[MUSIC PLAYING]

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SARAH HANSEN: Today on *Chalk Radio,* we're heading back into space.

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SARAH HANSEN: I'm your host, Sarah Hansen, and with us this week is Professor Jeff Hoffman, a former NASA astronaut. Over the course of five missions, he's logged over 1,000 hours in space-- and yep, some of those do include spacewalks.

Professor Hoffman teaches Aeronautics and Astronautics at MIT, but he's also committed to unlocking this knowledge for the world. He's shared course 16.00, Introduction to Aerospace Engineering, on MITx, and 16.885, Engineering the Space Shuttle, which can be found on MITx and OCW. One of the things I loved about my conversation with Professor Hoffman was his take on perspective, and how a grander-scale view-- like, say, from outer space-- can dramatically shift the way we live here on Earth.

JEFF HOFFMAN: We fly so much in airplanes, and probably most people don't remember the first time they look out of an airplane window and see the Earth. I mean, it's a completely different perspective that you get. And now rockets and space travel, which allow us to go even farther and to try to give people the perspective of looking at the Earth from space-- is very important.

I mean, I was an astronomer. I know the Earth is a planet. I mean, give me a break. But nevertheless, when you actually see it from the perspective of being in space-- I mean, imagine you go up into space and you look at this thin, blue line on the horizon, which is the Earth's atmosphere. I mean, you go out here from the surface of the Earth on a clear day in the big blue sky, and it looks like it goes on forever.

And unfortunately, that gives many people the idea that it doesn't matter what you put into the atmosphere, because it's so big that it can absorb it. And it's the same thing with the oceans. And when you finally get that gut feeling of the finiteness of the Earth-- the oceans, the atmosphere-- and you realize we live in a closed system, that the Earth is a finite system-- that makes a difference, because exponential growth cannot continue forever in a closed system.

SARAH HANSEN: Professor Hoffman's first expedition into space was in 1985. Before that, he was actually doing work here at MIT, launching telescopes into space. Long before that, though, like many kids since the second half of the 20th century, he wanted to go to space himself.

JEFF HOFFMAN: When I was a little kid, I used to love looking up at the stars. Of course, early part of my life we lived in New York City, and more often, it would be looking up at the stars in the planetarium. But I was fascinated with that. And it was the dawn of the Space Age, and there were lots of articles in newspapers, magazines, television shows about the coming of the Space Age.

And I ended up-- in fact, my best friend from the second grade, after I became an astronaut-- he said to me, you know, Jeff, this is incredible. I used to play spaceman with you, and now you're actually going up into space. It was a combination of the fascination with how far away things were, and the fact that by going up, you got a completely new view of things. And also that space travel represented the future, and I found that really exciting. So then when the first astronauts started to fly, they were our heroes, and I just wanted to go up there and look down.

Unfortunately, I soon realized that all the astronauts were military pilots, and that was not really a career for me. But that desire to look further out, to understand what's above, what's out there-- that remained with me, and so I ended up with a degree-- advanced degrees in astrophysics. And I was launching telescopes to look at X-rays-- and you have to go above the atmosphere to look at X-rays. That's what I was doing here at MIT.

Then NASA started to develop what was then the brand new Space Shuttle. Now we're up to the late '70s, and the thing about the Shuttle was they had a crew of seven, and they only needed two pilots. So that was great, because that's what really opened things up for scientists, engineers, medical doctors, and that's what gave me my chance. And I applied for it, and was lucky enough to get selected. And so then I could get the real overview from space.

SARAH HANSEN: Five missions later, and Professor Hoffman is back on Earth. And since 2001, he's been teaching a series of courses on aeronautics and engineering here at MIT. Luckily for us, Professor Hoffman infuses much of his NASA experiences and learnings into his courses. To help the students really understand the big picture-- like he had to at NASA-- he emphasizes the concept of systems engineering. Understanding systems engineering helps students and astronauts alike to tackle complex problems, and it all starts by looking at the bigger picture.

JEFF HOFFMAN: Particularly anything having to do with space, with complex systems in general. We try to teach systems engineering here. You have to have the big picture if you're going to be able to manage a complex engineering or scientific project. In the AeroAstro Department at MIT, we don't really teach systems engineering as a specific subject until the graduate level, because really, if you're going to be a professional systems engineer and be gooc at it, you really need a background in some of the basics of engineering.

