



THE HENRY FORD

COLLECTING INNOVATION TODAY

TRANSCRIPT OF A VIDEO ORAL HISTORY

INTERVIEW WITH

CHARLES ELACHI

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JET PROPULSION LABORATORY

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01 ELACHI A HISTORY OF THE JET PROPULSION LABORATORY

BARRY HURD:

01:00:49;01

I'll tell you what, just tell us, lotta people don't know, tell us where we are, and what goes on here, maybe a little history of JPL.

CHARLES ELACHI:

01:00:54;11

Okay, yeah. This place started in the 1930s. And it's like any kind of very innovative place, started by small group of people. And they were couple of students at Cal Tech, at the California Institute of Technology, a small private university in Pasadena working with a professor called von Karman. And they were to learn about rockets.

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And the way they tried to learn about rockets is mix different chemical and see which one blows up, anymore, I mean, that's how you start doing work in the lab. And the campus got very nervous about them blowing up a building. Matter of fact, they did blow up a shack, you know, on the campus. So they were told, "Why don't you

go to Arroyo where there is nobody there, and try your chemistry?" And that's how JPL started.

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So we are the group of four students and a professor, came to Arroyo here, and they were just mixing chemicals, and see which one works better, and then they got a little bit better at it, and then a little bit better at it. And then during World War II we started working on small missiles to help aircraft take off on short runways. And that led to after World War II to do the strategic missiles and rocketry.

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And then when Sputnik was launched, and there was a concern in the United States about the Soviet Union getting ahead of us, and so on, then JPL working with a team of Von Braun, who was brought from Germany, but was working at the Marshall Center. We built the first American satellite here.

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And, in a sense, that was a stage where we have moved from being a rocket house to being a satellite house, or an

exploration house if you want. And then shortly after that, NASA was formed, and JPL became part of NASA, but managed by Cal Tech. And then we moved on the track of actually exploring the solar system. So, what you are here, is what we tell people, you are the center of the universe.

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And we literally are the center of the universe. Because that's where we guide all the spacecraft across the solar system, are literally about 50 feet from where we sit here, is where we're monitoring and guiding all these satellites, which are all over the different planets, some of them are leaving our solar system, some of them are in Earth's orbit.

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So, it's really a place, what I call it, it's the Venice or the Seville of the 20th century, where we are exploring and moving out, you know, doing that exploration on behalf of all human kind.

02 ELACHI HOW INNOVATION HAPPENS

BARRY HURD:

01:03:11;04

You said there were a lot of innovative things that came out of the whole process here. Tell us a little bit about that.

CHARLES ELACHI:

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Yeah, in a sense, I mean, people first, just launching anything was a major thing to do. So people have to come with all kind of innovation of how do you put the satellite in orbit, how do you communicate with the satellite? How do you put the instrument to make measurement of different thing? How do you guide it to the planets? You know, after when we started doing planetary thing. And part of it was trial and errors.

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Matter of fact, some of our early mission to get to the moon, you know, and impact the moon or land on the moon, we had four, five failures. But you learn from every step, and that's, in my mind, a key element of innovation. Is to remember things, most likely, will not work the first time. And if you get discouraged after you have a failure,

you'll never be able to innovate.

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So you have to keep trying, comes new ideas, try different things, get other people ideas, and so on. Things don't happen just a flash bulb, you know, happens. Sometime it does happen that way. But, it's really the interaction between intelligent people, which then create, you know, innovation. And then, the dedication and the passion that people have, which really will take you beyond the failures and the problems and the setbacks, and so on.

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And then, all of a sudden, you get these great innovative things like landing a rover on Mars, which for people here, seems like it's a routine job. But in reality, it's a very tough job.

03 ELACHI FROM LEBANON TO THE JET PROPULSION LABORATORY

BARRY HURD:

01:04:36;12

Now, what about you? How did you become a member? You've been here a long time, but you run the place now, or manage the place. What was your background, how did

you wind up being...

CHARLES ELACHI:

01:04:43;27

Yeah, it's interesting, I mean I was born in Lebanon, in a little village, you know, in the middle of the country. And when I was a kid, I was always fascinated by looking at the sky and looking at the stars, and wonder, are there other people on those stars, you know, looking at me, you know, or doing the same thing. Then I was fortunate, I was very good in science, you know, I had a great teacher. My mom used to be very, make sure that I do my homework, you know, before I go playing, and so on.

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Then I went to France, and did my undergraduate. And then by pure chance, I had ended coming to Cal Tech in Pasadena. Part of the reason is when I looked at the map, I saw it's very close to Hollywood, and I said, "Gee, I'll see movie stars," and so on. You know, when you are 21 years old, you know, you are thinking about these things.

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And then I showed up at Cal Tech, got my PhD in science,

and JPL, which is part of Cal Tech, you know, kind of got attracted to come here as a student, you know, basically to earn my living. And then I said, "Gee, I'll stay for a year, then I'll stay for two years." And forty years later I'm still here.

04 ELACHI SPACE EXPLORATION

BARRY HURD:

01:05:47;01

Tell us a little bit, for those who don't know the history of when you became more of the exploration house, I guess you called it, some of the projects. I mean, was Voyager the first big one, and then take us up...

CHARLES ELACHI:

01:05:55;02

Yup.

BARRY HURD:

01:05:55;01

...through the rovers. I mean...

CHARLES ELACHI:

01:05:56;02

Yeah, we had, I mean, first, of course, we started by trying to get to the moon, because that was easiest, or the, I mean, relatively speaking, the easiest to get to. But since then, we have basically visited all the planets in the solar

system, ranging from with the series of Mariners missions, which went to Venus, Mercury, and then to Mars. Basically just to do first a fly-by, then to learn how to orbit.

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Then we have Voyager, which basically went through all the major planets and now it's leaving the solar system, to the next step of doing orbiters around Jupiter and around Saturn. So, as we speak today, basically we have two spacecraft in orbit around Mars, and two rovers which are working on the surface. So now we are exploring both from orbit and on the ground.

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We have an orbiter which is orbiting Saturn, it's called Cassini, has been operating now for five years, and made all kinds of discoveries, you know, to understand, you know, how Titan operate[s] and the methane cycle on, you know, on Titan. We have spacecraft which are heading to comets, spacecraft heading to asteroids.

01:06:57;00

So literally, we say we have about a dozen, dozen and a

half spacecraft across the solar system. So, the lingo here at JPL, the solar system is our backyard. So we go and play, you know, in that backyard, but in a serious play.

05 ELACHI ANATOMY OF A SPACE EXPLORATION PROJECT

BARRY HURD:

01:07:11;20

Well give me an example of like...

BARRY HURD:

01:07:40;13

Actually, take one of the examples, maybe one of the rovers 'cause it's current, and how does that start, does a voice come on and say, "Build a rover," I mean, is it built here, is it designed here? Take me through that process.

CHARLES ELACHI:

01:07:51;23

Yeah, you know, I think first the idea of wanting to go on the surface of Mars, I mean, after we do the orbiters, and we see things which are geologically very interesting, then you do what a typical geologist want to do, is to go to the surface and walk around and pick a rock, and look at it, and test it. Now, of course, we cannot do that on Mars by sending an astronaut, because that's too, I mean, that's beyond our capability.

01:08:14;29

So, we build these rovers at factory to be the equivalent of a geologist. So, first a scientific community thought, you know, this would be an important thing, the government agreed to it, but at the same time, we had people here sitting down and thinking, "Well, what kind of rover would we build? What are the things we need to make sure it lands, you know, on the surface. What kind of techniques do I do?"

