



How (and Why) SpaceX Will Colonize Mars

📅 August 16, 2015 By Tim Urban

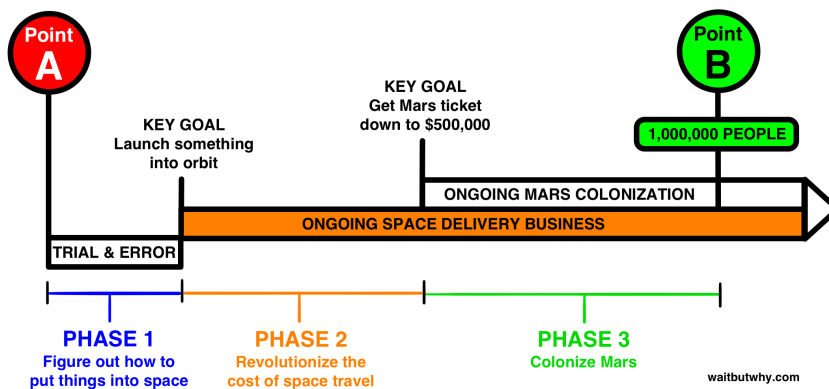
Phase 2: Revolutionize the cost of space travel

Main Characters: Falcon 9, Dragon, Falcon Heavy

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The SpaceX Business Plan



Today, many people have heard of SpaceX. Few know what SpaceX does. And even fewer know what SpaceX *really* does.

Here's what SpaceX does: It takes things to space for people, for money.

And as we established, here's what SpaceX *really* does: It's an innovation machine, trying to solve one big problem—the astronomical cost of space travel—because that's the key to making humanity a space-faring civilization that can become multi-planetary and back itself up on other hard drives. It supports itself by taking things to space for people, for money.

We'll get to the *really* does part later. First, let's look at what it means to take things to space for people, for money.

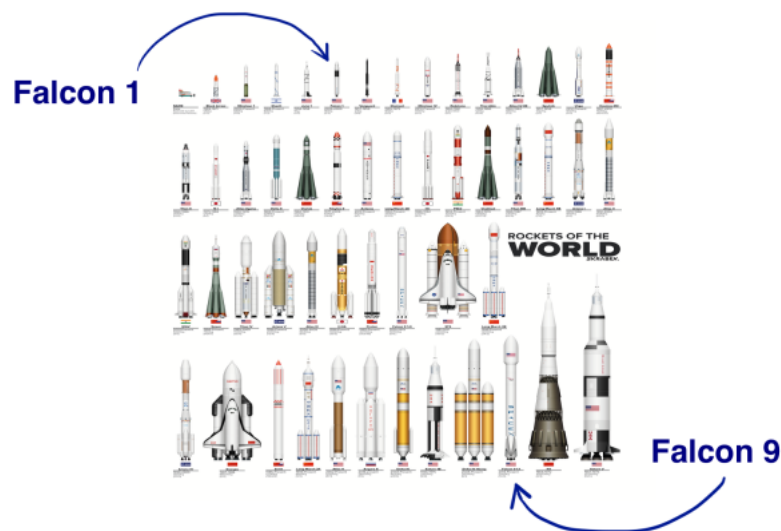
Falcon 9

In 2008, with a successful orbital launch achieved and a slew of new customers eager to sign up for SpaceX's weirdly cheap space delivery service, it was time for SpaceX to take off the training wheels and build themselves a Harley. Meet [Falcon 9](#):¹



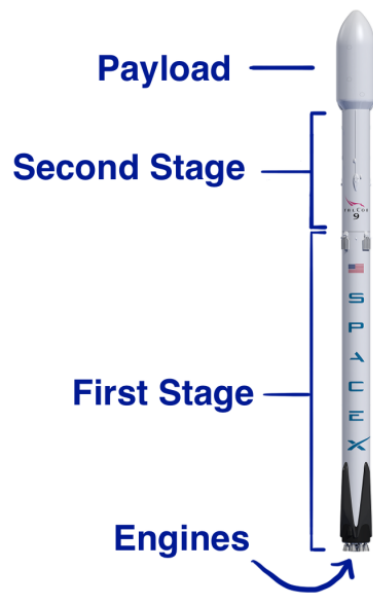
Let's just go ahead and get it out of the way right now—Falcon 9 is the world's largest dick-shaped sculpture. It's something every SpaceX employee has learned to endure, an unmentionable fact that hovers over their professional lives, and it's something we're all going to live with as well.

That issue aside, Falcon 9 is the world's most advanced rocket and a huge upgrade over Falcon 1. Falcon 9 is [huge](#)—at 224 feet (68 m) tall, it's over three times the height of Falcon 1 and the height of a 20-story building. On its side, it would stretch 3/4 the way across a football field. And while Falcon 1 could bring less than one ton of payload to orbit, Falcon 9 can carry 13 tons. In every way, Falcon 9 puts SpaceX in the ring with the big boys. ²



Learning about rockets will make you respect the shit out of rockets. A rocket has to be unbelievably rugged—it's a 1,000-ton object filled with explosive material that soars at blazing speeds through hurricane-force winds—but also meticulously designed down to the millimeter because it's full of very un-rugged things like computer circuit boards, delicate satellites, and living people. Normal manufacturing techniques don't always cut it for an object so particular—in the SpaceX factory, I was shown bizarre-shaped Falcon 9 [parts](#) that had to be 3D printed (and [3D designed](#)) because there was no other good method to make them just the right way. ¹

But since none of that is our problem, let's ignore all the details and oversimplify: ³



The First Stage

The first stage has a very important three-minute job—blast the second stage and the attached payload up to an altitude of about 100km before peacing out and falling into the ocean.^[4]



The first stage, like almost all parts of Falcon 9, is manufactured in SpaceX's California headquarters (here's a [fast-motion video](#) of the manufacture process).

Most of the first stage is a big fuel tank with two key parts: a huge tank of [rocket-grade kerosene](#) next to a huge tank of liquid oxygen. It doesn't work on a rocket to draw oxygen from the air because, among other reasons, the rocket quickly gets too high up for there to be much oxygen around. So it has to bring the oxygen with it. Oxygen becomes a liquid at -297.3 F (-183 C), and once it does, it's around 1,000 times more dense than gaseous oxygen—so you can pack a lot of it. These two ingredients are mixed together into explosive propellant.

How Rocket Engines Work

It might seem odd that the guy who's super not into burning fossil fuels with [his car company](#) would choose to blow through hundreds of tons of it during every launch with his rocket company. The problem is that rockets *have* to burn fuel—Musk has even said he thinks all transportation will eventually go electric, *except* rockets.

The reason is Newton's Third Law: *Every action has an equal and opposite reaction.*

Newton's third law is why a deflating balloon will move in the opposite direction that it's shooting air out, why a gun jolts backward when it shoots, and why this incompetent man's canoe goes away from the dock when he runs toward it:^[5]



When you think about propelling a vehicle, think about this same idea.

One way to make a vehicle move is with a propeller. Propellers work by pushing air in one direction, which pushes the propeller and whatever's attached to it in the other direction—kind of like standing a foot away from a wall and pushing the wall with your hand—which forces your body away from the wall. The problem is that in space, there's no air for the propeller to push against, so trying to use a propeller there is like standing in a room far away from the wall and pushing your hand out toward nothing like a weirdo, which wouldn't push you backward at all. Even in the upper atmosphere, where there's still some air, if the air is too thin it's like trying to get a big pushback by pushing your arm into a hanging curtain—it won't work well.

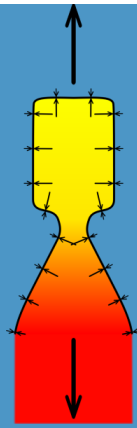
On the other hand, if you deflated a balloon in space, the balloon *would* shoot backward—in the same way it would on Earth—because the force in that situation isn't created by pushing on air outside the balloon (like a propeller), it's created by the air pressure being much higher inside the balloon than outside of it and the air being forced out of the balloon by the pressure difference. In fact, if you were floating around in the middle of space and had an air-filled balloon, you could move yourself a bit by deflating the balloon in the opposite direction—and for those few seconds while the balloon was deflating, the balloon would be an engine.

The engines at the bottom of Falcon 9 are just more powerful deflating balloons. A fiery explosion creates extremely high temperature and pressure, which makes the exploding gas want to rapidly *expand* into the lower-pressure space all around it. And if something blows up in the middle of an empty field, it can expand outward in all directions but down:

6



A rocket engine creates an explosion that wants to do the same thing—but the engine, like the balloon, won't let the force move outward in any direction except *one*. And being “rejected” from all the other directions just adds to the force: 7



So that's why rocket engines work in a vacuum. They don't need anything external, like air, to push down on—by expelling a mass of hot gas, they're essentially pushing down on *that*.

