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22 seconds – and many months: the long way to doing research in weightlessness

5 August 2008

As a doctoral student at the Technische Universität (TU) Darmstadt, Olympia Kyriopoulos does research on fluid mechanics and heat transfer. Her doctoral research focuses especially on the behaviour of fluids impacting hot surfaces as finely atomised sprays – for instance during carburetion in combustion chambers, spray coating in surface treatment of materials or spray cooling of high-performance electronic components. Certain effects come into play that can only partly be investigated in a laboratory on Earth, where they are influenced by gravity. Therefore, Olympia Kyriopoulos needed to conduct experiments in weightlessness as well – whether she wanted to or not. And she definitely wanted to! "It was a childhood dream come true for me," she writes about her parabolic flight, which gave her 30 times 22 seconds of weightlessness and a wealth of important data. Still, she does not just describe the exciting moments spent in weightlessness, but also the long way to get there...

By Olympia Kyriopoulos

Weightlessness changes everything

Who is not familiar with the images and video footage of researchers in blue suits, "floating in a most peculiar way", conducting their experiments in weightlessness on board a converted passenger aircraft? Whenever I saw such images, I would immediately be captivated by the idea of weightlessness and it would make my heart leap. If someone would have told me a couple of years ago that one day I would be one of these floating scientists and I would be doing research in weightlessness myself, I would have taken him for a fool...

When I graduated in General Mechanical Engineering from TU Darmstadt, I knew that I would like to continue my academic career by completing a doctoral dissertation. After careful consideration, I decided to conduct my doctoral research at the TU Darmstadt, at the Chair of Fluid Mechanics and Aerodynamics led by Professor Dr Tropea. I still vividly remember the moment I received Professor Tropea's e-mail suggesting several different options for my research topic. One of these concerned a project called "DOLFIN – Dynamics of Liquid Film/Wall Interaction". The description of this project also mentioned that it would include parabolic flights. I quickly wrote back: "Would I be allowed to participate in these parabolic flights myself?" The reply came swiftly: "You would actually not have any other choice!"

I started in May 2006, and I immediately had the honour to supervise experiments in weightlessness as part of my project, and to one day conduct experiments on board the Airbus A300 myself. I was, and still am, grateful that I have been given this project, which is supported by the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) and the European Space Agency ESA! It was right at the top of my wish list, and so, with a little bit of luck, a childhood dream came true for me.

22 seconds of weightlessness on board the A300 ZERO-G

My research project concerns 'spray impact onto a heated surface'. A spray impacting onto a heated wall creates a thin, fluctuating liquid film, cooling the wall down in a very effective way. The flows in this film are influenced by waves, 'craters', uprising sheets and jets, caused by drop impact. The transfer of heat is mainly determined by convection in the liquid film, evaporation and thermal conduction. Preliminary theoretical estimates show that gravity influences the impact of a single drop. But what happens in reality? How do the weightless conditions prevailing during a parabolic flight influence the average thickness and the stability of the film? And how does this affect the heat transport associated with spray impact?

The challenges of parabolic flight

In order to answer these questions, a measurement duration of 22 seconds of weightlessness at the time would be sufficient – as long as it would be repeated often during the course of the flight campaign, of course. I still had a long way to go before my experimental setup would be completed and ready to help answer all these questions. The preparatory work concerned both technical issues with regard to the experimental setup itself and formal aspects, such as strength calculations, revision of safety data sheets, etc. It was quite a challenge, as during the design and construction of a parabolic flight experiment, you constantly need to bear in mind that both weightlessness and increased gravity pose very specific challenges. All functions need to be guaranteed for conditions between 0g and 2g (twice the standard gravitational acceleration on Earth, 'g' denotes gravity) and for safety reasons they even need to be designed for 9g – so no less than nine times the Earth's gravitational pull. To give but one example: under 0g conditions (weightlessness), the functionality of an oil-lubricated vacuum pump can no longer be guaranteed, as the oil will float to the top of the reservoir. This means that you have to use a so-called dry-running vacuum pump.

Assembling the experimental setup

When the greater part of the equipment we ordered had arrived, we could start putting it all together. As in a jigsaw puzzle, the trick was to integrate all the individual parts into the experiment frame, which in a way determines the overall structure. It was 13 September 2006 – 18 days later, we travelled from Darmstadt to Bordeaux, the site of the parabolic flight campaign. On the basis of previously prepared CAD models of the completed experimental setup, as well as prototypes of the most important parts, made from polystyrene foam, positioning the components went smoothly. With only five days to go, the experiment was slowly starting to take shape. With the addition of a water tank and two nitrogen cylinders, the base of the experimental setup had already been completed, and the test cell – as the centrepiece – was sitting in the upper section, surrounded by high-speed cameras and a large number of measuring devices and controls. Two computers, two monitors and a laptop were attached and the last cables were connected. We had done a lot of work over the past few weeks – day and night. In the race against the clock, we needed to work straight through the night on several occasions, but now the experiment in which we had invested so much sweat and diligence was finally ready. We still had one day left before departure to test the system and we managed to achieve the spray of distilled water we were hoping for. "Bordeaux, here we come..." I rejoiced. The next day, we loaded everything into the van.