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Because Mars has much less atmosphere than Earth, so you cannot use a traditional parachute. But it has enough atmosphere that it create heat, you know, on whatever you descent on. So it's kind of the worth of both places. If there was no atmosphere, you don't have the heat issue, if you have a heavy atmosphere, you can come down on a parachute like Earth.

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So we have teams of people which get together and start thinking crazy ideas. You know, about what ways can we

do to land these things. And in the case of the rovers, I mean, one of the idea which came said, "Okay, we start first with the heat shield to slow us down, then you use a parachute to slow you even more down, use a rocket to slow you even a little bit more."

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But then we were worried about the last ten meters, how would you drop the last ten meters. So somebody came with an idea, "How about if we put bunch of airbags, you know, around the rover, and let it bounce?" So, and that's how we, at first people thought, "Gee, that's crazy, you know, how you do that." But that's actually what we ended doing.

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So we come in, and as we get about 30 feet above the surface, this huge airbags blow up, and then you let the thing bounce, bounce, bounce. And then once it stop, deflate the airbags, and the rover comes out, you know from now, it sounds all simple, until we started doing the testing. Like, the parachute broke before we launched, the

airbags, you know, were punctured, you know, so we had to make them harder.

01:09:54;00

So, literally every day there was an issue that the team had to address. And as I said earlier, where the innovation come, partly you need smart people. But also partly, you need people who don't take a setback, you know, that it's impossible to cross this.

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The thing I keep saying in this business, you have to stay calm, calm, calm. Which mean, when you have a problem, the first reaction is, "Okay, now how do I solve the problem." You know, I have a challenge now, how do I solve that challenge, versus, "Oh God, you know, we are in deep trouble." So, I think that's a characteristic of innovators.

01:10:29;28

You know, they don't take a setback easily. You know, or they don't get discouraged or disheartened, you know, by a setback. They keep saying, you know, "I'm going to try

again," or bring some additional people who have some different ideas, and figure out how do we do that.

06 ELACHI BUILDING A GOOD TEAM

BARRY HURD:

01:10:43;09

Tell us a little bit about the design process. Is it true they go in a room and put Lego's together and there's some, and then they go to the computer? Or how does that work?

CHARLES ELACHI:

01:10:50;03

Yeah, I mean, well, particularly today is heavily computerized. So first really, it starts by people mind. So what we start doing is bringing a group of people with different background, people who have mechanical engineering, electrical engineering, and so on. We also make sure we bring some young people who nothing is impossible for them, with some more experienced people who have seen it before and they've seen that, where you get in trouble, and so on. And get them together and brainstorm.

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And then as you come up with some ideas, you know, then you can go and do the analytical analysis, using computers and tradeoff using, you know, graphic design, and so on. And the first time things don't work well, so you come back, and then you discuss it. And that process takes many months of doing that.

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And as you home in, then the next step is to start building things and testing them, and see how well they would work on doing that. And then once that goes through, then you can convince a sponsor, that yeah, they have their act together, they know how to approach it. And even when we start on a project, sometime we're not absolutely sure, you know, about all the problems, and how we're going to solve them.

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So I say, the most important thing on an expedition of exploration is that you need to have a good team, because problems are going to happen. There is guarantee problem are going to happen, and probably will be a

problem every other day. And your best bet is a team that is with you, to be able to address those problem and overcome them, and move them. So no matter how good you design at the beginning, once you start building it, you're going to find issues. And the key thing is to make sure you have a first rate team coming with you.

07 ELACHI ARTICULATING THE VISION

BARRY HURD:

01:12:21;13

Now your role here now is to, you help assemble those teams, you manage them? Tell us a little bit about [that].

CHARLES ELACHI:

01:12:26;02

Yeah, in a sense here, we have about a dozen projects going on at the same time. So as a center director, I say I have the following things which are the key things on my list to make things work. Number one, you have to have the vision so you can articulate to the team, you know, particularly when you have 5,000 people where you are heading. And get them excited about that.

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So you have to have passion yourself, you know, for doing

thing, and be able to transmit that passion and that leadership and that vision. Number two, you bring the best people in the world, you know, to work on these things. You give them a good environment, and you get out of the way. That's how you get the teamwork, because as the leader of the organization, I don't know the detail. You know, that's why you bring the expert, the people who are really knowledgeable.

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The challenge on the leader, is how do you get the team to be charging, and basically they are excited and passionate, and think that there is a purpose for what they are doing. And then help guiding them. The other side of the coin which is very important is to make sure the team knows, and that's the kind of a description that I will give, that if there is a success, they'll be sitting at the podium. If they fail, I will be sitting at the podium.

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So they know that calculated risk is encouraged, we ought to be thoughtful about it, not foolish about it. But I'm not

going to let them down if they take a risk that I agree to, and then they fail. My first reaction is not who to blame, my first reaction, okay, how do we lift them up? You know, how do we bring all the support to make sure we overcome, you know, that setback.

08 ELACHI LEARNING FROM FAILURE

BARRY HURD:

01:13:58;03

Now, when you first took over, was it back in 1999?

CHARLES ELACHI:

01:14:02;01

2000, yeah.

BARRY HURD:

01:14:02;22

2000, right after a couple big problems, and morale...

CHARLES ELACHI:

01:14:06;04

Right.

BARRY HURD:

01:14:06;02

...was kinda low, there had been government cutbacks, so you kind of inherited sort of a down cycle, right?

CHARLES ELACHI:

01:14:11;29

Yeah.

BARRY HURD:

01:14:12;00

What did you do to try to turn that around?

CHARLES ELACHI:

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I mean, and a little bit applied what I just said, you know, about the leadership. I mean, number one, is to tell people how exciting it is, what we do. Matter of fact, we're fortunate, you know, that what we are doing, you know, we are allowed to do, and even get paid to do it. And recreate that passion. And then to assure people that, look, when you are doing exploration, it is a risky business.

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If we are always successful, sometime I wonder if we are trying hard enough, because in this business, you know, it is a challenge. And sometime, as you push the limit, you know, sooner or later you are going to overstep the limit. And the key thing is, when you overstep, is to be able to get back, learn from it, and move on. And one thing I do, I enjoy, is to read a lot about biography, like of Captain Cook and Lewis and Clark.

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And people on the surface say, "Oh gee, it was easy, they just got in a boat and went around the world." But in reality, when you look at their, you know, biography, and their notebooks, every day they had a major problem. Either the crew was in, all miffed at the captain, or things were breaking down, and so on.

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And the challenge for the leadership, you know, particularly when you explore, is to make sure you keep moving ahead, and you don't let these setbacks, you know, you give up on it. Matter of fact, Magellan didn't even make it back. You know, he died halfway through the trip.

BARRY HURD:

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That's definitely a down thing.

CHARLES ELACHI:

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Yeah, no I, no, we don't have that risk here, you know, I don't think there is a life risk in the, but the point is, for people to appreciate that when you do exploration, it's very tough. And you need a team which can overcome,

you know, adversity, you know, without getting too discouraged.

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And that's what I try to send a message to the team. I kept telling them, "Look, failure is going to happen." You know, sooner or later it's going to catch up with us, and it's going to happen. The key thing is to make sure that we learn from it, and then move on.

09 ELACHI HIRING THE RIGHT PEOPLE

BARRY HURD:

01:16:01;15

And define those kind of people who can work on that kinda team, who motivated that way. Is that easy, is it difficult? How do you do that?

