Taylor Wang adapts to weightlessness inside the Spacelab. With gravity reduced, legs no longer are needed to get around, faces change shape and feel different, and time must be taken to forget a lifetime on the earth's surface.

A Scientist in Space

by Taylor Wang

WHY DOES A SCIENTIST want to go into space? Scientists have one fatal flaw — they're obsessed by their experiments. And I'm no exception to that; I will even go out of this world to do my experiment.

Space has one thing to offer that you cannot get anywhere else — extended zero gravity. One type of experiment that takes full advantage of zero gravity is what we call containerless experiments, and this is what I happen to be interested in. Now for the first time you can do an experiment without a container — you can leave the thing in mid-air and take your hands off. In the laboratory when you do this the sample will start dropping; it will hit the ground in less than a second, and the experiment's over. So if you want to do anything, you have to do it fast or you don't do it at all.

The particular experiment that I'm interested in is called equilibrium shapes of the dynamics of a rotating and oscillating drop. It requires about 30 minutes of zero gravity because everything has to be very slow moving; it's always in an equilibrium state, a quasi-static condition. You can do it on an airplane, flying up and down like a rollercoaster, with the plane essentially flying in formation with the experiment package, which is free floating inside it. If the pilot or the weather isn't so good, the package will bounce around inside like a Ping-Pong ball, and you will have lost your lunch for nothing. Unfortunately, on an airplane zero gravity can last only about 20 seconds. You can make it last a little bit longer, but by that time you will have dived into the ground. I'm not sure I want to go that far yet.

Or you can use a drop tower. You could dig a very deep hole, say, all the way to China, and in principle you could get about 30 minutes experiment time. I don't think the two countries are that friendly to each other yet. So the only option to do the experiment is to go into space.

I'm really looking at two experiments. Investigating the equilibrium shapes of a rotating spheroid is one of them. This is actually a very old experiment, going back 300 years. Newton, looking at the equilibrium shape of the earth, was the first to pose this question. And lots of calculations have been done since then but there hasn't been a single definitive experiment to verify the theory. The second experiment is on large-amplitude oscillations of drops, and this calculation is about 100 years old. (I only do old experiments.) Both these experiments require an extended gravity-free environment. It is not that they have been waiting for me all this time; it just so happened that the space environment was not available until now. I have been interested in this area for a long time, and I was fortunate to be in the right place at the right time when the space opportunity turned up.

When you rotate a drop, you start from a perfect sphere. As it rotates, it goes to an axysymmetric shape, a little flat at both poles. But once you get to a certain point, the so-called bifurcation point, the axysymmetric shape is no longer stable, and it goes to a non-axysymmetric shape. We are trying to understand what this bifurcation point is. Everybody accepts it because a lot of people have calculated it. In fact, almost every mathematician at one time or another has done some calculations on the bifurcation point. So the point itself is very well defined. The question we're concerned with involves the stability of various shapes, how they behave to one another, and how the system works dynamically.

In the large-amplitude oscillation experiment, we stimulate a droplet and it goes into various oscillation modes. If you introduce a larger amplitude, the drop not only goes into oscillation but into a fission process. Now, you may ask the question: If this is a containerless experiment and you're not touching it, how do you stimulate the drop? There are many ways you can do it, for example, with an electric or a magnetic field. We use an acoustic field, which causes less perturbation to the droplet. We create a potential well, which is almost like a bag to hold the drop. Since we can control the frequency and the beating, as well as modulation and amplitude, I can make the drop do what I tell it to do — rotate, or oscillate, or change its shape, or move around, or sit someplace. The acoustic field gives me a great deal of freedom to do what I want with the sample, but yet not touch it.

After NASA accepted our proposal in 1974, we started to develop the experimental hardware, which we finished in 1980. Now, during all that time it never occurred to me that I might actually conduct the experiment in person. But in 1982 NASA started thinking about the crew for the Spacelab 3 mission, for which our experiment was scheduled, and asked the question: Is it better to train a career astronaut as a scientist or to train a career scientist as an astronaut? NASA headquarters finally opted for the latter, since this mission would be primarily science oriented.

