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Safety and health in commercial spaceflight

A change in perspective for risk assessment of future technologies

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German Social Accident Insurance Institution
for Commercial Transport, Postal Logistics
and Telecommunication (BG Verkehr)
Directorate of Occupational Safety and Health
Ottenser Hauptstraße 54
22765 Hamburg
Tel.: +49 40 3980-0
Email: praevention@bg-verkehr.de
Internet: www.bg-verkehr.de

Project management
Dr. med. Jörg Hedtmann (BG Verkehr)

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Introduction

Today, roughly two thirds of all astronauts are working for national agencies. In the next twenty years the tables will have turned and commercial and private astronauts will be in the majority. If Germany wants to maintain its claim to shaping the future, there is no alternative to spaceflight, including astronautic spaceflight. So, we urgently need to turn our attention to spacecraft or the space station as workplace – as research location, but also as workplace in the context of the transport industry.

Apart from that, we sense a rare opportunity here to analyze a completely new work environment, with basic conditions that could hardly be compared to a workplace anywhere on Earth. It affords us with an opportunity to reconsider whether methods that have proven themselves on Earth are sufficient or whether, in view of the opportunities and risks of new technologies, we need to be open to new risk assessment approaches.

Together with Martin Küppers and Dr. Christoph Caumanns, on January 22, 2024 in Cologne Dr. Jörg Hedtmann spoke with experts who can contribute to this change of perspective.

In the conference room of the German Aerospace Center (DLR) from left: Prof. Dr. Reinhold Ewald, Prof. Dr. Claudia Stern, Dr. Christoph Caumanns, Martin Küppers, Dr. Jörg Hedtmann

Prof. Dr. Reinhold Ewald

Reinhold Ewald studied physics in Cologne and received his doctorate in the field of radio astronomy, with minor degree in human physiology. As spaceflight coordinator at the German Aerospace Center (DLR), he was selected in 1990 as member of the German astronaut team and was trained as research cosmonaut in Moscow until 1992. On February 10, 1997 he lifted off aboard the Soyuz TM 25 to the Mir space station, conducted numerous life science experiments on board, and returned to Earth on March 2. Ewald has been a member of ESA's European Astronaut Corps since 1999, and trained ground crews at Columbus Control Center near Munich for international space station missions, ISS. In 2015 he was appointed professor for the field of astronautics and space stations at the Institute of Space Systems at the University of Stuttgart. In 2018 he retired from ESA and in 2014 from the university post.

Prof. Dr. Claudia Stern

Claudia Stern studied human medicine in Bonn and received her doctorate in Hamburg for a subject on aerospace ophthalmology. She is ophthalmologist and Aeromedical Examiner. She has been working at the DLR since 1996, and since 2013 she is head of the Department for Clinical Aerospace Medicine. She lectures on this subject at the Technical University of Braunschweig, and also teaches at the University of the Federal Armed Forces in Munich and the International Space University in Strasbourg. One of her primary fields of research is eye changes in astronauts.

Dr. Jörg Hedtmann

Dr. Jörg Hedtmann was Directorate of Occupational Safety and Health at BG Verkehr until the end of March 2025. He is specialist in the field of occupational medicine, with roots in aerospace medicine. His responsibilities at BG Verkehr included preventing accidents and health hazards in the transport industry on the road, at sea and in the air (and beyond...).

Martin Küppers

Martin Küppers is physicist and participated in the dialog as head of the Occupational Safety competence field and the Aeronautics Expert Group in BG Verkehr's Directorate of Occupational Safety and Health.

Dr. Christoph Caumanns

Dr. Christoph Caumanns is specialist in occupational medicine and ear, nose and throat medicine. He participated in the discussion as interim head of the Occupational Medicine, Transport Medicine and Work Psychology department of BG Verkehr.

Interview

Hedtmann:
In 1914 as Shackleton set off on his “Endurance” expedition to Antarctica, he was said to have sought his crew with this advertisement: “Men wanted for hazardous journey, small wages, bitter cold, long months of complete darkness, constant danger. Safe return doubtful, honor and recognition in event of success.” Even though the first human flight beyond the atmosphere took place in 1961, we are still only in the early stages of going to space. What sort of person are we looking for today?

Antarctic expedition

After Roald Amundsen became the first person to reach the South Pole in 1912, even before the disastrous Scott expedition, Ernest Shackleton prepared an expedition with the aim of crossing the antarctic continent. Expeditions like this in the hostile environment of the poles were extremely dangerous and full of privations. Ultimately, Shackleton’s ship the “Endurance” got trapped in pack ice at the beginning of 1915 and sank in November of the same year. Under immense strain on marches, drifting, and lifeboats, Shackleton led his crew to Elephant Island. From there he set out with a small group in a lifeboat on the crossing to South Georgia, to initiate a rescue mission from there. It was only in August 1916 that he was able to rescue his crew on Elephant Island. The fact that everyone on the expedition survived is attributed not least to Shackleton’s leadership qualities.

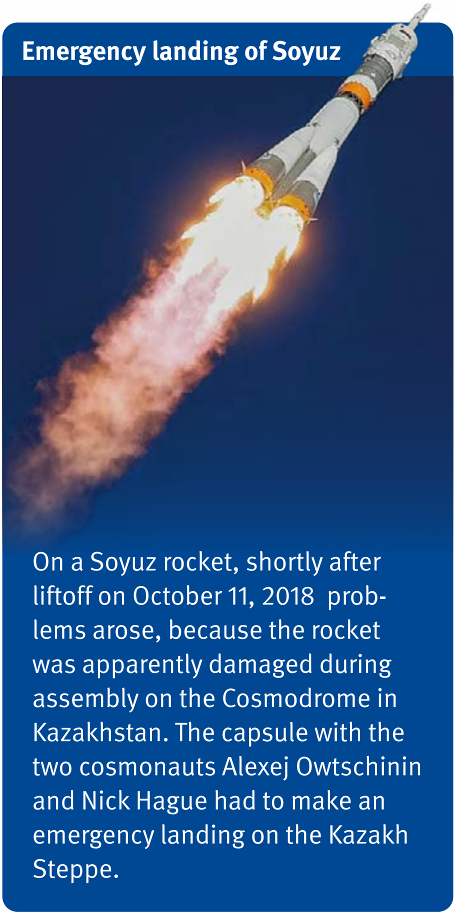
The “Endurance”, Shackleton’s expedition ship

Ewald:

If one's heart did not beat faster – if it were merely like driving a bus – it would naturally cheat spaceflight of its allure. As to the job of "astronaut", the surroundings allow it to be nothing less than a moment of the extraordinary. Fortunately, the technology is not extraordinary anymore, but tried and tested. After more than 60 years of astronaut spaceflight, the knowledge of the things that await us in space, particularly regarding the physical demands, has naturally grown enormously. We are now not only able to select the type of person who can specifically withstand the strain of spaceflight, but we can also ensure that they do not lose their ability to work up there. We are now talking about time spans of more than a year during which these people remain motivated and physically healthy, without any signs of any relevant permanent damage. So this is the framework: on one hand – because of the rocket technology – the spectacular, and on the other hand – because of the systematic collection of data – the predictable.

Naturally, the risk has remained unchanged. Statistics have improved, and experience has been gained from successful and not-so-successful liftoffs. But, ultimately, it all comes down to details: whether the liftoff day is canceled (the more favorable scenario) or whether something crucial will go wrong during liftoff itself. Like at that time in October 2018, when a bent pin prevented the release of one of the side boosters from the Soyuz rocket, which then lost control. The two colleagues in the capsule were catapulted into space with the emergency booster, only had a very short flight, and landed again. On the next

Emergency landing of Soyuz



On a Soyuz rocket, shortly after liftoff on October 11, 2018 problems arose, because the rocket was apparently damaged during assembly on the Cosmodrome in Kazakhstan. The capsule with the two cosmonauts Alexej Owtschinin and Nick Hague had to make an emergency landing on the Kazakh Steppe.

flight a few months later they arrived safely. Nevertheless, Shackleton faced considerably more uncertainty than we do.

Hedtmann:
In fact, Shackleton wanted to explore new paths and travel routes. This is often the case in other fields of research, too: researchers are so filled with enthusiasm that they tend to gloss over the hazards of their undertaking somewhat. The area of aviation is notorious for the death-defying attempts of people taking their own lives into their hands. John Paul Stapp from the U.S. Air Force, for example, with his rocket sled experiments...

John Paul Stapp, Colonel, USAF (11.07.1910 – 13.11.1999)

Stapp's self-experiments on a rocket sled are legendary. During the acceleration and particularly the rapid deceleration he subjected himself to such heavy strain that he even suffered bone fractures and hemorrhages. Among other things the results led to improvements and new developments in safety systems in aircraft and other means of transport. With the Stapp Car Crash Conference, a transport safety conference named after him still exists in the U.S. By the way, one of his team members was a certain Edward A. Murphy, whose special safety philosophy became world-famous as "Murphy's Law" and who most certainly also contributed to the improvement of safety on Stapp's trials on the rocket sled.

The rocket sled "Sonic Wind 1" of 1954, driven by nine solid-propellant rockets, generated 40,000 pounds of thrust for five seconds.

Stern:
... up to 46 g!

Hedtmann:
Exactly, somebody does something for the very first time, and nobody knows what to expect. There was also a first time that someone climbed out of their space capsule, without being certain what would happen. Is that the way it is still done today?

Stern:
The main difference in the scientific experiments with and on astronauts, is the attitude of those affected toward it. In former times, there was an extremely high level of curiosity among everyone involved. Everything about what the space environment would do with people was entirely new. But, when you try to arrange an experiment on the International Space Station today, you have to first go through an incredible number of committees. Once you have finally finished with all these ethics commissions and medical boards – which always include an astronaut representative – the astronaut is introduced to the research project, and it is then up to them to decide if they want to participate or not. In the past, enthusiasm used to be much more palpable if one got an experiment for the D1 or D2 mission, or a German-Russian Mir mission. Those were "our" missions, and "we" made the experiments! The question of whether you would do it or not was secondary. They were there, and you just did them. But today, for years the agencies have been looking for astronauts who would have a lumbar puncture (spinal tap) done during a flight, to measure intracranial pressure. But so far nobody has volunteered. It is likely that the aviation physicians advise against it. So, this question will come to the fore in the commercial missions.