So just like at NASA Mission Control you don't start out being a flight director. You start out working in one of the individual disciplines. And usually, the most successful flight directors have worked in at least two disciplines. And then you understand how a disciplined engineer approaches a problem, and then you can be more useful trying to get the big view of things.

SARAH HANSEN: Another really wonderful part of Professor Hoffman's courses is how they combine theory with real hands-on experience.

JEFF HOFFMAN: The majority of our students-- they are going to be working engineers. They're going to go out into the world. Many of them get jobs in aerospace companies, and they're going to build the next generation of space vehicles. And we want them to have had some experience actually building something.

For instance, here, I teach the freshman course in introduction to aerospace engineering and human spaceflight, and we have the students build a project-- a lighter-than-air vehicle. We give them the material. We give them some radio control equipment, motors, servos, propellers, and lead them through, in a systems engineering way of going about the project, without formally telling them that they're practicing systems engineering. I mean, even if you're going to be a disciplined engineer and just concentrate on one aspect of a system, it still helps to have the concept that somehow all these systems have to play together.

SARAH HANSEN: Another way Professor Hoffman ensures that these ideas really sink in is with something called CDIO. CDIO stands for Conceive, Design, Implement, and Operate, and it's a learning tool that helps students to think through a problem "from soup to nuts," as he puts it. What's wonderful about it-- beyond the fact that it's helped us put humans into space and on the moon-- is that it can be useful in tons of different contexts, even beyond engineering.

JEFF HOFFMAN: The bottom line, and the moral of all of this is you really need, from the very beginning, when you're designing a system, to think about the end user. Very often, the people who design it never have to use the system. They come up with a design, and they throw it over the fence, and somebody else builds it. And they don't have to use it, they throw it over the fence, and then the end user takes over. And so it's really critical.

So the CDIO-- it's a way of approaching engineering particularly complex systems that, from the very beginning, you take into account all of those phases of an engineering system. I mean, it's not just engineering systems. When you build a house, I mean, you better figure out what it's going to be to live in this house before it gets built. Otherwise you're going to have a lot of bills with a contractor to make changes at the last minute. And that's one of the other things you learn, and one of the basic principles of systems engineering-- and particularly in the space business-- is that the further you get into the implementation of the system, the more expensive it is to make any changes.

SARAH HANSEN: I feel like that's one of the beauties of this course. You might be working in a completely different discipline, but you can find something useful.

JEFF HOFFMAN: That is kind of the subtext of the course-- is it's not just about the Space Shuttle. It's learning how a very, very complex system was initially conceived, designed, implemented, and operated. And that's why, after the central part of the course, where we talk about the design and building of all these complex subsystems, then we brought in people who actually operated the shuttle-- the launch director, the flight director, the payload operator, an astronaut pilot who flew the shuttle, and so on-- because that's the final phase of the whole CDIO. As I say, from soup to nuts, this is what the shuttle was all about.

SARAH HANSEN: To really understand the development of the space program here in the US, it helps to look at the interconnected series of systems that built it. And they go well beyond engineering and mathematics. For example, politics played a huge role in aerospace engineering.

JEFF HOFFMAN: We really thought it was important to devote the beginning lectures of the course to what were all these influences which had such an important impact on the design? Economically, it was no longer possible to treat NASA in such a special way as had been done by Apollo. I mean, 400,000 people working on Apollo at the height of it, 4% of the federal budget going to space exploration-- this is not normal for space activities. It was a very special time in our history.

Then you get to the late '60s. I mean, even John Kennedy, after having made this commitment to go to the moon, started to have second thoughts about how much it was going to cost. Then, of course, he was assassinated, and getting to the moon by the end of the decade sort of became our way of honoring Kennedy's legacy. So it wasn't a question. We did it.

But along came the Nixon administration following President Johnson's Great Society program-- huge increase in social spending-- and then the Vietnam War. And space-- it was clear, and Nixon was explicit about this-- the space program has to take its proper role among all other national priorities, and that really involved a huge decrease in NASA's budget. And the people running NASA saw that coming.

And so how do you continue to explore space? They were faced with the real possibility that human space flight in this country might come to an end. And NASA realized-- quite correctly-- that reusability was a key.

But then you get into all of the social, economic, political influences that put a lot of very, very tight requirements on the shuttle-- particularly since, in order to justify the expense, NASA basically sold the shuttle as capable of doing anything we needed to do in space, we could do with a shuttle.