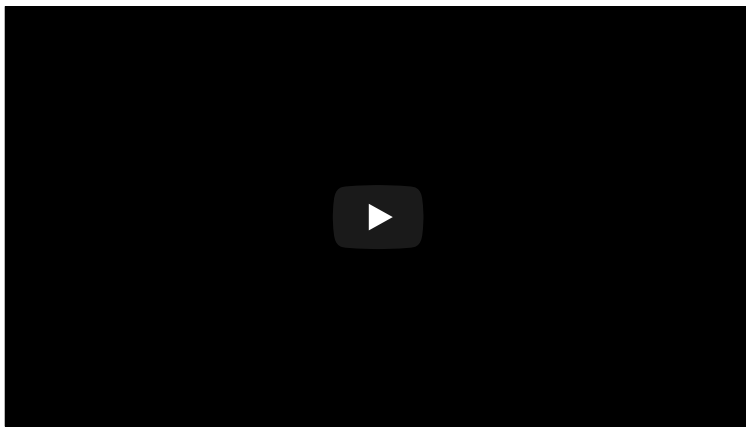
Musk would love to have a better way than exploding fuel to power rockets, but he's not sure we'll ever find one. I asked him about it, and he said, "For rockets to go electric, there would have to be a few Nobel Prizes awarded."

The Merlin

Falcon 1's ascent was entirely propelled by one ragingly powerful SpaceX-invented engine, called the [Merlin](#).⁶



Merlins are rad. One Merlin engine has a thrust of over 73 tons—i.e. it can lift 73 tons of weight—which means if you stacked 40 cars on top of the engine in that picture, it could lift the whole stack into space in about three minutes. It's one of the most ² efficient, advanced engines in the world. An important statistic in the rocket engine world is thrust-to-weight ratio—i.e. how many times its own weight it can lift. Weighing about a half ton and peaking at over an 80-ton thrust, the Merlin's ratio is 165:1, which [blows away](#) all other engines like it. Here's a Merlin test firing:



How intense is that shit. ³

Now imagine *nine* of them firing together. That's what happens during each Falcon 9 launch—the rocket's name comes from the nine engines, which are arranged in an “octaweb”: ⁹



Together, the nine Merlins generate 650 tons of thrust, enough to shoot a stack of 360 cars into space (a stack that would be the height of [One World Trade Center](#)), and they burn through a combined 540 gallons (2,044 L) of fuel every *second*—enough to drain a swimming pool in less than a minute. Most of what the engines end up lifting is the rocket and its fuel, which weigh in at a combined 550 tons, but there's still plenty of leftover muscle to add a sizable payload on top.

The Second Stage

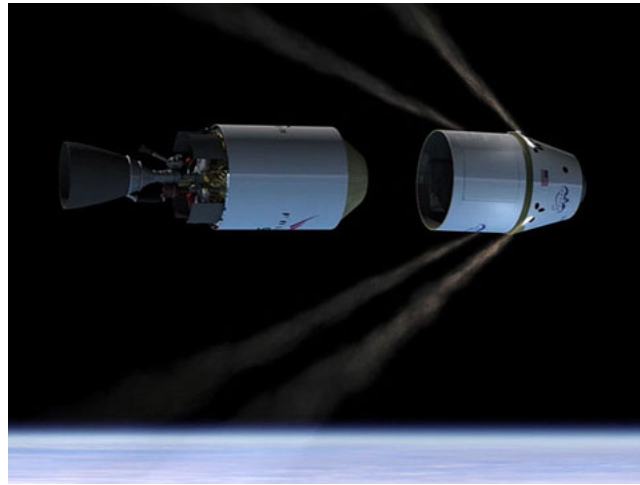
Three minutes after launching, the first and second stages separate: ¹⁰



The first stage [falls back](#) to Earth, and it's now the second stage's big moment to shine. The second stage is just a mini version of the first stage, and it's also mostly filled with fuel. But instead of nine

Merlin engines, the second stage only has one—a special version made to be used in the vacuum of space, with a bell extension to increase its thrust. Fewer engines are needed here because A) no more thick atmosphere, B) it's lifting a lot less weight without the first stage attached, and C) it's already going really fast so much of the work is done.

The second stage's job can be over in a few minutes or last multiple hours. Its engine can go off and on, and it has directional maneuverability. Its job is to be precise and get the payload to the exact right location and velocity. Once it does that, it separates from the payload and drops off:¹¹



Speaking of payload, there are two ways the top of a Falcon 9 can look, and the difference is which type of payload it's bringing with it. Here's the first way:¹²



When it looks like this, it's usually carrying a satellite. The bulge at the top is a two-piece protective clamshell thing called a fairing. It tends to look about the size of a bathtub, but it's actually the size of a school bus: ¹³



Once the second stage gets going at a certain speed (about four times the speed of a bullet), the fairing's two halves separate and fall back into the atmosphere to burn up. ¹⁴



The second way the top of a Falcon 9 can look is this: ¹⁵



The more triangle-looking top means the rocket is carrying a Dragon spacecraft.

Dragon ¹⁶



SUV-sized [Dragon](#) is SpaceX's spacecraft, made for transporting cargo, and one day people, to and from space. NASA's big 2008 contract with SpaceX was for 12 Dragon missions to the ISS. In the picture above, the cone-shaped thing on the right half is the Dragon's pressurized capsule and the only thing that returns to Earth. The cylindrical part on the left is an unpressurized trunk, which can carry additional cargo and holds the solar panels (which is what gives Dragon power in space). Together, the two can hold around six tons of cargo.

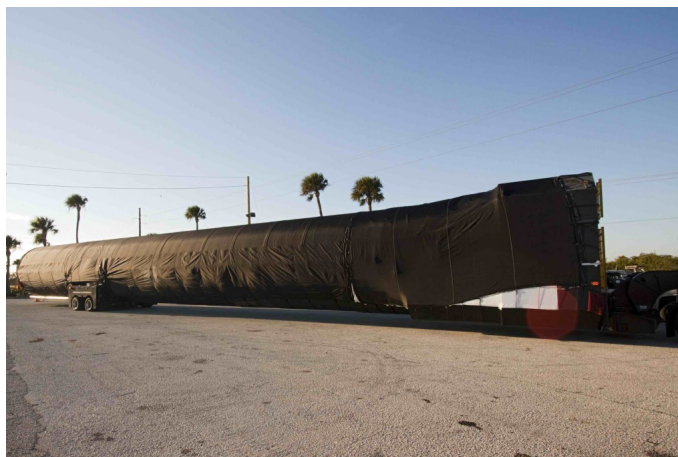
Those little holes on the side are mini thruster engines Dragon uses to maneuver in space, and on its bottom is a [heat shield](#) for re-entry.

Falcon 9 starts its career

As all of this new equipment was in development, Falcon 1 made its fifth and final launch in the summer of 2009, launching a satellite for the Malaysian government—SpaceX's first paying customer, and successful launch #2. But with the taller and more handsome Falcon 9 in the womb, Falcon 1 wouldn't be needed anymore, and it was retired.

Falcon 1 had made its five launches from a tiny Pacific island called [Kwajalein Atoll](#). But having joined the big boys club with Falcon 9, SpaceX took out leases at America's prime time launch pads—[Vandenberg Air Force Base](#) in California (for launches to the south) and legendary [Cape Canaveral](#) in Florida (for launches to the east).

And in the summer of 2010, the first Falcon 9 headed off for the launch pad, causing thousands of highway-drivers to say, "What the hell is that?" ¹⁷



Its inaugural voyage—a demo run—was a success.

Then, SpaceX started doing things commercial companies aren't supposed to know how to do.

Sending a spacecraft out to space is hard—but bringing it back might be even harder. You know how if you jump into the ocean off of a dock, nothing bad happens (except the water being probably freezing because everyone likes to pretend that immersing yourself in cold water is an okay activity)—but if you jump into the ocean off of a bridge, you die? With the only difference being your body's velocity when it hits the water? Same situation with the Earth's atmosphere.