CHARLES ELACHI:

01:16:06;24

Yeah, you need some certain type of people. I mean, one of the things I tell, I try to meet with all the new employees, which come to the JPL every couple of weeks. And I tell them, "Look, if you are looking for a job, this is the wrong place for you. But if you have passion for exploration, if you'd love to go home and tell your

girlfriend or your mom or your wife, 'Guess what, I just landed a spacecraft on Mars, or I just brought a sample from a comet, or I just flew by Jupiter.' And you feel passion about that, then this is the right place."

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Because to work here, you have to have that passion. You know, to that and passion will allow you to overcome, you know, setbacks from doing that. If you were just looking for a regular job, and you have a setback, then you will give up, you know, very quickly. But if you believe in what you are doing, you are excited about it, you are passionate about it, you will take setbacks. Sometimes it's hard, but you will overcome them. You know, if, I think much easier.

10 ELACHI DISCOVERING THE SECRETS OF THE UNIVERSE

BARRY HURD:

01:17:04;16

I'm sure you've had the question before, but what, why are we doing this? What do we get outta this? Do we get Velcro? Or I mean, what's the point?

CHARLES ELACHI:

01:17:11;06

No, I think it's more fundamental than Velcro, or the

immediate application, even though that those are beneficial. I mean, and I typically have two answers for that. One, which is more a kind of popular answer, is that if our ancestors were not curious, probably we are still sitting in caves, just doing drawings on wall. But they were curious, they wanted to see what's outside. They knew it was dangerous, but they wanted to explore.

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I mean, that's part of the human character. Same thing, I say, I'm sure many people told Jefferson, "Why in the heck are you sending Lewis and Clark, you know, and spending those \$2,000 to send them to the West, there are all kinds of problems on the East coast." And if he would have listened to them, you know, probably things would have been very different, particularly living in California, you know, here on the West.

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So there is that urge to get to know things, be it for intellectual purpose, or economic purpose, or political purpose, but that's an urge that we have as a human. On

a more scientific basis, what I find fascinating is somehow, 13 billion years ago, there was a Big Bang. At least, that's what we think, how the universe started. A bunch of particles were created.

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Somehow, these particles got together, and they formed galaxies and stars, somehow some of those formed planet, and somehow, on one of these planets, these molecules got together, formed cell, and here there are human being, like you and I, you know, kind of having a discussion. When I think about, that's absolutely amazing. How did that happen? Starting from those little particles, here you have intelligent people talking.

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And what we are doing in exploration of space, is to kind of write the book of how did these things evolve from that Big Bang and a bunch of particles, to creating galaxies, to creating planets, to creating life, and to have intelligent life. Now, we don't do that in one single sweep, but step by step, we are trying to learn, first in our solar system,

first on our planet, then in our solar system, then beyond our solar system, is how did that happen, and how common is it?

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I mean, if we find there are planets around other stars, which are very common, similar to us, that's most likely life could have evolved somewhere else. That will be mind changing. If on the other hand, we find that we are the only people, in this huge universe, this billions of stars, and the only place is Earth, that will be equally mind boggling to do that.

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So that's what I find fascinating by this. And I think when I describe it, particularly for young people, even for older people, they get absolutely fascinated, you know, about that.

11 ELACHI "SERIOUS PLAY"

BARRY HURD:

01:19:34;12

Let's go back, you said the solar system is your backyard, you get to play in it, but you said, "But it's very serious."

Tell me a little bit about that contrast between trying to be playful, but in a very serious, high budget, high stakes business.

CHARLES ELACHI:

01:19:44;00

Sure. Yeah, no, I mean in this business, as I said, part of the passion, and so on, is also to have fun. So, on one hand, it's a very serious matter, because every time we launch a spacecraft, you are talking anywhere between couple hundred million, and a few billion dollars. These are very sophisticated, you know, machines. So we have to be very serious about because we are spending tax payers money, and these are mission that people spend years and years and years designing, and so on. And then you have an instant of time when you are landing on another planet, and so on.

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But on the other hand, it has to be fun. Because it is really hard work. This is not done on 40 hours a week, you know, that people work. I mean, people come here and work until the job get done. Takes 60 hours, 80

hours, whatever it takes, you know, it takes to get it done. So you always have to create the balance between one, having fun on what you are doing, but the other one is take it seriously.

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I tell people, you know, when I drive every morning here, I'm looking forward to whatever problem I'm going to face. Sometime they are not fun problem, but I look forward for it, because I'm going to learn something new. And even if it's serious, I'll be enriched a little bit more by end of the day, you know, about what I have learned, and have addressed, and I'm a little bit smarter. And I think most of the people think about it that way, that it is a playground, but this is serious playground.

12 ELACHI CHALLENGES--TECHNICAL, HUMAN, AND POLITICAL

BARRY HURD:

01:21:00;02

And what about, and what were the challenges that you face every there's gotta be constant challenges. I mean, you've told us some of the things you try to do, but what are the really, some of the hard things that you face?

CHARLES ELACHI:

01:21:08;08

Yeah, I mean, there are technical challenge, and there are human challenge, and there are political challenge. Clearly, on the technical side let me give you, for instance, an illustration to give you a feel about the challenge of, you know, the kind of things that we have to do.

01:21:22;16

When we send the two rovers to Mars, after traveling about 450 millions miles, we have to get them within literally a mile distance on the top of the atmosphere of Mars to land accurately and not to burn in the atmosphere. This is equivalent of standing in California, hitting a golf ball towards Saint Andrews in England, and get it straight in the cup. That's how challenging we have to do this navigation.

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And to make it a little bit more challenging, the cup is moving at high speed, and we still have to get it in the cup. So that illustrate[s] in a day-to-day way, the kind of things we work on, you know, every day here. When we

are coming into the atmosphere on Mars, we're coming at a speed where it's about 12,000 miles per hour. That mean you can go from here to New York, from Los Angeles to New York in like, ten minutes, or fifteen minutes. And literally in six minutes, we have to slow down, and stop, and land very softly on the surface, otherwise we crash.

01:22:16;00

The heat that we get on our heat shield, makes the heat shield hotter than the surface of the sun. And within those seven minutes, a thousand of things have to work, parachutes have to open, heat shield have to be dropped, airbags have to open, retro rocket have to fire, and everything has to be done, all autonomously, 'cause it takes ten minute[s] for the signal to go to Mars, so you cannot joystick it. It all has to be done autonomously.

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So your spacecraft, your rover has to be smart enough, that it can adapt very quickly to this new environment that it never encountered, you know, before. So, that's a little bit of the challenge that we do. Now human challenges,

how do you get the team of 1,000 people to all work together, and build these things? 'Cause no one person knows everything. It's really the collective knowledge to build these complicated machines. And the political challenge is to make sure we keep the politicians supporting, you know, what we are doing, and excited about what we're doing, even when we get adversity, you know, to do that.

01:23:12;27

So that's kind of what I spend my time, kind of divided between all of this, including parking lots and getting parking for everybody. So it's a whole spectrum of fun things that I have to do.

13 ELACHI THE VALUE OF DEBATE

BARRY HURD:

01:23:23;17

Is it a business where there's a lotta big egos, a lotta arguments, and I mean, is it really intense?