They are considerably shorter, and commercial astronauts tend to add special importance to their paid

lumbar puncture

In a lumbar puncture, or spinal tap, a hollow needle is inserted through the dural sac in the lumbar region and fluid (cerebral fluid) is extracted. This procedure can be used to diagnose illnesses such as multiple sclerosis or meningitis, but it can also detect bleeding. In a spinal tap it is also possible to measure intracranial pressure.

flights, and make a contribution to research for the history books. Like, the first human to have their intracranial pressure measured in space, for example. There is a big difference compared to professional astronauts who enjoy the world's most expensive training, are expected to fly multiple, mostly very long missions, and want to – and must – stay healthy the whole time, and for a long time afterwards.

Matthias Maurer on board the ISS, his living and working environment for many months

Hedtmann:
If one can limit the question of staying healthy to a relatively short mission, it would certainly be attractive for commercial missions. The DLR is conducting what is known as "bed-rest studies". Following a suitability test, participants lie in bed for 30 or 60 days in a head-down tilt position. They get paid for this, and subsequently a lot of data can be collected. To obtain such important data, wouldn't it be possible to entice test subjects with shortened training, money and a spaceflight?

Bed-rest studies

Bed-rest studies are a proven method of simulating certain effects of weightlessness. Since body fluid distributes itself uniformly throughout the body in space, an attempt is made to simulate this distribution by having the subject lie down constantly in head-down position for weeks, without interruption. Going to the toilet and personal hygiene must also be done in this position. It is thus possible to observe the effects of altered distribution of fluid on the different organ systems, such as the eyes.

Ewald:
At the very least, that would be coming very close to crossing a red line – regarding Helsinki. For participation in DLR experiments there is an monetary allowance, and you are free to leave the experiment at any time. At no time does the subject lose control. Naturally, a lumbar puncture is an extreme case. Another question would be a cardiac catheterization procedure during liftoff. Without having a cardiologist on board, who could remove it again if it became necessary. It isn't for nothing that there is an independent board to make ethical and medical assessments, and which may ultimately say: Listen guys, things are being taken a bit too far here, even if the test subjects are there of their own free will.

Back then we spent a long time negotiating with ESA about whether the agreements should include provisions on whether one must conduct medical experiments. But, that would be going a bit too far. In actual practice it is handled differently. In a competitive environment, the person who allows a few needles to be stuck into their body will be better regarded by researchers than

the one who raises objections. That may sound unfair, but that was already the case with the D2 mission, that a certain competitive atmosphere existed among the astronauts as to who could demonstrate the most compatibility for the mission. So, naturally, the issue of risk takes a back seat. That ultimately doesn't help the cause. Regardless of the alternative – flight or no flight – one should be able to remain objective, otherwise things become somewhat hazy.

Cardiac cathetrization

In a cardiac catheterization procedure a catheter is normally inserted by an inguinal puncture and guided through a large blood vessel to the heart. On Earth, this procedure is often used for the visualization of coronary blood vessels (coronary angiography) or the function of the cardiac muscle and heart valves.

Küppers:
Do I understand correctly that you view an "ethical separation of powers" as an advantage of our scientific spaceflight program over private spaceflight?

Ewald:
Viewed black and white, yes. It starts with familiarity with the spacecraft, where one can rightly say that a substantial amount of training is required to get to know the spacecraft and all the rescue options and their variants. On an Axiom flight (note: Axiom Space is a commercial provider of flights without their own spacecraft) – which is decided in two to four months and takes place three months later – the idea that people are knowledgeable of all that is built into their SpaceX capsule, to save them from this or that situation, is something I rule out. That is the major difference. And then there is the accompanying project supervision, which is assured for example by the crew surgeon (note: the aviation physician looking after the crew). With a person like this, you build a relationship of trust over a one-and-a-half year training program. So it is possible to come to a meaningful agreement on what is feasible and sensible from the crew surgeon's point of view. If you do not have this option, because you are the customer of a sub-contractor, then you are missing an important aspect. So, the opacity of agreements in preparations for commercial flights is certainly a crucial difference compared to the agency; i.e. publicly funded flights.

Küppers:
In the preliminary discussion, we talked about the social characteristics of the Rhinelander, we talked about a sound scientific education and we talked about the aspect of medical aptitude. If we were to weigh these three aspects against one another, for example, what defines the astronaut? Are we looking for first-class scientists, physically top-fit people, and what role do social skills play?

Axiom Space

The term "axiom" does not only mean a self-evident truth, but as "Axiom Space" it is also the name of an American aerospace company that among other things is working on preparing for the commercial (re-)use of a space station. At the moment Axiom Space is organizing flights with the SpaceX spacecraft, Crew Dragon.

Ewald:
I would never have climbed into this rocket if I could not have explained to my wife and my three children why I think it is important and what I intend to accomplish up there. And that doesn't mean looking out the window up there and saying "Oh, my God, it's full of stars!" rather it means that because of my training and my conception of the experiments, I was convinced: Only you can do that up there. And, at the moment, you – and the back-up astronaut – are optimally trained to do just that. The same applies to a second flight, by the way. In the astronaut corps there are different opinions on this. The risk isn't lower of course on a second flight. The rocket is new, the liftoff team is new, the production of the equipment is new, and all of them are just as likely to lead to a catastrophe or a liftoff cancellation as on the first mission. But there is one difference. With your first mission, you have had your coming-out in the public as an astronaut, and on the second mission that aspect does not play a role any more. We have people who were up there seven times. So, that is when personal career motives begin to play the more pivotal role in flying again.

Caumanns:
The ideal person may perhaps never exist, of course. However, there needs to be as much overlap as possible between the three aspects.

Reinhold Ewald (center) in a Mir simulator with his two cosmonaut colleagues Wassili Ziblijew (left) and Alexander Lasutkin (right).

Ewald:
For me, the scientific aspect was most important. Even if only so that you aren't focusing on the imminent danger during liftoff: “What is going to happen? You have 300 tons of fuel below you!” Rather: “What will you do first following arrival when the door opens and you start your experiments?” Okay, naturally, during the moment of liftoff I couldn’t remember anything anymore, but once we got up there I was able to concentrate solely on my experiments. And it wasn’t heroism that motivated me, rather it was the special combination of physical, medical and human sciences experiments that entitled me to make this flight. It worked! And despite all the perils, we delivered solid results. It went so far that on the morning after the fire we had actually arranged a press conference. But, that was ill-timed, because we were of course all still wearing respiratory masks, and this wasn’t the image we wanted to communicate to the ground. Our contact man, the first German cosmonaut, Siegmund Jähn, then asked whether I would at least come to the microphone, and our commander answered, truthfully, that it wouldn’t be possible, because Ewald is working on his experiments again. And even if Siegmund Jähn, as native of Vogtland (a German region), was not exactly known for his exuberance, this visibly pleased him. It wasn’t because I wanted

to be recorded in the history books as unflappable scientist, it was just that in the brevity of the mission the experiments could not wait forever, and in the situation at hand, it was simply possible and sensible to continue.

Mir space station

The Mir (Russian for “peace”) was a Russian space station and the first with a modular construction. The interior dimensions of the core module were only 13 x 4 meters. It was in operation from 1986 to 2001. For Russian but also international crews it served as location for research and to gain experience with long-duration stays in space. There were a number of mishaps. On February 24, 1997 an oxygen supply cartridge caused a fire at the time Reinhold Ewald was on board.

Hedtmann:
Well, the fire on your mission is one of the things that actually did lead to a note in the history books. Fire on board a spacecraft can be a delicate matter. Memories of Apollo 1 immediately come to mind. What is physically different about fire in space, and what is so unique about it? And, how did you experience it, personally?

Apollo 1 disaster

Apollo 1 was the mission name (which only later became official) for the first liftoff of an Apollo spacecraft. On January 27, 1967 the three astronauts Edward H. White, Virgil I. Grissom and Roger B. Chaffee conducted a routine test – a plugs-out test – which involved disconnecting all lines from the rocket and spacecraft to the service structure. The atmosphere on board consisted of 100 percent oxygen, and the capsule was under slight overpressure. Near the life support system a fire broke out, which spread rapidly due to the oxygen atmosphere. It was not possible to open the hatch anymore, and all three astronauts died. The investigation of the accident revealed a whole series of problems that contributed to it, and was vital for the continued development of the Apollo program.

Interior of the space capsule following the fire

Ewald:
Physically, fire in space is difficult to maintain. On Earth, because of the chimney effect, with the supply of fresh, oxygen-rich air, it basically burns on its own. The heated air rises upwards, and the fresh air is fed from below. But it doesn't work that way in the absence of gravity: there is no convection. This causes a bubble of oxygen-deficient air to form around a fire. The supply of oxygen is only possible through diffusion, not convection. But, since diffusion is very slow, the flames are meager, and round like a sphere. This has been reconstructed in many experiments. This field is of very high interest for the energy industry, because it is not only for car engines that the optimization of combustion is of supreme importance. Up there in space, it is possible to study virtually in slow-motion how to make combustion more effective. And an increase of only one percent can open up a large market. That is why research on it in space continues.

So, based on these unique physical characteristics, some hasty colleagues on Earth prematurely speculated that not much could have happened – at most we would have had a smoldering fire. But, it didn't happen that way, because an oxygen cartridge was involved. These look like pneumatic tube cylinders, and are roughly the same size. Such a cylinder is filled with a chemical – lithium perchlorate – which is also used for the production of bombs. It is a quick source of oxygen and burns exothermically from the inside out in a twenty to thirty-minute process. In the process it releases 600 liters of oxygen, which is the daily ration for a person on board.