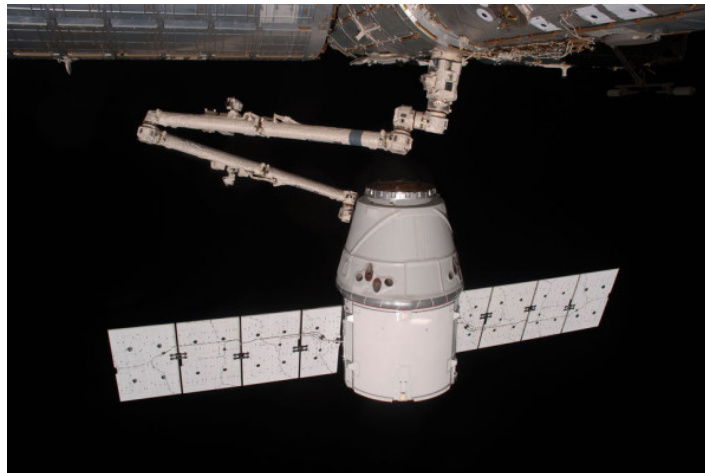
You don't feel the atmosphere right now because of your minimal velocity, but open your hand and vigorously move your arm back and forth like a psycho and you can *feel* the atmosphere. Speed yourself up even more by riding in a convertible or a fast-moving boat and you're quickly pummeled in

the face by the atmosphere. But the speed isn't just about *you*. It's about your speed relative to the speed of the atmosphere. Putting your hand out the window in a car going 50 mph feels the same as putting your hand out the window of a parked car with 50 mph winds outside. So when an object in orbit—which we established earlier has to be traveling at about 17,000 mph (27,300 km/h)—decides it's over it and tries to come back to Earth, it experiences the equivalent of a 17,000 mph hurricane. Our official hurricane "levels" go from category 1 (74-95 mph) to category 5 (which starts at 155 mph), going up a level roughly for every 20 mph increase in wind speeds. At ground level, moving 17,000 mph would be like hanging out in a category 842 hurricane. The force of a category 842 hurricane would be lower in the thin atmosphere at the high altitudes where objects first enter—but *still*.

What scares us about hurricanes is their *force*. But in a category [three-digit number] hurricane, you have much bigger problems. The spacecraft's blistering speed in the upper atmosphere means the air in front of an incoming capsule doesn't have time to "get out of the way" and becomes super-compressed and blazingly hot. Lower, where the atmosphere is thicker, the spacecraft has to handle the heat of the intense atmospheric drag. Rocks can't handle it—which is why they turn into shooting stars—and building [a spacecraft that can](#) requires a lot of fancy technology.

Up until 2010, only five governments had ever managed to get a spacecraft out into space and recover it successfully. Falcon 9's second launch pinged the first Dragon into orbit on a demo run for the new spacecraft, and after two orbits, Dragon came barreling through a category 842 hurricane and still existed on the other side, making SpaceX the first company, and sixth entity of any kind, to recover an orbiting spacecraft. Not bad for a company on their seventh launch.

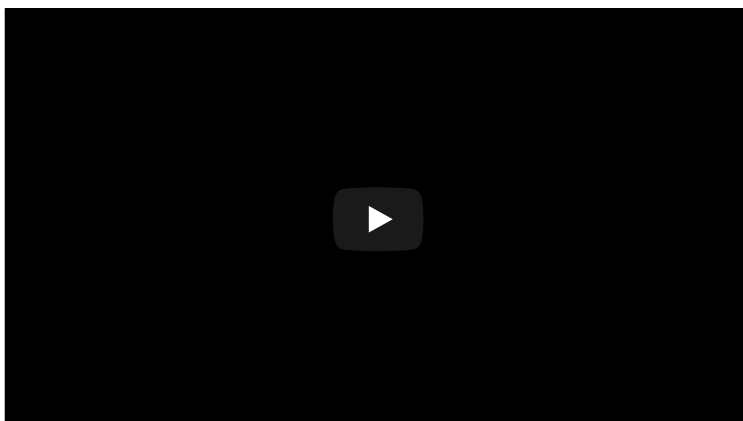
Falcon 9's third launch made history again, when on a demo mission for NASA, Dragon became the first commercial spacecraft to attach to the ISS. ⁴ ¹⁸



SpaceX made a little triumphant [video](#) with the highlights.

Falcon 9 was the real deal. Vance writes, "Where the Falcon 1 blasting off from Kwajalein was the work of a start-up, the Falcon 9 taking off from Vandenberg is the work of an aerospace superpower." ¹⁹ And with two of three planned demo missions done, NASA had seen enough to scratch the third demo mission and get started with the official resupply missions to the ISS on Dragon.

If you're curious what a launch is actually like, here's a video of mission CRS-6, an ISS resupply mission that launched out of Cape Canaveral on April 14, 2015:



Things to note:

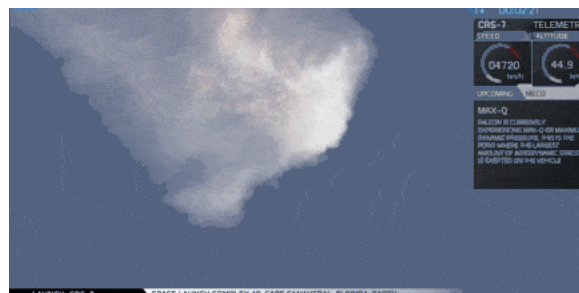
- The plumes of white smoke coming out of the rocket before launch is oxygen from the liquid oxygen tank in the rocket as some of it escapes as gas.
- About five seconds before liftoff, a deluge system called “Niagara” starts flooding the launch site with water. The purpose of this is to muffle the deafening sound of the engines, because otherwise, the sound waves would be so powerful that they’d actually damage the rocket.
- The engines start firing a couple seconds before liftoff. What’s happening is that huge clamps are holding the rocket down as the engines fire so a computer can quickly test them to make sure they’re all working. If they are, the clamps release at T-0 and the rocket takes off.
- Timing is critical down to the *second*. Even one second off schedule will mess up the rendezvous with the ISS.
- Launches are *hectic*.
- Over the first three minutes, the bright orange stream of delicious fire coming out of the rocket becomes increasingly spread out, icky-looking, and gray. This is because as the altitude increases, atmospheric oxygen thins out, and combustion has a harder and harder time taking place outside the rocket.
- The first stage separates at 3:26.
- After stage separation, the big black bell you’re looking at is the second stage’s sole Merlin engine. You can’t see any fire coming out of the engine because combustion is impossible at that altitude so it immediately stops after leaving the engine.
- Nothing much happens for the next seven minutes.
- At 11:09, the rocket is sufficiently in orbit and the second stage separates.
- Most of the rest of the video is a view of the now on-its-own Dragon taken by a camera on the second stage.
- In the last 25 seconds of the video, you can see the Dragon’s solar panels unfold.

After five Falcon 1 launches and three Falcon 9 launches, most of which were tests and demos, SpaceX was ready to start its space delivery service. Falcon 9’s fourth launch and the first official ISS resupply mission was the first in a string of 15 straight successful deliveries (six Dragon missions for NASA, nine satellite missions for other customers), bringing us to May of 2015, when I wrote this sentence and accidentally jinxed the whole company:

Since their first three failed launches, SpaceX has launched 20 times—all successes.

And after that 20th straight success, Musk tweeted, “Rocket launch good, satellite in geo transfer orbit. Still so damn intense. Looking fwd to it feeling normal one day.”

Then—on the very next launch—this happened: ²⁰



A launch failure is a horrible thing, even when no people are involved. It’s why SpaceX VP Mark Juncosa told me that each launch day is constant, torturous anxiety. It seems kind of like a pitcher throwing a pitch with two outs in the ninth inning of game 7 of the World Series, except the ball takes a few months to get to the plate, and they have to watch the moment when it finally gets to the batter on TV.

But devastating failures are part of what you sign up for when you get into the space game. After the demoralizing third failure of Falcon 1, Musk wrote to his employees, “It is perhaps worth noting that those launch companies that succeeded also took their lumps along the way. A friend of mine wrote to remind me that only 5 of the first 9 Pegasus launches succeeded; 3 of 5 for Ariane; 9 of 20 for Atlas; 9 of 21 for Soyuz; and 9 of 18 for Proton. SpaceX is in this for the long haul and, come hell or high water, we are going to make this work.” This puts SpaceX’s June 2015 failure in perspective and lets it serve more as a reminder of how impressive its 20 for 24 start has been.

The good news about failures is they show you exactly where your weak points are. In this failure, the culprit was a single two-foot long, one-inch thick steel bar—one of hundreds in the rocket—that was supposed to handle five tons of force and snapped after only one. From now on, SpaceX will individually test every steel bar that goes into a rocket. You can see Dragon slip away unscathed (at the top of the

screen, toward the beginning), and if it had software to deploy its parachutes earlier than planned, the contents in it would have survived. From now on, Dragon will have that software.