Darmstadt - Bordeaux - weightlessness

Driving to Bordeaux was a small adventure in itself, not just because my students and I were on the road with about half a tonne of experimental equipment in the back, but also because eight bottles of nitrogen were chained to the inside of the van. We would need these to supply our test cell with gas during all flight days and ground experiments. At the German-French border, I declared the cargo, referring to NOVESPACE, the company managing the parabolic flight – and we were allowed to drive on without any problems. What a relief!

The parabolic aircraft

After driving more than 1 000 kilometres, it was a wonderful feeling to have finally arrived – all the more so because the experiment had not been damaged in any way. After unloading everything from the van and bringing all the instruments to our designated workspace, we focused our attention on something even more interesting: the inside of the Airbus A300. I respectfully approached the aircraft with its characteristic ZERO-G markings, marvelling at its outer shell before boarding it. Inside, the sides were padded in bright tones, the centre of the cabin was waiting to accommodate the experiments, and fore and aft there were seats for the experimenters. Our experiment would be brought on board that same afternoon.

The experiment installed

We were approaching what could well be the most exciting moment before the actual flight days: the installation of the experiments onto the experiment tracks in the floor of the Airbus. Inside the aircraft, many people kindly volunteered to help us lift the heavy experiment and place it in the right position. I breathed my first sigh of relief when all drilled holes in the baseplate finally matched the attachment fittings in the aircraft and the eight huge mounting screws could be tightened. The next few days saw the first test runs, gas cylinders were exchanged and the water tank was refilled with distilled water again and again. The cameras, which had been removed to protect them during transport, had to be installed and calibrated again. It felt as if every day time just slipped away from us without much progress, but gradually there were less and less items left on my to-do list, until after a relaxing weekend the only ones left were 'test run', 'exchange gas cylinders' and, last but not least, 'apply logos'.

The Monday before the first flight day was dedicated to the safety briefing, as is the case for all parabolic flight campaigns in Bordeaux. In addition to this, we needed to finish the last items on the to-do list. Came nightfall, I fell into bed exhausted and slowly started to realise that the big day was now really upon us. The months preparing for the parabolic flight and for conducting our experiment had come to an end. I have to admit that I was rather excited. Before falling asleep, I went through the checklists for my team and for myself one last time, in order to be absolutely certain that I had not missed any step of the procedure.

The flight day

Today is Tuesday, the big day, the first flight day for which I have been waiting so anxiously over the past months. When I arrive at NOVESPACE, I can see the tension reflected on the faces of the other researchers as well. One last round of checks in the aircraft – our experiment is ready for any 0g and 2g phase! The Airbus ZERO-G's outward appearance is so peaceful: the seasoned expert is ready for yet another adventure. In contrast, we ourselves become even more tense as the motion sickness medicine is administered, but the experimenters try to lighten up the situation by joking around a bit. A few minutes later, we are at the famous 'point of no return', as the doors of the aircraft are closed and the ZERO-G starts to taxi away from its parking position.

The experimental setup as seen from behind

There are many experimenters on board and I am sure they are as thrilled as I am. The 'fasten seatbelt' sign is turned off much too soon and, following the other teams, I go over to my experiment while we are flying about 6 000 metres above the surface of the Earth. It is a strange feeling to be able to move around freely and even conduct experiments at these altitudes, whereas as a normal passenger you would remain in your seat. There are just a few minutes left before the 'zero-th', so-called fun parabola, meant to give you the chance to get used to the experience. However, my team members and I assume our working positions already. Even 'parabola #0' is too valuable to let it pass by without obtaining any data. And besides, our excitement and curiosity are simply too great: my fingers are itching to get started. I want to know right now if we can achieve a spray in weightlessness.

