Science and space travel

Transcript of public lecture on "Science and Space Travel" by former NASA astronaut Joe Edwards Jr at the Royal Irish Academy in Dublin on 14 November 2007, as part of Science Week.

Science and space travel – part one

Padraig Dempsey: "Good evening ladies and gentlemen. My name is Padraig Dempsey, and on behalf of the Academy and Discover Science and Engineering I would like to welcome you all here tonight for this, the second of our Science Week lectures. This event is what we call a 'public conversation' or 'public interview'. So what that means basically is that it gives you more of an opportunity to interact with our guest and ask your questions, so we hope you avail of that.

"Tonight's guest is ex-NASA pilot astronaut, Joe Edwards Jnr, who piloted the last US crew member to the Russian Mir space station and flew the closest flying manoeuvres around an orbiting space station in the history of man's space flight. The MC tonight is Leo Enright, well known broadcaster and journalist, and I hand you over to him now."

Leo Enright: "Thanks indeed for that Padraig. Failte mór díobh go léir go dtí an áit starúil seo, óg agus aosta. This is a very historic venue. The Royal Irish Academy has been promoting science for centuries. Many of the great scholars who have been members of this institution have contributed to our understanding of space and time. Some day, when astronauts are flying close to the speed of light to distant galaxies, they will be talking about the Fitzgerald effect, named after a great Irish physicist in Trinity, just up the street here, a member of the Academy who made some of the great contributions of the twentieth century to our understanding of the time-space continuum.

"We won't be going anywhere near as fast as that tonight. I'm very pleased to welcome Joe of course and I'm sure many of you have had a chance to talk to him already. We'll have plenty of opportunity this evening because this is a very relaxed evening of conversation. If you gentlemen feel more comfortable sitting around here on the floor, please feel free to do so. If any of the young people want to come and join us on the stage you're very welcome. We are just going to have a conversation. We would hope that particularly the young people will join with us in exploring space, which is a rather big place.

"Could I begin, before I talk to Joe, with just a little story? I got a phone call this afternoon from a woman down in Cork, Mary Deegan. The Deegans would be well known to Cork people. They run the big opticians shop there, just off Patrick's Street. Mary rang me to say that she'd had a phone call from her son-in-law. Now, as it happens, Mary's son is an astronaut, Dan Tani. Dan rang her from the space station where he lives. He lives in outer space. He rang her this afternoon and said, 'How's the weather?' Mary says, 'You rang me long distance from outer space to ask me what the weather's like?' 'Ah yes,' says Dan 'We're just about to fly over Ireland and I was wondering if it was worth getting out a camera.'

"So I mention that story by way of introduction because, as I mentioned, Dan is actually living aboard the space station. All his friends down in Kinsale and in Cork city will be following his flight quite closely. To everybody's great delight, Dan managed to take a space walk. I don't recommend doing this without a space suit, but he got out of the space station and he walked around in space doing some extraordinary engineering work. And he took a little bit of time, just a little bit of time, to enjoy the view. So I thought we would begin the evening, this was recorded in outer space about ten days ago as Dan Tani was in orbit. So we'll roll that piece of video."

Video: "Houston alpha step four, you have a go before turn to auto track. Houston copies. And by the way we can see beautifully from the [unclear]…I bet it's awesome. This is it. It's beautiful sky. And Dan? Yes? Are you there? On your left you can wave to Ireland and all your friends. Cool. I can't see it – it's cloudy of course because it's Ireland. Oh, I see some land over there. That's great Paul. Tell all my friends and family that I can't wait to get back there and tell them all about this. Wow, there's a moonrise over it too. That's fantastic. OK [unclear]…."

Enright: "That's Dan Tani. He had just a few moments to savour the view as he passed over Ireland. Joe Edwards, it's wonderful to have you here. Thank you very much for coming. What does Ireland look like from space?"

Joe Edwards: "You know in daylight, in a daylight pass, it looks like the little green jewel that it is. One of the fondest memories I have of flying over Ireland is a night pass during STS89 when we crossed the east coast of the United States and the sun set and as we were going across the Atlantic. We got a call from our geologist on board, Jim Reilly, who, as you might expect, has quite the Irish heritage himself, and he saw a little bit of land out there. And you know at night, flying over the Earth, you don't see land masses. All you can see are the little lights of civilisation outlining all the populated areas. So coming up on the horizon, from two hundred and fifty miles up was this little island. So he floated up to the cockpit and said, 'Joe, you know what that is?' And I said, 'Well Jim, you are the geologist here, if anyone should know what that is, you should.' And of course, it was Ireland.

"And as we…you know flying at seventeen thousand three hundred miles an hour, we passed over Ireland and the British Isles, over the English channel, over France, into the Mediterranean, over Sardinia, we could see Sicily out to the right, and then over the boot of Italy. All of it in one pass, all of it at night, where you could not see any international borders at all, you could just see where all the human beings had populated this planet and turned on their electric lights. We flew over, for Jim and I, everything that was kind of associated with us, you know, back to the beginning of humanity. Our ancestors came from this island, as well as, in the case of myself, Scotland, Britain and France, the Normandy invasion in 1066; and then all of the flying we had done in our careers, the Mediterranean, during the Cold War and what have you, it was all encompassed in, literally, seventeen minutes, that flight. So it was a very beautiful thing and in my experience, the only thing that's ever surpassed the beauty of Ireland in the daytime, is Ireland at night, from two hundred and fifty miles up of course."

Enright: "We've a great plan. The plan is that the people of Kinsale, just before Christmas, they're going to organise to switch all the lights off, all the lights on, off and on, so that Dan will be able to spot Kinsale. It'll be blinking out there in the darkness. You mentioned there how far you travel and how quickly. I suppose a lot of us don't really appreciate, this is a hundred tonne space plane travelling at, what is it? Five times the speed of a rifle bullet?"

Edwards: "You know, in a way, it sounds pretty pedestrian when you talk about time travel and Star Trek, or science fiction, you know, what we do in the space programme. But the space shuttle Orbiter is a pretty remarkably designed vehicle. It's remarkably designed because of the sound engineering and science that went into its design and construction, and the astronauts that fly it try to equal that in their proficiency.

"The vehicle starts at zero miles an hour and in eight minutes and thirty-two seconds. It's travelling over twenty five times the speed of sound and then it exits the Earth's atmosphere and circles the Earth at seventeen thousand five hundred miles per hour. So that's… the Sun rises and sets every forty six minutes and one rev is ninety two minutes long. Maybe to a very young person that reads Arthur C Clarke or watches the science fiction shows on cable television, it honestly can seem kind of pedestrian. But when it's your body in that spacecraft, in that rocket ship, it doesn't seem pedestrian at all."

Enright: "Do you have a sense of moving at that speed?"

Edwards: "Your body does not sense velocity. An example of that is, right now we are moving at around a thousand feet per second, that's the speed, the linear velocity of the Earth's rotation at the equator. But you do have a sense of acceleration. And if you have objects to reference, for example the Earth, clouds and particularly land masses, you're actually going around the thing pretty fast. For instance, when Dan was mentioning, 'Is it cloudy today in Ireland because I want to take a picture of it?' if you're going to take a

picture of a spot on the Earth as you orbit it, you can't wait until you see it. You have to have a camera set up, set the lens and the speed and everything and be ready for it to come because there won't be enough time to see it and then set yourself up. So, the answer is yes."

Enright: "I know someone in a few minutes is going to ask, 'How come we don't all fly off the Earth if it's spinning that fast?' but we'll deal with that when we come to it. The sunrises and sunsets, they must be absolutely gorgeous."

Edwards: "If you look at this picture here, this image is of a sunset in space and it's taken with a telephoto lens and when you look at this image you kind of get the sense that this atmosphere is very robust but from space, without a telephoto lens, it's this very thin sliver. There are not very more beautiful things I've seen in my life than watching the sun rise and set from space, because it happens very quickly and you can even see the shadows lengthening on the ground if it's the pass in which you're watching the sun set."