Since the life support system on Mir was chronically overloaded – at times there were six of us up there instead of only three – such cartridges were occasionally used to raise the oxygen content. It was routine. Of course, there must be no foreign objects inside, otherwise the reaction is ignited, and that is what happened with us. So, we didn't just have a smoldering fire, but a spurt of flame like on a flame cutter, which did not just melt away the surrounding structure of the cartridge, but also released fumes, smoke and various emissions into the surrounding air. The cartridge was placed in my line of sight, and I was the first to notice the flame. I shouted "pozhar", i.e. "fire" in Russian, not English. Our commander then tried to extinguish the fire, but it didn't work because the cartridge kept producing oxygen.

We then used Russian-made water extinguishers to cool the reaction, until it came to a halt, or the cartridge was simply burned out. But, the main problem, like with any fire, was the smoke. As we all know, most people die in a fire from smoke poisoning.

Caumanns:
How does one get rid of the smoke? Can it be blown out into space?

Ewald:
No, that would be a catastrophe. If we had made Mir airless, it would have been uninhabitable. The life support system contains devices that purify the air. One device filters out carbon dioxide, but its level was not significantly elevated. It was unlikely that carbon monoxide had been produced, because it was not a smoldering fire, but an oxygen-rich flame instead. But what we didn’t know was the composition of the other gases produced by the fire, which we could not measure at the time. So, initially, we wore a respiratory mask for two to three hours. It is an enclosed system with very dry, warm air, and quite unpleasant. Because the Russians were sparing with their training material, we never had a chance to test this on Earth. When we did, we trained with respiratory masks with the nozzle cut off. We had one other set on board, each, for the purpose of climbing into the Soyuz for an emergency escape. But we were not allowed to use them until the decision for that was made. So we kept an eye out to see whether anybody got blue lips or blue fingers, and we always moved about in teams, so nobody was left alone.

We had a doctor on board, who got the intubation equipment ready. But, finally we risked taking off the masks, after the atmosphere had become visibly clearer due to the work of the ventilators and filter systems. Naturally, the smell like something had burned was still prevalent. We then washed and vacuumed the entire station. The soot particles also stuck to the clothing. We could only contact the ground station the next morning, because the Russians were sparing with their communication stations, and back then we had communication outages up to nine hours long. But nobody could have helped us, anyway. We had to manage the situation on our own. The decision to remain on board, despite the breakdown of this particular oxygen system and despite the potentially toxic atmosphere, was made by all the crew as a group.

This is the kind of event we were prepared for in training. Another is sudden loss of pressure. That is very dramatic. You feel a popping of your ears and you start to determine the time left on board based on the speed of the pressure. If still possible, an attempt can be made to close the affected module airtight, so the rest of the station can be preserved. On the ISS a leakage of ammonia for example would be a catastrophe. It circulates in the outer cooling system. There are two barriers, but if they fail, this could not be managed anymore. But you never ever let all the air out of the station; that would be a total loss.

Küppers:
Looking back on it now, would you call the feeling you had at the time a fear of dying?

Ewald:
No, it was more like "fate is not being kind to me". It was the fourteenth day of the mission and I was involved in a very demanding (as far as this was possible on the Mir) scientific mission, and making good progress, but all the results would have been lost. I managed to stuff my pockets with all data storage media within my reach, all with the notion of a possible premature return to Earth in mind. For me, having to abort the mission was more of a threat than anything else. The way it was is that we had the option of returning in the night at any time with the Soyuz capsule, without anyone on Earth expecting us. That would have been a very eventful night à la Shackleton, but ultimately I was always convinced that we would return alive and well.

Hedtmann:
For yourself and your family you justified this flight as scientific mission. Nobody else can do it, and it can only be done up there. It seems, indeed, in such a dangerous situation to be the worst possible thing that can happen: The data are lost. And then the thought: But I will get back safely. As reflection on the technology and the organization, a very confident attitude, really!

Ewald:
Yes, and this confidence is the counterweight to the risk assessment. Unfortunately, on the two shuttle missions they lost, NASA did not perform this weighing of risk fairly. The Challenger astronauts were not informed that specifications for certain parts regarding cold temperatures on this winter day were not met. The commanders had every reason to be consulted about the liftoff decision. Regardless of any pressure to continue with liftoff, if it should not be done – if it is impermissible – you must not do it. That was the mistake with Challenger – and with Columbia the unsuspecting crew attempted to fly their craft until the last second. They had lost the left wing and still tried to steer against it, to compensate, supposedly. All because they were left in the dark as to what could happen on re-entry with the hole in the wing edge. Those are gross violations of trust – trust that astronauts must have in the organization that sends them to space.

Challenger and Columbia – two disasters that left a mark on spaceflight

On January 28, 1986 the Space Shuttle Challenger disintegrated 73 seconds following liftoff because an O-ring had lost its elasticity due to cold outside temperatures before launch, which allowed combustion gases to escape out at the side. Ultimately, the large hydrogen tank ripped open and the aerodynamic forces caused the spacecraft to tear apart. The seven crew members may have only died as the crew compartment hit the surface of the Atlantic more than two minutes afterwards. Engineers of the manufacturing company had expressly warned against the launch in the problematic temperature conditions. On this mission – for the first time ever – a person participated who was not a professionally trained astronaut. A teacher who would give lessons from space.

Remains of the
Space Shuttle Columbia

On February 1, 2003 as it re-entered the atmosphere, the Space Shuttle Columbia broke apart. Once again seven crew members died. At the launch of the space shuttle a piece of insulating foam from the external tank broke off and punched a hole in the thermal protection of the left wing. It was here that hot gases penetrated during re-entry, triggering the catastrophe. Despite evaluation of film recordings of the launch and warnings of experts involved, the damage to the wing was incorrectly assessed.

Küppers:
The two violations of trust you just mentioned occurred in a fully-developed scientific program, and not in the context of commercial spaceflight.

Ewald:
In an "agency program". There are naturally still conflicting reasons why the U.S. used a shuttle to go to space. The reasons space and the base of crew decisions was not exclusively scientific. Otherwise, Glenn would not have gone to space again, or Bill Nelson, who later became chief of NASA. Back then they already were taking influential passengers along. The shuttle program program served naturally also for the purposes of America's prestige. Following Challenger, you would have thought they would have sobered up and would recognize the shuttle's limits, but Columbia unfortunately demonstrated the opposite.

John Glenn, astronaut and politician

On February 20, 1962 on board the Friendship 7, a Mercury capsule, he was the first American to orbit Earth. From 1974 to 1999 he represented Ohio in the U.S. Senate and at the age of 77, on October 29, 1998 he flew once again into Earth's orbit, this time on the Space Shuttle Discovery.

Hedtmann:
It also shows that these missions, which are planned down to the last detail, taking every risk into account, still contain substantially more residual risk than is typical for our daily lives. You also mentioned just now that breathing through the oxygen mask was unfamiliar, because the Russians were sparing in their training. Overall, did you feel well prepared for your flight, or would you say, from today's perspective: It needs to be done differently?

Ewald:
This is another area where there are differences in approach between the U.S. and Russia. At least in my days, anyway. Compared to that time, things are not as homogeneous in the U.S. today. If a commander at NASA sayd, a certain line in the procedure must be removed and replaced by another one, then by the time of the next training, it was done. They have a staff of personnel whose only job it is to implement such remarks. Perhaps, sometimes, somebody would roll their eyes because the previous astronaut wanted exactly the opposite, but the opportunity was there to improve the safety and effectiveness of the flight, and that's how it was done.

In Russia I participated in two training periods. The commander and the on-board engineer remarked that a procedure was nonsense and that it would have to be changed. When the second training periods took place, the procedure in question was still there. In Russia the technicians, engineers and chiefs of the aerospace agencies have much more influence on what the cosmonauts must accept or do than in the U.S. This naturally has something to do with the different views of human nature in other countries. The Russia we got to know was not so sensitive with the individual wellbeing of people as what was considered normal in the western world. Not that I had ever felt exposed there. After all, not only did we get to know the redundant system, but also the backup system of the redundant system, and so on.

Caumanns:
But, ultimately, a person is on one's own up there.

Ewald:
It is up to each person to make their own decision. Back then I was visited by a delegation from the German Agency for Space Affairs (DARA), because before my flight two or three Soyuz rockets – freight rockets – had crashed in the forest for various reasons. In one case the upper stage didn't work, and in another the booster didn't function. And, this produced something of a crisis in the reliability of Russian spaceflight. But that had nothing to do with the Soyuz rocket for crew transportation – that is a different production line. Anyway, the commission made me an offer, in case I wanted to leave the training, to get me out using a fabricated excuse.

It certainly would not have looked good to say, the astronaut has lost confidence and the backup is not interested anymore, either. So, they were serious about the offer. But I knew that one is the Soyuz 2, which is for cargo, and the intention there is definitely to get the most out of the payload. And then there is the Soyuz-FG, with a history of several hundred successful liftoffs, which is used for crewed flights. Since I was aware of this information, I had a solid basis to make my decision to continue here.

Hedtmann:
It is the individual's decision that counts. It is okay if you say “I’ll do it”, and it is okay if you say “I won’t”. That is of course an important expression of culture, if we are talking for example about corporate culture. Officially, according to accident prevention regulations, employees are not permitted to follow instructions which are clearly adverse to health and safety.

But this here of course goes beyond that. It means: “Assess the risk yourself, and if you think it is too high, then refuse it!” An important factor for the trust we spoke about. But if we now turn our thoughts to commercial spaceflight, the allure of swiftly getting into spaceflight without years of training, based on all that has been achieved in the decades before, plays a big role. In the commercial sector they are now selling tickets, and what counts is setting records, like getting the oldest or youngest person to space. Captain Kirk goes to space at the age of 90. The hype is built. But it doesn’t all have to be viewed from a tourism point of view; research projects can be conducted faster and cheaper, too. How do you view this development, personally?

Ewald:
First of all, it is about the use of the term “astronaut”: You have people here who have paid for a suborbital flight, or who were called last week and told, you just won our contest and now have the pleasure of lifting off to space with Branson’s Virgin Galactic. And when you return, you are given the special astronaut pin for your space suit. It is something of a circus.

Caumanns:
How large is the tourist segment for spaceflight, then?

