



## Stanford eCorner

### Elon Musk's Vision for the Future [Entire Talk]

Elon Musk, *SpaceX*

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The iconic entrepreneur behind SpaceX, Tesla Motors and Paypal shares his predictions for artificial intelligence, renewable energy and space exploration, in conversation with DFJ General Partner Steve Jurvetson at Stanford on Oct. 7, 2015. University President John Hennessy introduces the future-focused discussion, which follows Musk's journey from his first Internet startup in the mid-nineties to his dream of a Mars colony in the next 20 years.



#### Transcript

Good morning, Stanford. I'll tell you, seeing so many students up this early in the morning is really a great experience for the president of the university. And I'm so delighted you're able to join us here. And I can tell, you're going to be in for a fascinating discussion this morning. If you think about our university and what makes it unique, it is that bold, entrepreneurial spirit, that pioneering spirit that Jane and Leland brought to us when they marched across the country to come to the West Coast and help found this university. Today, we remain committed to pursuing opportunities that will change the world, to using our knowledge in important ways to work on the grand challenges we face. But that entrepreneurial spirit is about more than just launching the next start-up. It's also about training and educating people who will go out and make our world better. And those innovations come in all walks, from the medical care we do and new ways of dealing with health problems, to energy efficiency, to robotics, to art, to everything we do. But every innovation begins with an idea.

And every idea began with somebody who imagined it. And that's what today is about. The Stanford Technology Venture Program's Future Fest is an opportunity to examine and celebrate the impact of breakthroughs and pioneering technologies on our world. And I'm delighted you could all join us this morning. This is organized by STVP in collaboration with Stanford Arts. The Future Fest will be the place where discussions about futuristic technologies occur. And today we'll hear from two forward-thinking individuals, Elon Musk and Steve Jurvetson. Steve is a Stanford alum and a partner at Draper Fisher Jurvetson. He was recently hailed in The New York Times as a space investor and rocket maker. His firm is invested both in Space X and a satellite company, Planet Labs.

Steve is a Stanford alumnus three times over, and he also has the important characteristic that he was once my advisee. Despite that disadvantage, he completed his actually there's a degree in electrical engineering in two and half years, was the Henry Ford scholar went on to earn his MS. And despite my attempts to convince him to pursue a PhD, went off and got his MBA from the Stanford Graduate School of Business, where he was an R J Miller scholar. He's recognized widely for being forward thinking. The San Francisco Chronicle and Examiner named him as one of the 10 people expected to have the greatest impact on the Bay Area in the early part of the 21st century. Now, Elon Musk, I think, is a name known to everybody who thinks about the future. He is a serial entrepreneur, inventor, engineer, and investor. He was born in South Africa, attended Queen's University in Canada before moving to the US, where he earned his undergraduate degrees in Economics and Physics from the University of Pennsylvania. He arrived at Stanford to pursue his PhD In physics, but left after two days. I said, what was wrong, Elon? Was it the food, the water, the weather? No, he left to launch his first startup-- Zip2, a successful internet-based city guide.

And then he went on to launch PayPal. He founded his third company, SpaceX, in 2002. And six years later, NASA

awarded him a contract for cargo transport to the International Space Station. He was an early investor in Tesla Motor, and now leads the company as its CEO and Product Architect. But Elon dreams big. As he told CNN a few years ago, we should not be afraid of doing something just because some amount of tragedy is likely to occur. If our forefathers had taken that approach, the United States wouldn't exist. Amen to that. I think when you see the kind of work that Elon is doing-- and I still remember my first trip down to Los Angeles to visit SpaceX and to see the first Tesla prototype before it came out-- I realized he was going to change the world. This will be a wonderful exchange.

After Steve and Elon's discussion, Matt Harvey, Executive Director of STVP will close the program. But now, please join me in giving a warm Stanford welcome to Elon Musk and Steve Jurvetson. Thank you, President Hennessy. And this is a daunting venue. I feel like we should sing or something. Dance, perhaps. Wow. OK, so a Future Fest. Today is all about the future. And I can't imagine a better person to speak with about that than Elon Musk.

He is forging the future, as you all know, across multiple industries repeatedly in the most spectacular way-- in a way that others have failed before him, and perhaps unprecedented in history. So I'm a big fan boy. Future Fest, originally, I think, bounced around. And why this month? Because this is a special month for Future Fest-- is that for those of you old enough-- and it looks like maybe five or six of you in the audience-- to have been around when Back to the Future, the movie, came out. They had this vision of the future in the second edition of that series, where they fast forwarded in a time warp to the future. And it was a October 2015. And they had flying cars, and hoverboards, and biometrics, and video calls, and what looked like Google Glass a lot of the times, and a lot of other stuff that was completely cockamamie. But some of those dreams were true. Some were not. And as a framework for Future Fest, we can think to the past and our dreams that did or didn't come true.

