jonas Friedmann • a year ago

Well, it's always about the quantitative facts. It took Mars (hundreds of?) millions of years to lose its atmosphere; if we come up with any way to terraform it within thousands or tens of thousands of years, that method will easily be able to keep up with the solar winds.

As for Phobos and Deimos, I haven't heard of that. They're pretty small as far as moons go -- 6 and 10 km radii -- so their impact wouldn't destroy everything for 100,000 years. Could be a problem, but a civilization able to terraform a planet should have some ideas about that -- e.g. blowing them into smaller chunks to make the impact far less severe.

However, in any case, what matters for whether or not people go colonize Mars isn't what will happen in the end, but what they believe will happen. If people believe that colonizing Mars isn't a doomed venture, and want to do it, then they'll do it, right or wrong.

Reply • Share ›

inservo ➚ Steve • a year ago

you definitely need to work on your perspective. There are much much much more non-US citizens on planet earth and maybe (hard to imagine for the standard US dickhead, I know) some have political systems that are maybe not perfect but at least do soemhow work.

If you want to throw your country in the trashcan, do us all a favour and go on but do not take everyone else with you.

Reply • Share ›

Steve ➚ inservo • a year ago

Was this supposed to be a reply to me? I don't see the connection.

2 Reply • Share ›

Hayley Mac • 2 years ago

Is anybody else up for moving to Mars for four years to escape the Trump presidency? We can clean up the mess when we're back in 2020.

2 Reply • Share ›

guest ➚ Hayley Mac • 2 years ago

Stop bringing politics into this. Your type is exactly the kind of tribalism that's makes the Squeegle alien or whatever his name is root for humanity's imminent demise. All I pointed out above is that there are people who stab each other over sneakers and start world wars over "measuring contests" like the article talked about, and that maybe Musk is trying to back up junk data that belongs in the recycle bin. He should focus on saving polar bears and elephants, instead of "Never Trump" or "Never Hillary" monkeys who fling poo at each other because their guy is better.

1 Reply • Share ›

Hayley Mac ➚ guest • 2 years ago

That comment was meant in light-hearted jest. I assure you I have no intention of moving to Mars.

Ironically I've just watched the latest episode of South Park and it appears Cartman has had the same idea.

1 Reply • Share ›

Yian Huang • 2 years ago

Why aren't they colonising the Moon first or simultaneously, as a proof of concept and/or to get people excited?

Reply • Share ›

Dan Apted ➚ Yian Huang • 2 years ago

Your question is very appropriate. Colonization of LEO is the first step, Colonization of Geosynchronous orbit is the second step. Colonization of L1 and L2 orbit is 3rd step. Lunar colonization is 4th step and industrial mining/colonization of the asteroid belt is 5th step and colonization of LMO (Low Mars Orbit) is the 6th and final step before we invade Mars. Just figuring out where to land on Mars as a first step in the invasion is a decades long study and decision making process that should be left to the people living in LMO. They will be the ones who supply the products and knowledge about living and operating so far from home to the souls who descend to the surface.

Reply • Share ›

Amit Vikram ➚ Dan Apted • a year ago

Because Mars is more hospitable than moon. Mars' gravity is 38% of Eath's gravity while moon's gravity is nearly 16.7% of that of Earth's. So humans can get use to Mars' gravity much easily. Also there is cosmic radiation. Mars has an atmosphere although relatively thinner than that of Earth, it shields off some cosmic ray particles and humans can build their habitats underground for extra protection. While moon has no atmosphere whatsoever. So

habitats underground for extra protection. While moon has no atmosphere whatsoever. So underground habitats would also not protect from radiation effectively at moon. Also there is possibility to terraform Mars. The main reason Mars and moon don't have a thick atmosphere like earth is because Earh has it's own magnetic field which protects atmosphere from charged particles of solar wind, while Mars and moon don't. Mars didn't had any protection from solar winds which stripped apart it's atmosphere. Mars has Dry ice (frozen CO2) sheets in it's poles and if we nuke them, it will release that CO2 in atmosphere and hence thickening it's atmosphere in which plants can grow, increased atmospheric pressure will prevent water from boil off at low temperatured and hence liquid water would be able to sustain on it's surface and the green house effect will warm up the mars a bit which is currently very cold. The solar wind will again strip that atmosphere, but it is a very slow process and therefore we would have millions of years to get a solution for that problem.