CHARLES ELACHI:

01:23:27;27

Yeah, no, I mean, it's [a] debate, and what is important is, what is critical is people respecting each other. So we do

encourage people to debate and argue. Matter of fact, I see some of the most valuable people are the one which are the biggest pain in the neck. Is the people are always thinking of problems, always saying, "Well, what if this happen, and what if that happen, and what if that happen, and what if..." so we are prepared, you know, for all of them.

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And as long as it's done professionally, people strive on that. You know, it's done in meeting, and people are really arguing and passionate about what they thinking, and passionate about their idea. But then, unfortunately in a scientific world, technical world, we are accustomed to that.

BARRY HURD:

01:24:20;09

So we were talking about the egos and the debate, and the, let's pick it up there.

BARRY HURD:

01:24:25;28

Okay, just tell us about that, you've encouraged people to argue...

CHARLES ELACHI:

01:24:27;20

Yeah, no I think we do encourage people to debate and argue, because how do you that's how you come up with new ideas. We do appreciate particularly the people are the biggest pain in the neck, that mean the people that keep asking question, "What if this happen, what if that happen, have you thought about this, have you..." even if the idea's done, but every once in a while, they might come up with a nifty idea that we ought to be prepared, you know, to address, or a problem that ought to be able to address.

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The key thing is that for people to respect each other. And the way you respect other people is if they are knowledgeable, if they are constructive, if they are well thought of, we have some people here, we call the gurus, that a lot of people go to because of their experience. So no, I think debate is encouraged, you know, as long as it's done in a professional way. We do what we call peer review, so which means, if I'm designing something, I look

at people who are not involved in it, to come and look over my shoulder and say, "Well, what did you do here? I mean, is that the right idea? Have you thought about this?"

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And I think it constructively, because I think they're trying to help me, you know, in getting my job done. So the key thing we tell people here is, you should not be afraid of saying I don't know. Matter of fact, we like people to say I don't know unless you're absolutely sure.

14 ELACHI HOW DO YOU MAKE DECISIONS?

BARRY HURD:

01:25:38;20

So, there's sort of a process in place, that you resolve these difficulties if you're gonna hit a golf ball to England, at some point, you're gonna tee it up.

CHARLES ELACHI:

01:25:46;08

That's right.

BARRY HURD:

01:25:46;24

So how do you resolve this process when you have all these smart people, and rabble-rousers and how do you

get 'em all, finally say, "It's time to go?"

CHARLES ELACHI:

01:25:53;02

Yeah, I mean, and that's where come the, what we call the project leadership. I mean, for every project, at the end we have a person who's responsible for that project, and he or she build a structure under that. And there are usually very experienced people who have learned from a lot of past mistakes. And they are the people who sit down, listen to all that debate, and all of these things, sometime we bring outside expert, sometime inside expert who come and give opinion.

01:26:16;08

And then that person has to make a decision. And there is no guarantee of 100 percent accuracy. You have to go with your experience, with your gut feeling, with advice of people who have made mistake in the past. We do have what we call project rules, that we have here, which is a guidance, if you want. And what I tell people, all of that is, is collection of past mistakes. You know, it's mistakes we have done in the past, we say, "Oh, now, this is an

issue you have to be careful for. You know, pay attention to this, or pay attention to that."

01:26:45;14

And that's what guide[s] the young people, I mean, the people have not had that same experience. So that's what we call the project, the rules, and what the experience bring in, you know, to the picture. But also, we want people to be innovators, who are coming with new ideas, you know, there's new technology, and so the project manager challenge is how to balance all of these things.

01:27:04;07

But at the same time, if somebody feel[s] that they have not been heard, or the project manager has made a mistake, they'll elevate it up to me, and then I'll sit down and listen to it, and then I might agree with this person or that person. And even sometime I might elevate it even higher, you know, to NASA headquarter, where they have to make a decision, particularly when it's on the critical, you know, very critical event.

15 ELACHI THE ART AND SCIENCE OF SPACE EXPLORATION

BARRY HURD:

01:27:25;25

How often is there, sort of a kindness between what's sort of scientific and engineering, and something's more artistic? Is there a blend between those two sides of this kinda work?

CHARLES ELACHI:

01:27:35;08

Yeah, I mean, on the artistic side, there is a little bit, you know, of that part. I mean, at the end, the engineering kind of, you know, have to rule. And there is also a debate between scientists want to do a lot of things, but the engineer want to make sure it's done safely. So, for instance, on our Mars missions scientists will look at sites, say, "Wow, this looks like an exciting site, this look[s] like an exciting, and we would like to land here or land there."

01:28:00;11

And then an engineer will look at that and say, "Hey, wait a minute, this is in the middle of a canyon, and I cannot target it that accurately. And this is too risky, or there are too many rocks in here, or this is too high an altitude, and therefore the parachute will not slow us enough." So there

is always that give-or-take kind of thing.

01:28:18;18

And then also, there is an element of public interest, you know, which is a little bit an artistic kind of thing of would that be something exciting for the public to do that. So some of the things we do, for instance, for the public is like now we're in the midst of having a competition for naming the next rover. So the way we approach to engage the public, we worked with Disney, and we informed all the middle schools in the country, saying, "We would like your kids to work on essays, and name the rover."

01:28:45;24

And we got thousands of inputs, where basically kids said, "Well, you should name it this and this because," and write an essay, so it became like a scientific project for young kids. And then a committee would look at them, and matter of fact is looking at them as we speak. And then at the end, come with a name.

01:29:02;17

So that's a way of engaging young kids, engaging the

public and we might, you know, one thing we are going to do is probably pick the names of all the people who participated, put it on a little disk, and put that disk on the rover, so it actually will go to Mars. So people will say, "Yeah, we got it to Mars, on doing that." So we have to balance these different things.

BARRY HURD:

01:29:21;02

What about somebody who's interested in this and they say, "Well, I'd like to do that." What kind of training, should they start in high school, take a lotta math and science classes, or...

CHARLES ELACHI:

01:29:29;06

Yeah, you, in a nutshell, I tell people you need it across the board. Clearly science and engineering is needed, but also we have people who work on the administrative side, on the financial side, on the mechanical side, I mean, basically doing hand work on it. So you really need a whole spectrum of people to do these things.

01:29:48;12

One thing I keep telling our employees here, everybody is

important for our mission. From the PhD to the cleaning lady, or the cleaning janitor who's doing that. All of them are needed, you know, to make sure we have the right environment, to have a pleasant environment, that contracts are going out, that we get paid, that salary get paid at the end of the week, to the geniuses who are doing the engineering side.

01:30:11;14

And we all celebrate together, and we all feel bad together when we have a failure. So that kind of spirit is critical in the large organization when you are working on these kind of projects, because you need everybody to be pushing in the right direction, to make something happen.

16 ELACHI ROBOTS VS. HUMANS IN SPACE

BARRY HURD:

01:30:27;19

What are some of the...

BARRY HURD:

02:00:04;07

Before we were talking about Elon Musk 'cause we were down to his place and had talked to him. He's got this theory that by nature humans are multi-planetary. It's

just a matter of time before we, you have any thoughts on that or have you worked with him or what he's doing or what's your thought?

CHARLES ELACHI:

02:00:19;14

Yeah, I know, I mean, I know him reasonably well and we have worked a little bit with him. I mean, one thing I admire about Elon is his enthusiasm, you know, about exploration as well and putting his money where his mouth is. And trying to make space become more accessible, you know, for the general public. Now on the question about expanding, you know, human beyond our planet, I mean, that's a good goal.