Enright: "What scares me about that picture is I get the feeling, the impression, that if you're looking at the limb of the Earth, the edge of the Earth from orbit, your pinkie would cover the entire atmosphere."

Edwards: "Oh yes, much less than that. It looks about as big as your fingernail is thick. Humanity, in fact all life, has had a huge impact on the planet and will have a significant impact on how it is developing in the future. The fact is that we are the only species that we know of in the universe that can not only impact that but give ourselves the opportunity to populate other bodies in our solar system, perhaps even in our galaxy. That's the most basic, that's what we're really doing in NASA, is exploring the universe."

Enright: "Now I think we all agree that you've managed to make us all green with envy to watch this from almost a God-like position in the sky. How do you get to be an astronaut? How did you start?"

Edwards: "Well, let me move to a different slide here. Apart from good looks there is no real secret to the whole thing. Astronauts come in all shapes and sizes. Men, women, they are all nationalities. I can't tell you the number of times in the last forty eight hours that I've had people say here, 'We're just waiting until an Irish astronaut flies.' I don't know if there's a family who emigrated in the last hundred years to the United States who doesn't have Irish blood in them in some form or fashion. Myself, easily one half of me is Irish, and John Young certainly is and he did it long before I did – so many Irish people have flown. The next comment I got was, 'Well, we'd like to hear someone with an Irish accent.' And I said, 'Well, a good six months in the States and we pretty much turn you into some sort of accent, you just pick one part, one region of the country that you'd like to speak.

"We have military pilots who are astronauts, we have doctors, we have a veterinarian, we have scientists and teachers. But myself, to cut a long story short, I started out in military aviation. I was a Navy fighter pilot, a US fighter pilot. I was a test pilot. In fact, all the pilot astronauts we have at NASA and always have

had are former military test pilots. Why is that? There is no military aspect to the programme, but the military is really the only place in the world – and it doesn't have to be the US military, could be Canadian, could be Russian – that you can get the experience quickly enough that you can actually pass the flight physical to enter the place.

"For all the young people out there, the average age of an astronaut when he shows up at NASA is thirty-five, which sounds really, really old to a few of us in the audience – to other people I see out there it doesn't seem old at all any more. I feel the same way. That basically is my story of how I showed up there.

"You know you have to pass a pretty rigorous physical but more than anything, you have to be interested in the line of work. And you know, as a young person, as parents out there like myself, you can see that in a young person fairly early. An interest in maths and physics, those are the heart of what we do at NASA, and without it we wouldn't have a space programme at all."

Enright: "Tell us the story of this picture. It's quite interesting."

Edwards: "This is a - I'll make this really short - it's a…back during Desert Storm actually, in 1991, I was flying this particular airplane. It's a picture of me landing it. The entire front of the airplane, the nosecone, came off. You see the airplane at the very top of the picture? And you see the picture that's in the middle? You don't have to be an aerospace engineer to know that generally you want the nose of an airplane to be pointy rather than flat. So this thing came off smashed into the canopy, injured me, blinded my right eye, broke my collar bone, collapsed my right lung and broke my right arm, destroyed all the flight instruments. And we were going at about six hundred miles an hour at twenty-nine thousand feet at the time. It was just a material failure of the thing.

"We had to bring it back and land it and frankly, I was thirty-five miles from the ship and one hundred and twenty five miles from a little island in Bahrain in the Persian Gulf, and I thought my backseater was severely injured or worse, so I wanted to get him back to the ship where I knew he would have good medical attention, so I had to bring the aircraft back and land it on the boat. And I was very fortunate.

"Couple of things, one is that I had landed on the aircraft carrier six hundred and forty-nine times before that and I knew that this was going to be my last carrier landing because, you know, they don't keep Navy pilots out there that only have one eye. I ended up literally having to hang my head out of the cockpit at one hundred and sixty miles an hour, close one eye and land the aircraft with no instruments. May sound cool. It wasn't really. You know, it was a really good day, but there was one microsecond of it that was really, really bad.

"But it's an example of team work. You see it on the athletic field, you see it at NASA, on the aircraft carrier as well, because there's a whole team of people, the flight deck crew, the captain of the ship and what have you, who do a lot of things that actually allowed us to use the backup procedures and actually land that aircraft on the ship. And it's no different at NASA. I have the great honour of being with you here tonight but the engineers, the scientists, the technicians, who design, build and maintain the space shuttle Orbiter, or the Mercury, Apollo or Gemini spacecraft, they don't have the opportunity to spend some time with you. So we put a little video together for you here.

"The audio is not important, but we tape every landing on the ship. I was a very handsome man before this happened. I told you the story before I showed you the video because the video makes it look really, really easy, but man it wasn't, I have to tell you. OK, we'll go to the next slide, thanks."

Science and space travel – part two

Leo Enright: "And that, of course, is the cockpit of the space shuttle, and you got to fly that. It must have been a breeze compared to landing a crippled aircraft on an aircraft carrier. You were talking earlier about the speed you go in orbit and getting up to that speed must be a very violent event."

Edwards: "It's actually incredibly smooth. It's a very well designed vehicle. This is the cockpit. There are over two thousand switches just in the cockpit of the space shuttle and it's really about as complex as that aircraft carrier that I used to fly on and off of when I was in the navy, except that it's operated by only seven people. There are about fifteen systems in the vehicle, whether the computers, the electrics, the hydraulics or what have you. Each of those systems is as complex as one airplane, so it takes a lot of study. And if you want to become an astronaut, you really start laying the foundations when you're five or six years old in the academics and sports you participate in throughout your whole life.

"So we thought we'd show you – if you could go to 'video' – we'd show you just a little bit of a space shuttle launch.

"It's really a pretty remarkable vehicle. It weighs four and a half million pounds at launch and produces seven and a half million pounds of thrust to continuously accelerate the vehicle for eight minutes and thirty-two seconds to get it safely into orbit around the Earth. During the assent, the three engines in the back of the space shuttle, the main engines, are pumping liquid hydrogen and liquid oxygen at a temperature of minus 300 degrees at a rate of one swimming pool's worth every second for eight minutes and thirty-two

seconds to get you into orbit. We really want really good scientists and engineers designing this thing, you know what I mean?

"Two minutes and ten seconds into the launch, at 3.7 times the speed of sound and an altitude of 150,000 feet, the solid rocket boosters that you saw there are jettisoned and the vehicle continues uphill on its back, powered by the three space shuttle main engines, until main engine cut-off, at which point you become instantly weightless.

"It takes us about eight and a half minutes to get to orbit and at two minutes into the launch itself, two of the three rocket motors that power the vehicle, the two on the side, the solid rocket boosters, kind of burn like a firecracker really, they have a solid fuel in them. And when that is expended, the computers jettison them from the vehicle so that you don't have the drag. Those solid rocket boosters are recovered by parachute and we reuse them for all the space shuttle launches."

Enright: "Aren't you afraid to get into that thing?"

Edwards: "No, actually. Maybe insanity is a prerequisite to be an astronaut. But no actually, we're not. If I didn't understand how to fly the vehicle, if I didn't have a thorough understanding of the eighty-two pounds of documentation that we take on orbit of how to operate it and how to handle emergency and what have you, it probably would make me a little bit nervous. But it doesn't because, you know, we man up the vehicle knowing that we can do anything that is humanly possible to manage the vehicle throughout its mission, and if it's not humanly possible it just doesn't matter."

Enright: "Are you disappointed that President Bush has decided that the space shuttle should stop flying – that by the end of 2010, that's barely three years from now, there should be no more space shuttle missions?"

Edwards: "No actually. It's time to get out of lower orbit, that's our opinion. We'll talk a little bit about orbit later, about what we're going to do after the space shuttle but there will be no replacement for the space shuttle – the next vehicle will not have the versatility the space shuttle Orbiter does. It will be designed for an entirely different mission, a mission that NASA and the astronauts have wanted to embark on for well over thirty years now."

Enright: "On your mission on the space shuttle you went to a space station."