Commercial spaceflight gains momentum

The first amateur astronaut to complete a privately financed space flight was the Japanese journalist, Toyohiro Akiyama, who was to report from space in 1990 for the Tokyo Broadcasting Corporation. Back then, such an undertaking was only possible with the Russians, and the rather unathletic chain-smoker did not enjoy himself, as he had an extreme bout of space adaptation syndrome.

In recent years competition between private spaceflight providers has been at the center of public interest, each vying to be the first to make a suborbital flight. On July 20, 2021 Jeff Bezos flew with the spacecraft New Shepard of his company, Blue Origin. A few days earlier on July 11, Sir Richard Branson lifted off in SpaceShipTwo, of his company, Virgin Galactic. By all accounts a lot of games were played surrounding the launch dates. Technically, the two systems differ considerably, and only New Shepard reached the crucial altitude of 100 km (Kármán line, edge of space according to FAI definition). Early flights were already focused on setting records, like who could be the oldest or youngest space passenger.

In yet another league altogether is the company SpaceX of Elon Musk, which, with the Crew Dragon, not only flies to the ISS, but also takes paying private crews into orbit. The Inspiration4 crew did not fly to the ISS with the Crew Dragon, "Resilience", but remained in its own orbit from September 16 to 18, 2021 with four passengers, instead.

Ewald:
In 2023, more people took suborbital flights than went into orbital space. However, this is not least due to the enormous technical challenge involved. Achieving an orbital speed of 7.5 km/s is a completely different story than shooting a payload 100 km into the sky, where it loses its kinetic energy and comes down again. There is a huge difference in effort.

Suborbital flight

The Blue Origin and Virgin Galactic flights are what is called suborbital flights, which means they do not reach the altitude required for an Earth orbit. In principle, they are simply very high parabolic flights at altitudes of 80 to almost 100 km, on which a period of weightlessness takes place for roughly three minutes. Technically, the requirements for such flights are quite demanding, but still nothing like the effort required for an orbital flight or a flight to the ISS, which orbits Earth at an altitude of some 400 km.

Caumanns:
What kind of costs are we talking about? Is it something only tech-billionaires can afford?

Ewald:
These days there are contests. Who is the social hero? Who deserves it most? The youngest, the oldest, the sickest? A veritable contest of irrelevancies has emerged.

Hedtmann:
They say that 250,000 euros is all it takes for a short suborbital hop. But anyone who wants a flight right to the ISS has to spend considerably more.

Stern:
50 million.

Hedtmann:
These are completely different dimensions. But for a lot of people, a suborbital flight is all it takes. They were up there, and they have a pin to show it. Perhaps we need to have a talk about the extent to which that could call the significance of spaceflight into question. And, to what extent do the stresses differ on such suborbital flights compared to actually flying to the ISS? Dr. Stern, would you have advised William Shatner to go on this flight, if he had asked you?

William Shatner

The actor William Shatner, here in his role as Captain Kirk, in which he gained popularity in the American series Star Trek. At the age of 90, Shatner was invited by Jeff Bezos to take a suborbital flight in the New Shepard spacecraft on October 13, 2021. Naturally, this was a fabulous PR coup for Blue Origin, and Shatner became the oldest person to go to space.

Stern:
From conversations with the Chief Medical Officer of Virgin Galactic, Dr. Jim Vanderploeg, I know that a lot of research is carried out with sick people there – diabetes, high blood pressure – on the centrifuge, posing the question: How do they cope with the g-profiles? They naturally all handled it well. I value my colleague Vanderploeg, also as scientist, and I am not surprised by these results. The main problem is a) the g-load and the g-profile; and b) that they don't vomit in the brief phase of weightlessness. That would infringe of course somewhat on the enjoyment of the other people on board, too. And, it would be bad for business if people died in the process. At the astronaut corps, there are very high requirements on health. The candidates we select need to be completely healthy. Well, anyone who thinks they are healthy has simply not yet been examined meticulously enough. But, what is important is that these people also stay healthy for a long time. We have boards with representatives from every aerospace organization with extremely high expectations, whether the astronauts are healthy enough for the respective mission. When they are selected, the applicants are roughly in their mid-thirties and must be completely healthy. And if you take a look at a 90-year-old compared to that, it is medically impossible for this person to be just as healthy. It is not possible. So, advise someone?.... if the possibility exists to go to space, I would always say, yes; always, it is amazing. And, at 90, I would say all the more: so what, who cares? There is no nicer way to die.

Gravitational force

G-force (also g-force) is a measurement of acceleration. 1 g corresponds to acceleration in normal Earth gravity (9.806 m/s^2). Weightlessness is correspondingly written as 0 g. On some roller coasters up to 6 g can occur for brief moments. Fighter jets can reach up to 9 g or more, in a curving flight path. With 5 – 6 g in the body's longitudinal axis, without special training and countermeasures people lose consciousness, because the blood is drained from the head into the legs. When a rocket lifts off an acceleration of 4 – 5 g takes place; at re-entry into Earth's atmosphere up to 10 g (Soyuz), depending on the spacecraft and entry method. Since g-forces can be better tolerated perpendicular to the body's longitudinal axis, astronauts are often in a lying position during these phases of flight.

Hedtmann:
Right, if the goal is only to fly to space, then the role of health is only secondary. But today, we are also talking about new tasks that commercial spaceflight can get done up there. What requirements should be placed today on the people who go along – not as payload, but with technical, scientific, journalistic or other jobs to do? In future, space will of course have to be viewed as "normal" workplace. There won't only be people with scientific jobs, rather for some their only job will be to maintain the spacecraft.

Ewald:
I want to make something clear. If I was offered a seat on a suborbital flight – about which I just spoke somewhat disparagingly – with an experiment kit beside me, I would have no problem at all with it. This is nothing else than an extended parabolic flight, which is still used to pre-test experiments. Weightlessness lasts a good twenty seconds and makes it easer to evaluate whether an experiment has potential to function. If ESA said they were going to purchase a few seats on a Branson or Bezos flight instead of using a high-altitude research rocket, to have more time to test in weightlessness, it would make perfect sense. There is another reason, however, why some in the astronaut community tend to view suborbital flights as beneficial. We have united ourselves in the "Association of Space Explorers", which is a group of people from around the world who have all undergone the experience of an

orbital flight. Over the years there have been some 350 – 360 members, from 600 people who have been in space. There are some 80 suborbital passengers (note: as of May 2024). So, this is an organization of some relevance. Its mission is to use the view of the Earth from the orbital perspective to call for fair distribution of resources and to point out that from up there, no borders are visible and it makes no sense from this perspective to fight wars to shift boundaries. This is the principle that guides us. If an increasing number of people can bring this message home – even from a suborbital flight where you are well above the atmosphere and you can see the blackness of sky; above you space, hostile to life, and below you the beautiful blue and white planet – the more people there will be to join the great choir of those who have had the privilege to see the world as a spacecraft for all humankind. Our Russian colleagues currently up there in the ISS are not what you would call fervent proponents of the Russian war, but they are caught in a tense position in respect to this message; so there is a big unspoken elephant in the room up there.

Parabolic flights

In a parabolic flight the aircraft follows the trajectory of an object in projectile motion. People on board experience a phase of about 20 seconds of 0 g. It is also possible to simulate reduced gravity, such as can be found on the moon or Mars. Parabolic flights are used to train astronauts and to prepare and conduct scientific experiments.

Claudia Stern prepares an experiment for the ISS.

But we also have now, as was just mentioned, some who have other, ostensibly philanthropic motives. There was a flight with four tourists who went to space for a few days with the intention of using the flight to collect donations for a children's hospital. Sure, making the flight was not actually necessary, and the money spent on it could have been donated directly. On the other hand, one person on the flight had an amputated leg, which is something that ESA now wants to research in a project too, but with a longer lead time. On one suborbital flight there was an Egyptian woman of Muslim faith, who now tours the lecture halls as influencer to show what she was able to achieve as role model for young women. Yet another person who also used a competition win to launch a career. But there is a big difference between that and professional astronauts who, after a competitive selection process, go through basic training for four years, training diligently in Houston and Cologne, waiting for their flight.

Küppers:
So, if I understand you correctly, the scientific side of your motivation plays a big role? Is that the only justification?

Ewald:
It is the most tangible justification, but not the only one. It is why all the philanthropists fall back on some kind of experiments. These all then have to do with AIDS, or vaccination, or fighting the world's misery.

Küppers:
You said that an important requirement for trust is transparency. What is your own attitude towards technology? Does your trust in technology have its limits?

Ewald:
To be honest, in my days as physicist – I made myself useful with a radio telescope – I quite admired engineers who had a knack for technical solutions. Because, from experience they always added a second backup in case the first one failed, and that is something I would never come up with. As such, the interaction between my understanding of a technical system and the way the technical system actually does function is something I naturally enjoy. It has always been fascinating, especially in space. Sometimes, when the technical system fails, one can still start using one's brains, whether this or that

alteration should lead to success, according to the way one understands it. Alexander Gerst once struggled with a safety bolt that was fitted in a sensitive device for liftoff – an oven for material samples – but the bolt just couldn't be released. After long debate it was decided to saw the bolt off. And what did Gerst do? First he covered the bolt with shaving cream, to make sure that tiny metal particles wouldn't spread out all over the place while sawing inside the sensitive device. So, it was a good idea, even though not envisaged in any procedure.

Alexander Gerst on the ISS

Stern:
It seems clear that the ability to conduct a risk assessment or a risk-benefit evaluation in a reasonably objective way is influenced by what the motivation is for the spaceflight. When looking for spaceflight personnel we look for scientists, but also pilots. That is how Apollo started. They were all test pilots. And that was also practical, because they are used to following procedures and, unlike scientists, don't constantly ask questions like why or what for. (note: Ewald laughs.) If the focus is on science, each individual can decide for themselves whether the knowledge to be gained justifies the risk or not. Things have changed in society, too. In the past the agencies would say, whatever the situation, we ultimately know what is best for the astronauts.

That was probably an attitude that was common among employers back then. We know what is best for our employees. But, that has changed in the direction of transparency and taking responsibility for yourself, so that astronauts can now say: “No, we refuse to do it.” But, if the motivation is to have fun or even the hope to write history and be famous – which is how Shackleton’s advertisement started – the influence it can have on such an assessment can be radically different.