And that brings us to today.

In an industry full of middleman price hikes and decades-old equipment, SpaceX's tightly controlled in-house supply chain and cutting edge technology has made it the world's cheapest option for space delivery. For years, the US government has relied on two major aerospace companies—Boeing and Lockheed Martin, along with their joint venture, United Launch Alliance (ULA)—for domestic launches. ULA charges the government—and the US taxpayers—\$380 million per launch. For a similar launch, the US government only pays SpaceX \$133 million. For launches with other customers, without all of NASA's special requirements, SpaceX charges \$60 million per launch.

Given the unbelievable bargain, SpaceX unsurprisingly has a long line of customers vying for their services—they currently have a backlog of over 50 planned launches, worth over \$5 billion. They're doing everything they can to ramp up production, aiming to soon make 40 Falcon 9s a year. Musk believes that within a few years, SpaceX will cost less than a tenth of the industry average, and he believes SpaceX can take over the majority of the world's commercial launches.

This is a big deal for the US, not just SpaceX.

The US, through Boeing, is proud to be one of two major airplane producers (with Europe's Airbus being the other), but for some reason, the country has allowed itself to become an insignificant part of the global launch industry—while Europe, Russia, and China dominate. The main provider of US launches, ULA, gets most of its business from the US government, and gets the most expensive part of its hardware equipment—the engines—by buying them from Russia. SpaceX is making the US a big player in the launch industry again as business increasingly pours in from all around the world—and they manufacture almost everything domestically.

More Angry Giants

While SpaceX might be a terrific development for both Americans and the future of space travel, not everyone is so pleased about their arrival on the scene.

Remember last post when we took a deep look into what's going on under the hood of the auto and oil/gas industries, and it turns out it's all pretty messed up and humanity is kind of being taken for a ride without realizing it? Because that's what happens when opaque industries have a "special" relationship with the government and barriers to entry that keep out competition from underdogs? And how Tesla is kind of exposing all of that and forcing a fat, happy, and docile industry to innovate, and how they all desperately wish Musk would disappear?

I could almost just copy and paste that section into this post as well.

The space launch industry is like a handful of auto mechanics in a small town that all charge about ten times as much as they need to, but because A) customers are clueless about the process and what it should cost, and B) all the competition overcharges as well, there's no incentive to upgrade equipment, increase efficiency, and bring down costs. SpaceX is like a newcomer to town who sets up an auto shop, comes up with newer, better ways to fix cars, works harder than anyone else, and is able to charge a fraction of the price for the same service. Which ruins *everything* for the town's other auto mechanics.

In 2014, Europe's Arianespace—a major player in the global launch industry—asked European governments for additional subsidies to handle competition from SpaceX. A Falcon 9 trip to GTO (the highest satellite orbit) now costs \$15 million less than a launch on China's historically-cheap Long March rocket. As for the other major player in the launch market, Musk has said, "My family fears that the Russians will assassinate me."²¹

All around the world, launch customers are noticing what SpaceX is doing, then looking at their own launch company and asking, "Wait why am I paying so much?"

When I asked Musk about all the industries that want to drop a piano on his head, he said, "It's a roomful of toes—it's hard to avoid stepping on them." And of all the toes SpaceX is currently stepping on, it's stepping the hardest on ULA.

ULA is a Dick Blue Box

ULA, the Boeing and Lockheed joint venture, charges more than anyone for a space launch. But it doesn't matter what they charge. ULA doesn't have to compete with the rest of the world's launch market—because ULA gets a constant flow of automatic business from the US military. Here's how it works:

- 1) The US military needs to launch a lot of things into space, so there's plenty of business.
- 2) Because military equipment is tied to national security, the US wants the launches done by an American company.
- 3) Because space launching, like auto repair, is an opaque process to the public and to politicians, no one knows that ULA's launch price tag is much higher than it needs to be.
- 4) ULA works with the government on a "cost plus basis," meaning their payment for a launch is a percentage of whatever the launch costs them—i.e. they're incentivized to make it cost more, not less.
- 5) There's ample money to go around because of the US's *astronomical* military budget.
- 6) Most infuriatingly, many of the decision-makers in the US Department of Defense are friends with the leadership of ULA, and ULA is a common place for DoD officials to work when they retire from government. So ULA is more likely to get a nod and a wink from the DoD than an audit into how they spend their money.

What that all adds up to is at best, a flawed system that puts zero pressure on lowering costs and at worst, a grand-scale government scandal—all paid for by the US taxpayer.

And do you know what a ULA-DoD circle jerk *really* doesn't want around? A company like SpaceX. SpaceX had succeeded in winning much of NASA's business, but in order to be awarded a military launch contract, a company needs special certification, and curiously, SpaceX had a *very* hard time becoming certified. Calling bullshit on the process, and knowing that the law requires there to be fair competition for the military's launching needs, in 2014 Musk brought the issue to Congress, making the case that "SpaceX is not seeking to be awarded contracts for these launches. We are simply seeking the right to compete."²²

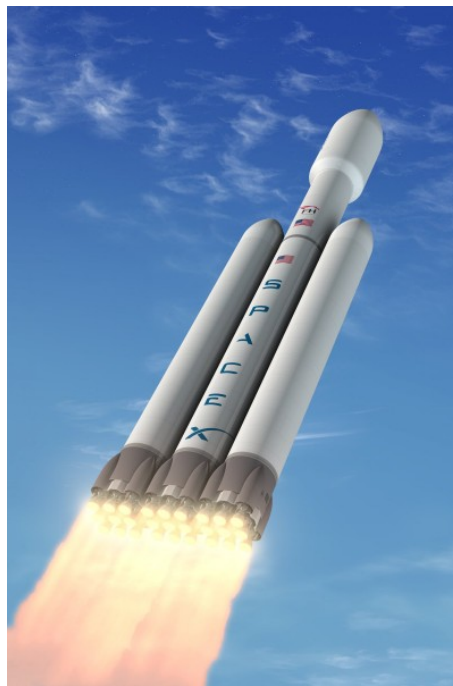
But he received a lot of pushback. Despite clear evidence that ULA charges *six times* SpaceX's rate per pound of payload, politicians like Senator Richard Shelby of Alabama (one of whose biggest donors is the aerospace industry²³) argued that it was a national security issue—an odd line of argument, considering that ULA pours money into Russia, buying their engines and other parts, while SpaceX does all of their business in the US. In an *interview* a few months ago, Musk vented about the situation: "ULA has decided that they're afraid even of an unfair competition. They don't want a fair competition. They don't even want an unfair competition. They want no competition at all...they're afraid that we'll take some of the huge gravy train they have exclusive access to, or that it's not going to be as big."

SpaceX has made some progress in the last year and has been awarded a small number of military launches, but only a tiny fraction—this is a battle SpaceX will be fighting for a while. I asked Musk about the difficulty of competing against ULA. His response: "These are not pushovers, it's the military-industrial complex. You know in movies, how they do terrible things? Well yeah, those guys."

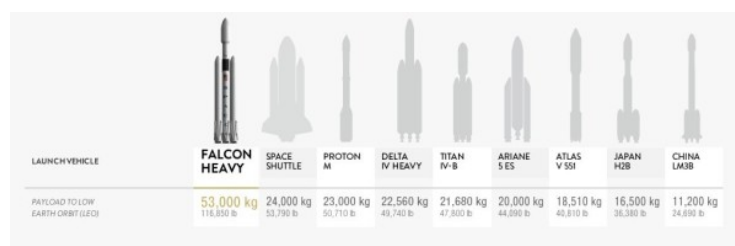
The SpaceX revenue model will be growing and expanding in the coming years. Here are three of the coolest things in the pipeline:

1) Falcon Heavy

Remember how I made a whole big deal about putting nine Merlins together and being able to lift a skyscraper-high stack of 360 cars? *Falcon Heavy* is a Falcon 9 except instead of having one first stage, it has *three*.²⁴



With 27 Merlins, the Falcon Heavy engine platform can lift about 2,000 tons, or a mile-high, 1,100-car stack. Launching for the first time in 2016, Falcon Heavy will be able to take more than double the payload of any other rocket in the world—and do so at the lowest price per pound of payload in history (ULA charges three times what Falcon Heavy will charge per launch and will take less than half the payload). Here's a little payload comparison of the industry's most heavy-duty rockets:



2) Quadrupling the number of satellites in orbit

Actually though. A couple months ago, Musk [announced](#) that SpaceX would be starting a satellite-production operation in Seattle that would put 4,000 internet satellites in Low Earth Orbit by 2030—three times the 1,300 *total* satellites that are in orbit today. His reasons:

- Bring costs down to bring technology up.** Today, it typically costs about a quarter billion dollars to make a satellite and around the same amount to put it in space. That makes every satellite launch super high stakes, which makes companies risk-averse, so they tend to use older, proven technology and make sure to get at least 15 or more years of usage out of each one. The result is that a lot of the satellites performing services for us today were made in 1990, with 25-year-old technology. SpaceX wants to figure out how to make satellites for a much lower cost, and combined with their ability to launch much more cheaply, they'll be able to put cutting-edge satellites in orbit, do so frequently, and replace them just as frequently.
- Bring internet to anyone, anywhere.** I sat down with Rajeev Badyal, SpaceX's VP of Avionics Engineering, who is in charge of the satellite project. He explained that SpaceX's constellation of 4,000 solar-powered satellites will work together intelligently to cover every part of the Earth and beam lightning-fast internet to places where it's badly needed. He talked about how really only a few places on Earth (Europe, the US, parts of India and East Asia, etc.) are truly blanketed with good internet, and how this would be a game-changer for many other parts of the world, especially the most remote. All you'd need to make it work is a small, pizza-box shaped receiver, which could be put anywhere outside, and you could have fast internet on the North Pole, the middle of the Pacific Ocean, the top of Mount Everest—anywhere. He also talked about other ways the satellites could be used—you could attach cameras to them to use for crime reports, live Google Maps, weather—anything.

- **Even more angry giants.** Wouldn't Time Warner Cable and Comcast be a great addition to the pile of big, low-quality, monopoly-like companies Musk is finding a way to compete with? In his announcement, Musk mentioned it: "In cases where people are stuck with Time Warner or Comcast, this would provide an opportunity to leave." (This got a huge cheer from the crowd.)
- **It's lucrative.** Between selling satellites it manufactures and creating revenue off of those it puts in orbit, SpaceX can make a ton of money from this.
- **Solves the Mars internet problem.** Physical cables are the way of the past and Mars will be a planet of the future. Musk plans to have SpaceX-manufactured internet satellites circling Mars down the road, bringing fast internet to the future Mars colony.

3) Manned Space Travel

In 2014, the US and Russia got mad at each other, as they are wont to do—this time over Russia deciding that it would actually be super cool if Crimea were part of Russia—and the US responded by imposing sanctions against Russia's space program. To which the Russian Deputy Prime Minister tweeted:

After reviewing the sanctions against our space industry, I suggest that the United States deliver their astronauts to the ISS using a trampoline.

Well played.

This is what happens when your once mighty space program becomes so lame that it can't launch its own astronauts into space anymore. You have to rely on countries you might get mad at, which puts you in a terrible position.

The only other country that can launch people into space is China, and the US is even madder at them—so mad that Chinese astronauts are prohibited from hanging out at the cool kids' club on the ISS. It's like a town with three rival mob bosses, but awkwardly, only two of them have a car, so the third needs to get a ride to work with one of the others. Not ideal for the third boss.

Elon Musk chimed in with his own tweet soon after:



The Space Shuttle program retired in 2011, starting this window we're in where the US has no way to perform manned space flight. The next Space Shuttle-style full US space program is supposed to be the creatively-named [Space Launch System](#) and its [Orion](#) spacecraft, but delays have pushed the program's commencement back to at least 2021. The US doesn't want to rely on Russia until 2021, so in the meantime, NASA held a contest to choose private contractors to use for crewed launches. NASA ended up splitting up the \$6.8 billion contract between Boeing (who would get \$4.2 billion) and SpaceX (who would get \$2.6 billion). ²⁵

In May of 2014, SpaceX [unveiled](#) the second iteration of Dragon—Dragon 2. ²⁶



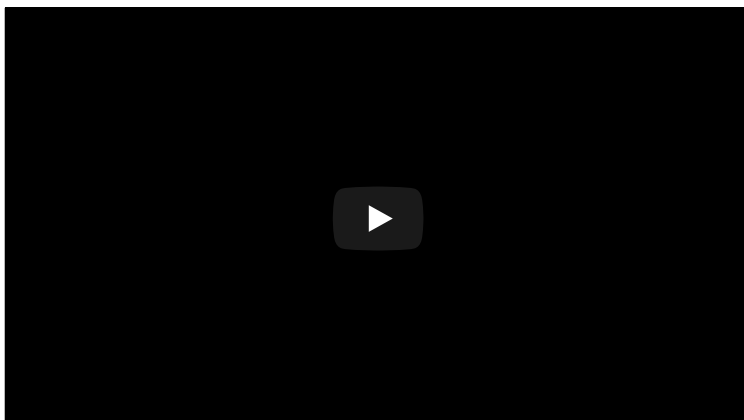
The first Dragon is cool—it's one of the only spacecraft that can return to Earth intact, and it's currently the world's *only* operational spacecraft that can bring cargo back from the ISS.⁶ But Dragon 2 is much cooler.

Dragon 2 can [dock with the ISS](#) without being pulled in by the ISS's arm like an infant.

Dragon 2 has seats inside and fancy touch screens (most of today's spacecraft were designed in the 60s and still have buttons and knobs like an old radio):²⁷



But the coolest thing about Dragon 2 are its *engines*. The spacecraft has eight super-powerful little engines, called SuperDracos, each of which could lift four cars. SuperDracos are so specifically designed that they're entirely manufactured by 3D printing, the first rocket engines to be made that way. I'm going to embed another engine-firing video, because it's so fun to watch. Here's a SuperDraco being tested:



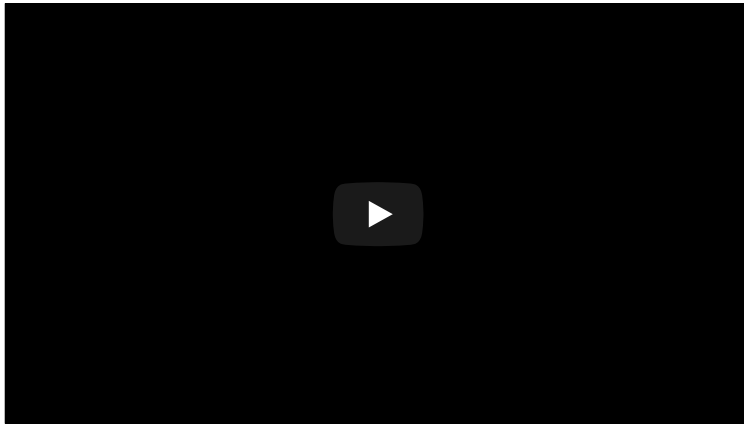
Dragon 2's SuperDracos have three main purposes:

1) Maneuvering in space

2) **Propulsive landing** – more on this in the next section

3) To abort the astronauts if something goes wrong

The third is a critical feature for crew safety. Even the best rockets sometimes fail, often in catastrophic fashion—as SpaceX just demonstrated for us—and Dragon 2’s abort system allows the spacecraft to get the hell away from the scene before the bomb goes off. If the two Space Shuttle disasters had had this feature, the astronauts might have been saved. Here’s a recent test showing Dragon 2’s abort system in action, which for some reason struck me as kind of adorable:



The power of the abort is hard to fully grasp in that video. The eight SuperDracos are so powerful that they take the Dragon more than the length of a football field in two seconds, and over a third of a mile (about half a km) in just over five seconds. And while other manned capsules have had abort capabilities before, the others have only been able to abort during launch—Dragon 2’s abort system works all the way up to orbit.

Musk also wants to redefine what it means to be an astronaut, explaining that a person shouldn’t have to *be* an astronaut to fly in space. His vision has ordinary people hopping on top of a SpaceX rocket and going to space with relatively little training or skills—the same way we fly in planes today (kind of reminds me of how at one point, only a computer scientist could use a computer, and how outdated that concept seems today). Following the theme of acknowledging that it’s 2015, not 1965, SpaceX is also redoing the concept of the spacesuit—Musk has specifically insisted they be cool looking and ditch the Marshmallow Man style.

The timetable has the first SpaceX and Boeing manned flights launching in 2017—but there’s currently [a push in the US Senate](#) to slash NASA’s funding, which would delay things by at least two years. Nahhh.

So that’s what SpaceX does and how it makes money. The delivery service is doing its job—SpaceX is profitable and should have a long runway ahead to stay afloat. A recent investment by Google and Fidelity valued the company at \$12 billion.