Edwards: "We went to the Mir space station. The International Space Station is orbiting the Earth today. The flight test programme to build the International Space Station was a series of missions that we flew to the Russian space station back in the late 1990s. Space station Mir - anyone here speak Russian? Mir means peace or Earth in Russian – was a vehicle about half the size of a football field. It was launched in

1986, intended to have a life of only three years, but lasted well into the twenty-first century. So we constructed part of Mir, we sent American crew members up there for long duration missions and we learnt how to rendezvous and dock with the space station with the two hundred and forty tonne space shuttle Orbiter."

Enright: "And, of course, you also learned how to work with foreigners. It was the first real international effort to work together in space."

Edwards: "Very true. Through the Cold War, you could have actually knocked me over with a feather if you had ever told me I would actually fly with a Russian cosmonaut on the space shuttle. But as a matter of fact I did in [unclear] Sharapov, and we had American crew members with those guys as well. And what we found out is of course we had a thousand things in common, the astronauts and the cosmonauts did, and astronauts of all nationalities. And also that the language barrier early in the programme really wasn't much of a barrier at all because we had the common language of science and engineering to talk to each other through, and it actually made things very easy."

Enright: "The whole business of living in space, obviously if you're like Dan Tani or any of the people he lives with currently, the commander on board the space station, they have to live normal lives as well as do their experiments. How can you conduct any sort of normal life when there's no up or down, and all your body fluids are redistributed and…"

Edwards: "It sounds pretty gross."

Enright: "It sounds like it could be pretty gross."

Edwards: "Well, I guess the answer is that becomes your normal life. If this vehicle, if this room were a spacecraft, we would not be limited to just working here on the floor. We could work on the walls, we could hang off the ceiling. We'd have a tremendous amount of volume to…"

Enright: "Don't try this at home, OK? Don't try to hang from the ceiling."

Edwards: "If you figure out how to do this, clue me in. So the things that on Earth seem to be abnormal, such as hanging from the ceiling, working on a computer and what have you, just become part of the normal routine when you're on orbit."

Enright: "Is it true that astronauts are told never, ever, ever to burp?"

Edwards: "No, not at all. I think we're probably gross as individuals."

Enright: "Is it not true that some things that you would take normally for granted on Earth, you have to be very careful about when you're in space because stuff might come up?"

Edwards: "There are some bodily functions that gravity is a tremendous asset for, that you don't have that in space. But in space, the advantage that you have is the ability to move objects of very large mass. If we were in space we could take a refrigerator and move it with our finger in this room.

"But the down side to being in space is, if I can borrow this prop, if I had a set of procedures here from which I was working on a piece of equipment, and if I were in space and just released it, it would float – and I can tell you from personal experience – to the most remote corner of your spacecraft, through passageways and everything, and you'll never find it until after the end of the mission. It's the most amazing thing. So that is why at NASA we probably use about half the world's supply of Velcro, because if you're done with something, you stick it somewhere so that you know where it is."

Enright: "I saw a very clever trick recently, and there's lots on NASA television nowadays which is available online – if you have a decent broadband connection, which most, some schools have now, most and all should but some schools do – you can actually watch the astronauts in the space station go about their daily work in orbit. And one of the clever things that I noticed was Peggy Whitson had a big sheet of plastic and she taped it to the wall. Every time she needed to look at something, to read something, she shoved it in under the plastic and the plastic kept it in place."

Edwards: "Yes, that's pretty imaginative. They're the kind of engineering solutions you come up with when you spend a few months up there."

Enright: "Yes, I was quite impressed. I think that young lad there wanted to ask a question. Go ahead."

Audience member: "I forget the question."

Enright: "Oh right, well when you think of it we'll have plenty of opportunity, we're going to spend quite a bit of time having a chat."

Edwards: "I think there's one right behind."

Enright: "Yes, we'll take all the questions."

Audience member: "Why not use robots instead of humans on the shuttle?"

Edwards: "In fact we do. Right now there are over two dozen robotic spacecraft that are exploring just our solar system. We have one spacecraft that has actually left the solar system, Voyager. So the exploration of space is really complementary, using both manned vehicles and robotic vehicles."

Enright: "That's an extremely good question. Well done. That's a common controversy in the business. We have a young lady just behind there."

Audience member: "In 'The Simpsons' when Homer went to space, he opened a bag of crisps and they started floating into the air and he was able to eat every single one of them while crashing an ant farm. Would that be able to really happen?"

Edwards: "OK, let me restate that. I've got to say that we got the biggest kick out of that episode of 'The Simpsons' when Homer is floating through the space shuttle and munching on the crisps as he goes along, and I have no video to prove it but I can tell you that, yes, it has been done, and multiple times. And not just with crisps either. M&Ms are kind of a favourite – little easier to get those things into orbit."

Audience member: "Even Maltesers?"

Enright: "Maltesers? Yes, these are very good questions and you're exactly right, Maltesers would be terrific."

Edwards: "We're covering the important aspects of space flight."

Enright: "Absolutely. I saw a man in orbit recently, eating, or drinking Japanese tea, with chopsticks. Now that's some trick."

Edwards: "It's an interesting thing, to go back to what's it like in space. Let's imagine that this is a squeeze bottle of some sort, that there's water in it. If we were to hold it here in the air and squeeze it, all of this water would come out…"

Audience member: "In bubbles?"

Edwards: "…No, not in bubbles, it would come out in a sphere, in the shape of the Earth, and surface tensions would hold all of those molecules together. And it would sit there and it would float like something out of a science-fiction movie. And you can actually squeeze it out and then take a straw and slurp it up. And it doesn't work quite as well for the camera if it's clear, but if it's a strawberry drink, it's all over the place. You always end up with it on your face every time you do it."

Enright: "The bubbles is an interesting question. In fact, one of the Irish experiments aboard the International Space Station is by a very distinguished member of this institution, Dennis Weir. It does, in fact, involve exactly that, bubbles. And he's using the space station because there's no gravity, to study the way that bubbles perform in weightlessness, where they float around and there's not gravity pulling them down. Your point about bubbles is very well taken."

Edwards: "I should probably mention something here – the occasional antics that you may see being performed by astronauts is not the routine. In fact, every minute of every day is scripted, it's oversubscribed with regards to what the crew have to do. The media love to show the pictures of the spinning banana or a floating sphere of strawberry drink or whatever, but the fact is, the only reason we ever do that stuff is, there's really no time to play around, we do it to take some images of some things that are kind of funny on orbit, in particular to take back to the primary and secondary school faculties in the States and try and capture young people's imaginations."

Enright: "In fact the company that are filming here today have actually filmed aboard the space station exactly that, the toys in orbit and the physics of weightlessness and what happens to various objects when you introduce them into a new environment. There's a whole set of videos – if there are any teachers in the audience that are interested – produced by Agtel aboard the space station with the European Space Agency over the past few years.

"Actually, let's talk a bit about the European involvement. Obviously the big, big European thing is the launch, hopefully, everyone cross their fingers, hopefully the European Columbus module will launch aboard the space station next month after twenty-five years of development and delays. It's finally going to be launched to the space station to allow European astronauts to work in their own laboratory aboard the International Space Station. Of course, you've worked with Europeans at NASA, we have quite a few now attached to the astronaut corps. The whole Columbus module, this is obviously the next step, it makes the space station so much bigger."

Edwards: "It does. This is a picture of the space station pretty much like it looks today, we've just recently attached a new solar ray onto the vehicle. But it's a good opportunity to tell you what's really going on up there. This is not just a very expensive vehicle circling the Earth every ninety-two minutes, it's an orbiting laboratory. The idea is to do research that benefits life here on Earth. Of course, it's a platform to observe the Earth in a variety of wavelengths. We have unmanned, robotic vehicles that can do that. So with all that, do you guys have any idea how much we spend on the space programme back in the States every year? How much?"

Audience member: "Billions."

Edwards: "Billions. Seventeen billion dollars. Now, I'm the first to admit that based on the state of the dollar, seventeen billion is not as much money as it was two years ago, but regardless… Seventeen billion."