Hedtmann:
I think that is an important point. The objectivity of a risk assessment is highly influenced by the specific motivation for doing something. This is something that applies in general, and everywhere, but for activities that are out of the ordinary and reflect a personal need, it is naturally particularly decisive.

Stern:
And I need to be capable of perceiving that cognitively, regardless of my personality, my mental level or even with a pschological disorder. When we announce training positions for astronauts we get an extraordinary number of applicants with substantial psychological abnormalities. They are seriously ill, but they believe they are the world’s top astronauts and that they are ready for liftoff tomorrow. The kind of personality necessary is one that is able – and willing – to understand a risk assessment that the company or agency produces. That is why the mental and psychological selection process beforehand is so important. There was once a certain Mr. L. from Germanwings, who was popular among colleagues, and no nerd, and known as a really nice guy, but nevertheless killed a whole plane-load of people. That is why, for me, personally, this is a very important aspect.

Ewald:
That is why their true motivations come out in the books written by my colleagues after their missions, much more clearly than before the mission. Withholding the real motives is widespread.

There are dominant personality types who deliberately train themselves in social skills to avoid performing badly in this particular characteristic during the selection process or even shortly before the flight. Another example is described by Scott Kelly in his book. The carbon dioxide content of the space station almost broke him, because it gave him a splitting headache.

The man has been an overachiever all his life. Whatever he wants, he makes happen with the kind of toughness toward himself and others that is sometimes so extreme it would not make a good impression in an application procedure. He suffered from the high carbon dioxide content the whole time, and he was up there almost a year. He preferred to be alone in the American module, because there the carbon dioxide concentration – which cannot be reduced by the filter system down to levels like on Earth – was somewhat more bearable. People like that who are exceedingly successful and can only do things well, suddenly reach their limits, and it throws them off balance. By the way, he mentions his Russian colleague only twice in his book, even though he was with him on board the whole time.

Pilots psychiatric disorder

On March 24, 2015, co-pilot Andreas L. intentionally caused a Germanwings Airbus A320 with 150 people on board to crash. L. suffered from episodes of depression and, up until the time of the accident, had paid visits to numerous doctors, and was even certified as unfit for work on the day of the crash. But, for reasons of professional discretion, his employer had no idea about any of this. To this day, the Germanwings crash remains a subject at numerous international flight medicine conferences. Some procedures related to the determination of pilot fitness were modified. Likewise – as consequence of this incident – for some time it was not permitted for one person to be alone in the cockpit.

Hedtmann:
A person cannot simply shed their personality. Perhaps they can cover it up for a while, but not unlearn it.

Ewald:
Until now things have gone well. We have had no flight cancellations due to personal flare-ups. Occasionally restrictions in the mission profile, a few things have had to be alleviated, something nice packed into the Progress transporter for a change, but no serious problems.

Küppers:
So, you consider the selection criteria to be sufficient?

Ewald:
It is a wide spectrum. The selection criteria for the shuttle astronauts were completely different than for those who are now to work together in six-month or one-year cycles on the ISS. The final word has not yet been spoken regarding the criteria.

Stern:
You just spoke of the dominant personality type of person. It is of course on one hand good to have people who are capable of leading, but who can at the same time also be a very good team member. With European astronauts we have a similar situation where they are initially merely a team member for half of the mission, and then become commander of the space station. And, sometimes that can be very difficult. That says something about the quality of the long and good training, with three years of basic training and the one-and-a-half to two-year mission training. The participants really get to know their environment, and in extreme situations, such as survival training in the Russian winter, the team leaders are certainly pushed to their limits. In the commercial offers, none of this is included anymore. After the "you're in" decision, half a year passes, perhaps, and you are already sitting in the spacecraft.

Hedtmann:
If you were asked to offer a recommendation to the young colleagues just getting started, with respect to the mental and scientific preparation for a space flight, what would you advise?

Ewald:
Now, as far as scientific preparation goes, the first-time fliers approach things somewhat more adventurously – such as with various biopsies – than an experienced colleague might consider. Ultimately, that which one does or does not do is also a question of the professional attitude.

I would like to mention one aspect, however, which might spook many of the young colleagues: the encroachment on private life associated with astronaut training. Your priorities shift completely away from family to your job.

Professional astronauts are given a trip plan, which literally includes trips for two years around the world. Under Covid conditions it was exacerbated even more by the fact that they did everything exclusively among themselves, and there was no chance for the family at home to take part. As soon as the training begins, the rate of change in partner relationships is astronomical. But to achieve the goal of becoming an astronaut and going on a flight, many even sacrifice their private life.

Hedtmann:
Is it advisable to recommend asking the partner before submitting an application?

Ewald:
Harmony between job and relationship has the potential to motivate a person up there, even over six months.

Hedtmann:
Even in some earthbound professions there are jobs in which the most important thing is not the work-life balance. There are also the kind of people who have concluded that the only thing they need for fulfillment in life is work. People who find it difficult to let go when they reach the end of their career. Through an exertion of the will, this can possibly be changed. But for somebody training for a spaceflight, there is no escaping this obligation, unless of course they give up. Which means, from the decision to undertake the mission until you finally land again ...

Ewald:
... you relinquish control over your private life.

Küppers:
But do relationships exist that hold up well under these circumstances? Did your relationships hold up well?

Ewald:
That is a very personal question indeed, and it can only be answered individually. In my case, at the time of my initial training, the children were still very small. They did not go to school yet and my family could come along to Moscow. The Russians made the majority of training possible locally.

Today, that is naturally not possible anymore, if you are training for the International Space Station. At the time of my second training period the children were somewhat older, and because of certain features of the Russian education system and the language, the family stayed home. You have made it your objective to succeed no matter what, and so the balance was achieved. However, even if theoretical: On a second flight opportunity it would have been the decision of my wife, whether she believed that the reason for it was justified. By the way, in the movie "First Man" there is an interesting scene: Neil Armstrong is sitting at the kitchen table with his family and his wife asks him to explain to the children what kind of mission he is going on and why. And he isn't able to do it, at least in the film.

Neil Armstrong's historic moon landing

Neil Armstrong was commander of the Apollo 11 mission, and the first person to walk on the moon. On July 21, 1969 he set foot on the moon. It was preceded by the spectacular approach of the lunar module Eagle, crewed by him and Buzz Aldrin. Because the intended landing site was strewn with rocks, Armstrong had to search for an alternate site and only succeeded with virtually the final drops of fuel budgeted for landing. By the way, the astronauts of the Apollo missions estimated their chances of a safe return at 50:50.

Conversation during a break at the DLR short-arm centrifuge (from left: Prof. Dr. Claudia Stern, Dr. Jörg Hedtmann, Prof. Dr. Reinhold Ewald)

Stern:
This is the essential reason why it is so important to include the family. It is not merely the spatial distance. Back then of course there were no cell phones, and keeping in touch was much more difficult. But, the horizon of experience and the personality are changed so radically by this phase. If you do not have an opportunity to include the family in these changes, and if there is no way for the family to share in the experience because there is no way to talk to each other about the extraordinary things happening, a separation of worlds occurs, and it is impossible to put that back together again.

Hedtmann:
In training it is not always possible to predict all that can happen in an environment with unknown hazards. Can you describe some accident hazards

you experienced, and which are related to the typical conditions on board a spacecraft or space station?

Ewald:
The transition from an operational to a hazard situation: One example of an extreme situation was when a module of the Mir station was hit by a Progress transporter and sprung a leak. The first thing the crew had to do was remove cables from a hatch – which had been fed through it – because it had to be closed quickly. Some of the cables were thick, and some were thin, and some scientific and some electric cables. And to cut these electric cables in such an emergency situation with whatever tools were at hand, is naturally not covered by any standard procedure. The air hoses, which had been fed to less ventilated areas, were also running through the hatch. It was careless. Quick-disconnect connections are of no use here either, and so one switched to consistently feeding these cables between two modules through special outer rings. These are typical routine situations, in which a kind of laziness made you forget any thoughts of potential hazard. So much is written in safety reviews regarding rotating elements, for example, or centrifuges, pressurized containers, and hot surfaces, etc., sometimes to a point that it is impossible to even use the device any longer. Careful balancing is definitely a must. Astronauts are also called to a crew-station review at regular intervals, where they are confronted with all of these safety regulations. Even if you assume that nobody in their right mind who just started up a rotating centrifuge is going to reach into it, it still has to be ruled out formally.

With every crew change, knowledge of these things on board is lost. One crew figures it out, and then the next crew starts from scratch and cannot make sense of it again. But, continuity here is very important. This is also why the careful placement of devices, cables and equipment for experiments is so important. Certainly, it takes a lot of time, but it makes all the difference in hazardous situations. For some items a “search list” exists, which lists things whose whereabouts are unknown, or behind which panel an item may have disapeared. This is a direct consequence of weightlessness. But, for quick reactions in hazardous situations, often the wrong behavior becomes a habit.

A space station is a constantly changing research facility. Cables and air hoses are laid out again differently for each new experiment, but not always taking the consequences for safety into account. Here, Canadian astronaut Chris Hadfield struggles through the tangle of cables.

Hedtmann:
In an area so relevant to safety, which requires such safety consciousness, where thousands of safety procedures are run through before a device is even switched on – this is where a cable or hose is fed through a hatch? This makes me think of a safety inspection in a company on Earth. The first thing that is checked is whether emergency exits are free of obstacles, or whether things are lying around – okay, on Earth this is important, so that nobody can trip. But who would think of simply feeding a hose through a hatch? Whether weightlessness or outer space – first and foremost the space station is a flying research laboratory. Even in research labs on Earth, I have seen cables hanging from the ceiling, and here or there tape is used to fasten something. It wouldn't surprise me if this basic attitude among researchers like "just fix

that in place or tighten that up" – because they are so focused on the actual experiment – is just as prevalent in outer space.