I think that's where we'll start, and then move to the future, where sitting here today, what do we think the future may bode. So Elon, maybe as a starting point, as you think back to your high school days 30 years ago-- we were both there and dreaming of that future-- what about today is or isn't in accordance with what you thought back then? Where have your dreams of the future, the bold visions, met or not met reality today? Well I think the most remarkable thing that we have we do have today is the internet and access to all the world's information from anywhere. So having a supercomputer in your pocket is, I think, something people wouldn't have predicted in Back to the Future. So that's the biggest thing. And probably what they would be most surprised at is that we haven't progressed more in space. So the people would have expected, I think, to have a space hotel. In fact, Arthur C Clarke-- 2001. Yeah, exactly, though 2010 was really crazy for space advancement. So we would, like, be going to Jupiter and that kind of thing. So that's probably the most surprising thing, particularly if you go back even further.

If you say in '69, when people first landed on the moon, if you'd asked people-- if you'd asked the public-- what would the situation be in 2015? I think they would imagine that we would have a base on the moon, a base on Mars, and be all over the solar system by now. That's probably the biggest-- What happened? I mean, is there any pattern you can sense for where our dreams in science fiction's realities drift from reality, and where they are reality? Is there some reason, you think-- because we have dreams today that we're going to have these Mars colonies in the near future and-- unless something jumps to mind, let me-- I have a bunch of questions, by the way, from the audience as well here. I want to move to something a little more current as we move forward in time. 20 years ago, when we first met, you were starting your first internet company of two-- the one before PayPal, Zip2. And I know that in your youth, you envisioned a variety of industries that needed to change. When you were pursuing your first one, did you imagine you would get to the next one and the next one? No, I mean, when I was in college, I just thought, well, what are the things that are most likely to affect the future of humanity, just at a macro level. And it just seemed like the internet and sustainable energy, making life multi-planetary, and then genetics, and AI. And I thought the first three, if you worked on those, they were almost certainly going to be good, and then the last two a little more dodgy. In terms of the net benefit? Yeah, in terms of a double-edged sword, and you're not sure which edge is the worst. Interesting.

So it would seem like begging the question-- are genetics and AI the ones that are right for students today to be thinking about as they look to the future? I mean, they are. My cousin, younger cousin, who is just finishing up a physics and computer science degree, actually at Berkeley-- We know. And he says everyone there in the Computer Science Department is working on AI. So I think we're going to see some crazy breakthroughs in the next few years on that front. Yeah, I want to come back to that later as we look more to your vision of the future. As you think back, though, to your younger self-- or many of the people in the audience are themselves college students in either undergrad or grad programs, and are thinking about the world they're entering. I'm curious-- this may be an odd question, but one that I find fascinating-- as you think here today, back to your younger self, is there any advice you wish you could have given your younger self with hindsight, given what you know now? Well, I mean, I'd give a lot of advice-- Dating, a whole bunch of things like that. Yeah, I got you but just in terms of how to think about a life trajectory perhaps? Or how to pursue your passions? I'm reasonably happy with how things turned out. So it's like-- Touche. Yeah, not terrible.

Yeah, that's a good point. So I'm trying to think if there's anything. Well, if something jumps to mind, let me know. But let me-- I mean, apart from the obvious-- like just telling my younger self exactly how the future will unfold, which is-- Right. But

that's not exactly advice. That has been encapsulated into time-warping wisdom. Yeah, exactly like wisdom. I mean there's a lot of things. Listen more to critical feedback. A lot of things I learned in college actually were pretty helpful.

I mean, I think the physics approach to thinking is very good-- like the first principles approach. And you applied that broadly? Yeah, applying the first principles in process of thinking is, I think, a good way to figure out counter-intuitive situations. And I thought that was really a helpful thing to learn. That's good. Feel free to jump in. Because I don't know how it ends for that question. Yeah, what would you do? What would you tell your younger self? It will be all right. You weren't as dorky as you think-- advice like that-- nothing really too actionable. Don't worry about it? Well, just don't be so insecure about everything you're insecure about, would probably be my advice to myself. But let's move on.

I'm not used to thinking about me. So I may be roughly overgeneralizing here. But it seems to me that there's often a trigger problem that generates in your mind a great solution for when you come up with a new company. So for example, when trying to negotiate with the Russians for launch capacity, the aha that we should just build a better rocket to solve this problem comes forth. Or when you deal with the commute on the 405 or whatever in LA, it's, like, oh my god, what is wrong with mass transit? And then perhaps Hyperloop, and then with a variety of ideas, there seems to be some trigger-- something that's broken in the world and you have an idea of how to fix it. And I guess what I'm curious about is not how you pick the areas of interest and the solutions, but how have you decided what not to fix? In other words, there's many things that need fixing in the world. And students here probably could think of a long list, many of which you could probably imagine solutions to using the physics' first principle approach. But has there been any framework or idea you've used to filter out what you don't do-- what you don't pursue? Yeah, I mean, if you sort of follow what I did initially, was-- to go back to college times-- was working on energy storage technologies for electric vehicles. And that's what I was going to pursue at Stanford, actually, was work on advanced capacitors and batteries to improve the energy density for electric vehicles. And then the internet was kind of happening.