But Musk has said that his nightmare would be for SpaceX to end up in the hands of someone who will milk it for short-term profit. Because as we laid out at the beginning of this Phase 2 section, everything we just discussed is what SpaceX does—but not what SpaceX *really* does.

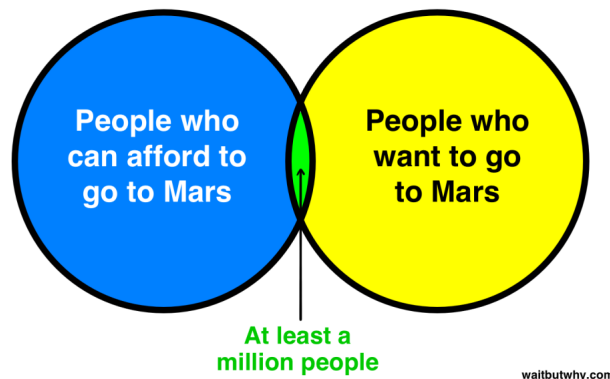
What SpaceX really does has been happening ever since the development of Falcon 1 and is evidenced by the unbelievable deal you can currently get to deliver something to space on a Falcon 9 versus any other way.

But SpaceX’s low prices would still be classified as an *incremental* improvement—not a transformative game-changer.

What SpaceX is *really* doing is something much, much bigger—they’re working on an innovation so groundbreaking that if they can pull it off, they’ll reduce the cost of launching a rocket by *100 times* more and completely alter humanity’s future in space—and make a multi-planetary future possible.

Changing the Game

Remember this whole thing from before?



Musk estimates that \$500,000 for a ticket to Mars might be the magic number that makes the blue circle big enough that the green zone reaches a million people. The way he describes it, with a \$500,000 ticket, it would be like buying a middle-class home in California, and "most people in advanced countries, in their mid-forties or something like that, could put together enough money to make the trip."²⁸

So how close are we? In 1989, when Bush Sr. proposed an initiative to bring US astronauts to Mars, NASA estimated it would cost \$450 billion. To send 4-6 astronauts. About \$100 billion per seat.²⁹

Close. Just 200,000 times Musk's per-seat goal of \$500,000.

In 2004, Bush Jr. entertained the idea of sending Americans to Mars. NASA said it would cost \$50 billion. \$10 billion a seat. Still 20,000 times too high.

So how the hell do you bring the price of *anything* down 20,000 times.

Musk's plan is to attack the problem from two angles.

1) Bring lots of people

The Falcon rocket family is SpaceX's moneymaker, but neither Falcon nor Dragon will ever take people to Mars.

For one, Dragon is the size of an SUV—going to Mars takes three months at the very least. Not a good plan.

Secondly, if you're gonna go all the way to Mars, you should make it a big carpool.

That's why SpaceX has a long term plan to build a rocket that will make Falcon 9 look like a hot dog—

The Mars Colonial Transporter.

The MCT rocket will be a giant, powered by a much more powerful SpaceX engine, called the Raptor, that's currently in the works—and its spacecraft will be able to hold *at least 100 people*.

So right there, if SpaceX can do that, they've cut the current cost-per-seat estimates by at least 20.

Now we're down to this being 1,000 times too expensive.

But there's another thing—SpaceX has, through its Falcon innovations, already reduced the cost of a launch to one-fifth of the industry standard, and Musk believes it'll be down to a tenth of the industry standard in the coming years. Since the Bush Jr. figure was assuming industry standard costs, that brings things down to only 100 times too expensive.

A bigger spacecraft can help lower the per-seat cost of going to Mars, but it doesn't change anything for today's commercial launch industry, it doesn't get us anywhere close to cheap enough to bring large numbers of people to Mars, and it doesn't solve what Musk calls "the fundamental problem with space exploration."

So what *is* this big game-changing innovation I keep hyping up but not telling you about?

2) Reusability

Imagine the current air travel industry with one key difference: an airplane works for one flight only. Each flight is on a brand new plane, and after the flight, passengers exit into the terminal and the plane is broken down into scrap metal and possibly-reusable parts that are sent off to be refurbished for use in a future plane.

An airplane costs around \$300 million to build. So in this new model, in addition to paying for the crew's time and fuel, airlines have to spend \$300 million extra each flight to build a plane. How would that change things?

First, there would be very few flights available—the schedule would be limited by the pace of plane production. Second, the price of a round-trip ticket between Chicago and San Francisco would now cost about \$1.5 million per person. For economy.

Air Force One would still exist. Wealthy countries would have a small military air fleet. A few governments would fly in order to perform certain types of science experiments. People with 10 billion dollars would probably fly a decent amount, but people with only one billion dollars couldn't really afford it. And you? You would be born, live your life, and die without ever riding on a plane.

If this were the situation, people would probably look at the non-existent air travel industry and determine that clearly, there was no public will to travel by air. Politicians would argue against putting much government funding into the exorbitant activity. Most people wouldn't even fully understand how airplanes worked, and they wouldn't waste any time imagining what the world would be like if everyone could use them. It would become a non-topic. We'd travel by car and railroad and ship and that would be that.

Can you see where I'm going with this?

No one in history—not the US, not the Soviets, and certainly not the stagnant fat cats at ULA—has figured out how to make rockets reusable. Rockets spend months getting built, head up to space, and either burn up in the atmosphere or crash into the ocean as scrap metal. It's not that no one has tried—the US and Soviets have both put tens of billions of dollars into the problem—it's that no one has figured it out.

The Space Shuttle system was supposedly "reusable." But there are three parts of a Space Shuttle—the spacecraft, which was genuinely reusable, the rockets, which were technically reusable but took nine months of refurbishment that nullified the cost benefits, and the big orange gas tank, which was totally un reusable and converted to immediate trash after the launch. So it was 1 for 3, and as a result, Space Shuttle missions cost a laughable [\\$1.6 billion apiece](#) (over \$200 million per astronaut).

A bigger spacecraft, coupled with SpaceX's cost-saving innovations, has theoretically brought things to within two orders of magnitude of the goal—\$50 million per person. And that cost assumes a new MCT would have to be built *for every flight*.

The first game for SpaceX was figuring out how to launch something into orbit. Now they're onto a new, much harder game—reusability. If SpaceX can create what they call "a fully and rapidly reusable rocket system"—leaving the only launch costs as fuel, maintenance, and interior support systems, *just like an airplane*—it'll reduce the cost of space travel by a factor of 100. Maybe more.

So how do you do it?

First, you need a better way to *land*. Musk describes the three ways a rocket and spacecraft can land:

Landing Type 1 (most basic): Parachuting into the ocean

This is how almost all spacecraft land today, if they land at all.

Problems: Parachutes don't work in places with no air, like the moon; landing in corrosive salt-water heavily damages the equipment; it's undignified (imagine an alien trying to be intimidating by landing in our ocean with parachutes and having to swim to shore).

Landing Type 2 (intermediate): Wings and wheels onto a runway

This is how the Space Shuttle landed.

Problems: Wings don't work in places with no air, like the moon, ⁷ or no runways, like everywhere besides Earth; while this method can be used for a spacecraft, it's much harder to do with the rocket—and full reusability means landing *both* the spacecraft and the rocket stages.

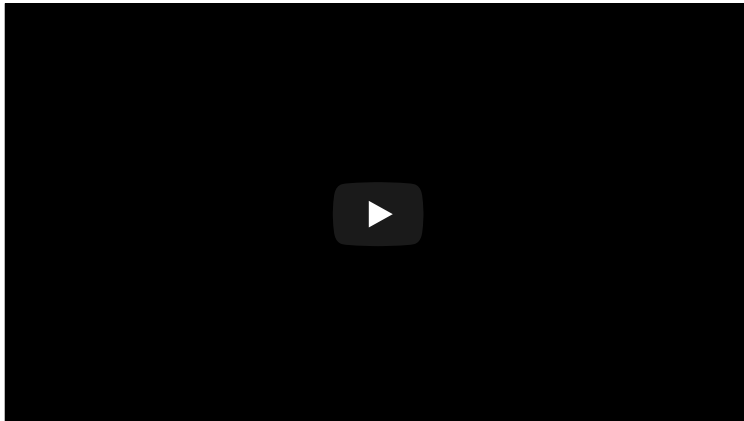
Landing Type 3 (advanced): Propulsive landing

Propulsive landing means coming down the same way rockets take off. This is how the Apollo Lunar Modules (like Apollo 11's "Eagle") landed on the moon.