Audience member: "So eighteen billion the year before?"

Edwards: "I guess so, I'm with you. For all of the money, that's just one year, that's a lot of money in the life of the programme, do you guys feel connected to the space programme at all? Because to the astronauts, it's not just an American programme. Obviously it's an international partnership today. But do you really feel connected to the space programme? But do you really feel connected to the space programme at all? Has it impacted your life one iota over the last forty or fifty years? Tell me one way, just one. One specific thing that you've encountered in your daily life that has come from the space programme."

Audience member: "Digital watches."

Edwards: "Digital watches, well maybe."

Audience member: "Frying pans."

Edwards: "Not Teflon, it already existed. Velcro existed as well. Do you guys know what Tang is? The orange drink?"

Enright: "It's not a product in Europe. MiWadi would be the equivalent here."

Edwards: "OK. Just one thing, anyone?"

Audience member: "The CO2 emissions and all the atmospheric changes."

Edwards: "Certainly, space-based remote sensing of the Earth and the ability to diagnose things like global warming, climate change, what have you. Did you know there are over thirty thousand things that you encounter in your daily lives that come from the space programme? Name one. No, not cortex – I mean something really specific. Let me give you an example. Anyone ever have an MRI or CAT scan? Anyone here know someone that did? Come on, work with me. I've had one. A couple."

Audience member: "I haven't."

Edwards: "Good for you. Keep it that way. The digital signalling process that we use in MRIs and CAT scans came directly from software development for Apollo so that we could communicate with the Apollo spacecraft when we were going to and from the Moon.

"Have you ever driven on a highway with grooves in it to channel the water away from the tyres? NASA invented groove highways for airplane runways in the late 1970s and now today they're used on highways. Kidney dialysis machines. Freeze-dried food. The first laptop computer was built under contract for the space shuttle in 1981. Anyone here own a cordless power tool? A battery operated drill? Those things didn't exist until NASA signed a contract with a company called Black and Decker to develop the first battery powered tools so we could use them when we were space walking.

"Like I say, there are over thirty thousand things that impact our daily lives, not the least of which is satellite communications and being able to monitor the climate of the planet, but most of them are highly technical, critical parts of machinery that we use on a day-to-day basis. And frankly it's difficult for the scientists and engineers to familiarise ourselves with that kind of technology. I became an astronaut because I wanted to explore space but also wanted to better things for mankind. And that's what we're doing with the International Space Station, doing basic scientific research. It may be surface tension. It could be some sort of applied physics. It could be something that has to do with the climate here on Earth. Basic scientific research to try to better life here on Earth for humanity."

Science and space travel – Part three

Leo Enright: "Well indeed there are some examples here in Ireland of applications of space technology. One that springs to mind immediately is CAPTEC in Malahide who have done a huge amount of work with robotic spacecraft going to the other planets.

"And CAPTEC developed in the course of all of this – very similar to what you were saying about software algorithms to reduce the amount of information you have to carry to deliver a good signal – they developed a system which is now being used by the regional hospital in Sligo to send heart images, three-dimensional images of people's hearts, to specialists in Dublin so that people don't have to travel to Dublin to have their heart ailments diagnosed. So there are definitely applications, even here in Ireland, from the space programme.

"Just to finish the whole story of humans travelling into space and the space station I should incidentally say, just to give you a perspective, before we leave the whole issue of the space station, we're looking along the long axis of the space station there.

"The space station is about the length of the football field in Croke Park – and those two panels that you see there, that span is four times the height of the Cusack Stand. So you're talking about a very large structure. It's by far the largest structure built by humans in space and it's one of the biggest civil engineering projects in history. So as I say, we might have some interesting conversations afterwards about what is the point of all this.

"But I thought that before maybe we leave humans in space, because we want to talk a little bit about Mars and the Moon and the future, did you ever meet any aliens?"

Audience member: "No."

Joe Edwards: "Me neither actually. But I have some measure of notoriety. I'm probably the only person you've ever met that has a two-page spread in the 'News of the World' written about them. In my case it was for bringing alien bodies from the Mir space station back to Earth.

"You know: the American government, all kinds of secrets and that kind of stuff. I don't believe that beings from another planet are visiting this Earth but I probably want that to happen more than anyone."

Enright: "You had a little joke with your friends about this, about this newspaper story."

Edwards: "Yes, we were flying; we flew to the Mir space station in 1998. We came back and this newspaper hit the stands during our – no you can just keep forwarding, we can always come back…"

Enright: "It must be gone. Never mind. OK, I think we've got a few young people here who are just bursting to ask questions."

Child: "How come when the robots have wheels when on Mars they don't float up into outer space?"

Edwards: "Why do you float up into outer space?

Child: "The robots – how do they not fly up into outer space?"

Edwards: "When the robots are on Mars – you know we have a couple of robotic vehicles on the Martian surface today – why don't they float up into space? Mars is a smaller planet than the Earth but there is enough gravity so that these rovers and the rocks that are on Mars and the sand and what have you stays attached to the planet. So it's gravity."

Enright: "Gravity, yes. It's just a little bit less than the gravity you have here. It's not like the Moon. We have a nice picture here actually from the Moon of an astronaut jumping. You can see just how high somebody can jump when they're on the Moon, just to illustrate the lunar gravity.

"That's Dave Scott, wonderful man. He lives in London, would you believe? But if you look closely you can see that Dave is a good metre off the surface of the Moon. And that's not just some huge piece of athletics. That's just a little jump and he suddenly found himself a good metre off the surface of the Moon. So the Moon obviously has a lot less gravity so our questioner probably wasn't entirely wrong in worrying about what would happen if you were on an alien surface. On some of them you could end up leaving the surface.

Child: "How long does it take to make a space shuttle?"

Edwards: "About two years."

Enright: "And how much does it cost?"

Edwards: "Four billion dollars. It's not cheap. It sounds like a lot of money but Bill Gates has about forty billion in cash so…"

Child: "Why is Mars a ball of gas?"

Enright: "Well, it's partly gas but it's mostly rock."

Edwards: "The Moon you mean?"

Child: "Mars"

Edwards: "Mars. Mars is rock. It has a very thin atmosphere. Jupiter and Saturn are two gaseous planets."

Child: "Yes. I meant Jupiter."

Edwards: "They are planets that formed kind of like our sun did but never quite got big enough to become a sun themselves."

Child: "Are they hot?"

Edwards: "They are hot."

Enright: "Yes, actually Jupiter is very hot once you get inside. Good question."

Child: "How hot?"

Enright: "Well, hot enough to melt rock once you get down there, down deep."

Edwards: "Maybe 300 degrees or so. Very hot."

Enright: "Another question here? Did you want to ask a question?"

Child: "How can you sleep in space?"

Enright: "Very good question."

Edwards: "You float. You float in a bag. That's pretty close to the truth. We have sleeping bags that have tethers on them and we just strap ourselves in there. In fact, you have to strap your arms in as well, it's the strangest thing. When you sleep on orbit, when you're microgravity, zero G, and you don't restrain your arms, your arms float up like this. Everyone's do. Like Frankenstein.

"And it's the funniest thing, if you have to get up in the middle of the night and you have to go visit someplace, the men's room or something, three dimensionally you have to float around everyone because by the time anyone gets up in the middle of the night, all the arms have worked loose.

"And these bodies are floating in these sleeping bags and they're all like Frankenstein. You don't want to wake anyone up because you don't get much sleep as it is."

Child: "Do you get uncomfortable?"

Edwards: "No actually, I think it was very comfortable. It was like sleeping on air because you were. It's great."

Enright: "We had a lovely question from a young lady in Limerick who wanted to know do you dream in space. And if you do, what do you dream about?"

Edwards: "About space puppies? About aliens? Actually, no. About aliens attacking the shuttles? I hope not. About the ship exploding? No, I don't think so. You do dream in space but the most vivid memories that you have are of flying in space and sleeping is not dreams."