It was clear the internet was happening back in '94, '95. And I wasn't sure if what I worked on in the PhD would actually be useful. So I was really concerned that if I-- Why, timing? Or what was your intuition? Meaning it could be academically useful, but not practically useful. It could result in a PhD and adding some leaf to the tree of knowledge, but then discovering that, well, it's not really going to matter. Is it going to be a good enough thing to actually be used in an electric vehicle? I wasn't sure. I mean, I was uncertain as to whether success was one of the possible outcomes. I thought maybe it was, but I wasn't sure. And then I thought, well, if I watch the internet get built while I'm doing this, that would be really frustrating. There's a sense of that eminent timing-- like that was the time for the internet. And maybe the other stuff could wait or be on the back burner of your mind.

Was it always there, like one day I'll get back to that? Or was it-- Yeah, I thought probably I'd get back to it, and did end up doing that. But I thought the internet was happening-- really taking off, although most people weren't aware of it in '95. And so I figured electric vehicle technology, energy source technology-- there will be some sort of natural progression in that and I could come back to it later. But the internet-- that was the moment to really do something. Although in '95, it wasn't obvious that you could actually make any money on the internet. Until Netscape went public, I think at the end of '95, nobody even thought you could make a valuable company on the internet. It wasn't as obvious as it seems now. Yeah, now it seems really obvious. But back then, it was not at all. So it was really from the perspective of-- it wasn't like, I want to make a bunch of money.

It was actually from I want to just be part of following this thing that I thought was like a nervous system. It was like previously, people had communicated effectively by osmosis. And you'd have to basically physically connect with somebody to really communicate-- like a letter. You sent letters on paper. And with the internet, anyone who had a connection anywhere in the world would have access to all the world's information, just like sort of a nervous system. So humanity was effectively becoming a super-organism, and qualitatively different than what it had been before. And so I wanted to be part of that. But initially, the goal was just to make enough money to pay the rent. It wasn't to do anything beyond that. And then as many of you know, much of that capital then got plowed back into your next businesses.

Right, exactly. And then the internet is also helpful, because anything to do with software is a low-capital endeavor. So I didn't have any money. I just had a bunch of student debt. But software you can just write by yourself. And you don't need a lot of items. You don't need a whole lot of tooling and equipment. So it's not capital intensive. So the ability to start a company, if it's software related, and it's the first company, is much, much easier. It seems obvious now that, of course, the easier place to start.

And then as you get more of a persona/ reputation and have more personal capital-- in summary, I know SpaceX was entirely funded by Elon for its first period, partially from-- and in an era when others probably wouldn't have funded it in those earliest days. And actually, the precursor to SpaceX wasn't really to create a company. It was to try to figure out why we hadn't sent people to Mars. So we went from step two to PayPal. And then going from PayPal to the next thing, I was sort of thinking, well, is there some way to reignite the dream of Apollo? And I thought, well, it was maybe a question of we'd lost the will to explore. But I actually think that my original premise was wrong. We have not lost the will to explore. But people did not think there was a way. If people don't think there's a way, then they just don't bash their head against the wall continuously. They'll

sort of give up so.

But in the beginning, I thought it was a question of will. So if we can send a small greenhouse to the surface of Mars, and you have seeds, and a nutrient gel, and you hydrate it upon landing. And then you'd have this little greenhouse on the surface of Mars. And people tend to respond to precedents and superlatives. And this would be the first life on Mars, as far as we knew-- furthest that life's ever traveled. We have this great shot of green plants on a red background. And I thought, well, maybe that would get people excited about sending people to Mars. So the headlines were clear in your mind once you had success, and what that would lead to, to catalyze action. And actually, the goal was to get the public excited about that, and get NASA's budget increased. So that was actually the original goal.

And so I went to Russia to try to buy out some ICBMs in 2001. It was an interesting experience. A lot of vodka. Yeah, a lot of vodka. Yeah, it's crazy. But I couldn't afford the regular rockets, like the Boeing and Lockheed rockets-- too expensive. And-- Still are. Yes, still very expensive. That's true. I had to, sorry.

Wait, may I jump in here for a sec? Because the anecdote you brought up of wanting to change government policy and inspire the world to have a Mars program, if you will, whether it's a popular uprising or space programs at the government level, I think it's a fascinating anecdote. Because in a sense, what you were saying is, I, as an individual, want to start an entity-- business or otherwise-- that will catalyze change even beyond the company level or the industry level. And I see a parallel in other initiatives you've taken on, in that if you look at the goal of Tesla under your leadership-- it is to usher the transition to all vehicles being electric, not just the cars that currently are produced by Tesla. And with Powerwall and SolarCity, arguably the description is one of ushering in a wholesale shift to renewable energy. Many of the solutions required wouldn't be provided by the companies you're starting. So I think, as I deal in entrepreneurship as a venture capitalist every day, we see this incredible scope of ambition here that is breathtaking. Like change the world, which Steve Jobs and others talk about, in a company maybe shifting an industry. But we're talking about shifting the entire zeitgeist of the world, in a sense, and maybe eventually other worlds. So my question is, do you start always in your mind with that as a-- what is the starting point? I see this arc of a story, like the Mars example or renewable energy. And then do you pull back to where is the best product to get it unstuck? Why isn't this happening? And if I solve that problem, then it unlocks value.