Propulsive landing allows you to land a rocket or spacecraft neatly on a landing platform, with minimal damage to the vehicle.

It's easier to envision a spacecraft doing a propulsive landing than a rocket doing one, because we've seen spacecraft do it before. Dragon 2 is being designed to be a landing specialist—those same SuperDraco engines Dragon 2 uses to abort in an emergency will also be used to land, and Dragon will be able to land on any type of surface of any solid body in the Solar System as easily as a helicopter can land on Earth. Landing a *rocket* that way is a more foreign concept, and much more difficult.

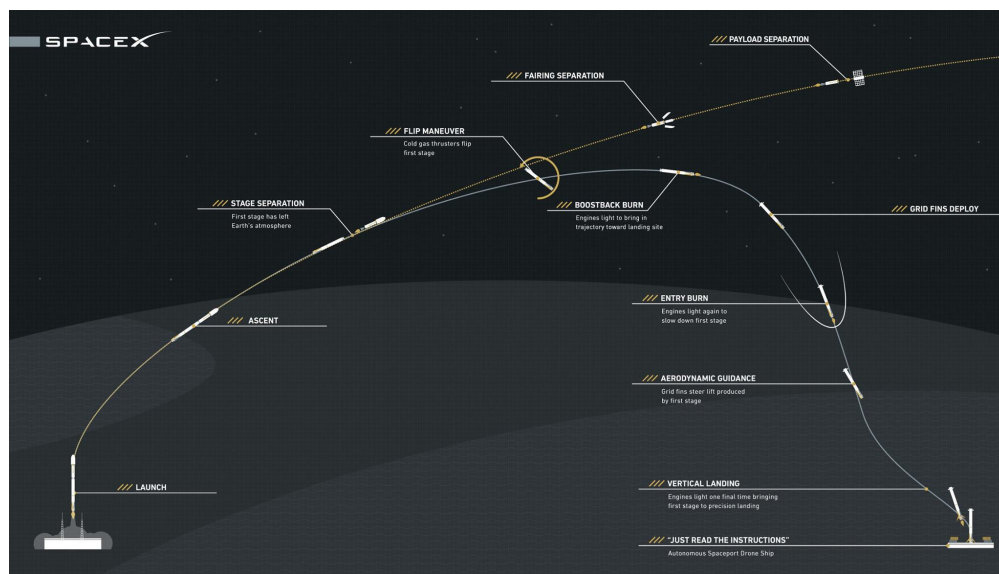
Here's SpaceX's vision for Falcon and Dragon reusability—worth the watch:



If it works, the idea is that a rocket and spacecraft could land, be refueled, and head back up within hours. Again—just like an airplane.

Juncosa explained to me that the first and most important step is to learn how to land just the Falcon's first stage. It's the most important because the first stage costs about as much to build as a jumbo jet and makes up the bulk of the rocket's total cost (especially the engines)—if they succeed at that, it'll be a giant step forward. And they'll show the world, including the currently-very-skeptical aerospace industry, that reusability is indeed possible. They'll have drawn a blueprint for how other rocket-makers can slash their own costs—and begun a new era in space travel.

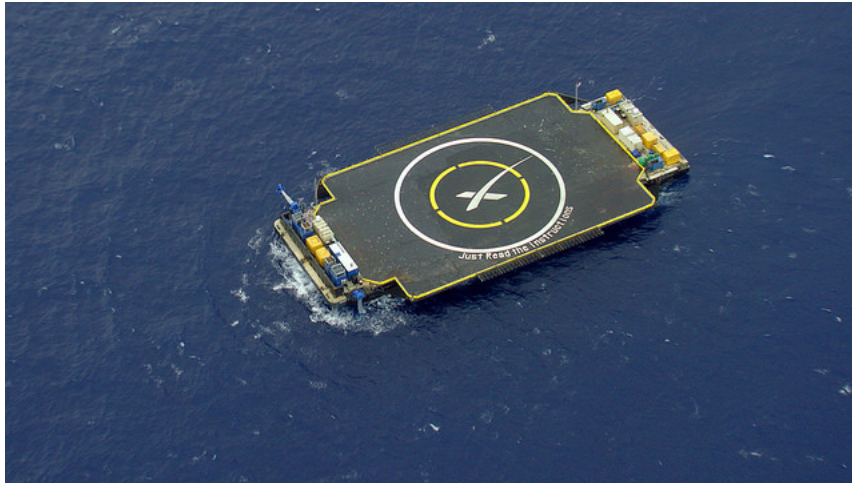
This is how landing the first stage is supposed to go (click for a larger view): ³⁰



When it says “burn,” it means that a single main engine fires (the one in the middle). Since weight is such a factor during launches (there's almost no room for added weight or the rocket won't be able to get a payload into orbit), the rocket will have enough fuel for exactly three burns. The first is used to stop the rocket's ballistic path (i.e. the normal arc it's naturally on) and direct it toward the landing site. ⁸ The second is used to slow down—from 3,000 mph to 550 mph (885 km/h)—so it doesn't burn up in the atmosphere. The third is used right above the landing platform, to slow it down to 5 mph (8 km/h).

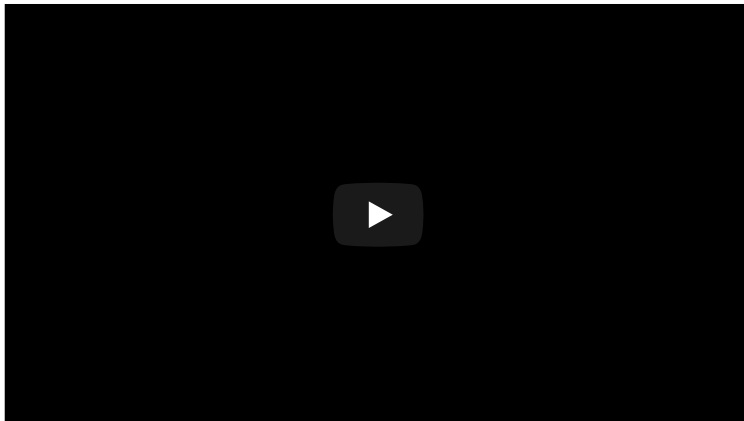
Since weather is moving and unpredictable, there's a lot of software in the rocket sensing outside forces and adjusting the trajectory. The rocket has little wing flaps called “grid fins” that open up and steer the rocket (the grid fins and landing legs also slow down the rocket, cutting the terminal velocity in half). Grid fins work when you're in the atmosphere, but up in space where there's no air, grid fins are useless, so the rocket steers with ejections from “cold gas thrusters”—little nitrogen jets that come out of the rocket.

If all works according to plan, about nine minutes after launch, the rocket will land on this floating platform in the ocean, 200 miles out from the launch pad: ⁹ ³¹



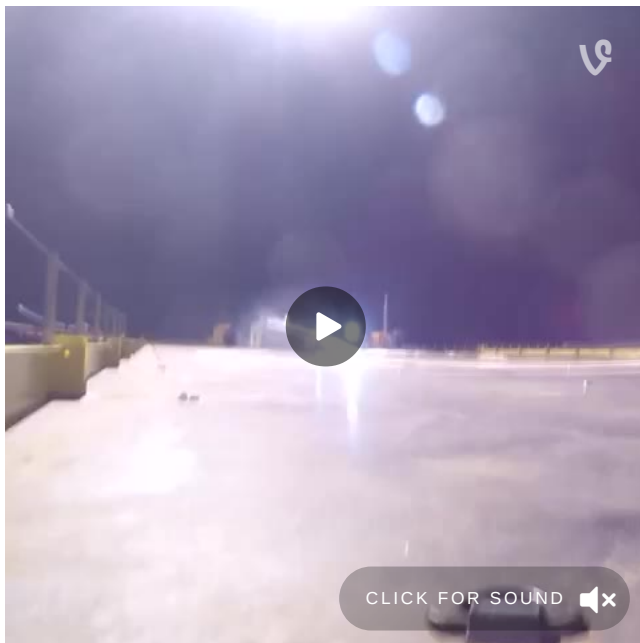
This is *hard*. If you scale down all the sizes, it's like firing a pencil over the top of a skyscraper and trying to land it on a shoe box on the ground—on a windy day. SpaceX likens the challenge of controlling the descent through the atmosphere to “trying to balance a rubber broomstick on your hand in the middle of a wind storm.” Popular Mechanics [calls it](#) “a tense juggling act, where any one of thousands of moving parts can push the entire system into mayhem. If the rocket does land softly on the barge, it's because millions of insanely detailed self-adjustments have kept the Falcon 9's composure as it dove through chaos.”