02:00:46;18

I look at it as a long term goal. But for me I look at robots as an extension of me. And particularly when I talk with the young kids, you know, for them robots is like another person. So we can do a lot with robotic, you know, mission, they are lacking the passion of a person, but for me when I land a space craft and I look at those picture as that rover is moving, it's almost like if I'm walking, you

know, in that area.

02:01:14;07

So I take a little bit different perspective about that. Even that I think the excitement of sending human is very important even for all of us but a lot of things can be done with robots if you think of them as your extension. I mean, we can go to our mission operations room where we're operating those rovers on Mars and put 3-D glasses and you can as if you are walking on Mars, you know, you think you are there, you know, unbelievable.

17 ELACHI WHO SHOULD FUND SPACE EXPLORATION?

BARRY HURD:

02:01:38;06

What about the private business versus government involvement. Do you think the government's always gonna have to be at the basis of these big missions or?

CHARLES ELACHI:

02:01:44;22

Yeah, in some areas it makes sense for the private to take the lead. But particularly when you are making major investment where there is a big uncertainty, you know, in those things. I think the private sector will be much more

hesitant. Because at the end the private sector wants to see some profit, and that makes sense, I mean, that's what the private sector is in our economy, you know, that's how it is.

02:02:04;08

So the government has to kind of do the high-risk, potential high payoff item. Even if you don't know what's an immediate, you know, benefit of that. And that's where I think our government and the US have done very well in actually in investing be it the National Science Foundation, NASA, National Institute of Health. And some of them are saying, yes, technology and science are very important for our economic and intellectual welfare.

02:02:29;15

And, therefore, investing, even if I don't know what's the outcome, is worth doing. And I think that has been a major payoff, almost and I remind people that we're a very heavily technological society. I mean, literally every few seconds in your life, when you think about it, you are using technology. From your cell phone to when you go to your

doctor and you do the x-ray or you enhance your picture to, wanna use your GPS in your car, to when you go to the supermarket and the price code on the product goes under that laser. When you go to your internet, all of this came out from some major investment made by the government or by advanced labs, you know, or companies.

02:03:10;13

And things were we didn't know the immediate payoff. Nobody knew when we developed the codes for communicating with our space craft that some entrepreneur is going to take that code and put it in cell phones. And be able to develop those cell phones. I wish I knew that, you know, because I could have taken patent on that.

02:03:24;24

But it's those kind of, you know, pushing knowledge and having the beliefs that knowledge will lead you to some economic benefit because some entrepreneur will come up with a good idea, I think is at the heart of our system. And we ought to keep nurturing that because that's how

we keep at the leading edge economically.

18 ELACHI WHAT ARE YOU PROUD OF?

BARRY HURD:

02:03:44;29

What are some of your proudest moments here at JPL, there's, I mean, there's a lot going on but there's gotta be a few things that just stand out.

CHARLES ELACHI:

02:03:50;03

Yeah, I mean, I would say a couple, I mean, there's always never one single one. It's like people tell me which one is your preferred mission and I say well they are all like my children. You know, I love all of them. But on a level I base as most exciting things is when you either land on a planet or you get an orbit around a planet.

02:04:10;12

And the reason it's exciting is because you spend six, seven, eight, ten, sometimes 20 years working on this and it's those few seconds, you know, which make you, either you are a hero or you have lost it. And that excitement in that time will either make you proud when land on another planet.

02:04:28;05

Like when we landed the rover on Mars, that evening I walked out, looked at Mars in the sky and said, "Wow, we just landed on that little dot in the sky." And that really make you feel proud, you know, as a team, you know, which have done that. On a personal basis, in a sense, sometime in my younger days when I was doing missions myself is actually when I see some of the instruments I build actually flying.

02:04:49;26

Because again that's something, a personal investment. And I started on my first mission which was on the shuttle, or first experiment. Here we're a bunch of 20 years old kids, which were trusted in building an imaging radar, I mean, specific instrument is not that important. But here a bunch of kids that we build something and you see it going up in space and then getting scientific data from, it just make you feel good.

19 ELACHI FUTURE MISSIONS

BARRY HURD:

02:05:13;09

And what are some missions down the road that we should be, is another rover going out sometime.

CHARLES ELACHI:

02:05:18;03

Yeah, we are in the process as we are doing now is to take the next generation of rovers, you know, to go to Mars. So the two rovers we have now up there are what we call walking geologists. They do the same function what the geologist does. They can grind the rock, analyze the rock, you know, with an instrument and so on.

02:05:36;17

The next one is what we call a walking chemist. Because we want to go the next step where actually we'll be able to take rocks, grind them, put them in ovens and do a chemical analysis of what's the composition of those rocks or the soil and so on. And that's a step toward the ultimate one we want to do is to do what we call a walking biologist.

02:05:53;22

Because ultimately what we want to see is did life evolve

on Mars? Was Mars a life-friendly environment at sometime in the past? If it was, did life evolve? If it evolved, where is it? If it didn't, why didn't it evolve? So the next rover that we are planning will have a much more extensive capability; to be able to drive for literally tens of miles at relatively high speed; relatively speaking. It will be nuclear powered, so we don't depend on the sun so we can operate day or night.

02:06:22;12

It will be able to go, you know, basically survive for years and years. And have all these chemical instrument capability and remote sensing capability on it. So it's about the size of a small car, if you want. And the question is how do we land that thing, you know, on Mars and we have to come with some innovative ideas to make, 'cause we couldn't land it in air bags. It was too big for air bags.

02:06:43;28

So the approach we took, or we're planning to take on this one is to come very close to the surface and hover and sky

crane the rover down. So it's similar to a helicopter which is sky craning a jeep or a car. So hopefully it will work. You know, it all works well on the computer, hopefully it'll work in reality.

20 ELACHI SEVEN MINUTES OF TERROR

BARRY HURD:

02:07:01;23

Well what is it, you don't know if we're seven minutes and is there real time in space I guess there is, but still it takes you seven minutes to know if it worked?

CHARLES ELACHI:

02:07:07;03

Yeah, well usually what happens, the reason we call them seven minutes of terror, typically take us seven minutes from the time we hit the top of the atmosphere on Mars until we land. So we call it the seven minutes of terror. Now the time it takes for the signal to get here, it's typically ten to 15 minutes.

02:07:22;09

So by the time here we say, "Hey, we are getting to the top of the atmosphere," in reality we have landed. And

somebody, God knows what happened and we are waiting until for another ten minutes to know what actually happened. So it's kind of, you know, when I sit down in that mission operation room and before when we start getting at the top of the atmosphere, you say, it's all done, now we're just sitting down and watching, you know, what happened. But the fact, if I was able to transpose myself at faster than the speed of light, I would know exactly what happened. But we are limited by the speed of light, so it takes ten minutes to get here.

BARRY HURD:

02:07:57;28

Now during that ten minutes, I mean, do people there like shuffle their feet? Do they twiddle their thumbs? I mean, what are some of their rituals?

CHARLES ELACHI:

02:08:01;27

Well it's not shuffling their feet. We are sitting there nervous. We are sitting on the edge of our seat. We are watching all the events which are happening delayed by ten minutes. And the excitement is building, you know, and the anxiety is building. And every time we see

something actually happening, I mean, that's a big relief. See the parachute open, that's a big relief. So, the retro rocket fire, that's another big relief. Until it lands and then usually I say, when it lands I count to three. And as long as I'm getting still a signal, we're in good shape.

BARRY HURD:

02:08:34;07

What about this story about everybody likes to have a few peanuts? I mean, what's that all about?