How does that happen in your mind? Sure. I should say when we started SpaceX and Tesla, I mean, I really thought the probability of success was very low. I mean it wasn't like I think, oh, it will definitely be successful. I thought it would be maybe 10% likely. Yeah. And we came very close to both companies not succeeding in 2008. We'd had three failures of the SpaceX rocket. So we were zero for three. We had the crazy financial recession, like the Great Recession. The Tesla financing round had fallen apart, because it's pretty hard to raise money for a start-up car company if GM and Chrysler are going bankrupt.

It's partly for the upside. Yeah, that was a tricky one. And fortunately, at the end of 2008, the fourth launch-- which was the last launch we had money for worked for SpaceX. And then we closed the Tesla financing round, as you know, Christmas Eve, 2008-- last hour of the last day that was possible. Yeah and thanks to you. For those who don't know, it's the most extraordinary act of entrepreneurial zeal and commitment I've ever seen, where Elon personally saved Tesla in those hours. When no one else would write a check, he spoke for it all. And that slipped the mentality from fear to greed. And everyone joined the bandwagon. And everything changed from divoting into the ground to success.

But you were willing to go net negative personally of his entire net worth. And it's a remarkable story. Thanks for supporting, by the way. That was much, much appreciated. We were happy to fall right behind in line, but it was all him. So I guess on this idea of the big picture, I'm curious in the way I heard you just now describe the greenhouse in the headlines is interesting. Do the marketing headlines flash through your mind as you introduce new products that are a step to a much grander vision? I'm curious, because it seems like it has two purposes-- getting employees, customers, everyone really gung ho about the vision. But it also makes it larger than life in so many ways. Well, I mean, if you're trying to convince the public to do something, you have to say, OK, how is this going to read? And what message are we going to try to convey? What will people respond to? What would I respond to if I was an objective member of the public? And so that's really-- if you're trying to change people's minds or get people fired up about something, then you've got to think, OK, what's that message? What's going to get them really excited? And that's really good advice, by the way, for all the engineering students, that answer. ...

as well. I'm curious-- as a adjunct sometimes of these grand visions, like making humanity a multi-planetary species, or shifting us to renewable energy, or making all vehicles electric-- that has a purpose-driven element to it. There's a higher calling than the quarterly bottom line. In fact there was a Tesla quarterly report, I remember famously, where the opening-- the literally opening line was while profits are not a priority, comma, nevertheless-- In the short term. Exactly, and I was struck by it at first. And it did occur to me that it's not like some sort of misdirected fiduciary question. To me it seems like, how could you lead an industry transition if your business model was worse than what's already there? If you weren't more profitable in the long term, and a better business, why would anyone shift? So it almost seems like with the right purpose, profits follow. Yeah, well, if the output is more valuable than the inputs, that's profit-- the output's more valuable than the input. That says you have a useful company. But in a high-growth scenario, you have a lot more inputs for future output, so that you have negative cash

flow and lack of profitability, which we currently have at Tesla.

But in the long term, of course, that has to be fixed. There can't be a negative cash flow in the long term. And there needs to be a net positive output, which is sort of profits in the long term. But in the short term, when there's high growth, that isn't the most sensible thing. And then there's also related things, like open-sourcing patents, and acts that, to me, relate to the purpose. That's led the whole auto industry to this. And so I'm curious-- what do you see, from your vantage point, as the benefits of a purpose-driven company? Meaning when you have this thing that every employee and customer knows is the purpose of the company, how do you see that flowing through to benefits for the company? Well, I think having a purpose, certainly, is going to attract the very best talent in the world. Because if there's something that's intrinsically enjoyable, and the financial rewards are good, but then also it's something that's going to genuinely change the world, then I think that's a pretty powerful motivator. But I don't think like everything needs to change the world. I mean, honestly, there's lots of useful things that people do.

And I think really it should be a usefulness optimization. Just say, is what I'm doing as useful as it could be? You're talking about the goal of an organization? Or a goal in general, yeah. And even if something isn't changing the world, if it's making people's lives better, I think that's great. And even if some things, like making people's lives only slightly better, but it's a large number of people, then the area under the curve is quite good. This is that mathematical first principles point-- utility and numbers. Yeah, exactly. I mean, one could say, is some app really making people's lives better? But if it's affecting a lot of people, even in a small way, then yeah, I think the sort of area is good. So let's shift gears a little bit, since it is Future Fest-- looking to the future, we started 30 years in the past, but the future keeps accelerating. So let's maybe look 20 years in the future for an equivalent leap. Arguably, five years in the future might be equal to the past 30, but let's say 20.

So the year 2035, what does the future look like as far as you can tell? What would you-- 20 years, yeah, 20 years. It's always really tricky to predict the future. I mean, some of it's pretty obvious, like computing power is going to be just crazy. And the big change is the cost of computing power, not so much the circuit density-- the Moore's Law thing. But if you look at, say, what is the actual dollars per instruction-- and that cost is dropping exponentially. Now, if you think about it like if you're making a computer, you're rearranging silicon and copper on a little chip. And once the capital cost of the development and the chip plant is paid for, the marginal cost of a chip is very, very tiny. So I think what we'll see-- massively parallel computers, and computing power, and storage being really as much as you want. And it's interesting. I, too start with that.