Ewald:
Absolutely right, and physicists in particular are focused primarily on success, and not everything that is cobbled together in the experiment setup would be officially acceptable. But, this is not how it should be on the ISS, if only for reasons of continuity. Since 2000 there have been 70 crews up there, and they cannot learn everything on Earth, because on Earth it is simply impossible to reproduce a lot of the situations. That is why it is so important to keep things relatively under control. Another matter is that of a lack of humility. In his book, Matthias Maurer writes – you see, I do read what colleagues write! – that it was an awful experience with the tourist crew, because they were constantly overestimating their potential and abilities. Even the highly experienced astronaut who accompanied the group could hardly keep them in check, not to say anything of going after them constantly. Perhaps they did not want to impose too many restrictions on them, because, after all, they had paid a lot of money. Up there, before anything else, one is merely an apprentice. The crew that greets you up there, they know for sure what works and what doesn't. Anyone who then presumes to say, "in training I always did it that way," risks destroying something that had long worked that way and should have stayed that way. You need a mindset that is prepared to ask – even the ground station – before doing something. In high spirits about one's knowledge or training, one easily forgets this. Things can get dangerous very quickly.

I have accompanied many flights from the control center, and I have seen a lot. Once, somebody's foot accidentally hit an engine controller on the Soyuz, and the space station immediately veered off course because the rockets fired in a certain direction. I could feel the commotion just by listening to the broadcast. As newcomer it is important to keep yourself in check until the task is explained to you and you can perform it responsibly. A conflict exists with the astronauts' autonomy – whether they can decide things themselves, whether they should ask the old crew, or whether they should involve the ground station. This at first is not compatible with the "yes, I can" attitude, but this change in mindset is something you simply have to go through, otherwise you find yourself looking quite dumb and ignorant.

Stern:
At the start, everything is new in any case. The experience with microgravity is a big thing. And despite training, orientation is difficult; with the fluid shift the body's fluids rise to the head, and you get a "puffy face". Some call it "space fog". It becomes considerably more difficult to think – one of the reasons for the checklists. If you start thinking after a while that now you can do everything, and you do not need checklists anymore – that is when the mistakes begin. For the experiment that we sent up on the Matthias Maurer mission we had to perform an unbelievable number of safety checks and tests, and fill out long checklists.

Fluid shift

Because of the fluid shift in the body, which is a consequence of weightlessness, a phenomenon called "puffy face" occurs. In 0 g conditions, the blood and interstitial fluids, which are found in the lower half of the body on Earth due to gravity, are distributed uniformly throughout the body. This causes the face to swell. Naturally, the puffy face phenomenon is merely a visible expression of the same fluid shift that affects other organ systems, like the brain, heart or kidneys, and which leads to changes in physiological processes. Here, the change is visible in Chris Hadfield.

Hedtmann:
Nevertheless, a lot here seems very much like Earth to me. If someone accidentally hit a lever and it triggered an unwanted reaction, here on Earth we would say that mistakes had already been made in the risk assessment – it should not have happened in the first place. Why was it active, and why was it so exposed? I assume such thoughts also play a role in the engineering and construction of a space station? Or, is it simply the fact that operating personnel do not play a primary role during the planning stage, as so often in technical developments?

Ewald:
Planning is very difficult because of the extremely limited space. It is impossible to prevent the unexperienced from accessing areas where actually only the experienced should operate. I have never trained for the Dragon and I don't know what Axiom and SpaceX teach their people, but I assume that in the Dragon capsule it is inevitable that untrained persons come into close proximity with complex systems. You just have to always restrain yourself. "Do not touch" – even though, to tell an astronaut "do not touch" … (tapers off in laughing)

Küppers:
It is a similar case in maritime shipping. They are always nervous about untrained personnel coming on board and raising the risk potential, or behaving wrong in critical situations. A prominent difference, though, is the confined spaces, which is usually not the case on a seagoing ship.

Hedtmann:
The assumption is that these people are specialists. But when we look into our companies, you never know what kind of people you will find there on-site. That is why everything needs to be locked up, switched off, and secured against switching on again. But in the work environment of a space station, I would expect people to be highly trained and to know what not to touch or to put their hands into. However, an unclear situation is different, because you never know how things will turn out.

As layman, I imagine there are all kinds of things floating around in the weightlessness. Is that a serious problem? Screws, dust particles … Large things can be seen, and they can be caught again. But what about all the

Crew Dragon approaches the ISS for docking

NASA collaborated with Boeing and SpaceX to develop a new generation of astronaut spacecraft. Those spacecraft transport astronauts to the space station and expand research possibilities in orbit.

micro-sized stuff floating around? Does it get into your eyes? Do you breathe it in? What is it like?

Ewald:
We had a situation like that after the fire. We had no idea how much asbestos and other material had been released from the insulation. There are filters for microparticles, but it takes more than two hours for an effect to occur. For that reason eye protection and mouth and nose protection is worn when a new

transport vehicle arrives. And then, first of all an air purification device is put in and the hatch closed again. Dust does not settle, it simply floats about. What is much worse is getting beard stubble – which is set free when shaving – in the eyes. That is why a vacuum cleaner is always connected to the shaver. Or hair, which takes on a life of its own during a haircut ... If you do not clean the atmosphere consistantly, hazardous situations can arise.

Stern:
Sometimes, floating around can cause small wounds, scrapes or impact injuries. A whole range of maintenance tasks need to be done, and for some, wearing protective goggles is extremely important. When the crew is in the cupola, to look outside, it is important to wear sunglasses, because there is considerably less radiation protection there. But that is not very popular, because the sunglasses change the perception of color. We also have the high carbon dioxide concentration, which is the cause of the headaches. Sleeping is a "never ending" topic, because it is so overpopulated up there. Normally, everyone has their own sleeping space. But, when you have so many people your space is not guaranteed, so some sleep in the space capsule, or a random emergency sleeping space. We often hear complaints about the SpaceX capsule, that it all looks super chic, but is totally non-functional, because everything is so smooth, and it is impossible to fasten anything down, even yourself.

Hedtmann:
What kind of mental and physical challenges or changes await people in space? And, how do we know that?

Stern:
We know it from the astronauts who report it, especially the ones with a scientific interest. Mostly from the Americans, by the way, because European astronauts traditionally do not like to report on such medical topics. They do not want to put their second flight at risk, unnecessarily. So nobody complains of discomfort, or medical problems. In the U.S. the astronauts often publish about their illnesses themselves. We do not have such a tradition here. But, aside from the reports, we of course also have the scientific experiments. The fact that initially people are not well up there, is something we have known for a long time. It subsides after 72 hours. Seventy percent get space adaptation syndrome, with nausea and vomiting. Countering it with medication is an option. And then there is the fluid shift we talked about, with puffy face, and

the large amount of fluid in the brain, which can make it so difficult to think. We also observe loss of bone and muscle mass, loss of muscle strength. And alterations of the eyes; 70 percent are affected here, too. Those are the main problems. Added to that is the radiation, which plays a role everywhere. Our two DLR ladies have now orbited the moon, to measure radiation exposure...

Hedtmann:
... Helga and ...

Stern:
... Zohar! Our only other source of knowledge about the effects of high doses of radiation is the dropping of atom bombs or atom bomb tests. What are the effects of radiation, where does it play a role, what influence does it have not only on the body, but also on food and medication, etc. These are essential questions – also for the Mars mission. But, the main changes affect the bones, the muscles and the eyes.

Helga and Zohar

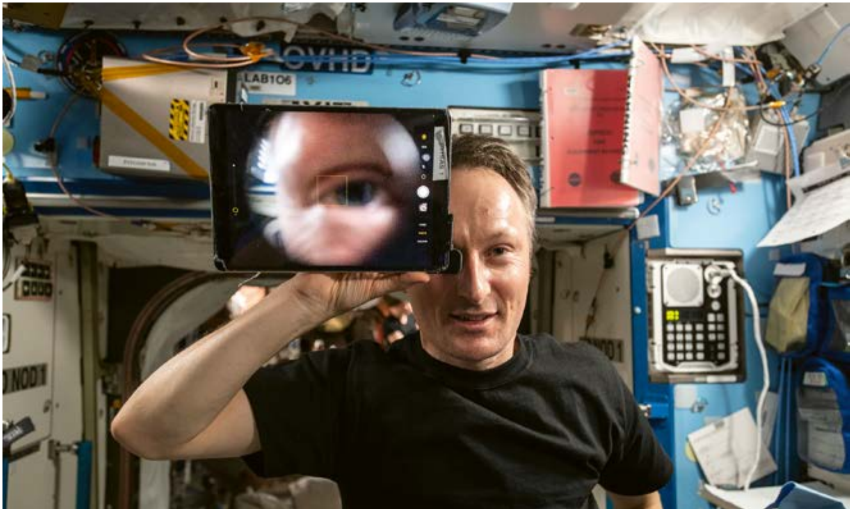
On the Orion capsule, which orbited the moon in NASA's Artemis I mission (11/16/2022 – 12/11/2022), there was in fact a "crew" from Germany on board. The two female measuring mannequins Helga and Zohar were prepared by the German Aerospace Center (DLR) for purposes of measuring radiation exposure. For this experiment, Zohar wore a radiation protection vest from Israel. The results will be tremendously important for mission planning for moon and Mars flights.

Caumanns:
What happens to the eyes?

Stern:
The eyes can experience a papilledema (swelling of the optic nerve head), a flattening of the eyeball with a hyperopia and changes to the retina – e.g. cotton wool spots – with corresponding defects in the field of view. On Earth no equivalent to these changes can be found. In contrast to the musculature, for example, which regresses if one does not use it for a long time. All of that happens more quickly in space.

Hedtmann:
These eye changes are your special field of research. And part of it was the experiment you had on the Matthias Maurer mission. You are attempting to reproduce that in your research lab with studies in head-down position? How can the changes on board the ISS be measured? There is nobody there with an ophthalmoscope.

