

Tuesday, May 25, 2004

## ON TO MARS: A MULTI-PLANETARY DISCUSSION

---

**ELON MUSK** CHAIRMAN AND CEO, SPACE EXPLORATION TECHNOLOGIES (SPACE X)  
*hosted by Tom Standage, Technology Editor, The Economist*

---

**Tom Standage, The Economist:** We're on!

This is Elon Musk, who is the CEO and founder of SpaceX, which is a "low-cost carrier," you could say, but not an airline. *[To Elon:]* You launch rockets, or intend to.

We're going to talk about the future of space exploration as a private enterprise – how the public and private sectors should fit together, and where you see all that going.

This whole question of private firms building spaceships: there's a whole lot of them, and a lot of them are doing it with dot-com money. There's you, there's Jeff Bezos, there's John Carmack, there's Paul Allen... Why do you think that is? Is that just because, like the bank robbers say, "That's where the money is," or is there an enthusiasm for going to space among people who have grown up in technology generally? Are you continuing from one thing to another in that respect?

**Elon Musk, SpaceX:** I wouldn't say that's where the money is. I'm pretty sure of that. In fact, I can't tell you how many times people have told me the joke, which is applied to a lot of industries: "How do you make a small fortune in the space launch business? You start with a large one." I've started pre-empting people after a while and explaining that's the reason why I entered the industry, after having heard it so many times.



**Standage:** What I mean is, was the money in the dot-com business? The people who cashed out, like you did, and then said: "What are we going to do? Let's build rockets."

**Musk:** Yeah, I think there is a lot of that. If you track back into the history of launch vehicle development, for a long time you were not allowed to develop rockets if you were a private

individual. Around the mid-'80s, in the U.S., that changed with the commercial Space Act Agreement.

So for about 20 years, people have been trying to develop privately funded launch vehicles. There has not been any success so far. No one has ever developed a launch vehicle with private capital that has reached orbit. There are a few that have gotten part of the way there, but usually they've either not been able to get to the launch pad or once they got to the launch pad it took off and blew up. Hopefully that doesn't occur with us.

**Standage:** Just a quick housekeeping thing. This timer here: could it display something, please? I don't have a watch. Sorry – I don't know who controls this magic box.

There's an important difference between you and the people I mentioned earlier on, which is they are all competing for the X Prize, and you're not. The X Prize is going to be in the news in the next couple of months; it looks like somebody's going to win it. You think it's a sideshow, I believe. Is that fair, or what do you think? Do you think it's a dead end?

**Musk:** I should clarify. Some people may know what the X Prize is and some people may not. It's a \$10 million prize for the first person who can build a ship that can take three people to 100 kilometers altitude and back, and repeat the trip within two weeks.

**Standage:** But the key is that it's suborbital. So you go up, you fall down, that's it.

**Musk:** That's correct. In fact, getting to orbit is all about velocity; it's not about altitude. Gravity is almost the same 100 kilometers up as it is on the surface of the Earth. So it is, I would say, at least an order of magnitude easier to develop a suborbital craft than an orbital craft. But this is still a good thing, and the intent behind the X Prize was to spur amateur development that would perhaps turn into something more significant, in the same way that maybe an Apple computer as a hobbyist sort of thing turned into something much more serious down the road.

In fact, I provided some financial support to the X Prize; I'm one of the funders of the X Prize. So I think it is a good thing.

**Standage:** But you're looking beyond it.

**Musk:** Right. What we're doing is also a lot more expensive to do. I mean, we're sort of engaged in a \$100 million-plus development, and we're going all the way to orbit, albeit initially not carrying any people. So where we are, we're about six months away from launch. The maiden launch will carry a navy communications satellite. It's about a \$30 million satellite. So we're actually very proud of the fact that the navy is willing to entrust their satellite to the first launch of our rocket. Our initial vehicle is actually a light-class launch vehicle. It's capable of putting about 1,500 pounds into orbit.