I don't know what else to predict. But as a foundation, this seems like the safest starting premise. But then, what does that ripple through to in fields like genetics and AI which you mentioned-- autonomous driving, space-related topics? Just ubiquitous computing everywhere. I think AI is going to be incredibly sophisticated in 20 years. When does that first ...? It seems to be celebrating. And the tricky thing about predicting things when there's an exponential is that an exponential looks linear close up. But actually, it's not linear. And AI appears to be accelerating, from what I can see. And for that, do you look at autonomous driving and point AI, like Siri functionality, as your guide post? Yeah. I had sort of a debate about someone, like is AI accelerating or not? And he was saying, well, what's the y-axis? If it's accelerating, you've got t on the x-axis.

But what's the y-axis, as it were? I thought about that. I think you could have a recursive y-axis, so that if at any point in time your predictions for AI are coming sooner or later, that actually would help define whether it's accelerating or not. Whatever that axis was. So you mentioned net change. It's a recursive axis. So if in any given year, if you find your predictions are going further out or coming closer in, that actually is one way to think of acceleration. Because otherwise, what's the qualitative or quantitative measure of AI? A given technology is always 20 years in the future. Yeah, if it's always 20 in the future, it's more logarithmic. So does AI seem like it's one of the most fastly accelerating things that you're aware of? Yes. And I can certainly say that with autonomous driving, where three years ago, I thought it was 10 years away.

And two years ago, I thought it was five years away. Now I think it's three years away, or less than three years away. Wow. And when you say away, released to market, available for consumer adoption as opposed to prototyping? No, I mean the technology works. There's a sort of second question as to when regulators would approve it. Yeah, yeah. Yeah, but-- Good luck with that. Technology works as a general solution. So autonomous driving ... anywhere.

So it could be sooner for point things-- highway only, or-- Highway only, we're already in public beta with Tesla. So we'll be, hopefully, in the next several weeks releasing to all of the cars that have the autopilot hardware, which is all cars built in roughly the last 12 months. Wow. And so this seems like one of those things that, once you've experienced it, the inevitability of it becomes more apparent-- kind of like the first time I sat in an electric vehicle-- it's just so clear, and same with autonomous vehicles. Do you think that will help persuade public opinion? And the regulatory question is an interesting one, because as technology continues to accelerate, human nature doesn't. And acceptance of change-- I'm just not sure if there's-- as we look out in the future, should we assume that, no matter how fast something like Moore's Law accelerates, there's always the counterbalance and force of human nature and habit? Yeah. I mean, yeah. I think there's always going to be human nature. And it's difficult to predict, and I think how that will affect things. But I'm not sure if I fully answered your question in terms of what I think of 2025.

Yeah, please. So for sure, ubiquitous computing, AI that's beyond anything the public appreciates today. I think we'll have most of the new vehicles being produced being electric, and we'll probably have the super majority of energy being produced being sustainable. So I think we're headed .... Solar primarily, in your mind? Primarily solar, yeah. And so I think that those are sort of some good things that I think will be on, hopefully, a good path for sustainable energy. Sooner is always better, but I think by 2035, I think we'll be substantially-- like most of transport, most of new energy being produced will be sustainable. Broadband everywhere? Broadband everywhere, yeah. Mars colony? And hopefully, a small base on Mars, or city on Mars in 20 years, yeah. City, did I hear? Well, OK, fine-- town.

Village. Hamlet. I mean, that's exciting. That could get people fired up about the future. Yeah, I agree, exactly. I think that the idea of being a multi-planet species and getting up there and exploring the stars is one of those really inspiring, exciting things. I mean, just as Apollo was incredibly inspiring to everyone around the world, and even those-- I mean, only a very tiny number of people went there. But vicariously, we all went there. And I think that's true if we have a Mars base, as well. And it's very important that we have things that are exciting and inspiring in the future, because otherwise why get up in the morning? If it's just about one sort of sad problem after another, life's not worth living.

Are there any other things that excite you a lot about the future, beyond the multi-planetary species, perhaps AI-- although it may scare you as well as excite you-- the autonomous vehicles. Are there any other planks that you think looking forward 20 years, this is what I really get excited about? Well, for sure Mars and sustainable transport-- those items, I think, are really-- and sustainable energy-- those are really cool things. And in terms of getting excited about, I think we'll probably start seeing more truly cyborg activity, like brain-computer interfaces. Alongside the AI's that are purely synthetic? Yeah, I think so. It's the only way we can relate, I think, and have a conversation. Yeah, there are amazing things happening these days, like they've been able to figure out how to do an artificial hippocampus in rats and monkeys. And now they're looking at doing that to solve severe epilepsy. About half of severe epilepsy cases originate in the hippocampus. And by having sort of an artificially augmented hippocampus, they can actually solve the severe epilepsy cases. That's amazing.

So it's like, wow. And you can read and write information back to the chip from your brain at the individual neuron level-- today. Pretty exciting. Now, the whole field of biology, and things inspired by biology, and the information systems biology fascinate me personally as a computer science-oriented person. Before I go to the student questions, which I'm about to do, there was one last story I wanted to share that we experienced together, and ask your thoughts about. We were in Hawthorne, Texas when the Grasshopper Vehicle occurred or happened-- spectacular explosion right in front of us. Right. I brought the SpaceX board out to take a look at one of the critical takeoff and landing tests. And of course, that's the one that blows up. And we're all in a tent, with a glass of wine.