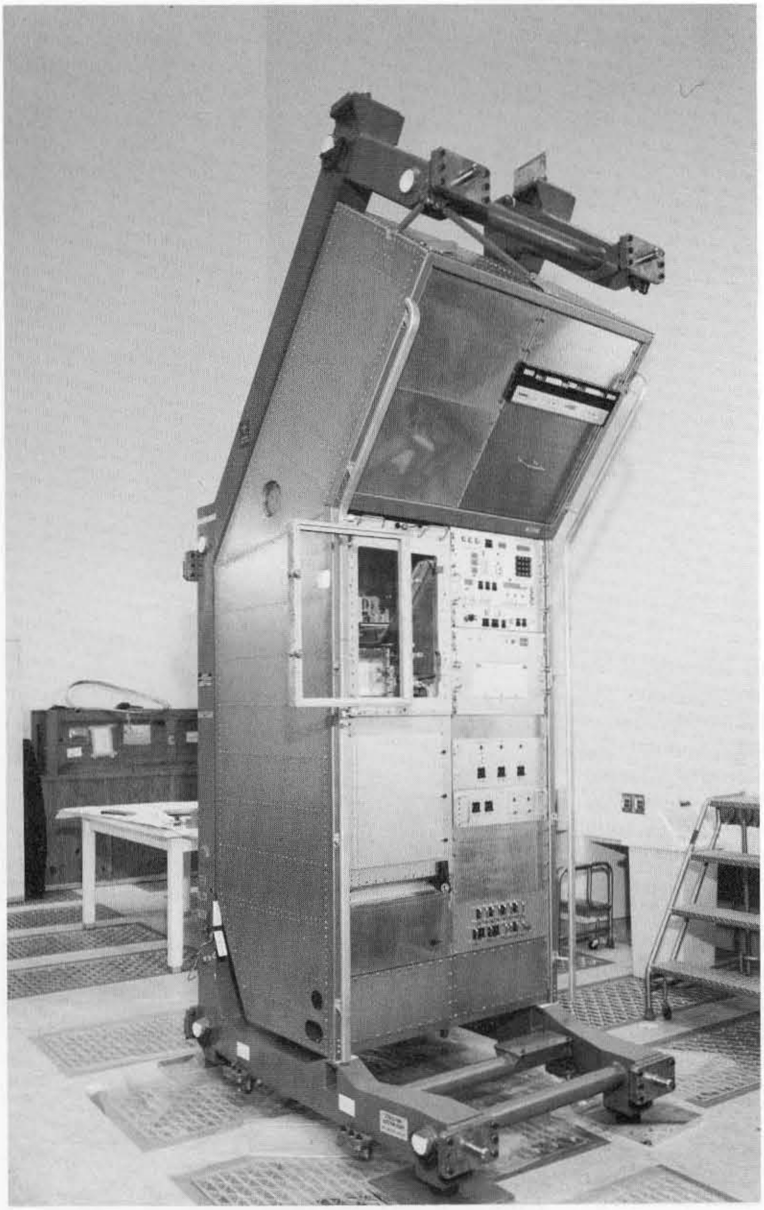
So NASA announced an open selection for scientists to train as astronauts, and I put my name in. I didn't think I would get selected, but I thought I could at least establish a bottom line. For a potential astronaut you couldn't get much worse than me.

I still haven't figured out why they chose me as one of the four candidates. But since they did, I wasn't going to make a big fuss out of it. The others include Eugene Trinh, a fluid dynamicist, also at JPL by way of Yale; Lodewijk van den Berg, a materials scientist from the Netherlands; and Mary Helen Johnston from the Marshall Space Flight Center; she's also a materials scientist at the University of Florida.

Since we had to be full-fledged members of the flight crew, that is, we had to carry our own load, the training (which consisted of four components) was quite rigorous. The first component is scientific training, that is, we are trained to conduct other people's experiments, not just our own. There were 14 experiments on the flight, covering many disciplines that we had to learn something about. It's very interesting because we normally wouldn't have a chance to be exposed to some of these things — life science, materials science, fluid mechanics, astrophysics, atmospheric science, and so on.