Stern:
We developed an adapter and fitted it to a system that already exists on the ISS. Actually, it was intended for a cell phone. But there are no mobile phones on the ISS, because of the fire hazard. That is why we built a lens system in front of the camera of an existing tablet computer. This way, Matthias Maurer and his American colleague could take pictures of the optic nerve head and check whether it was swollen. On Earth that would be an emergency situation. If you have a papilledema you will be sent to the clinic to check whether intracranial pressure is elevated. In space this is also a pivotal question. It is known that changes to the brain take place, and also shifting of the brain and loss of brain substance. And so the question is posed: is intracranial pressure elevated up there or not? We do not know that, because we have not yet been able to measure it. We have data from astronauts who have returned, but the data says nothing about the time beforehand. We are still concerned about it, and indeed it is red risk number two on the way to Mars. Number one is the radiation. And, linked to number two are the eye changes, of which we do not know where they come from. What we do know is that the changes increase with the length of mission duration. And, we also know that the problem occurs again on a subsequent mission. What we do not know is how it develops beyond twelve months.



On the ISS, Matthias Maurer conducts the experiment to diagnose papilledema.

Hedtmann:
Does it regress following return?

Stern:
It varies. With some people it regresses quickly, and with some it regresses within six months, and with some people it never goes away.

Hedtmann:
Which is definitely unsettling. Compared to puffy face, which, of course, regresses as soon as gravity returns. Does it actually also feel unpleasant?

Ewald:
I was on the fortunate side of the 70/30 ratio (note: 70 percent of astronauts suffer from space adaptation syndrome following arrival at ISS). Even though I had no way to know that in advance. Because, on parabolic flights I felt sick, and I am not the kind of person who likes rides on carousels. As such, I was curious as to how things would work out, and I approached it initially without the help of medication. And I felt well! So, I did not notice much from this puffy face thing, either, except that my taste was gone. That is why we added a lot more salt than usual to our food, so that we would at least taste

something. But, I was not permitted, unfortunately, because I had to adhere to a precise menu for the purpose of an experiment, and so I only ate a specially prescribed menu, particularly with respect to salt. It consisted of a lot of broccoli. Since this meant that the input was known and the output was measured, we were able to acquire new findings. One of the most irksome things we noticed was the weakness of the immune system. No scratch or skin infection would heal in the usual time. I had a pimple which was very noticeable throughout the entire mission. Okay, we were told in advance that the immune system was weakened, but it was impressive to experience it first hand. Our Russian friends opened up the hatch to us on arrival and their hands were completely blue. They had been working deep in the belly of the Mir station and disinfected the various injuries with iodine, if only to prevent any risk of longer-term skin infections. But, overall, there was really quite a sense of amazement at how well the body could adapt to the altered gravity situation without any aids. Perhaps there are some impairments to vision, and a few other things in the long term, but there is not one vital bodily function that is dependent on Earth's gravity. That is fantastic. The kidneys work, the digestion works, peristalsis works. Heart and lungs adapt to the new situation. That the ventilation is not exactly perfect is something we are aware of, but that does not hamper you to an extent that you need artificial aids. So, that is the good news – that the body has reserves that evolution could not have foreseen as useful.

Caumanns:
How long is the trip to Mars? Outbound flight, return flight, and of course spending a certain amount of time there. Reason enough to come up with ways to endure the effects for longer?

Ewald:
That is the big problem. The radiation exposure is a big factor. We are relatively well shielded in an orbit close to Earth. I had an exposure of 700 microsieverts per day. An amount that is naturally far too high for a normal workplace on Earth. Relatively, it looks like this: on Earth, factor 1, in the mountains 2, in the stratosphere 40, in low Earth orbit 250, and interplanetary, 770-fold! On Mars it is 260, because it is rotating and occasionally you have the planet between you and the solar wind.

Hedtmann:
That sounds like a major wet blanket. But we also have the unsettling development in the eye, with changes to the retina or optic nerve head. What happens if it increases during the mission? Naturally, everybody wants the crew to return home with functioning eyesight.

Stern:
From the point of view of mission reliability, the essential thing is that the crew can see properly when they arrive on Mars. Upon arrival back on Earth it would naturally be tragic if vision had deteriorated. This would be first and foremost an occupational health and safety matter. But when they arrive on Mars, the aim is that everything functions properly. On Earth, having an enormous crew of people who help after landing is standard. Lifting out of the capsule, giving infusions, propping up, ensuring that they do not collapse. The brain first needs to adapt itself to the Earth again. You have to learn which way is up and down. For three weeks following arrival astronauts are not permitted to drive a car. Thankfully, the brain can of course adapt relatively well. Only, when the crew arrives on Mars, following months of travel, there will be nobody there to help! Upon arrival they need to be fit and to stand on their own. They must not collapse suddenly, and properly functioning vision and thinking are essential. That is indeed still a problem. With

Long space missions and the long stay on Mars are researched in what are called “analog missions”, for example in Israel’s Negev desert. This is how it could have looked.

the moon, it is not so bad, because it is relatively close by, and the flight is not so long; so it is manageable. Mars is an undertaking of vastly different dimensions entirely.

Hedtmann:
Mars has a third of Earth's gravity, the moon a sixth. If you are in transit for many months and then suddenly accelerated to a third of the Earth's gravity, the things that should prepare you for that are important furnishings of the spacecraft.

Ewald:
There were experiments with a Soyuz crew having being asked to walk through a small obstacle course shortly after landing. It was terrible. Even the movements of the ones who were well and not preoccupied with holding back the nausea were lumbering and manifested impaired coordination.

Stern:
This is another place where we use ISS returnees in the context of the "ISS for Mars" program. In other words, letting them manage on their own with as little intervention as possible following landing.

Hedtmann:
Together with your team you assess the suitability of astronaut applicants. The fact that there are no published criteria is something I am aware of, and it is not my intention to coax you to reveal those secrets. But, what must I possess to qualify, if I want to go to space as scientific astronaut these days?

Stern:
You simply have to be healthy. That sounds a lot easier than it actually is. So, first of all, no medication, because it would have to be kept stocked there. You have to be able to see well, hear well and all organs have to function well. We are not looking for superman or superwoman, but you have to be healthy in all areas and functions. You cannot have any deficits in the psychological selection process, either. So, as I said, you do not have to be super, but good in every respect. In the psychological examination, priority is placed on logical thinking, ability to concentrate, three-dimensional powers of thinking, but also manual dexterity. We have already mentioned the aspect of maintenance tasks. Leadership, but also the ability to work in a team, are required. And,

to defuse critical situations, a certain sense of humor is not unhelpful. This is something you often notice when working with current-day astronauts.

Ewald:
In the past a reasonable willingness to learn languages was expected. Today, it is not in demand much anymore, because current crews hardly ever go to Russia and conversely, the Russians to the West. Since I learned Russian, the language helped me to become an integrated crew with my colleagues quicker than it might be today. Some hardly speak any Russian, and others get by with broken English. In this respect I still view willingness and ability to learn languages as important qualification.

Stern:
For the training, it was obligatory to go to Russia. If you want to live there for a long training program, possibly also with family, knowing Russian is a must. Which brings us back to the subject of the importance of a long and good training program.

Hedtmann:
If we apply this aspect once again to commercial or tourism spaceflight, how can we assess it? For astronauts on scientific space flights where the crews stay in Earth's orbit for half a year a different and more comprehensive suitability is of course required than if you were only completing a two to three-week special mission. Can the criteria be customised depending on the mission? What would be the illnesses where you would definitely advise against sending such a person to space?

Stern:
Certain suitability criteria must always be met. But for professional astronauts, there is no doubt that deviations from the requirements for the commercial sector exist, where the requirements are lower. Most important there – apart from requirements of the special task – is that they do not endanger the mission in the short time they are flying together. Nobody wants to have an emergency return-transport situation. But, the requirements in the psychological and mental areas are high, too.

Hedtmann:

We now also have a parastronaut for the first time; i.e. a physically disabled astronaut. He is missing his lower leg. I once experienced him at a speech presentation, and I can tell you the story is quite impressive. Now, the question of whether a person needs both legs in space is one that is certainly not out of place. But, is that something that can be built upon? Is that a typical job for inclusion?

John McFall, the astronaut with amputated lower leg, during training.

Ewald:

We have thought about this a lot. Actually, you do not need any legs at all. Except perhaps to hold on. On the ISS you are fixated by inserting your feet into straps. Jokingly, you could say that you lose the calluses under your feet, because you do not walk anymore, but you get new ones on the instep, because of the constant friction in the straps. If the straps or something else could be used to fixate the prosthesis, I wouldn't see any big problem there. But, if I think back on how limited the space was in the Soyuz, and how the various emergency scenarios require one to wriggle out, it would naturally be necessary to first design a new space suit and other material suitable for this kind of situation. Getting caught must always be avoided and you must always be able to push yourself away. But the people they have included in

the selection process – there is no doubt they are already winners, because they have learned to live with their disability.

The selected parastronaut is an athlete and bronze medal winner, so he is fully compensated for. Not only that, the accident, which led to the loss of his leg, gave him an opportunity to begin a very special career. That is why I have no doubts that he meets the criteria for spaceflight. But now he is entering a project where he has still received no confirmation for an orbital flight. So, I could imagine it will become difficult if he is now placed into a group of top-performers, but has a disability which is fully compensated for, but nevertheless that is exactly why he is not yet scheduled for all assignments. Even though he is possibly even more physically fit than his colleagues. By the way, he is not the first anymore, because someone with amputated leg flew in the private mission named “Inspiration”. Another NASA astronaut was grounded after undergoing a laser surgery on the eye. He then bought himself a private flight and used the opportunity to thumb his nose at them. It was his way of showing that the laser operation was no reason for not going to space and back safe and sound. It is becoming a race of the agencies to see who they can bring into space.

Stern:
It is a political issue. The basic notion of what it is essentially about gets lost. To the benefit of a questionable space race.

Ewald:
That is why it would be more consistent if today’s parastronaut could be recruited in the regular way, should the prosthesis not be a problem for the space suit and the required activities.