We used it for scientific experiments. We used it to launch satellites. We used it to test out new engineering systems. We used it to repair satellites like the Hubble Space Telescope. We used it to build the International Space Station. For me, all my flights were in the space shuttle, so I look on it with a great fondness-- recognizing its limitations, but also understanding the incredible things that it allowed us to accomplish.

SARAH HANSEN: While Professor Hoffman's classes offer incredible insights into what he's learned at NASA-- not to mention some deeply important skills for any student or intrigued OCW user-- it's not every day that I get to sit down with a real astronaut. So of course I had to ask him what it was all like-- being launched into space, being in orbit, doing a spacewalk.

JEFF HOFFMAN: Before my first launch, I asked many of the astronauts who had already flown, what's it going to be like? They put us in simulators, and they shake the simulator a little bit, but they said, forget it. That's nothing like the real thing.

It's hard to prepare yourself. It's an exciting time, the last few minutes before launch, as the shuttle really comes alive, and then all of a sudden you get this big kick in the pants, and you look out the window, and there's the ground falling away, and everything is shaking, and tremendous noise. People told me that there was going to be more vibration than I could ever imagine, and they were right, because I couldn't imagine it.

45 seconds later, you're going straight up, and you break the sound barrier. And that gives you even more vibration, because you get all of these shock waves. And I remember thinking to myself, no, this can't be normal. The wings are going to fall off. Something's wrong.

But I mean, the structural engineers knew what they were doing, and the wings did not fall off-- or else I wouldn't be here talking with you. With the Shuttle, it was those two big, solid rocket boosters that caused all of the vibration, and they burn for the first 2 minutes. Once they fall off, it's a really smooth ride. I mean, everybody then talks about it's an electric ride all the way up into orbit. So that contrast between the extreme vibration of riding on the side of a solid rocket booster, and then just the burning of the hydrogen-oxygen engines was really quite extraordinary.

SARAH HANSEN: Did anyone ever just get really scared right before lift off?

JEFF HOFFMAN: There are some astronauts who will tell you they don't like launches because of the risk involved. For me-- I mean, I remember, before the first flight, riding out to the launch pad and looking up at this incredible vehicle that I'm going to get in and thinking to myself, first of all, this is not the time to be asking yourself if you really want to do this.

But then what was really going through my mind is ever since I was six years old and I saw Flash Gordon take off in his rocket ship in science fiction, and I always dreamed of doing it, and I'm about to leave the planet-- it was exciting. I mean, so my idea was sit back and enjoy the ride. I'm not a pilot, so I didn't have to even worry about flying the shuttle. I could just look out the window and enjoy this incredible experience-- which it certainly was.

Then all of a sudden, you feel yourself floating up in your seat. You're weightless. I remember unstrapping and floating over to the window, and there was the coast of Africa coming over the horizon, and that's when it really hit me. Oh, my God. I'm in space!

SARAH HANSEN: While launching into space is certainly an incredible ride, Professor Hoffman also did a number of spacewalks during his career. He shared with us the story of one of them.

JEFF HOFFMAN: I remember my very first spacewalk on my first space flight. I went out, and we had to attach some special tools to the end of the robotic arm as part of an attempt to rescue a satellite which had been deployed but didn't turn on. And then we had been out for about two hours or so, and the sun set, and then they didn't have the right lighting conditions. And I'll never forget the call that came up from the ground-- hey, Jeff and Dave, would you mind staying outside for another 45 minutes while we wait for the sun to come--

SARAH HANSEN: Oh, my gosh!

JEFF HOFFMAN: And I had nothing to do. I was just-- I mean, I was a tourist out in a spacesuit holding on. I thought to myself, I'm just going to have some fun. So actually, I was sort of crawling all over the shuttle. And thinking back, I crawled halfway up the tail, and the commander told me he was doing his best to keep the TV cameras off me. I mean, I was so ecstatic. I was thinking about the fact that maybe some people on the ground wouldn't want to see an astronaut hanging from the tail of the shuttle, but I did it.

SARAH HANSEN: It's all a matter of perspective. To broaden your own horizons from the safety of your own home, be sure to check out Professor Hoffman's course materials on MIT OpenCourseWare, or on the MIT Open Learning library.

Thanks so much for listening. Your comments have inspired me to keep learning. Until next time, signing off from Cambridge, Massachusetts, I'm Sarah Hansen from MIT OpenCourseWare.

AUDIO BUMPER: Ma, park the car.