**Standage:** And that's a low-Earth orbit.

**Musk:** Correct.

**Standage:** Now, my understanding is you expect to be able to do launches like this for about \$6 million.

**Musk:** Right.

**Standage:** What's the going rate normally, for low-Earth orbit?

**Musk:** The next-cheapest rocket is about \$25 million.

**Standage:** Right. So this is why you're sort of the Dell of the industry.

**Musk:** Something like that, I suppose.

**Standage:** So how is it that you're able to undercut – okay, you're the easyJet.

**Musk:** Southwest Airlines, or something like that.

**Standage:** Okay. How is it that – so you're not having on-board meals. How are you cutting the price?

**Musk:** You just get a bag of peanuts. *[Laughter]*

**Standage:** Exactly. But how are you cutting the price by that much? What's your "special sauce" – or is it not to have any special sauce?

**Musk:** You know, there's no silver-bullet answer. We're certainly employing some technologies for the first time in the engine system, in the structural design, in the avionics system, in the launch operations... and I think we're a very low-overhead company as compared with any of the major U.S. aerospace companies. And if you combine those five factors, they result in really a much lower cost. Cumulatively, they result in a much lower cost.

Something else that's noteworthy about our vehicle is that the first stage is recoverable. So it actually re-enters at about Mach 9, slows down by itself to about 300 miles an hour, and then deploys a chute and lands in the ocean, about 600 miles offshore of Cabo, basically. For the first launch.

It will be recovered by a San Diego-based salvage operator and brought back to our factory in El Segundo. So the vehicle is about 80% recoverable.

**Standage:** And what impact does that have on the cost? A great deal?

**Musk:** At this point, we have not priced in reusability. We don't know how well those economics are going to work. If those economics work well, then you could expect to see a drop in the price.

**Standage:** Right. Well, I suppose the question is, then, because I had remembered – obviously wrongly – that one of your claims to fame was that you weren't trying to reinvent the wheel. I believe you're using a kind of engine that other people didn't want to use but is very good, or something of that sort. But I had understood that you were kind of keeping it simple, and that that was what was going to allow you to succeed where all those other private launch firms have failed. Why do you think you'll succeed where they've failed?

**Musk:** I think I've heard just about every anecdote of every launch vehicle startup, and there's a lot of them. There's probably at least a dozen.

**Standage:** What do they get wrong? Is it the management? Is it the technology?

**Musk:** I think they've suffered from one of three issues. They've either not been able to put together the critical mass of technical talent, or second, they have had insufficient capital to reach the finish line, particularly if they have encountered a setback. Or three, they may have had a strategy where success was not one of the possible outcomes. *[Laughter]*

**Standage:** Fantastic. Okay, so let's assume that you do your launch in the six months; that all goes well. Now, this first rocket, the Falcon I, I think it's called – that is a stepping stone to the Falcon V, which is a much bigger rocket.

**Musk:** Right.

**Standage:** And that goes to geostationary orbit for something like \$12 million instead of about \$60 million.

**Musk:** Right. Absolutely. And don't you like the fact that we've skipped Falcon II, III, and IV?

**Standage:** Well, I can see that your strategy has a fallback plan to Falcon III that's not quite as big, or something.

**Musk:** Actually, the Falcon V is because it has five engines.

**Standage:** Okay. Cool.

**Musk:** So the I is... and so it goes.

**Standage:** But this is really a means to an end: the I is a means to getting to the V, I believe. Is that the case?

**Musk:** Yeah. I think the Falcon I will be a self-sustaining business in its own right, as a sort of product line for putting small satellites into orbit. Falcon V is I think going to be more of the workhorse.

Part of the reason for starting with Falcon I is we wanted to do the smallest useful rocket that we could, anticipating the possibility of failure. So we wanted to make sure the capital would sustain us through at least three failures. And if we get three failures in a row, then we don't deserve to be in the rocket business, is the basic theory that I had.

**Standage:** But on the other hand, if you have a successful launch, then you will establish your credentials and you can go ahead with the V next year.