Enright: "OK, we've been around the Earth and we've been around the Earth and we've been around the Earth and we've gone around, and around, and around, and around. And really you begin to wonder when are we going to stop just going around and when are we going to go somewhere?"

Edwards: "Well, we are actually. We're going to go back to the Moon. In 2010, we'll stop flying the space shuttle. It'll be retired. We'll take the vehicles that are left and put them in the museums around the world and we're going to go back to the Moon. You know how many people have walked on the lunar surface? 12. Why would we want to go back to the Moon?"

Audience member: "To finish work that we started."

Edwards: "That's a pretty darn good answer actually. Anyone else? What was the work that we started?"

Enright: "We've got a suggestion here.

Edwards: "There were rocks that we didn't actually look at yet. OK, that's pretty much the answer."

Enright: "A budding geologist. I absolutely agree with you, you're absolutely right."

Edwards: "Let me give you the answer. This planet, we believe, based on our scientific research, was formed about four and a half billion years ago. About 500 million years into the life of the Earth a celestial body came careening through our solar system and hit our planet.

"And when it did, when this Earth was very young and obviously couldn't harbour life of any kind, it knocked off a huge chunk of our planet, and that body and the chunks that were knocked loose from our world, most of them were retained by the gravity of Earth and they formed, they coalesced into a planet that orbits our planet today that's called the Moon.

"It turns out that most of the Moon is actually that planet itself, it's not from the Earth at all. It's from somewhere else. We assume it was originally a body within our solar system. That's interesting. About 100 million years into the life of the Moon, a huge storm of asteroids entered the orbits of the Earth and the Moon as well. In fact, most of the craters you see on the Moon, and you can see many of them with the naked eye, are a consequence of that asteroid storm. An interesting fact, though, is that we believe that nearly 10 times more material impacted the Earth other rather than the Moon itself.

"Additionally, occasionally rocks from space will track straight through our atmosphere and hit the Earth with such force that pieces of our planet will be knocked off. Some of them will enter an orbit around the Earth and eventually fall back down.

"Others will reach escape velocity and leave the gravitational influence of our planet. We believe that on the Moon there may be as much as 1,000 pounds of earth per square mile on the planet itself.

"Now, today we are only beginning to understand the geological and the climatic processes on our planet and we know that they are changing to a certain extent. We have some ideas as to why they may be changing, but we are pretty sure of this: that this planet has changed immensely throughout its life.

"When it was first formed it was probably very hot because there is a lot of molten lava around the planet. It was probably very volcanic. And the atmosphere was probably full of acidic gas, like sulphuric acid. Eventually the planet started to warm – we believe because there was an abundance of carbon dioxide in the atmosphere itself.

"And that carbon dioxide caused life to spawn, or at least it fermented, or stimulated the growth of life, such that organisms began consuming the carbon dioxide and excreting oxygen. And then the atmosphere became relatively rich in oxygen. At one point, we believe, this planet was completely covered in ice, though we believe that life still existed.

"So why do we want to go back to the Moon? Because, certainly not at the level of my education even, perhaps the level of some of your education, if you're a geologist who has spent his or her life studying this planet and all the other bodies in our solar system and our galaxy, you can glean a great deal of information and data from understanding, by investigating the Moon, by finding our why it died geologically and being able to examine the material that exists on that planet.

"So bettering life here on Earth and understanding it better on a scientific level is a reason to go back to the Moon. The other part of it is exploration.

"We're not going to just stop at the Moon – we're going to Mars. American, Canadian, Irish, English, Russian crews, we're going to go back to the Moon and we're going to go on to Mars. We want to go to Mars because Mars is a planet a little bit bigger than the Moon that, we believe, about 200 million years ago had an atmosphere much like our planet's, but it's very different now.

"Today the atmosphere on Mars is about as thin as it is on the Earth at about 100,000 feet and it cannot harbour most of the life we have here on Earth.

"But also, we believe in our hearts that it's time to get off of this rock, you know, and explore the rest of the solar system and see if humankind can live on another planet and see if we can begin to populate this solar system and perhaps go beyond that.

"In this image you can see the poor Moon, God bless him. He's just taking it on the chin for eons. And he has a huge crater up at the rim, at the horizon; you can see a crack going through the crust. The Moon, when it was very early in its life, was geologically active. It actually had liquid magma right underneath the surface.

"And if you go to the next slide there, the Moon looks quite featureless and dead from here on Earth. In fact, it even does when you're orbiting it. But the entire periodic table practically is found on the lunar surface, and in this enhanced image every different change and shade of colour basically represents a different mineral, a different number on the periodic table.

"We know that we can actually take lunar material, crush it into powder, and extract hydrogen and oxygen out of it. We can make rocket fuel with that. We can breathe the oxygen. In fact we can take the hydrogen and oxygen and make water as well.

"So we're going to establish a permanent human presence on the lunar surface and we're going to develop the processes and procedures and the machinery we need to go to Mars.

"Mars is so similar to Earth in so many ways, but for some reason things went desperately wrong on that planet. Did its orbit change? Did something impact it? Was it destined to become what it is from its very birth? We just don't know the answer.

"But we do know this: there's enough water at the poles of the Martian planet and in its surface that were it all to melt, there would be water to a depth of 33 feet across the entire planet. And we know that everywhere on Earth that there is water, even at the depths of the Marianas trench where there's really no oxygen, where it's very, very cold, and pressure is tremendous, there is still life.

"It's not life that survives by photosynthesis, in this instance it's a microbe that feeds on sulphur, and lives down there at the base of the ocean. Everywhere that we look on this planet that there's water, there is life.

"We know that water is much more prevalent in the universe and in the solar system than we thought it was when I was taking ninth grade science, back in Lineville, Alabama in the good old US of A.

"And like I say, everywhere on Earth that there's water there's life. It seems that, at this point in our scientific research, it appears that there's been one substance that is viable to have life, and that is water. Any place that there's water, somehow life finds a way. Well, we want to find it, you know?

"Certainly there are all kinds of benefits to us here on Earth. Cordless power tools, groove tyres, spending 17 billion dollars a year which, by the way, is less money than is spent on carry-out pizza in the United States every year, and it's less money than women spend on makeup in the United States every year.

"Not that there's anything wrong with that but that's just the way it is. Some people have that drive for exploration. That's what NASA's all about and we are taking one step, the international space station, another step, back to the Moon, and then we want to get to Mars and the outer planets.

Science and space travel – Part four

Audience member: "Did Mars have water on it?"

Joe Edwards: "It did – at one time we think it did have liquid water. The question was, 'Does Mars have water on it?' Yes, in the form of ice and we believe that at one time it had liquid water.

Audience member: "Just to do with the dark side of the Moon, is that something you can explore, any of that?"

Edwards: "Well, there really is no dark side of the Moon. There's a far side of the Moon. The Moon spins on its axis, just like the Earth. It spins at the identical rate as the Earth itself so no matter where you live on the Earth, you only see one side of it.

"But yes, one of the more interesting things that can be done on the far side of the Moon is to establish an observatory. Get a place at which we can build a very large structure, much more powerful than the Hubble Space Telescope.

"And it could be a vehicle, it could be an instrument which we use to look at a variety of wavelengths of energy around the universe and be able to service the thing and keep it going for decades.

"Interestingly enough, it would also be on a planetary body that is no longer geologically active, so there are no earthquakes or earth tremors or things like that upsetting its delicate scientific balance.

"Would it be too cold? The colder the better because the space telescope sensors utilise liquid oxygen to cool them down as close as we can get to absolute zero and it's pretty darn cold, you know? Certainly for one half of a lunar day it would be very cold, minus 240 degrees or something."

Audience member: "You know the docking stations that you have at the moment? Could they be transported over towards where the Moon's orbit is, as opposed to, say, building new ones?"

Edwards: "We will actually build a new spacecraft to go to the Moon, and this is the reason why. Because every ounce of a spacecraft, we have to send that thing 240,000 miles away, and it's much cheaper and much more efficient to design a very light vehicle that is purpose designed to go to the Moon and return. That's why we wouldn't take the space shuttle. That darn thing weighs 240,000 pounds and you don't need wings, or a rudder, or a variety of equipment that's on the space shuttle to go back to the Moon."