CHARLES ELACHI:

02:08:39;14

Well that's kind of a tradition which we inherited from, I don't know, 20 or 30 years ago. And I don't know how it started but became a tradition that when we're coming to a critical event, we just pass peanuts around, you know, for everybody to get some peanuts. So I don't know who started it, but it sounded good. You know, whatever helps, we'll do it.

BARRY HURD:

02:08:59;00

I mean, you couldn't get rid of that if you wanted to probably, right? That will be...

CHARLES ELACHI:

02:09:02;04

That will be, if we get rid of it then something doesn't work we'll say, gee, why did, but anyway, tradition sometime is a good thing.

21 ELACHI ENGAGING THE PUBLIC

BARRY HURD:

02:09:10;09

Let me ask you, we were talking before about keeping the public's interest. Does that enter in a big way in what you do? Because I mean, it's been said that like these things are landing on Mars but more people on the internet are like searching for, you know, rock star's names on the day this happens. What, tell me about that.

CHARLES ELACHI:

02:09:26;16

No, if this one, if it's important then I think we do engage the public. I mean, to give you an idea when we landed the two rovers, the number of hits we had on our website hit the record of any website at any time now since then things have evolved. I don't remember it was like a billion hits, you know, which happened that day. I mean, our server went down. So it was clearly an expression of the

excitement, you know, that the people had on it.

02:09:51;09

We typically have 20 to 30,000 students who come and visit JPL. We give them homework or we work with their teachers to give them homework. And kids, you know, love it. When we landed also the rovers, somebody told me, they did this survey, we were on the front cover of every single paper around the world.

02:10:09;02

So that shows the excitement of people, I mean, it's something positive. And I think part of it is that people are striving to see something positive and exciting. All what we hear about the war here and this person killing this person and the economic crisis and all of these things, people want something positive. And exploring, gaining new knowledge, seeing the excitement in the people who are doing this landing, people then I think get more trust and confident that there is something positive in this world. And it is true. I mean, when I look at it, I mean, it's something which is uplifting, you know, and exciting.

And I think a lot of people see it that way.

22 ELACHI THE IMPORTANCE OF OPTIMISM

BARRY HURD:

02:10:46;05

You seem to have an enormous amount of enthusiasm.

Were you influenced by parents or (UNINTEL)? Where did you get this passion?

CHARLES ELACHI:

02:10:51;06

Well I look, I mean, I was always an optimist. You know, my parents use to always tell me when I was a kid and then my teachers said, "Look if you put your mind to something you can do almost anything." And here I came from a relatively poor families. My parents, they didn't even have a high school degree. But for them education and knowledge was very important. And they did everything to help me and my brother and sister, you know, to do that. And it is something that in my mind that's what's uplifting about life.

02:11:17;14

You know, you have to be positive. Somehow I have the belief that if you are positive and uplifting you live longer.

I keep telling my wife, let's not get frustrated about this thing. You know, I'm sure it will pass by, so. So it is important, you know, to do that.

23 ELACHI ADVICE TO KIDS

BARRY HURD:

02:11:30;04

Let's say we have a bunch of school kids in here and are there some lessons you've learned from what you've done? Some advice you can give them for as they start to grow up into this world?

CHARLES ELACHI:

02:11:36;29

Well one of the lessons I learned from the kids is they always ask questions that I have no idea how to answer. You know, we get kids and their first question is and I tell them about the Big Bang and then always the kids say, "Well what was before the Big Bang?" Or, "What is the edge of time?" "What was before time?" And what I tell them, keep asking those questions. You know, because you have to be curious.

02:11:56;16

And it's to encourage their curiosity. Even if I don't know

the answer, you know, if they don't know the answer, I keep telling them when I was your age many of the things I know now were crazy at that time. And nobody knew the answers about them. But you need to keep asking the question. You keep your curiosity and so on.

02:12:13;05

And that's if I have to give any two messages for kid, one, stay curious. And number two, do things you love. 'Cause no matter what you end doing, if you are becoming an artist, a lawyer, a scientist, as long as you are excited about what you are doing, you will do well. And you will enjoy your life. So these are the two advice I give to the kid. They don't have to be doing always science or math. They could be great artists. And we need artists, you know, today.

24 ELACHI MESSAGE TO THE FUTURE

BARRY HURD:

02:12:40;10

But about, you know, you were talking about sending that plaque up with the kids who named it so that their names would be on Mars. We have something in this interview

which we plan to preserve forever. I mean, imagine a couple of years from now you can talk to the future, is there something you'd like to say? A message for maybe the scientists or the people down the road?

CHARLES ELACHI:

02:12:57;25

You know, I'm, for sure, that's an interesting thing is, you know, in my mind you never reach, you know, the full knowledge. Every time we send a mission, every time we do a new experiment, we learn things but we create more questions. And we delve deeply into understanding, you know, of how did the solar system evolve? How thing[s] you know, have evolved. So for future scientists, you are never at the end. I mean, people 100 years ago probably, Edison, thought okay, we know now everything.

02:13:27;01

Well we didn't know everything. We think today we know everything, but in reality we don't know. So you know, and the all, one of the best way to look at that is when I look at pictures of galaxies, I say, wow, there are literally billions of these galaxies, each galaxy billions of stars.

Each stars have planets and imagine the diversity of things which are happening all over the place? So that I think that wonder has to stay with us, even as scientists, we have to wonder about the world around us.

BARRY HURD:

02:13:57;08

What about this one, you were talking about the 20 year old kids who launched scientific instruments into space and JL is mine, now you're managing this, the JPL. Is there something next that you wanna do? Or is this gonna be it? I mean, are you gonna retire from here and take your...

CHARLES ELACHI:

02:14:10;16

No, this is fun. You know, next is the next mission. No, I mean, if I have to repeat my life, I'll do it the same way. I mean, this is exciting thing. I mean, doing exploration, no matter what kind, you know, be it exploration in space, be it exploration at the bottom of the ocean, be it exploration of the desert or I mean, as much fascinated when I go to the Huntington Gardens which is a garden here and I look at the flower and I sit down looking, I say, wow it's amazing how you get those colors.

02:14:39;08

How you get those leaves. Isn't that amazing? All of this coming from that little seed that this thing started. So no, I think I'm, I enjoy what I'm doing. It's fascinating. It's exciting. Everything there is something new every day. There are ups and downs, but the downs is what make me learn to enjoy the ups. You know, so I think now sooner or later I have to retire, you know, but we'll worry about that at that time.

25 ELACHI IS AMERICA STILL A NATION OF INNOVATORS?

BARRY HURD:

02:15:29;07

I mean, is America still a nation of innovators and do we need to have more science education in school? Tell us about that.

CHARLES ELACHI:

02:15:34;26

Yeah, I think one of the great thing[s], I mean, I'm an immigrant. You know, I came here, you know, to go to graduate school and what I like about America in addition to the political freedom and the whole philosophy of America is the spirit of innovation. And even before I

came to the US, always we thought of Americans as people who are innovator[s].

02:15:58;07

They are gutsy, they like to take, you know, risk, I mean, or thoughtful risk. They are upbeat about the world around them. And I saw that in the system, you know, even in our education system. In Europe the education system of my, you know, when I was younger, when I was educated in France, everything was organized. You know, you take this course, you take that course and so on, and that was great.

02:16:21;04

You know, we got good fundamentals. Here, I come here, or you can take couple of courses here, you can take that course if you want to. And you can take that course. You can go to the lab and work in the research on the lab or tinker around in doing things. And that's what create innovation and curiosity.