Whoa. I mean, you feel the repercussions, and then walking through the steaming-- They call it a RUD. It's a rapid, unscheduled disassembly. That's right, a RUD-- rapid, unscheduled disassembly. Anyone in rocketry-- like a hobbyist or professional-- knows what that one is. Every component part is just strewn across. And as we walked, one of the other board members asked-- and maybe in a cheering up kind of method, but some quoting Bill Gates or somebody-- that said if you haven't failed, then you're not learning. It's a paraphrase of the quote. And I remember your reply-- and I have it written as a quote, because I want to put on a placard-- "Given the options, I prefer to learn from success." Which I think is a great comeback. And so I guess I was curious in general-- what do you think of the Silicon Valley mantra-- fail fast, fail often.

Or as Esther Dyson says, always make new mistakes-- as if failure is the crucible of learning. I'm curious if you have any further thoughts on that maybe off-the-cuff comment you made out there. Well, I mean, there are many-- I mean, I think there's some entropic basis for this. There are many more ways to fail than to succeed. So you have to explore. I mean, particularly for a rocket, there's 1,000 ways the thing can fail, and one way it can work. So you can have a lot of rocket failures to explore all the ways in which you could fail. So I do think that one great thing about Silicon Valley is that failure is not a big stigma. So if you try hard and it doesn't work out, that's OK. You can learn from that, and do another company.

And it's not a big deal. And I think that's really one of the great things about Silicon Valley. Interesting. Do you also-- I'm curious. It seems to me that on the system design side, you can accommodate a likely failure of subcomponents. And so much of the elegance of Falcon 9 or of Falcon 9 Heavy is an ultimate incarnation of this vision of how the rocket should be built, to say, hey, parts will fail. But here's how the system can succeed. And I'm curious if there's any other thoughts along that, how to accommodate anticipated failure. And then also maybe managerially-- are there ways that you motivate the team, either in advance of failure, or to coach them on this is going to happen, or in the aftermath of failure, to get them fired up to solve it and move forward when it might be dark times? For example, the notion of failure to launch, exploding on the pad-- there's all these-- it's very visual. It's public spectacle when you have a setback in the rocket industry.

I'm curious how you manage around failure. I mean, I think it's quite painful and difficult, honestly. And it feels terrible. But yeah, the company is sort of looking to me to rally them. And so I do. But I honestly feel super bad. Like a punch in the gut? Yeah. Yeah, I remember it's almost like the stages of grief, I remember. In Texas-- It's a sort of denial and then it really hits us at dinner. It's like, oh my god, what just happened? Yeah, I mean, particularly with rockets-- space is hard.

And rockers tend to fail, unfortunately. And even when you've got a lot of really smart people working super hard to minimize the probability of failure, it's still there. And it's quite significant. And people have asked me, why are rockets especially hard? And part of it is, everything has to work the first time. You can't do a recall. You can't patch it. It's nine minutes to orbit or it's over. And then you can never test the rocket completely in the environment that it's actually going to experience. You can't fully recreate something that's moving super fast in a vacuum on the surface of Earth. You can only really recreate that in space.

So is that a limit of the simulation tools? Pardon me? Is that a limit of the simulation tools today? Or is that ...? Yeah, absolutely. If there's any error between the simulation and reality-- and there's always some amount of error-- then that can result in a failure. So it's a really, really tricky one. In a software analogy, it would be like if you had to write a whole bunch of software modules, and you can never run them together. And you can't run them on the target computer. When you're testing them, you'd have to test them individually, and not in the actual computer that they're going to run on. Then you put all the modules together, run it for the first time in a completely different-- very different-- computer. And it has to run with no bugs. That is difficult. The software analogies to rocket design are deep-- modular reuse.

There's many of these. Those who aren't familiar with-- it's not like this is an aerospace engineer by traditional training, coming, but is, in fact, radically changing an industry. I think applying a CS perspective to industry after industry-- how would a computer scientist or a physicist approach the problem? Which oftentimes gives a solution very unlike the initial incumbent. There's a certain elegance to it, at least from the outside observer like myself. Let me switch, if I may, to some student questions, which would be in a completely different direction. The first one comes from ..., in architectural design culture. So this will be switching more to the other side of our brain for a moment. What do you look for in design? And related, if you'd like, what do you look for in art? Design might be more immediately relevant, but that's where he's coming from. Sure. I mean, I think there's if you want to make something beautiful, you want to trigger whatever fundamental aesthetic algorithms-- like in your brain, you have, I think, some intrinsic elements that represent beauty, and that trigger the emotion of appreciation of beauty in your mind.

And I think that these are actually relatively consistent among people-- I mean, not completely. Not everyone likes the same thing, but there's a lot of commonality. But I think it is important to combine aesthetic design with functionality. If you say what was really hard about, say, the Model S or the Model X was to combine aesthetics and utility-- so to balance the two. You can make a car look very good by giving it certain proportions-- like making it sort of low and slim. But if you do that, the utility is significantly affected. So the big challenge with, say, the Model S was trying to figure out how do we get five adults plus two kids-- because we wanted to have a seven-seater. It seems like the Dragon and every Tesla has room for seven. Seven. Five children, I can see that might be an important design parameter.