Enright: "Somebody asked a question about why they didn't send robots. Well, let's talk a little bit about that and let's talk about these babies. These are real robots. These are the Mars exploration rovers, Spirit and Opportunity, and they're already working on the surface."

Edwards: "And have been for about three years."

Enright: "This is a hugely successful effort by the United States, with a lot of European involvement. The instrument package at the front of this rover is supplied by the Max Planck Institute in Germany which has been absolutely central to what they have been doing to study the rocks.

"There's a European Rover planned for launch in 2012, landing in 2013, which is called Brigit. Brigit will be landed on Mars in 2013 to search for evidence of life.

"To finish up, I thought we'd talk a little bit about Mars, since this is, ultimately, the stated objective of the American space programme and of the European space programme under the Aurora programme which has been adopted by the European Council of Ministers.

"Ireland isn't a direct contributor to the Aurora programme. It's in keeping with our tradition of really just being basic members of the European Space Agency. We're there but not with knobs on. Most of our partners in Europe, however, are contributing significant funds towards exploring Mars.

"So I thought what we'd do is just, while we're talking, take a look at some pictures that have come back, literally in the last couple of weeks. There are two (European) Rovers on the surface of Mars. One is called Spirit and the other is called Opportunity.

"This first sequence shows where Spirit landed. It's a vast crater called Gusev Crater, about the size of Munster, and the Rover has made some astonishing discoveries of rocks which have been affected by water – they've been changed by water a very long time ago.

"The hills in the distance are called the Columbia Hills, rather sad of course, because they're named after your late colleagues, friends and colleagues, who died aboard the Columbia space shuttle accident in 2003.

"Now this is a crater of a different kind. This is the Spirit Rover on the other side of Mars and it has arrived at a place called Victoria Crater. And this, I think, is just one of the most stunning places I have ever seen anywhere.

"As I say, these pictures came down just in the last few days, and they show us a place – when we talk about exploring Mars and about going to distant planets, it's often very difficult to work out or to think: 'What is this place?' And this is our first real opportunity to get a sense of place in the way, of course, that is so familiar to Irish poets among others. As I say, this is Victoria Crater. The Spirit Rover has been exploring that crater for about 12 months.

"But both rovers have been very quiet for the last best part of a year because of a huge dust storm on Mars, but fortunately they've survived it. They've lived to tell the tale and send back these extraordinary pictures which I think are just absolutely stunning. It is possible to imagine that some day a young man or woman will step out onto that surface. Could they be here today, that person, the first person to step on Mars?"

Edwards: "Yes, it's certainly possible. The question that goes through our mind in NASA is: 'As you walk along the surface of Mars, what are you going to find?' Was there enough liquid water in the past that you might actually find a fossil? Even if it's a fossil of microbial life. So it'll be a pretty exciting day.

"When I first went to NASA my wife made me promise her one thing and it was: 'You won't go to Mars'. Because it's a one and a half to three year trip. 'So you have to promise me you won't go to Mars.' And I said: 'OK honey, I won't', knowing of course, in a heartbeat, you know?"

Enright: "How soon is it going to happen? Is it possible that the young people here today could be the right age when the mission to Mars…"

Edwards: "I think so. Maybe 2030, 2040. I really hope that we make it to Mars in our lifetime. We'll just have to see. It's not that hard to get to Mars actually. We have much of the technology today. It's more willpower, just to spend the money and go do it."

Enright: "How many people here would like to go to Mars? OK! Alright!"

Edwards: "It seems to be only the younger folks in the crowd."

Enright: "OK, let's open it out a little bit."

Audience member: "Joe, two questions. The first question is while it is the stated goal to get to Mars, how realistic is that? And do you think that goal will survive George Bush leaving office? And sorry, the second question is more general: how do you think the space community and people working in space should actually reach out? There's a lot of children here tonight but I'm sure you could have filled this place three times over."

Edwards: "The first question – the effort to go to Mars will outlast anyone that is currently in politics anywhere around the world. Because we're talking 2030 or 2040. It will be an iterative approach. We at the international Space Station will go on to the Moon and then we'll find a way to get to Mars.

"And I think as we go back to the Moon and establish this permanent human presence there we'll find, as a country and as a species, that actually it's a little bit easier to do then it was thought at first.

"The second half of your question was what?"

Audience member: "[Unclear]…talking about people actually feeling connected to the space programme."

Edwards: "Oh yes. I can't tell you the number of times I've had someone come up to me and go: 'Joe, I love the space stuff, but NASA has to do a better job of marketing.' You know, NASA is an engineering organisation. It's a science organisation. By and large, we don't have people going to get their MBAs and taking a marketing course.

"Almost as a consequence of the good work the European Space Agency does, the Canadian space agency, Japan, Russia, the United States; almost a consequence of that is a lack of money, a lack of time to spend on marketing itself. So what I've always told NASA is: 'Don't worry about marketing, the best marketing that a space agency can do, regardless of its nationality, is to have successes. You know, the worst marketing that you have is to have failures.'

"It's a risky business. It's a business that's very difficult to do. It will never be perfect. What I espouse is: 'Let's just try and do our jobs well. Leave the marketing to Madison Avenue or wherever.'

Audience member: "I just have two questions that I wanted to ask. The first question is: you were saying that you were a naval aircraft pilot and you were travelling at 600 miles per hour, about 10 miles per minute, 0.6 of a mile per second. Then you said in the space shuttle lower orbit you were travelling at 17,300 miles per hour, which is 300 miles per minute or five miles per second.

"For manned human interplanetary travel and manned human inter-solar system travel, like for instance travelling to Alpha Centauri or exploring space, what speed would be required per second for maximum efficiency?

"And what speed can we achieve now, in 2007? And the second question I had for you was: you mentioned an asteroid storm on the Moon, did that form 10% of the craters formed or 90% that we see today?"

Edwards: "OK, let me answer the first question first. The fastest that we've ever had an object go at with a human being in it is 35,000 miles per hour. Other than in science fiction, we do not have a propulsion system that effectively allows us to leave the solar system and travel to other parts of the galaxy, much less to other galaxies themselves.

"But in space exploration, you know we've only been doing this for 40 or 50 years, it's very much at an embryonic stage. Yes, we have made great gains. But imagine if it were several thousand years ago and we had been sailing. Someone had figured out how to make a sail for a boat, and now it was 50 years later. There were thousands of years of human progress that allowed us to go from square-rigged ships, to sloops, to catamarans, to heavier-than-air craft and those kinds of things. So we don't have the answer right now.

"Right now, to go to a place like Mars requires a tremendous personal sacrifice – one and a half to three years out of your life, with perhaps a permanent effect on your body and your bone mass and those kinds of things.

"But think back to the early explorers like Captain Cook, Magellan or Amerigo Vaspuci. Those early explorers endured tremendous hardships themselves, perhaps being at sea for two, even three, years, and the effects of debilitating diseases such as scurvy and other kinds of things.

"So we don't see space flight as something that's easy. We see it as something that's very hard and it requires tremendous personal sacrifice. But we are willing to take that risk because we believe that it's very important and that as a species, as human beings, it's worth the risk and we'll be better off for it."

Enright: "I'll answer the lunar cratering question. It's entirely dependent on how you date the Serenitatis event, which is controversial, and I recommend Bill Hartman's paper on the subject from 2002."

Audience member: "I have two questions. The first one, it's just on the poles of Mars. Do you believe that there is actually liquid water under them, like liquid ocean?"

Edwards: "On Mars, no. What we actually have proven to ourselves with the two Rovers that are on the surface today, is that there is ice in the permafrost and that there are various geological features on the planet that lead us to believe that in the distant past that ice was actually liquid."

Enright: "There is some new information which is quite exciting, it's still controversial, but the European Mars Express Mission – a team using data from its radar sounder which penetrates deep into the Martian surface – they published in Science magazine, I think it was, last Thursday, a report claiming to have discovered a very large amount of frozen ice at the equator of Mars in a region that has always been puzzling because of the features on it.