**Musk:** Yes. And the Falcon V uses the same engines, avionics, and the same approximate structural geometry as the Falcon I, so Falcon I effectively tests almost all the components of Falcon V, at a much lower cost level. Falcon V actually has about six times the capability, because there's some scaling advantages of Falcon I; so it will do about 10,000 pounds to lower-Earth orbit.

**Standage:** And what to geostationary orbit?

**Musk:** Geostationary orbit? I think it's about 3,000 pounds. And it'll do about 2,000 pounds to escape. So, for example, Falcon V could have done the Mars-exploration Rover missions. It has

sufficient power to do that. One of the other things that we'd like to do with Falcon V as a longer-term development is make the upper stage reusable as well, which is a much more difficult thing.

**Standage:** Is the upper stage actually a Falcon I?

**Musk:** No. The upper stage is – it's a larger version of the upper stage that's on Falcon I with... it's a long story.

**Standage:** Alright, fair enough. Well, let's assume that everything goes right for you: that you launch the I this year, that works; you launch the V next year. Where do you see things going after that? Do you then say, "Well, then we sit back and we take a nice chunk of the space launch business" – which isn't as big as everyone thought it was going to be in the mid-'90s –

**Musk:** True.

**Standage:** – but it's still a multibillion-dollar business, and you'll potentially be able to own a nice chunk of it, if you can undercut everyone else. Is that the plan, or do you have slightly grander ambitions than that?

**Musk:** Well, we'll see how far we get. The basic plan of action is launch Falcon I this year, launch Falcon V next year, and then as I mentioned, we want to make the upper stage of Falcon V reusable, which means that it returns.

I think that the right way to come back and land for an upper stage, particularly if you want that upper stage to eventually do interesting things like go to the moon or Mars, is to land propulsively. A propulsive lander is the only thing which is independent of gravity. It's independent of local gravity and atmospheric conditions. So I think the most likely scenario is that the reusable upper stage of Falcon V looks a bit like, if you've ever heard of VCX or – some people, if you're familiar with the space industry, will have heard of VCX, vertical takeoff and landing craft. Or certainly the Eagle, the craft that landed on the moon? That was a propulsive landing system.

**Standage:** So it will have legs.

**Musk:** Yes. Sort of legs, and it will reuse the engines to land. That's the smart way to go.

**Standage:** Right. Now, this is the point where what has hitherto been a fairly sensible conversation about business models and private enterprise and so on becomes a "Let's all go to Mars!" discussion. *[Laughter]*

Help me paper over that crack a bit here. *[Laughter]*

**Musk:** Right.

**Standage:** Because I'm right with you on this, you know. I think this is a very exciting prospect. If you can fly the V next year, then potentially you can do things like allow private companies to send things to the moon and Mars, and there's a whole bunch of them that have expressed interest in doing this. I believe you're going to carry some inflatable habitat on the first V.

**Musk:** That's right.

**Standage:** I mean, this is science fiction stuff that I've been interested in since I was little.

**Musk:** I know; it's crazy.

**Standage:** And you're talking about flying it next year. Now, either we're heading for a big change in how practical these things are, or this is just wishful thinking, and it's not going to happen. Convince me that this really is going to happen, and that this isn't just more pie-in-the-sky.

**Musk:** Well, first of all, I'd say there is a nontrivial possibility of Falcon I blowing up. You know? "Nontrivial" is probably a kind word. And Falcon V may also do the same thing. I'm optimistic that they won't. But if they don't, then I think you can expect a natural progression that will eventually lead to us being able to take private individuals to orbit and back. I think one very interesting trip would be to do a loop around the moon. You can do a low-energy loop around the moon, sort of see the dark side of the moon, see Earth from a long, long way away. That would be a pretty cool trip. *[Laughter]*



And it's very hard to – it requires a huge amount of energy to slow down to moon orbit, and then land on the moon, and then take off again. That is an order of magnitude larger of vehicle that's required. But Falcon V could do something like that. It could do a loop around the moon, a low-energy loop.