I think we should take the whole family on the spacecraft. But the big challenge with the S was having a car that had a high utility and looked good. And the same with the X. So to make a sports car look good is relatively easy. But to make a sedan look good, or an SUV look good is quite difficult. And I think another principle is, you want to have it feel bigger on the inside than it looks on the outside. And that's also a really hard thing to do. And then really pay attention to the little details. The nuances of design, and shape, and form, and function, and just the way it looks in different lights. When something's off-- the little thing-- how do you experience that? It drives me bananas.

The problem is, you can train yourself to pay attention to the tiny details. I think almost anyone can. Although this is very much a double-edged sword, because then you see all the little details. And then little things drive you crazy. But most people don't consciously see the small details. But they do subconsciously see them. Sort of your mind takes into yourself an overall impression. And you know if something is appealing or not, even though you may not be able to point out exactly why. And it's a summation of these many small details. So most of us experience that as a-- oh, I think that's ugly, or I think that's beautiful, or wow, that's elegant, but can't break it down.

You mentioned something in passing-- you can train yourself in this, though? Yeah, you can train yourself, I think. You can make yourself pay attention to why. You essentially bring the subconscious awareness into conscious awareness. I wish I could do that. How do you do that? Just pay really close attention. Almost like a meditation on the object, and trying to find the details? Why do I not like this? Is that what-- Yes, look closely and carefully. And for any given object, it's geometry. I heard someone worked for Steve Jobs. And the thought occurred to me as well. I worked briefly with him, and I could only experience as a visceral agitation with imperfection.

And that's just wrong. Like, that has to be fixed. I have to turn it off. Otherwise, I can't go through life. It's just-- The world around you, or even in-- Yeah, yeah. Because there's always something wrong somewhere all the time. And so you really have to turn it off. Otherwise, the mental list of things that are wrong just drives you crazy. I just wish there was a way you could record it for everyone else to go fix-- just a running tally. Right? So let me go to one other question.

I found that one interesting. I had no idea where that was going to go, so I really appreciate that question, Nick. Thank you.

Let's see, which one of these do I want? There's some combination of questions. Let me mention both, and you can pick which one you like more, because they both relate to colonizing Mars. One comes from Henning Roedel, a PhD candidate in Civil and Environmental Engineering, which just asks, Elon, given your plan of bringing a million colonists to Mars, what are the pressing future technologies that need to be developed in order to support a robust and thriving surface colony-- so technology for, I guess, survival? And then maybe related from the Stanford Space Initiative students, how do you envision humans governing a separate planet? I'm not sure if you've had to think about that yet. I've thought a little bit about those things. I mean, obviously the first challenge is just getting there at all. So SpaceX is working super hard on just how to get large numbers of people and cargo to Mars. And I think we've got something that I think works at a sort of fundamental physics and economics level.

So it's a question of figuring out the detailed design, which we're working on. We're only spending half an hour a week on it, because of pressing near-term priorities. But I'm kind of excited about how it's coming together. So just getting that transport thing solved, I think, will then open up a tremendous number of opportunities for people on Mars. Just like having the Union Pacific Railroad to California. And look at what resulted after that. A whole system of other companies figure that out. It's like once you get there, then the opportunities for entrepreneurs are tremendous. And that ranges everything from everything you can imagine, like starting the first Italian restaurant or something on Mars. You know, somebody's got to do it.

And it'd be kind of cool, like an iron refinery, like a resource foundry, like the entire space industry. And then there'd probably be things like that are just unique to Mars. But we've got to get, effectively, that Union Pacific Railroad there in order to get the entrepreneurs there, and then create a fertile environment for them to create companies. So once you're there, it's going to be, I think, a lot of exciting things that can be done. And in the beginning, people would live in kind of glass to homes. But over time, we'd terraform Mars, and make it like Earth. And so I think there would just be a lot of super exciting things that are hard to predict, just like when they were building Union Pacific, nobody would predict Silicon Valley and Hollywood. Right. That's sort of been-- And urbanization in general. Yeah.

Or that California would be the most populous state in the country. They'd be, like, that sounds crazy. But then gold was discovered. Yeah, so I think it's really incumbent on SpaceX, or maybe other organizations, to figure out how to get there. Otherwise, nothing else matters. And then once you get there, there's a lot that can be done. From a governance standpoint-- I mean, obviously, ultimately, the governments of Mars will be up to the Martians. But the-- Good that we have a name for them-- you become a Martian when you go there. But I think if you said, how would you do democracy 2.0 or some new version, I think we'd probably have more of a direct democracy than a representative democracy. And when the United States was formed, really it was impossible to have a direct democracy.