02:16:35;24

And I think that's important to have it in our system. All

the way from young kids of building curiosity. Human are smart by nature. It's the question do you encourage that imagination and that smartness? And in our education system we ought to keep that in mind of keeping encouraging curiosity and people being, you know, wanting to know new thing or learn new things versus forcing people on doing A, B, C, you know, doing that because that kind of tend to discourage us.

02:17:03;00

And the other one is to show that, particularly in science, it's fun. You know, I'm having a ball, you know, doing what I'm doing. So science is fun, to do that. And not that people who are in white coat, you know, just sitting in the lab all their life. As a geologist I do all kinds of things. I have been to like, 50 countries by now going to the most odd places.

02:17:23;20

You know, from Western China to Tibet to Oman to Egypt in the desert and all these places, you know, so I include both armchair adventures as the same time as doing the

science, you know, that we do. So it is fun and that's kind of we need to make sure that the young kids feel that way. That education and science and knowledge is something fun, so.

BARRY HURD:

02:17:44;17

Do you think that we're not making math and science fun in school? Is that why we...

CHARLES ELACHI:

02:17:48;24

Yeah, there is some extent to it because I mean, you know, watching my two girls, you know, grow up and in their schools. I mean, they were very curious about science and they were very good about science and math when they were in fifth grade and sixth grade and somehow after I think maybe it became either the way we, they were taught, maybe a little bit duller or something, so they drifted away from it or they thought it was too hard or something like that.

02:18:13;29

So I think we need a way to make sure that teachers capitalize on the curiosity, the scientific or the

mathematical curiosity of young kids and try to build on it. And, you know, part of the reason is that we don't have many teachers who have a science background or they understand the science. You know, when you go in many of the other countries people respect teacher, teacher is somebody you respect, that's a profession which is very important.

02:18:40;00

Here I'm not sure we do the same. We respect the football player and the soccer player and the basketball player and the movie star, who are all important, you know, on this thing. But in my mind we should be respecting the teachers, you know, more than any of those people.

26 ELACHI COULD AMERICA LOSE ITS INNOVATIVE EDGE?

BARRY HURD:

02:18:56;01

Do you think America is in danger of losing its innovative edge?

CHARLES ELACHI:

02:18:58;26

There is that risk. If we are not careful, there is that risk. I mean, America have gained its edge for two reasons, one

in spite having a good educational system. And the other one is by welcoming immigrant. You know, people who come, like myself who came here for education and loved the country and we stayed here. And we're risking on both of them.

02:19:19;20

One we are becoming now more, I don't want to say antagonistic but not as welcoming for having immigrant come to the US, particularly educated immigrant because of security issue and concern and economic issue. And that's going to set us back. Because then what these educated people will do, they'll go back to their country and they build factories in their country and all of sudden we have more competition.

02:19:42;22

And the other one for some reason science have gotten a little bit less and less as very important to educate. So one of our jobs, try to keep that excitement, to keep sending the message to, be it people in the political world as well as, in the community that our economic welfare is

critically dependent on our scientific and technical, you know, promise, if you want. And that we need to all work to make sure the young Americans, as well as future immigrants, see that this is an exciting thing to do. And that is critical for our economy.

27 ELACHI THE ROVER IS A WALKING GEOLOGIST

BARRY HURD:

03:00:50;29

All right, tell us which rover this is and point out some of the things that make it do its work.

CHARLES ELACHI:

03:00:55;16

This is an exact replica and a full-size example of the two rovers we have on Mars, Spirit and Opportunity. And basically, think of them as a walking geologist. So, when we were trying to design them and so on, we thought, "Okay, when a geologist goes in the field, first thing they do is they look." So, here you have stereo cameras, you know, which are in here. This one and this one, which will give you the same view as it's your eyes.

03:01:18;02

So, you get the, which is in stereo. Then, the thing, then

the geologist, if they see an interesting rock, they go and grab it. So, we have an arm here, which has the same flexibility as your arm. You have the three joints, like the shoulder, you know, the elbow and the wrist. And then, at the end of it, here, you have the scientific instrument. And what the geologist does, they'll grab a rock.

03:01:38;19

The first thing they do, they have a hammer and they break, you know, they break the rock so they can look at fresh, you know, the crystals in there. What we have here, we don't have a hammer, we have we call a "RAT," which is a Rock Abrasion Tool, similar to what the dentist does, you know, to brush your teeth, except a lot more expensive. And that's what will brush the surface. And then, we have a little microscope like the lens. And we start looking at the detail, you know, in that rock.

03:02:02;02

So, it's literally, what a geologist does in the field. But in addition, what we have here, we have X-ray and what we call gamma-ray instrument, which we'll put on the rock

and it'll tell you what are their composition. And we have infrared cameras, which will tell you about the heat emission, or, so you can see similar to the night goggles that people use. So, these are the scientific aspects.

03:02:23;07

Then, once you do the science, then you say, "Well, in addition, I need to have power." So, these are the solar panels, which rely on the sun. So, this is exact height. Then, you have to communicate with Earth, you know, whatever data you get. So, you have the two antennas. That antenna, this antenna, and we have a third antenna. This one communicate directly with Earth. The other one communicate with orbiting spacecraft and then the spacecraft relay that down to Earth.

03:02:46;23

Then, you need to be able to walk, so you have the wheels that you have in here. There are six wheels. And we have to design them, each one is independent, so we can turn them independently, move them independently. So, this thing can spin on a dime, in its location. And then, you

have the suspension that we came up with so you can drive over rocks, you know, without really moving too far. So, that's kind of the basic ingredient.

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And then, of course, you have the computer, which process all the data and handle all of those mechanism. Now, at launch, when we launched it, we had to fold this thing, you know, like, this one was folded in. This one was folded in. So, we can put it in a smaller volume. Because the smaller we can get it, the easier to put the heat shield, you know, and the airbags around it. So, it's like a dolly. You know, we have to really twist it all inside a little box. And then, after, it had to unfurl, you know, once we landed on the surface.

03:03:37;03

So, the next rover we are thinking about is about four, five times the size of this one. So, it's about a car-size rover. And we will not be using the solar panel, because we want to operate day and night. So, we'll be using a nuclear power generator. Also, we will have ovens on top of it, so

we, the arm can grab samples and actually put them in the oven, crush them and put them in the oven so we can do the chemical analysis.

03:04:03;14

So, it's the equivalent of a chemist. But, the functions, the rest of the function have to be similar. We need to have cameras, we need to have communication system. We need to have electronic. The wheels on the next one is about this big. So, it's about three times the size, you know, of this. But we are learning, step by step, we are leaning on that.

28 ELACHI THE ROLE OF MUSEUMS

BARRY HURD:

03:04:20;02

Let me ask you as we stand, this is a museum. This is a replica and you were talking about people need to be constantly curious. We have to encourage our young people to be curious. What role do you think a museum could play in keeping this curiosity and this innovative spirit alive.

CHARLES ELACHI:

03:04:34;04

Well, it kind of give people a little bit of a feel of what's up there, you know, reality. I mean, you can touch this instead of seeing it on a computer screen, or you see it in a picture. You know, we can fold these things so people can see how do we actually mechanize them, you know, and how we do that. And it's for posterity.

03:04:50;06

I mean, in a sense, if you know, we have in this museum the first rover we flew to Mars, which was called Pathfinder, which was about six years before this. It was about this big. So, that shows the evolution of our, if you want, intelligence or knowledge, going from that little shoebox, you know, rover, to this one, which is much more capable. And then, we have, in some location, we put, also, the new rover next to it.