"That would be incredibly exciting. That would add another third, 30% more water, frozen water, to what we already know exists on Mars, which is very exciting."

Edwards: "I probably should choose my words carefully. I'm not saying that there couldn't be liquid water somewhere under the surface, but right now we don't see any evidence for it."

Enright: "We should emphasise as well – I think you clearly from your question realise this – that sometimes people talk about looking for water on Mars, there's plenty of water on Mars as Joe has said several times. The issue is: is there any liquid water? Would it perhaps be the way to allow organisms to thrive? Next question."

Audience member: "Hello Joe. First of all, welcome to Ireland. I'm afraid I have a bit of a meteor strike of questions for you. First of all, as you know George Bush is planning to put the space shuttle out of action by 2010. As an experienced pilot, how do you feel on the X-38 space plane programme? You know, we need something that's convenient, reusable and [unclear] Richard Branson's…"

Edwards: "There was a programme that didn't last very long where we tried to develop a new, reusable spacecraft with the capabilities of the space shuttle Orbiter. But it's not really George Bush that's cancelling the programme. €17billion may be less than we spend on carry-out pizza but it's still a lot of money and we don't feel like we can afford to keep both programmes running at the same time. It's time to move on from this vehicle that has served us very well and go on this next exploration, the next exploratory effort."

Audience member: "Secondly, you were just mentioning Arthur C. Clarke at the beginning. It's funny; he apparently worked with NASA. He came up with, famously, in '2001: A Space Odyssey' the idea of Velcro

shoes, or slippers if you will, to stick to the floor, to simulate gravity. When we think of artificial gravity we think of clumsy men out in boots or stations that circle themselves, but if it's convenient and less expensive, why not try it?"

Edwards: "Well, you could certainly do something like that. But with artificial gravity, the downside to it is that one of the reasons that you're going into space to begin with is to take advantage of the lack of gravity to study physical forces in the universe, inter-stitial forces between atoms and grains of sand, you know, and things like that.

"So primarily, you would like to have the benefits of not having gravity, or micro gravity which is when your lower Earth orbit is 1×10^{-6}Gs. But the real reason that you'd like to have gravity is so that you could perhaps expose the crew to it periodically to reduce the debilitating effects of long-term space flight, and that's a much more difficult problem that we do not have the answer to yet."

Audience member: "This is the final one, don't worry. As a pilot for a space shuttle, as all of us are aware the missions specialists certainly get to go on the extra vehicular activity, if you call them excursions. Is it possible for a space tourist or a space pilot to go on them? I don't know about either of those. I've never met Destito but as far as I'm aware he's never held the record for flying the closest to a space shuttle."

Edwards: "Well, can pilots do spacewalks? That's basically what you're asking. We used to joke around the astronaut office that we couldn't get into the union; the mission specialists did it all. The fact is that walking in space, extra vehicular activity, is a very highly honed skill and it requires months and years of practice. In particular in training for a particular mission, you train for months in the pool to be able to go and do those tasks that look so easy to do in video that's down-linked here to Earth.

"At the same time the pilots are engaged in the same kind of rigorous training but in the operation and flying of the vehicle itself, and there's just not enough time in the day for you to train for both of them. And that's the real reason why mission specialists do it and we do the flying."

Enright: "OK, I think we have a question down the back again."

Audience member: "For those who spend time in space, is there any long-term physiological effect?"

Edwards: "The long-term physiological effects in space? One is dramatic hair loss, which is the most severe of all of them. I'm kidding of course. Anyway, long-term space flight, what happens to you? Within three days of being on orbit your blood, your body has poured 10% of your blood plasma overboard in your urine.

"And very soon after that, your brain figures out that you don't need all this bone mass that you've built up so that you can work against the force of gravity, and it begins actually decreasing your bone mass. One reason you can't be an astronaut if you've ever had a kidney stone is because of that very thing.

"There's a lot of calcium in your urine. You'll start losing bone mass in your pelvis which is the biggest, most densest bone in your body. Then your brain moves on to your femurs and starts getting rid of that bone mass as well because you don't need your legs to stand up any more. The human body's a pretty remarkable thing."

Science and space travel – Part five

Joe Edwards: "To tell you the truth, you could show up there at the age of 35, you may fly by the time you're in your 40s these days, maybe later. And we've had astronauts in their 60s. I mean, John Glenn flew in his 70s.

"But in general if you're up there for a long mission of three to four months it will take you about seven months of rehabilitation. That's a personal trainer every day, starting with swimming and the rubber bands and all that, working back up to weights and running and those kinds of things."

Leo Enright: "OK, another question here in the middle."

Audience member: "Hi Joe. Thank you for being here. You said that space exploration is for basic scientific research for humanity. Now, with the power of the Internet we can find information about just about anything. Is it possible for us to access images and information about the latest updates on space stations and rovers that are going on Mars?"

Edwards: "Absolutely. One of the most difficult professions that there are today frankly has to be a science teacher below the college level because we have so many robotic vehicles around our solar system today – in addition to all the data that's being gathered by Earth-based sensors, telescopes and what have you – that we rewrite the science textbooks every couple of weeks now throughout the world.

"It turns out that the largest amount of content on the Web is contained on the NASA websites and it's updated on a daily basis. You can download videos and images from the Martian surface and a variety of images that come from things like the X-ray telescope, the Chandra X-ray observatory.

"We have a telescope that's 21 million miles away from Earth in an Earth orbit around the Sun. Two Rovers on Mars. Two vehicles orbiting Mars. A couple around Saturn. Voyager has left the solar system.

Voyager No.1 is on its way to leaving the solar system. We've got more stuff out there than you can shake a stick at and scientists all over the world that are analysing that data.

"So, yes, it's all out there and a lot of it's on the Web. If you want it you have to get it quickly because NASA puts it up there and then they get rid of it and they bring new stuff up there."

Enright: "I should just emphasise that a lot of these projects are joint ventures with other agencies including the European Space Agency who are partners for instance in the Hubble space telescope, they constructed the Ulysses mission orbiting the Sun. A lot of these are joint ventures between the United States and obviously ourselves in Europe but also Japan, Canada, a lot of other places. Sorry, you had a follow up?"

Audience member: "Initially it was a race against the Russians to get to space but now presumably it's all a global space community, it's a global effort now to explore and to release that information."

Edwards: "I would agree with you. And I hope that no one here has the impression that exploration of outer space is just an American thing. I mean, you don't, do you? I cannot think of a scientific instrument that we've launched in the last 20 years that has not been a cooperative effort with the European Space Agency at a minimum and probably several others around the globe. The data that's analysed is all over the world. It's not classified or anything, it's out there and everyone is working on it."

Enright: "OK, we have one question at the back and then we'll move on towards the front again."

Audience member: "Welcome to Ireland Joe. On the issue of governance, do you anticipate a space civil service?"

Edwards: "Well, we kind of do right now. It's called NASA, and the Russian Space Agency, and the European Space Agency, and the Japanese Space Agency. I don't envisage a Starfleet Academy any time soon, you know, but I'd sign up if we had it. So I think what will probably happen in the near term, rather than that, will be the exact opposite. That will be, to a certain extent, the commercialisation of space."

Enright: "That will keep the lawyers busy. Certainly the legal aspects of it are being hotly explored. OK, we're going to give some people up near the front a chance."

Audience member: "Hello Joe. Thanks for a very interesting conversation so far. It's very interesting that you mention the Japanese and the Europeans. The Chinese are in there now as well. They've got their man into space as well, and now are looking to go to the Moon as well. Do you feel that would force an issue in terms of a race, or are there collaborations with the Chinese in terms of setting up the base on the Moon as well?"

Edwards: "Human beings just seem to be naturally competitive, you know there's no doubt about that, but I don't foresee anything like the space race of our youth being something that we engage in with the Chinese.