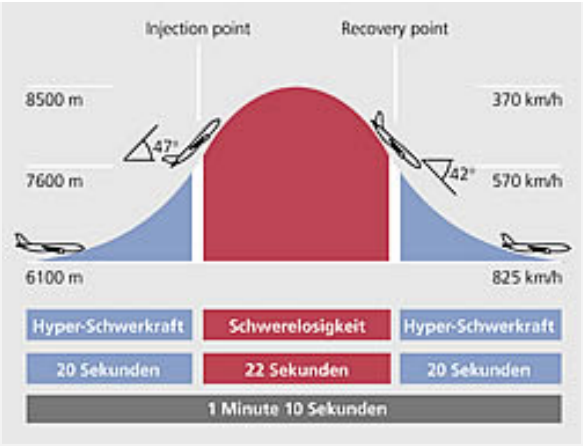
Countdown

We hear "30 seconds, 20, 10, 5, 3, 2, 1, pull up", and the Airbus A300 ZERO-G suddenly starts to climb steeply: the pilot is applying full thrust. As if gravity had increased, I am pulled towards the floor of the aircraft as if by magnetic force. Double gravity! It feels as if I am carrying my twin sister on my shoulders. Then, the moment I have been waiting for all this time arrives: one of the crew members in the cockpit shouts "30, 40, injection", and the pilot throttles back the engines of the Airbus, sending it into a parabolic dive. During the next 22 seconds – not a lot of time for conducting an experiment –, gravity has been cancelled out: the Airbus is in a state of free fall. Suddenly, I no longer feel the invisible power of gravity, from which we can otherwise never escape in daily life and which makes apples fall from the tree onto the ground. As if by magic, I begin to float in the air, completely overwhelmed by this fantastic feeling of being completely detached. Suddenly finding myself upside

down, I hold on to the handle of the experiment after having successfully triggered the camera. Where did the ceiling of the aircraft go and where is the floor? There is no up or down anymore and I have to find my bearings in a completely new environment.

In free fall

After 22 seconds, the pilot issues the warning "20", which means I need to move my body towards the floor as quickly as possible, before falling to the floor at the call "30, pull out". The weightlessness phase ends abruptly. As the aircraft reaches the 'bottom' of its flight path and takes a 'run-up' to the next parabola, the gravitational pull again increases to twice its standard magnitude on Earth. Again, I feel as if I am being pushed towards the floor by twice the usual weight. Again, the blood is rushing to my feet, apparently to catch up with my stomach which seems to be down there already. These seconds seem to last forever. But then the pilot has pulled the Airbus out of the descent and into a regular climb again: we quite literally feel alleviated. During this phase, we experience the Earth's standard gravitational acceleration. The next parabola will start in about two minutes.



Parabolic flight manoeuvres

Wow! So that is what the mystery is all about! This feeling brings a smile to the experimenters' faces, a smile that will not go away anytime soon. But is weightlessness the only reason for smiling? Definitely not! As far as I am concerned, it is precisely this unique combination of research and weightlessness that makes me smile. I am very happy with the way my experiment is going, as I was able to generate a spray under both 0g and 2g conditions, producing a liquid film – of different thickness – in both gravity phases.

I find the idea of having just investigated something that would not have been possible at all on the ground really overwhelming. Ahead of us are 30 more shifts between 1g, 2g, 0g, 2g, 1g – between regular working conditions, extreme heaviness and wonderful lightness. The physical strain should not be underestimated, though. My colleagues and I are working intently during each parabola, in order to obtain 100 percent of the data we planned to obtain. I prefer to see each parabola as an individual challenge, rather than looking at the whole series of 31 parabolas. Before each parabola starts, I announce the parameters to ensure that they are set correctly.

Floating in the air – freer than a bird

Nevertheless, at one point I can no longer resist going to the so-called 'free floating zone', which has been separated from the experiment area by a large 'cage net' and which does not contain any equipment or other obstacles. Inside this net, I can really indulge myself during both the 2g and the 0g phases, without getting in the way of any of the other experiments. I find that the 0g experience definitely involves more 'body awareness' over here. I am experiencing and exploring my new sense of space: I can move completely freely in all three dimensions, without equipment, belts or other things getting in the way. Free like a bird, I am floating in the air. I even attempt a few breaststrokes from this position – which of course do not cause me to move forward at all. Pushing off the floor, however lightly, on the other hand gives me a lot of momentum, and sends me flying off at very high speed in unexpected directions.

Floating in a most peculiar way during the parabolic flight

When returning to the experimental setup for the next parabola, I notice how naturally my team and I are handling the cameras and instruments throughout all of this. Many of us probably do not realise at this moment that we are simultaneously exploring another 'object': ourselves, our own human bodies. Thirty times in a row during the flight, gravity, the force that has accompanied us from birth, the force that dominates all processes taking place on Earth, appears to have been annihilated. Thirty times 22 seconds full of 0g data as well as 2g datasets, unique and non-reproducible in this form on the ground.

Looking back on about two hours of conducting research under extreme conditions, I would like nothing more than to ask the pilot to fly 'just one more parabola' to give all of us on board the opportunity to enjoy the 'lightness of being' for one last time at the end of this 'work marathon', without having to push any buttons.

In the end, all experiments have been successful completed and we shut down our system. Just like regular passengers we come in for landing. A short while later, I am on firm ground again, ready to meet the other members of the team who are eagerly waiting to hear if everything worked as it should have, and who of course also want to know what it is like to be weightless. I give them a full report about the flight, which instantly makes me long for yet another 22 seconds of weightlessness – but the reality of the checklists quickly catches up with me. We now need to store all valuable data, exchange the gas cylinders again and refill the water tank, so as to prepare our spray experiment for tomorrow's new rollercoaster adventure. I feel fascinated and inspired by this way of doing research and – just like a child – I can barely wait for another opportunity to do research in weightlessness again. And so I realise that these 30 times 22 seconds were worth all those days of hard work and all those night shifts in Darmstadt.