03:05:13;16

So, it will show you a little bit the evolution of our knowledge, the same way you put a little propeller airplane next to a two-engine airplane next to a 747 next to a, you

know, jet airplane and so on, to show you how the knowledge have evolved and the capability have evolved.

BARRY HURD:

03:05:30;03

And you think preserving these artifacts in different museums will help in innovation?

CHARLES ELACHI:

03:05:34;10

Oh absolutely. I mean, because, I mean when I go and visit museum like the Ford Museum, I'm absolutely fascinated with how did they start those first machines? Now, some of them might look routine to us now, but I tried to transpose myself to, at that time, all that you had are horses and carriages. You know, and how did you move to the cars and the, how you move to those big trains and so on. So, I think preserving the evolution of our knowledge is something fundamental, you know, to learning something about the future.

29 ELACHI LEARNING FROM OUR MISTAKES

BARRY HURD:

03:06:03;26

Let me ask you about this. I don't, last night, it didn't go well. And you've gotta now go, when you talked about

keeping people's spirits. Tell us a little bit about what happened and then what you're gonna do.

CHARLES ELACHI:

03:06:14;21

Yeah, no, I think what happened is, we were launching a satellite and the launch went very well. It was an earth-orbiting satellite. The launch went very well, but few minutes after it, the first thing we have to do, there is a fairing that you have to open so the satellite can be ejected. And that fairing did not open. So, in effect, you know, the whole satellite came back into the ocean.

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Clearly, that was a major disappointment. You know, people have worked on this mission for five, six years. And that was a major disappointment for them. But, after the first half hour of feeling bad about it, my next reaction is, "Okay, now, how can we replace it? You know, what do we do next? You know, how do we lift back the team up and then go for the next thing?"

03:06:53;22

And as I said earlier, setbacks are going to happen. You

just ought to be prepared, you know, to overcome those setback. Learn from what happen. I mean, now, we're going to do an investigation, see why did that thing did not open and then learn from it. So, the next time the same thing does not happen.

BARRY HURD:

03:07:09;13

So, there's no sense of blame or any...

CHARLES ELACHI:

03:07:11;10

No, I mean, but I never, my first reaction is definitely not to blame, my second reaction is not to blame. My third reaction is not, the first reaction or second and third reaction are to be, "Okay, now let's see, what do we learn from it. And that, what do we, you know, move ahead? And how do we overcome this?" The blame comes, I mean, not even later.

03:07:30;15

I mean, usually, the way I look at that is you are in a very high-tech business, very risky business. If people did something irresponsible, then that's something. But if people did their best and still there was a setback, that

should be accepted, you know, in this business. And we ought to move on.

30 ELACHI INNOVATIONS IN ROVER DESIGN

BARRY HURD:

03:07:48;09

On this particular replica, what, is there one item that was, like, the major innovation? Was it the arm in front, or is everything, like, brand new, or?

CHARLES ELACHI:

03:07:56;22

Well, there were a fair number of innova[tions], I mean, first, the solar panel had to be much more efficient than the typical solar panel. The suspension system, to be able to drive over, you know, over rocks was very important. The torque on the wheels is about the equivalent of a torque of Sherman tank, you know, because, you know, to be able to move. I mean, we move very slowly.

03:08:15;07

But it, you have to have a lot of torque, you know, to doing that. The scientific instrument are always very advanced instrument. Putting, you know, a drill, putting an x-ray instrument in this size, you know, all require

miniaturization. And all of these would have some technical benefit downstream or economic benefit, 'cause people then can use this X-ray machine maybe to go move around and, you know, do some X-ray imaging. So, all of them have innovation which came in them. And then, how do you fold it, put it all together required a lot of mechanical innovation, which goes with it.

BARRY HURD:

03:08:45;23

And how long did it take from a clean sheet of paper, if that's the right starting point to...

CHARLES ELACHI:

03:08:50;22

Well, that, this...

BARRY HURD:

03:08:51;02

That seven minutes of terror?

CHARLES ELACHI:

03:08:51;13

This one, we had a big pressure on moving on it, because when it was decided, it were three years away from the best opportunity to go to Mars. We can go to Mars every two years. And the opportunity changed, you know, how big a launch vehicle you need and so on. So, when this

one was approved, we were only three years away. So, this was a mad dash. Typically, it takes anywhere from four years to seven years from the time you get started.

03:09:16;26

That mean, it's not a clean sheet of paper, but you still don't have a lot of detail, until we are ready to launch. Then, the next challenge, as a matter of fact, a longer challenge is how do you get there? In the case of Saturn, it take us seven years to get to Saturn. In the case of Mars, it's only six months, so that's much easier. And also, the other challenge, how long it take you to convince the political side to fund the activity.

03:09:37;20

So, I compare, like, in the case of Cassini, it took us seven years to convince the government to fund it, seven years to build it, seven years to get to Saturn. So, it took us 21 years from the time we started until we started getting the science data. So, you have to be very patient in this business.

31 ELACHI DEEP-SPACE EXPLORATION

BARRY HURD:

03:09:56;09

And can you tell us the first, sort of deep-space exploratory craft, was that Voyager?

CHARLES ELACHI:

03:10:01;15

No, no, we had a number of ones before, like, we did the fly-by of Venus. The first one which went beyond the lunar orbit was a mission which flew by Venus. I think it was called Mariner, Venus, Mercury or something like that. So, that was one of the very early, that was about, in the early '60s that that was launched.

BARRY HURD:

03:10:18;14

And already they're still out there, way on the edge of...

CHARLES ELACHI:

03:10:20;28

Well Voyager is here. Voyager is still flying. Voyager went and visited all the large planets, Jupiter, Saturn, Neptune and Uranus and then Neptune. And now, it's leaving the solar system. That mean it's going beyond the boundary of where the sun impact, you know, transition into the interstellar medium.

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So, that's a total of almost 30 years, you know, that that machine has been working. And to give you an idea how big our solar system, the signal we receive at this instant of time from Voyager was sent 24 hours ago. So, it takes 24 hours at the speed of light to get that signal from Voyager to here.

BARRY HURD:

03:10:56;11

You ever think of that thing out there and...

CHARLES ELACHI:

03:10:57;29

Yeah, every once in a while, we think about the, if we were sitting there, what would we see? And what would be the environment? So, it, yeah, that sometime you need a lot of imagination to do that.

BARRY HURD:

03:11:09;06

Okay, let's pause just for a second. We cool? Thank you so much.

CHARLES ELACHI:

03:11:10;28

Okay.

BARRY HURD:

03:11:10;28

I think that's it.

CHARLES ELACHI:

03:11:10;28 Sure.

32 ELACHI TEDDY ROOSEVELT IS MY HERO

BARRY HURD:

03:11:15;13 You have heroes?

CHARLES ELACHI:

03:11:16;09 Yeah, I think the person who fits the best in and I use him always and his quotes, is Teddy Roosevelt. And the reason is because he was bald and he appreciated in all his statement that sometime failure is okay. It's better to try and even, every once in a while, fail than what he calls "stay in the twilight" and not dare to do anything.

03:11:36;18 And, in my mind, it fits the perfect model of what we need to do in exploration, is you always try, and then you can savor the joy of success, even that every once in a while, you know, you have a failure. So, he's a guy I use always, you know. And he had all kinds of very thoughtful quotes. So, he's my hero.