"I think geopolitical circumstances were very different in that time and I don't see it happening. However, I think the more people we have that want to go do this thing, that little bit of competitive nature in man is probably a good thing because it helps push us all along.

"I think, that gentleman in the grey sweater. I'm afraid his arm is going to fall off."

Audience member: "Thank you. I wanted to bring the conversation back into the spacecraft and ask you what was going through your mind three minutes before takeoff. What's the best meal you've had up there? And when was the scariest moment?"

Edwards: "The best meal is shrimp cocktail. I mentioned that NASA invented freeze dried food for space travel. When you are in space, in microgravity, your tastes changes. They're much less sensitive your tastebuds are much less sensitive than they are on Earth, so you crave spicy food.

"By the way, you crave comfort food also, meat and potatoes. When we went to Mir we would always go over to the Russians and try to trade them some food because they always had meat and potatoes and we had bean sprouts and broccoli. So the best thing I ever had up there was shrimp cocktail and they mixed that up special for us with lots of horseradish so it was very, very strong.

"One little anecdote: we were on orbit and Anatoli Solovyev, who is the space station commander on Mir 24, was over and eating dinner with us. So we gave him the shrimp cocktail which is very prized among space crews, you know, I ate it every meal.

"And the Russians don't eat spicy food at all. He didn't speak a whole lot of English at the time but he took one bit of it, looked at us and in perfect English said 'It must be good for you.' So anyway, that was the food thing, what was the next bit?

"Oh, what was I thinking of three minutes prior to launch? You know, I would love to have some very flowery answer for you that would sound great on the Discovery Channel and all that, right? This was a 4.5 million pound vehicle with six of my best friends on it. We were going to take this thing and fly it at 25 times the speed of sound and, we believed, do something very important with it. My thoughts were completely centred on the operation of my spacecraft and the safety of my crew. Three minutes prior to launch, in particular, I was setting up for auxiliary power unit start, which powers the hydraulics on the vehicle, which occurs at T minus two minutes and thirty seconds.

"The scariest moment – I've been much more scared in airplanes than I ever have in spacecraft. At some particular moments."

Audience member: "Talking about Mars and the Moon, when you are talking about exploration there, would you be thinking about creating artificial cities?"

Edwards: "You know, I don't have the answer. The science fiction writers have ideas and what have you. But if we're going to populate Mars or if we're going to establish a permanent presence there, we have to provide for basic human needs. We have to have food. We have to have water. We have to have something to breathe.

"There are a variety of ways to do that. You can process it out of the frozen water in the surface. Is there some way to create an artificial greenhouse effect and warm that place up? I guess it's possible. Right now we're taking those baby steps before we're able to solve those kinds of problems."

Audience member: "How many sleeping bags [unclear]?"

Edwards: "How many…?"

Enright: "Sleeping bags."

Edwards: "Oh, sleeping bags. One for every crew member so seven is generally the number of people that fly on the space shuttle."

Enright: "Are they comfy?"

Edwards: "Well, they're very comfy. You're sleeping on air, man. They could be made out of steel and they'd be comfortable."

Enright: "Very good. This gentleman here at the front."

Audience member: "I have two questions. One was your question on the regenerative process after a test flight or whatever. Do your bones grow back better?"

Edwards: "No, not any better but we think we can get back to pretty much the way we were before. You think about that – for someone who is 40, 50, 60 – that's pretty remarkable."

Audience member: What do former astronauts do or what are you doing now? Are you still working for NASA?"

Edwards: "What do former astronauts do? Actually, in my day job I work for a Fortune 100 company in the technology area. But I do spend a significant amount of my time doing things like this and other things that are related to the space programme like corporate leadership development.

"I've probably done a couple of dozen things over the last couple of years concerning industrial safety. In industry in manufacturing, you utilise the same processes and procedures as we do on the space shuttle. So other than that, raise my daughter, try to keep the wife happy."

Enright: "OK, we'll move over to this side here, the lady in the front who's been very patiently shepherding a group."

Audience member: "Thank you. I'm just thinking, when you were talking about your wife there. In my normal life, my husband comes home every day and I wait for him to help me with the kids and everything. So I was wondering, do I want my son to become an astronaut and leave his wife and children and come back in a year's time and do all this hard training and all that? I would just like you to comment, maybe, on the family life and those aspects that maybe you had the challenge to face."

Edwards: "Well, I think you probably hear the calling. You either hear the calling or you don't. And if you do, you end up spending the rest of your life with someone who understands that and probably wants to play a part in it as well. You touched on something that's really true and that is space travel, particularly launch and entry, can be very stressful for a family.

"Frankly I think it takes someone who is a little different, you might say someone that's special, to be able to manage the family and all the things associated with our day-to-day existence and then still perform that job as well.

"And the kids? The kids don't see you? You see, I was in the navy. I would go away for six or nine months at a time. My daughter wasn't born then but a lot of us had children and I'll tell you the way we looked at it, not to get too philosophical on you, is that when we went out on the ship or our airplanes, we believed that we were making a sacrifice that was very important to our country and to the free world, and there were some people who made those sacrifices so that other people didn't have to.

"And that's the same way we felt about space travel. So certainly it wasn't easy but rather than seeing it as a hardship when we approached middle age, frankly, we saw it, and see it, as an honour and a privilege to be able to participate in."

Enright: "OK, the young lady there behind."

Audience member: "If there is ice and water on Mars why don't you get one of the robots to scoop it up so that you can stop droughts?"

Edwards: "The reason is that the ice is actually several feet below the Martian surface. We're actually using pretty high-level scientific knowledge to indirectly deduce that that ice is there. So there certainly could come a day when we could drill down there and actually tap that ice itself and do something useful with it. That's a great question by the way."

Enright: "OK we have a young gentleman there."

Audience member: "Would it take you a couple of minutes to learn how to walk again when you touched down on Earth?"

Edwards: "What do they teach you in school around here? These questions are so good. Does it take a while to get used to gravity when you come back? Yes it does actually. The longer you're there the longer it takes you to recover.

"It turns out that it's not unusual to have a little nausea when you first get into orbit because your body's changing tremendously. You're getting rid of all this extra blood plasma that you have.

"As soon as the main engines cut off you become weightless and all the organs in your body cavity start riding up against your diaphragm, and the fluids in your body start to move up from your lower extremities to your upper torso and your head. Your face kind of swells up a little bit. And if you haven't managed to conquer the nausea, if you have it within 36 hours, your brain will finally flick a switch and say 'I've had enough of it. I can't take it anymore.' And it will ignore the signals that it's getting from your semicircular canals and your cochlea in your middle and inner ear.

"When you're coming back into the atmosphere during entry to land the vehicle, as gravity is building up, your brain doesn't know to turn that switch back on. So as you're flying through the atmosphere, streaking through it at 25 times the speed of sound, you start to get a little bit of gravity any time you move your head. Your brain thinks your body is translating through space. It doesn't understand what head movements are any more.

"So when the space shuttle comes in to land, it may look nice and easy but the pilot has a pretty severe case of vertigo throughout the entire manoeuvre. Why do we have these military test pilots to fly the airplanes? Because the worst vertigo I've ever had is not landing the space shuttle, it's landing on a boat in the middle of a dark night in a thunderstorm.

"So I had experiences, and we want all the astronauts to have experiences that they can translate into the experience of flying a spacecraft because so much of it is foreign to us."

Crew member: "Leo, we have time for one more question."

Enright: "OK, do we have a microphone? Oh right, we'll take this young man here who hasn't had a chance to ask a question."

Audience member: "Can you go toilet on space?"

Edwards: "Was I tired in space? [Muffled sounds from audience] Can you go to the toilet in space? Thank goodness you can. We actually have a toilet on the space shuttle and on the space station. And if I had a picture of it, which I do not, it would look pretty much like a regular toilet to you but it's somewhat sophisticated in its operation to mitigate some of the more unpleasant aspects of performing those bodily functions in microgravity."

Enright: "So it sucks."

Edwards: "It actually has a suction mechanism to it. It's not very effective though."