I think it's pretty doable; I think it'll happen. And you mentioned the inflatable space station. We sold the first flight

of Falcon V, and that's to a company called Bigelow Aerospace, that has this idea that they want to use technology that was actually developed partly by NASA for an inflatable space station, or piece of a space station. The advantage there is you get something which is low-volume on the ground, but once you inflate it, it's really very large. And they plan to launch a one-third-scale version of that in November of next year on our vehicle.

**Standage:** I suppose it's worth making the point that you have ex-NASA people working for you, don't you? No?

**Musk:** Ummm, not exactly.

**Standage:** Ex-Boeing people?

**Musk:** Certainly ex-Boeing. In fact, I lived in Silicon Valley for a long time, for about 10 years. And then in starting SpaceX, I moved to Southern California, because it has the biggest concentration of aerospace industry personnel in the world. So we've drawn from – we've been fortunate enough to be able to cherry-pick people from Boeing, from Lockheed, from Northrup Grumman, and from some of the small aerospace companies in Southern California.

**Standage:** I suppose what I'm getting at with the example of the inflatable habitat, which is an ex-NASA project, as it were – is that this isn't a completely wacky offshoot on its own, this private space industry. It has, in fact, got quite intimate connections with the established industry. The difference is the management, the funding, and so on. Presumably that, then, means that the reason this hasn't happened under the state-funded model is more to do with the management and less to do with the technology. Do you think that's the case?

**Musk:** I would say so, definitely. Yes.

**Standage:** If that's the case, and in fact the government monopoly of NASA, or however you want to characterize it – if that has been holding things back, what more needs to happen to allow private firms to go ahead? Or is the way now clear for you? Do you want to see more regulatory changes?

**Musk:** Actually, we've been working with Congress and with the FAA to enact a new space bill which clarifies some of the regulatory issues. I've actually given at this point four speeches, one to the Joint Senate and the House, one to the House, then to the Senate, and then to the Presidential Commission.

**Standage:** What have you been calling for? What would you like to see?

**Musk:** We've been calling for clarity in the regulatory structure, and to streamline that structure as well. The thing to bear in mind is that when aviation started, there wasn't any kind of regulatory structure. You could just do what you wanted, willy-nilly. You can't have quite the same thing...

**Standage:** Right. You have to fill in lots of forms if you want to fly something now.

**Musk:** We have to basically build a library of documentation. The regulatory hoops we have to jump through are unbelievable. Obviously, you need to have some level of regulation; you don't want people launching rockets and having them land on your head. But there needs to be some reasonableness applied to the regulatory structure, and that's what we've been calling for. And actually, some of that has happened. So I think the government has responded positively.

**Standage:** So that's going in the right direction.

You mentioned the early days of aviation. That's one analogy that's often drawn with the current state of private enterprise in space. Another one: there was a very interesting study which looked at the relative success of state-funded and privately funded explorations of Antarctica, and found that the privately funded ones cost much less and fewer people died.

And then the other analogy that's always drawn, particularly with Mars, is the colonization of the United States. Do you have a preferred analogy, or do you think they're all misguided?

**Musk:** Well, I think there's a role for both the state and private enterprise. There are some things where it's very hard to get a direct economic return, where there's perhaps some small amount of good that's distributed over a large number of people, and in that case the state is the appropriate actor. But I think as a general rule of thumb it makes sense to not have the government involved if it's at all possible not to have the government involved.

**Standage:** Right. So would you like to, say, see NASA send people to Mars but outsource the launching to you, or something like that?

**Musk:** Sure. Certainly I think as much as can be put out to private enterprise and – you know, NASA technically doesn't build any rockets. They're built by Boeing and Lockheed. But the difference between NASA and Boeing and Lockheed sometimes gets a little gray.

**Standage:** So you'd like to see more diversity there of suppliers.

**Musk:** Yeah. One of the things that I've actually been calling for in conversations with Congress is to be more outcome-focused in the way that contracts are set up – in fact, to be focused on prizes.