Reply • Share ›

David Sabo ➚ Dan Apted • 2 years ago

Musk intends to skip all that and go straight to Mars. His reasons are very appropriate - i.e., the intermediary steps aren't really necessary, and the Moon isn't all that well-suited to colonization in the near term. Tim's article lays this all out reasonably well.

To Yian's question more directly, colonizing the Moon has a different set of challenges - but most importantly, for Elon, it's aiming too low (literally and figuratively). The moon also is not as well suited to long-term survival of a self-sustaining colony and cannot be terraformed the way Mars can. So the proof-of-concept idea really would be proving we can build greenhouses on the Moon, but it's not the same.

That all said, if it gets cheap enough under SpaceX's leadership to toss stuff up into space, I am sure people will want to do cool things with the moon, too!

1 Reply • Share ›

IamGrimalkin ➚ David Sabo • a year ago

What do you mean that the moon can't be terraformed the way mars can? If you mean adding a breathable atmosphere that won't set on fire, the moon has a smaller surface area than mars so will probably need less buffer gas, and if you are launching it as nitrogen from earth you won't need as much delta-v to get it there. So in some sense it might be easier.

Reply • Share ›

Deven Kale ➚ IamGrimalkin • a year ago

The moon is too small. It's gravity isn't strong enough to support an atmosphere thick enough or dense enough to be breathable by humans.

Reply • Share ›

IamGrimalkin ➚ Deven Kale • a year ago

Yes it is. The atmosphere would eventually be lost to space without a magnetosphere, of course, but it isn't that much lighter than Titan, and that has an atmosphere thicker than the Earths.

Reply • Share ›

Deven Kale ➚ IamGrimalkin • a year ago

The mass of the moon is 54.63% of the mass of Titan. That's similar to saying $546,000 isn't that much less than $1,000,000. It's a huge difference.

The atmosphere on Titan is as dense as it is because of what that atmosphere is made of. In fact, Titan's atmosphere is not only thicker than Earth's it's also denser at 1.5 bars even though Titan is far less massive. Although this could partially be explained by being protected by Saturn and having a weaker Solar Wind as well.

Your question was about having an Earth-like atmosphere though, and I'm no physicist so I can't do the calculations myself but I trust the experts I've read/heard who say that you can't get a sustainable Earth-like atmosphere on the moon more than a dozen or so feet thick, and it would be nowhere near dense enough to be breathable.

Reply • Share ›

IamGrimalkin ➚ Deven Kale • a year ago

Just run the numbers and it turns out you're right, the moon can't have an atmosphere even for relatively short periods. You're right, Titan's higher mass can make a difference when you have an edge case like the moon, as can its higher density and lower temperature.

Reply • Share ›

IamGrimalkin ➚ Deven Kale • a year ago

Yes, you can't get a sustainable atmosphere on the moon. You can't get a sustainable atmosphere on Mars, either. The point is, it can take long enough to leak out for you to live there in the meantime, and you can help hold it there with an artificial magnetic field.