Even sending a letter took weeks. So there was no way that people could vote directly on issues. You had to have representatives. Interesting. So I think probably there would be a more direct democracy. And could this thing about the latency of communication from Earth be its own thing? Yes, there will be communication errors and communication latency, when you have letters that take weeks to get anywhere-- would have made governance almost impossible, I think, it hadn't been a representative democracy. You had a lot of people who couldn't even read or write. That's fascinating. I'm just wondering-- if you were to start over with a clean sheet of paper on governance, do you think a framework that could be envisioned that encompasses other sentient beings to come-- meaning the AIs and others who might clamor for their rights? It's difficult to predict, but I can say they probably would look aim for a more direct democracy. And then I was talking to Larry Page about this.

And he had a good suggestion-- we should limit the number of words in a law. Because we have these 1,000 page laws in the past. And nobody's read them. Twitter equivalent of parsimony. Yeah, like a thousand word/letter count or something like that. If you can't write the law in a thousand words, then probably it shouldn't be there. And we shouldn't have a single law passed that's the size of Lord of the Rings. And literally not a single person in Congress has read the whole thing. Like the tax code-- it's inscrutable. Yes, exactly.

So there's that. And I think laws also have an infinite lifespan, unless they're given some sort of sunset period. So probably it would be good to default laws to have a sunset period. And if it's not good enough to be renewed, then it goes away. And maybe some hysteresis in making it easier to remove a law than to put one in place. You can just imagine, over time, the body of law just gets bigger and bigger and bigger. How do you avoid that? And you have inertia associated with laws. And so maybe it would take 60% to create a law, but only 40% to remove a law. Interesting, fascinating. Yeah, something like that.

Those are like the rules of a Constitutional democracy. It's such a profound impact. And to have a new playground would be fantastic. There's something embedded in what you said a moment ago that I want to highlight on a transition to, perhaps, a closing question. I heard in passing-- I think about some of these things about a half hour a week, if I heard you right. And this is, I think, a profound thing to dwell on, is that he's changing the world in so many areas. And many entrepreneurs I see get-- and myself included-- enamored with all of the possibilities of a future Mars base, of the terra-forming, of every aspect of it that might need to come into being. And I find myself often distracted by those future questions that are a little less relevant today. What you just heard was, we got to solve the railway first. Let me put 90%, 95% of my effort into that, and not get distracted by

all the other interesting questions that need to come later.

And I remember a few years ago, maybe three or four years ago, trying to get you to brainstorm with Craig Venter about doing a sample return from Mars, and sending a genetic sequencer there to help understand life there that might exist, et cetera. And I remember profoundly that the response was, that is a really interesting topic, but I got to get these rockets to work first before that's going to be relevant to me. And let me hunker down on what's important here. And that ability to prioritize it on the stepping stones to a huge vision-- it's an interesting dichotomy. Not just pure visionary scattered across many things alone. It's a clear sense of where we're headed and chaining back to the present, and making sure we're taking the right steps to not fumble the future, if you will. I wish we could all do that in the way we try to implement change. So let me move, if I may, to one last question, which could be broad or not-- which is there's a lot of people here from all kinds of parts of the world. And I think everyone who hears your story-- an immigrant from South Africa to Canada to the US taking on four or five different industries with great aplomb and success-- is inspiring. But it's not just that you've had business success or technology success.

It's that you really are changing the world for the better in these areas. And so I guess maybe, as a closing question-- again, looking from the present to the future-- what do you see as the sort of the biggest pressing problems that need to be addressed? This may in fact, require you to pull that filter off for a moment on the things of the world that are broken. And if everyone here in the audience could be a change agent themselves in their area of passion, what would you hope to catalyze today? You can say let's go solve this big, hairy problem, and figure out why it's broken. You know, honestly, I don't think everyone needs to go try to solve some big, world-changing problem. I mean, I really think like we should just think, are we're doing something that's useful to the world? If you're doing something useful, that's great. Imagine it's like Animal Farm. I really think-- Some things are more useful. Sure, sure, but-- Maybe one of your personal .... I just think that use sort of a usefulness optimisation. That's a really good thing.

You know, if you've done something that's useful to your fellow human beings, you've done a really good thing. And people should be able to be proud of doing that. It doesn't always have to be something that's going to change the world. I mean, the world should just keep going in a particular direction. Yeah, it might be going in the right direction. And in a lot of ways, the world is-- we are in great shape, in that if you look at, say, violent crimes per capita in the world, it's at an all-time low. We're actually quite prosperous compared to history. And I think there's a lot of things to feel good about in terms of how the world is today. Access to information is incredible. I mean, anyone with a \$100 device has access to basically all the world's information, which is an incredible thing.

And yeah, so honestly, I think the best thing for people to try to do is say, hey, what is something I can do that would really be useful to the world? And just do that. That's great. Fantastic. Thank you so much for being with us today on Future Fest and Forging the Future. So just very quickly, on behalf of all the faculty and staff affiliated with STVP, we'd like to thank President Hennessy, the School of Engineering, and our Home Department of Management Science and Engineering, Math ..., Stanford Arts, and the amazing staff here at Bing that was so helpful to us this morning, DFJ, obviously, for your incredible sponsorship of Future Fest and also for your continued long-term support of STVP, and our hope to create entrepreneurship education opportunities for Stanford students. And of course, we offer our most sincere thanks. Please help me in thanking, again, Elon Musk and Steve Jurvetson.