**Standage:** This is the Centennial Prize idea?

**Musk:** Right. The X Prize is a good example of an outcome-oriented benefit, where anyone can enter, the rules are clear, as opposed to – it's sort of a natural Darwinian exercise that takes place, and it's the best company that wins. And it may be that that company may be using an approach that nobody ever expected. Whereas the normal state of affairs, which is 99% of the time in government contracting, is you have a committee that's got to review a bunch of proposals and decide in advance, many years before the thing is likely to reach fruition, which is the best approach.

**Standage:** So in particular, there's a contract that's just been awarded to Kistler that you think ought to have been put out to competitive tender. Is that the one you're thinking of?

**Musk:** Yes. Kistler is one of the sort of dozen or so entrepreneurial companies –

**Standage:** Have they flown anything yet?

**Musk:** They do not. In fact, they don't even have a prototype done.

**Standage:** Right. They're the previous generation of space startups, as it were, to you.

**Musk:** Yes.

**Standage:** And are they the only one left?

**Musk:** They are the only significant player we have left, yes.

**Standage:** Okay. And then they haven't flown anything yet. So if you fly the Falcon I this year, before they've done anything, then do you think that puts you in a good position to be able to say, "Hey, we should have had that contract"?

**Musk:** That's probably true. Our suggestion has been actually just in general to make as many of the government contracts outcome-focused as possible. In fact, one of the suggestions that's been made which I think would be excellent, was actually suggested to me by a congressional staffer – was to have a John Glenn prize, where the government would award \$100 million to the first company that could repeat the John Glenn flight. So, three orbits and come back safely.

**Standage:** Right. And what would be in it for the government, as it were?

**Musk:** Well, whatever would be in it for the government in doing space exploration today. I mean, what's in it for the government in building the space station?

**Standage:** Absolutely nothing, but it's costing \$100 billion.

**Musk:** Exactly. *[Laughter]* You know, I think most people don't know quite how large – how much money is spent!

**Standage:** And quite what a waste of time it is. They think it's all to do with science. Has anyone ever seen a peer-reviewed scientific paper that came off the space station? No, you haven't, because there haven't been any.

**Musk:** It's a little house that orbits the Earth...

**Standage:** ...where you have to spend your whole time...

**Musk:** ...fixing it. *[Laughter]*

**Standage:** Yes, exactly. And not doing anything else.

What about this idea that every government contract should have a parallel prize – what is it, worth 10% of the amount or something like that? How does that work?

**Musk:** Yes. I thought this would be an interesting thing. Let's say the government decides that some certain thing is important in space, whether it's, you know, retrieving rocks from Mars or finding out information about the moon – whatever it is. And they said, "This is what we hope to gain."

They'll go through the normal process of having bidders submit their proposals, and it will be, you know, sort of the typical billion-dollar project, and then whatever they decide on, what I suggested was to take that number, erase a zero, and make it a prize that sits there and parallels the contract, that any company can come along and win. And if they do, the contract to the original company is canceled. At a minimum it will serve as a spur to whoever won that contract, as opposed to "Now you've won it and there's nothing we can do" kind of a thing.

**Standage:** I should leave a bit of room for questions, but I have one last question, which is: Where do you think – if there is a commercial space market beyond satellite launch, which is where it is now – where do you think it is? Do you think it's tourism? What about the sort of "one hour to Australia" kind of air-travel model? Because you could use the same technology for that. Where do you think it is? Tourism doesn't look like a mass market to me, but maybe I'm just not being starry-eyed enough. Where do you think it is?

**Musk:** I definitely think there's some market in tourism. I mean, actually, if you look at the early days of aviation, all aviation was fun. People weren't using it for transport; they were just barnstorming from one place to another, taking people for rides. And that sustained the entire development of the aviation industry in the beginning.

**Standage:** Okay.

**Musk:** So I think it is quite significant. It sort of depends on how good we can make the economics of the whole thing. In the long term, there's obviously some potential for – if we can transport people and have a self-sustaining civilization someplace other than Earth, which is most probably Mars, there is obviously a substantial transportation market.

**Standage:** Big startup costs there, though.

**Musk:** Yeah, there's a pretty substantial activation energy, and that's a case where I think certainly some government funding to establish that infrastructure in a manner of the railways or the highways or something like that, can make a lot of sense.