To hone its skills, SpaceX created a first stage rocket they call Grasshopper. In 2012, they were able to launch Grasshopper to the height of a 12-story building, pause it there for a few seconds, and then bring it back down to the pad:



Over the next two years, they launched Grasshopper [higher](#) and [higher](#) until finally launching a real Falcon 9 first stage [a kilometer in the air](#) and returning it to the platform.

Finally, it was time to try it for real—on an actual launch. In January of 2015, SpaceX performed a routine launch and brought the first stage through the atmosphere and tried to land it. Here's what happened (kind of fun with sound):



Close! Ish! That's what the people at SpaceX call an RUD—a rapid unscheduled disassembly.

They were going to try again with the next launch, in February, but it was scratched because of weather. They finally got a second chance to try in April, and this happened (the video is sped up): ¹³²



Just...almost...got it...but then the rocket tipped over like an asshole and exploded instead.

The third attempt was supposed to be in June...but we all know what happened in June.

So if you're just tuning in to all of this now, consider yourself lucky that it *hasn't* happened yet. You can start following now and see it live when they first make history (the best way I've found to stay oriented about the SpaceX launch schedule is on [this](#) Wikipedia page, and the best way to keep up with major developments and find the link to live launch webcasts is by following SpaceX [on Twitter](#)). There should be several more attempts in 2015. If history is an indicator, once SpaceX nails it once, they'll probably be able to nail it every time.

UPDATE: On December 21, 2015, SpaceX launched for the first time since the June '15 failure. Not only did the mission go perfectly (to deliver 11 satellites to orbit), *they landed the rocket successfully*. They *did* it. I was lucky enough to be at SpaceX headquarters to watch it happen (I was guest co-hosting the webcast), and it was the most excited I've seen a room of 1,000+ people ever. [Here's the full webcast](#) (launch happens at about 23:00 and landing excitement starts at about 31:00).

As I was researching for this post, just to make sure Musk was for real about this \$500,000 for a ticket to Mars thing, I sent him an email laying out the logic as I saw it, to see if it's really what he was thinking. Here was his response:

Yeah, these are seemingly absurd percentage improvements, however not impossible. The critical elements of the solution are rocket reusability and low cost propellant (CH4 and O2 at an O/F ratio of

~3.8). And, of course, making the return propellant on Mars, which has a handy CO₂ atmosphere and lots of H₂O frozen in the soil.

The design goal is technically 100+ metric tons of useful cargo per flight, so maybe more than 100 people can be taken. Depends on how much support mass is needed per person and the luggage allowable.

Avionics, sensors, communications, aspects of vehicle structure, landing pads and a few other things get better with scale, plus it is more fun to be on a cruise ship than a bus, so I suspect that the 100 people per flight number grows a lot over time, maybe to several hundred. Also, we could subsidize the equivalent of economy by charging a lot more for first class.

Factor in all of the above and getting below \$100k/ton or person eventually is conceivable, as the trip cost is then dominated by propellant, which is mostly liquid oxygen at a mere \$40/ton (although a lot of it is needed per useful ton of cargo). That would be really awesome!

Just an affordable cruise ship to Mars nbd. ¹⁰

Making that possible is the job of Phase 2, and SpaceX seems to be on their way to getting it done—possibly in the next decade. Once they get there, they'll be able to start the final phase of their mission—the one that will change everything.

Phase 3: Colonize Mars →

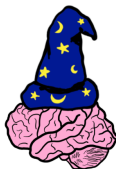
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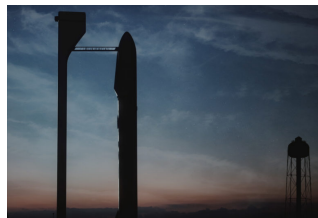
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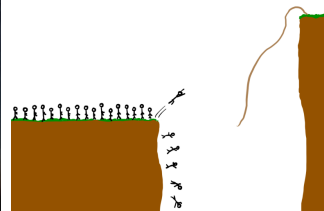
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maria juchkov • 23 days ago

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...

^ | v • 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?

^ | v • 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 ^ | v • 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 ^ | v • 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 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 was perpendicular to the object's trajectory, the trajectory would be a circle, not the one depicted above. If the

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 temperature 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 lifeforms, 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

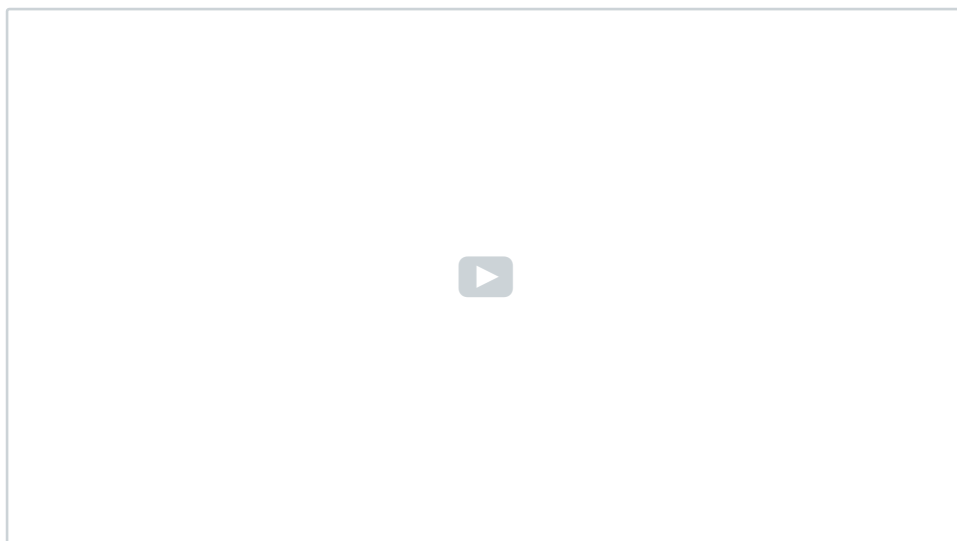
I'm wondering whether the Martian calendar will start at year 0 from the day the first human set foot on the planet. That would be so huge. Finally not a religious calendar, but a true scientific calendar celebrating every 669 martian days the moment the first humans set foot on the planet.

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?



^ | v • 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 ^ | v • Reply • Share >





Isabella Pintor • a year ago


 great article it took me an hour to read it but.. it was worth it
1 ^ | v • Reply • Share >


 **Nicolas Stabilini** • a year ago
I'm really concerned about horoscope... how would astrologys get an astro-chart for a human born in Mars?
(btw: I think horoscope is big big ball of bullshit)
^ | v • 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 ^ | v • 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 ^ | v • 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.
^ | v • 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).
^ | v • Reply • Share >

 **Drabes** → **IamGrimalkin** • a month ago
I think you mean muscle mass and bone density decrease...
^ | v • Reply • Share >

 **IamGrimalkin** → **Drabes** • a month ago
Yes, I did mean that, thanks for the correction.
^ | v • 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 ^ | v • Reply • Share >

 **iykcvth** • a year ago
good article ;)
^ | v • 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"

a local regulation, has blatantly 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."

^ | v • 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.

^ | v • 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 ^ | v • 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?

^ | v • 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.

^ | v • 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.

^ | v • Reply • Share >



Steve → inservo • a year ago

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

2 ^ | v • 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 ^ | v • Reply • Share >

2 ^ | v • 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 ^ | v • 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 ^ | v • 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?

^ | v • 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.

^ | v • Reply • Share >



Amit Vikram → Dan Apted • a year ago

Because Mars is more hospitable than moon. Mars' gravity is 38% of Earth'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 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 Earth has its 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 its atmosphere. Mars has Dry ice (frozen CO₂) sheets in its poles and if we nuke them, it will release that CO₂ in atmosphere and hence thickening its atmosphere in which plants can grow, increased atmospheric pressure will prevent water from boil off at low temperature and hence liquid water would be able to sustain on its 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.

^ | v • 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 ^ | v • 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.

^ | v • 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.

^ | v • 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 Earth's.

^ | v • 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.

^ | v • 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.

^ | v • 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.

^ | v • 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.

^ | v • 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."

^ | v • Reply • Share ›



jmac → ameba#23234 MdR • 2 years ago

Try this:

<http://onlinelibrary.wiley...>

^ | v • 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

^ | v • 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?

^ | v • 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.

^ | v • Reply • Share ›



Nobody • 2 years ago

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

^ | v • Reply • Share ›

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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...>

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**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--

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**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 SANTI 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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