Stern:
That is the way it should be in the normal case, but the emergency procedures must work as well. And, perhaps, getting through a commercial mission more-or-less problem-free for ten to fourteen days would be possible. But, half a year would definitely be more critical. Very likely, the volume of the musculature in the position where the customized prosthesis is attached would diminish. You could hardly prevent it, because the effect of weight would be gone and because of the shift of fluids. If the prosthesis were taken off for longer, it is questionable by the end of the mission

whether it could be put on again in case of emergency. But that is not all. Following the launch of the parastronaut project, enthusiasm for it is growing and NASA is watching ESA closely to see what comes next, because NASA would have really liked to have had the idea themselves. And, in turn, ESA is pleased for once to have been the first to do something. So, success here would be very exciting, especially since the parastronaut selected is a very appealing role model. And, to achieve a reasonable risk assessment in this situation, is a big challenge. ESA is approaching this challenge with a comprehensive feasibility study, to ensure all special risks are properly accounted for.

Ewald:
The two other criteria they intended to permit were dwarfism – I see no problem here, because as opposed to an aircraft interior, you can float anywhere – and different lengths of leg. That, too, should be easy to compensate for. But, for everything else, related to the hands, for example, or cognitive abilities, it simply is not possible. When you see the people they have short-roped up Mount Everest these days – at this elevation, with this effort, and how many die in the attempt – it is not something that spaceflight needs to experience. It is simply impossible to conceive of an emergency procedure in a spacecraft that could compensate for poor hearing, poor eyesight or limited manual skills.

Hedtmann:
One last question, with the future in mind: What changes do you anticipate, personally, in the next ten to twenty years regarding the development of commercial spaceflight on one hand, and on the other hand the major agency programs, with a return to the moon and departure for Mars?

A return to the moon is currently being prepared with NASA's Artemis missions. Planned is the construction of a moon base, where people can work and do research for long periods.

Ewald:
My fear, to start with, is that we shall see missions that are not as well prepared as they should be. A prime example of this is the famous submersible, in which the passengers and operator recently lost their lives.

And, if I apply that to outer space: On a mission of the "Inspiration" type – and soon there will be another one (note: in the meantime the Polaris Dawn mission has already taken place) – the crew is completely dependent on the ground station for control and the communication. If problems or even deaths occurred, it would immediately shine a bad light on professional spaceflight, the developments of which I very much enjoy following.

Submersible "Titan"

On a dive for tourists to visit the wreck of the Titanic, on June 18, 2023 the submersible Titan from the company OceanGate imploded. All five occupants, including the company founder and operator of the submersible, died in the process. Even before the accident investigation, concerns had been raised about the construction and the lack of certification of the submersible, which had not been classified by any classification society. A chief employee was fired after publicly criticizing the safety of the submersible.

Knowledge has increased considerably. Back then, so-called payload specialists did not get the same training as the commanders or mission specialists. They were simply brought along for a specific task. We are witnessing the same thing now on tourist flights. On one hand you have a highly specialized, highly sensitive environment of a space station with contact to multiple control centers, operated by numerous highly educated people, and then along comes something akin to a Sunday drive. The risk of this reflecting negatively on the entire spaceflight program one day is significant. Regarding the moon, exciting things await us; I consider the plans realistic, except for the projected number of years. The Artemis II time plan has been delayed, yet again. I know the crew, and they are aware of all there is to surmount, and the time necessary for preparation. Compared to Artemis, Apollo was a feat of daring. I think I would quite like to be around to experience a Mars mission in my time of professional interest. But first the problems we have talked about here must be resolved. Such a mission must not just be survivable, rather it must also have a certain guarantee of a safe return associated with it. The preparation will also be in multiple phases. It cannot become a mission which takes everything to Mars and at the end, brings everything back again. The movie "The Martian" portrays this kind of approach excellently. And then, I would also hope that it will be all of humanity that arrives on Mars, and not just one person, with their biographical or ethnic identity pushed to the forefront. Such a thing has no place here, because it is the interest of all humankind that stands behind it. Regardless who it is, they should not be patting themselves on the back, alone. Preferably, the first photograph should only be taken once everyone has arrived on the surface. That way, nobody can claim to be the first one.

It will also prevent anyone from neglecting necessary safety procedures, as they hurry to be the first to plant a flag.

The 2015 movie “The Martian” by director Ridley Scott is about an astronaut who is left behind on Mars following the emergency liftoff of his crew, and his fight for survival. An interesting aspect is that in the scenario of the movie a transport ship commutes between Earth and Mars, bringing new crews to the red planet on each trip. The base camp and the return module are both found already on the respective landing site.

Hedtmann:
Interesting question: How do you prevent a space race that leads to inadequate attention to safety-critical matters? Our requirement in our “Vision Zero” framework is that, at the end of the day, it is of essential importance for everyone to get home safe and sound. That is also your job, Dr. Stern. How do you perceive the future in this respect?

Accident insurance organizations in Germany have committed themselves to the international “Vision Zero” approach. Vision Zero is the vision of a world without fatal and serious occupational accidents and occupational diseases. Naturally, the Vision Zero subjects that concern BG Verkehr focus on the area of vehicles, like preventing falls and accidents that occur when driving in reverse or when coupling vehicles.

Stern:
In commercial spaceflight time, money and resources play a vital role. When you have competing interests, it is particularly difficult to avoid crossing red lines related to the maintenance of safety and health. If success and deadlines are all that count, in individual cases safety interests could be assessed differently than at the space agencies. One decisive difference is that at the space agencies the astronauts are employees. They are employees for whom the company bears responsibility. For the commercial aerospace companies they are often only passengers. One problem is the scaled-down training. The people are trained, but there is no proficiency check or exam which can demonstrate whether they are adept at all the procedures, and even if they know how to use the toilet. Additional parabolic flights are expensive, and within 23 seconds, it is not possible to demonstrate that the toilet works in a way that anybody can actually use it later. But, regardless how long it takes and how much it costs, intensive training and auditing of training success are of vital importance, for everybody on a space station. Regarding the moon and Mars, another important point comes to mind, which is dust. The Apollo crews gained specific experience with this. In our LUNA habitat training center we are currently attempting to simulate this with ground volcanic rock from the Eifel. On the Apollo missions the dust led to considerable skin abrasions; it was inhaled and was simply everywhere. That, I think, will be a tough challenge.

Simulation: Working on the moon

At ESA's European Astronaut Center in Cologne a simulation facility (LUNA habitat) recently began operating to recreate the moon's surface and conditions for working on the moon. The purpose of the facility is to train astronauts who are to fly to the moon.

Ewald:
There is always much to learn from the reports of accidents and incidents. For me, Apollo 13 and the two shuttle accidents have special meaning. A failure to coordinate with others, well-meaning changes, and habitual bypassing of standards that are identified as relevant to safety are frequent causes of these.

Return of Apollo 13

On April 13, 1970 during a comparatively uncritical phase of the flight of the Apollo 13 mission, an incident occurred between Earth and the moon. A damaged and repaired oxygen tank and a communication problem that occurred in the modification of the electricity supply in the planning phase played a key role. The failure in the electrical system led to overheating, and the oxygen tank burst, in the process damaging another oxygen tank and two fuel cells. The fact that the crew (from left: Fred Haise, Jim Lovell and Jack Swigert) were able to return to Earth alive was thanks to a combination of professional crisis management, outstanding feats of improvisation, and solid training. So, in fact Apollo 13 was a failed mission, but it is also known as one of NASA's greatest successes. A movie was made about it in 1995 with Tom Hanks playing the role of Jim Lovell.

Hedtmann:
A painful eye-opening experience, which we unfortunately also often observe here on Earth. And, also a good closing word. Thanks very much to you two for the exciting conversation. I believe that we have heard a lot here now that can also be of great importance for prevention work in other areas of the working world.

Closing words by Dr. Jörg Hedtmann

Our two dialog partners, Professor Dr. Ewald and Professor Dr. Stern, deserve an enormous thank-you for their candid words and the sharing of their special experiences. Such conversations help us to look beyond the horizons of our familiar spheres of knowledge so that our perspectives on the topics important to us can continually evolve. This time we had an opportunity to consider questions of safety and health at work, considered literally from great heights.

Two important insights stand out for me:

Firstly, even in an industry as safety-oriented as spaceflight, one is apparently not immune to making quite earth-like miscalculations, overlooking obvious hazards, or misjudging risks. Our principles of safety and health are something that we can also apply to spaceflight, and ensure their compliance. Naturally, a spaceflight accident prevention regulation is not realistic at the current time, and much of what it would contain has already been regulated. Much more important is the realization that the people in charge in the space agencies and private aerospace companies must not lose sight of the tried-and-tested, earthbound principles as they direct their gazes to the sky. The international Vision Zero approach, with its commitment to a world without occupational accidents and diseases, would also be very appropriate for spaceflight. Trips to space – whether for scientific, commercial or tourism reasons – are exploits that are still fraught with risk, so they should not be occasions for questionable attempts to set records or stand out from the crowd.

Secondly, it is fascinating to observe how an industry that should actually have been the inventor of the term risk assessment ultimately learned how to deal with risk. Driven by technical and scientific curiosity, risks have been and will continue to be calculated and accepted. Unfortunately, in the history of spaceflight this risk has manifested itself repeatedly, and cost people their lives. When a private aerospace company allows its rockets to explode to learn from it and later minimize the risks associated with the operation of spacecraft, it may indeed be an acceptable alternative to careful, small steps and theory-based risk assessment. But, what is important is that nobody is harmed in the process. A little more courage to achieve lofty goals is something it would be nice to see more often on Earth, too. For both methods,

the goal of maintaining safety and health for all is indispensable. As such, a sensible balance between the traditional safety philosophies – often enough learned from painful experience, so they retain their justification even in times of new beginnings – and the courage to learn from new technologies, is essential. Those who shape the paths to new times have the same right to the best-possible protection of life and health as all other people. Someone will go down this road and we need to prepare the way well, but not block it.

The interviewees in front of the Soyuz capsule, in which Alexander Gerst, Maxim Surajew and Reid Wiseman returned from the ISS on November 10, 2014.

List of abbreviations

DLR	German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt e. V.)
ESA	European Space Agency
FAI	Fédération Aéronautique Internationale
NASA	National Aeronautics and Space Administration

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BG Verkehr

Geschäftsbereich Prävention
Ottenser Hauptstraße 54
22765 Hamburg
Tel.: +49 40 3980-0
Email: praevention@bg-verkehr.de
Internet: www.bg-verkehr.de

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