**Standage:** And that's something that you'll be going into more detail in in the breakout session.

**Musk:** Right.

**Standage:** Okay. We have a difference of opinion between these two chronometers here. This is bad news if you're navigating at sea. Yours says 25 to [the hour], and this one says 29 minutes past.

**Musk:** I think that one's correct.

**Standage:** Okay. Well, in that case, that gives us five minutes for some questions. Go ahead, please.

**Frank Catalano, Catalano Consulting:** Question – and that's my watch, by the way, so it is correct. *[Laughter]*

**Standage:** Excellent.

**Catalano:** The one thing I'm curious about is, back in the 1960s there was a lot more public imagination, people basically looking at the space program as a “Gee whiz, this is really cool” thing – and basically a lot of popular culture grew up around it. Part of that was because of the political aspect of the space race, the communists, etc.

I think that part of it, though, was that the space program showed people things they had never seen before and had only been imagined in the genre of science fiction, which back then was still a dark and dank ghetto. What I'm curious about now is, now that we've seen *Star Wars*, now that *Star Trek*'s been on the air for about, oh, 500 years, now that there's been all these visualizations of the future, to the point where my 17-year-old son says, “Go to Mars? Oh, heck, I saw that in the movies already. I saw *Capricorn I*; it was faked...” When you have that kind of situation, how do you get the general public behind the space program now, and capture their imagination the way that our imaginations were captured in the 1960s?

**Musk:** Well, I think the most important thing is that you give people some hope of going to space themselves. I mean, right now it's a very abstract notion. There are just a few astronauts that get to go up every year. They're the only ones that experience what it's like to be in 0G [zero gravity] in orbit, seeing Earth from some level of distance. I think you get people excited if they think they can participate, and that's what I think we need to do. And I think that's more likely to come from the private sector than from the government. If you look at the X Prize, there's been a lot of excitement about that, and that's because there's the potential for people to go to at least suborbital space themselves.

**Lib Gibson, BCE Inc.:** I was listening to you talking about recoverable first stage, and I couldn't help but remember a job I had in high school when I was very, very young, in the '60s. I worked for a guy who had a *passionate* view – Dr. Bull, who went on to later infamy – but who had a passionate view that the way to get rockets most cheaply into space was to have a gun on the ground, so that the first stage was actually on the ground, and then have multiple stages of the rocket that then left the gun and did have some success in certainly getting to suborbital flights and so on.

Had you looked at any technology like that? I haven't kept up at all – has it been part of anybody's view of how they might do this? It sort of makes intuitive sense.

**Standage:** Wouldn't that turn everybody into strawberry jam?

**Musk:** There is a G-loading problem with being shot out of a cannon. Actually, the velocity that you need to get to orbit – only a very small portion of that can really be provided by a cannon, or any kind of reasonable cannon that we could imagine. You need to go to 25,000 feet per second, approximately, and then on top of that you've got aerodynamic losses, and you've got steering losses, and gravity losses, and all that sort of stuff. So effectively you need about 31,000 feet per second. So you're talking about basically about 30 times the speed of sound. There's no cannon that could really provide meaningful help there without crushing whatever was in the barrel.

You could provide *some* benefit from a cannon, or some sort of, say, steam-assisted lift device or something like that, but it's easier just to increase the thrust on the main engine. You'll solve the same problem.

**Standage:** Great. Is there anybody else? Okay, I think we'll leave it there. It's been fascinating. I hope we're here again next year, and I hope the exotic nature of what you're talking about, which is very exciting – every year I hope it continues to get less exotic, and that your launch goes well later this year. Thank you very much.

**Musk:** Thanks; I appreciate it.

**Mark Anderson, SNS/FiRe:** Thank you, everyone. It's time for a rest, to go out into the courtyard and have something to eat and drink; then we'll do breakouts after that. And let me just remind you one more time, please be there on time for this evening's cruise, 6:45 sharp in the lobby or the front of the hotel. See you there!