Reply • Share ›

Dan Apted ↗ David Sabo • 2 years ago

I understand his desire and share it, but he(read we) need to pay for it and we need people to be prepared for the trip and the stay. By putting up the aforementioned first steps we have the funding for the other steps. A LEO vacation or stunt or lark is far fetched as is a honeymoon on the moon. But I can rationalize how some people might be able to pay for it if the SpaceX re-usability model becomes reality. Furthermore I can envision how Hilton, or Amazon, or Trump might even fund a hotel or at least a bed and breakfast in LEO or even on the Moon. The profits from it and the taxi service to get you there are literally sky high. If they are as big as I can imagine then so is a convention center in LEO or at L1 or L2. With enough demand then we must mine asteroids or other objects to harvest the least expensive building materials if you want to attract the most visitors. That gets us the materials to go to LMO and with that distance orbiting farms and more harvesting of materials from asteroids. Then there is the money, the infrastructure and the people trained to work and live in space to actually invade Mars. You can't go to Mars and sustain a colony without knowledge and money. The first steps get us there. Attempting to skip those steps is attractive folly.

Reply • Share ›

ameba#23234 MdR • 2 years ago

I noticed a mistake or just can't find any source on that venus has any oxygen in upper or lower atmosphere.

" Randomly, at the top of Venus's clouds is a layer where the temperature and pressure are similar to those on Earth, and because oxygen and nitrogen both rise in Venus's dense atmosphere (like helium does on Earth), the air in that layer might actually be close to breathable."

Reply • Share ›

jmac ↗ ameba#23234 MdR • 2 years ago

Try this:
http://onlinelibrary.wiley....

Reply • Share ›

Mario • 2 years ago

"In the last few thousand years, humans invented the concept of being "inside," and now almost all people think of home as somewhere indoors—maybe in the future, a giant, artificial space habitat that has mountains and rivers and trees and millions of people will be the equivalent of the invention of "inside" as it applies to an entire world" That was beautiful! I just started singing "imagine" in my head

Reply • Share ›

Hendu71 • 2 years ago

I wonder which one is technically most difficult: "Fixing" climate change, building a colony on mars, or building a Star-Wars-like floating "Cloud City" on Venus?

Reply • Share ›

Michael Pang ↗ Hendu71 • a year ago

IMO they're easiest to hardest in the order you gave, but the first two mostly depend on peoples' collective will.

Reply • Share ›

Nobody • 2 years ago

Anybody knows what the hell did just happen at Florida? Or more like, what will it cause?

Reply • Share ›

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3 Comments

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Nadeem Adnan

The possibility depends is to enable individuals from different lands in the world to be the primary candidates to the another wave of people that will be selected to go to Mars. As reported by http://www.theboringstate.com. Even people from a nation such as Egypt, Pakistan, Saudi Arabia, have heavily shown affair and they really like to go The Red Planet. A very interesting text can be read here :
http://www.theboringstate.com/.../hello-houston-problem...

Like · Reply · 1 · 43w

Caleb Mayo

thanks for this and for rocking out in general. in case you go around updating things, the radiation shield idea seems real enough now to merit a mention under blue-green mars. many smarties note, given the missing martian magnetosphere, that cosmic and solar radiation will slowly strip away whatever atmosphere we whip up, so it seems there's some place in the convo for a note about making that evap not happen. NASA image here includes fun words magnetosheath, magnetotail and magnetopause:
https://www.popularmechanics.com/.../magnetic-shield.../

as exciting: looks like by blocking radiation we can probably start some of that sweet, sweet melting. seems relevant and likely. apologies if you already heard this stuff and thought about putting it in the piece and i'm now just one more voice telling you to spend time on something other than whatever should be your main project right now kinda like how i'm out here posting on a comment section instead of generating content oh dear god--

Like · Reply · 12w

Michelle Oblack Smith

great news say no to small penis i introduce you to DR SANTY JATTO herbal mixture cream …DR SANTY JATTO penis enlargement herbal cream and herbal remedies in Africa.This is the only Male Penis Enlargement Cream has been used by men around the world supplement that has been PROVEN to-enlarge your penis – safely, quickly, and importantly – PERMANENTLY.Full SANTY JATTO Penis Enlargement Cream when used will Increase in penis length by 1-10 inches Increase in penis width by 20%helps in preventing Premature Ejaculation.Achieved longer, rock hard erections All gains in penis length and width are 1... See More

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Mohammed Saud

How small is your penis exactly? I need to know... for research purposes only

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