



## Stanford eCorner

### Space Travel Today

Elon Musk, *SpaceX*

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Musk talks about the problems with space exploration in the US in the 22nd century. The long term plans are to have something cheaper and safer. In Russia, it is safer and cheaper and they have a better track record. They are constrained however by the weakness of the Russian economy. China is expected to launch their first person into space this month, becoming the third country to put a person into the orbit. They have great ambitions and are planning to set up a space station on Mars and eventually sending humans to Mars. In the US, once enterprises enter this space with an entrepreneurial spirit, Musk hopes to see the same growth seen in the internet. Musk talks about efforts that are already in the pipe line.



#### Transcript

Anyway, so I'll just talk broadly about space and where things are today. Obviously, U.S. government manned exploration is not in a great place. The three remaining shuttles are grounded. It looks like first flight might only be a year from now, if that. And we've got a vehicle that is incredibly expensive and really quite dangerous. For reasons mentioned there, it's got a side-mounted crew compartment, so if there's an explosion, that's basically instant death. You've got solid rocket boosters, which, once you ignite them you can't turn them off. And there's something fundamentally dangerous by pre-mixing your fuel and oxidizer, I think. And then you've got wings and control surfaces.

When you re-enter, you've got to maintain a precise angle at attack. Even a momentary variance in that can break the whole vehicle apart. And then, of course, you've got no escape system, so if anything does go wrong, you're toast. And then you've got a cost that is really pretty hard to fathom. The shuttle program, when you add up all the pieces, is about \$4 billion a year. And so you can divide \$4 billion by the number of flights and that will tell you what the cost is. And if there's, say, four flights a year, which there haven't been for a while, then you're talking about \$1 billion of flight. The plans in the immediate future, we've got to continue building the space station. So we're going to keep flying the shuttle, but I think it's probably going to be the minimum number of shuttle flights that we need to launch. The long-term plans are the Orbital Space Plane.

I say 'plane' in quotes because one of the options is a capsule, so it should be called maybe orbital space thing. But the basic idea is to have something that's hopefully a little cheaper and a lot safer than the space shuttle. So in particular it's going to have an escape system. So if something does go wrong you can abort to safety. The downside is that it's still--while it might be a little cheaper, it's still going to be pretty darn expensive. The estimated cost per flight of Orbital Space Plane is somewhere in the region of \$300 to \$400 million a flight. And of that amount, just \$200 million alone goes to Boeing for the Delta 4-Heavy expendable booster. It's a \$15-billion development effort and expected to be completed in nine or 10 years. Now typically, things have not been under budget and under time, so it's unlikely, I think, given historical precedent that it will stay within \$15 billion end of 2012 timeline. And a bit about what's going on elsewhere in the world.

In Russia, the Soyuz is our only access to space station. It's considerably cheaper, considerably safer. The Soyuz has a very good track record. The crew is top-mounted. It has an escape system. There are no wings or control surfaces to go wrong. Overall, it's a pretty good system. And the estimated cost is about \$60 million of flight, which is an order of magnitude less than the space shuttle. The thing that constrains them obviously is the weakness of the Russian economy. It's very hard for them to embark on ambitious programs with an economy the size of Belgium.

So China is probably the most interesting thing that's going on in space. This month, China is expected to launch their first person into space. It will make them only the third country ever to put someone in orbit. And they've put a lot of money and effort into this program. If anything serves as a spur for human space exploration, it is likely to be China's ambitions in space, and hopefully a sense in America that we want to at least keep up with China. And they have grand ambitions beyond just low-Earth orbit. They're planning on setting up a space station, putting a base on Mars, and eventually sending humans to Mars. So what's happening in the U.S. that I think might ultimately surpass all of that stuff is entrepreneurial space activities, where things are led by the spirit of free enterprise. And I think there's perhaps an analogy here where just as DARPA served as the initial impetus for the internet and underwrote a lot of the costs of developing the internet in the beginning, it may be the case that NASA has essentially done the same thing by spending the money to build sort of fundamental technologies in the beginning, and then once we can bring sort of commercial free enterprise sector into it, then we can see the dramatic acceleration that we saw in the internet.

So there are several serious launch efforts underway. I'll talk about each one. There's Burt Rutan of Scaled Composites. Burt Rutan is one of the world's foremost aircraft designers and he's developed a suborbital vehicle that they're actually flying out of Mojave. And this is an X Prize-class vehicle. There's John Carmack, who wrote Quake and Doom. He's probably one of the best software engineers in the world--one of the best engineers that I know, period. And he's developing a vertical type of landing vehicle. Jeff Bezos, who I understand was here last week, is a huge space advocate. And to my understanding he intends to spend something in the order of a billion dollars over the next 20 years on space exploration.

And then my company, SpaceX. And I think within the next several years, these entrepreneurial efforts will actually be what drives space exploration.