The second component of the training involves adaptation training. Going into space often causes problems with so-called "space adaptation syndrome," which is sort of like car sickness. NASA is very concerned about this because, with a limited number of crew members, each with his own assignments, if some members get too sick to function, the others will have to pick up the slack. And since we are very busy, this is difficult to do. Even worse is what could happen when some individuals become irritable when they feel physically uncomfortable. If some large, strong individual decides to pick a fight, we might be in trouble — maybe not even coming back.

Unfortunately there's no way to determine who will and who won't get sick, so NASA has a rather different screening process — they make everyone sick. And then they observe us to see if we can still function. They blindfold you and stick electrodes all over you (they want to find out everything about you, more than you care for them to know), put you in this thing that they rotate at a rapid speed, changing speed just for fun. They also make you do head movements. When you just sit there it's no problem, but once they make you move your head, you start to feel the sensation. After you've gotten to the stage where they want you, they make you do things to see whether you can still obey orders and do things in the proper order.

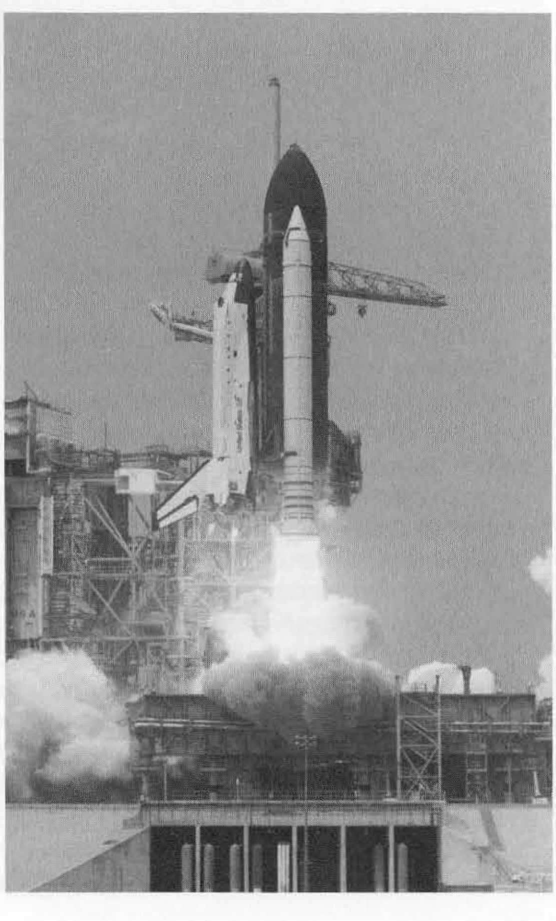


After fabrication and testing at JPL, the Drop Dynamics Module (DDM), for the study of free liquid drops, awaits the Spacelab 3 mission.

If that doesn't get you, they put you in a small room, called an elevator, and after checking whether you have claustrophobia or not, they close it up. The elevator goes up and down and twists and turns and yaws and does whatever is necessary to guarantee that you will have space adaptation syndrome. Then there's further testing. None of us is very belligerent, and we all survived. I didn't exactly enjoy it, but I survived.

The third component involved space shuttle training — familiarizing ourselves with the whole spacecraft. There are about 4,000 switches and 6 computers on the spacecraft. We are supposed to know what all the switches are for —so in case the five career astronauts all die on me, I can bring the spacecraft back. But it's mainly to train us

Several hours before liftoff, the astronauts don their suits and helmets in the "white room" at the launch pad. After entering the shuttle and strapping themselves in, the payload specialists relax for two hours while the flight and ground crews prepare for liftoff.



The ultimate E-ticket ride — liftoff of the Space Shuttle Challenger on April 29, 1985 carrying Spacelab 3 into orbit for a week of scientific investigations.

not to panic when the alarms go off and the lights start flashing.

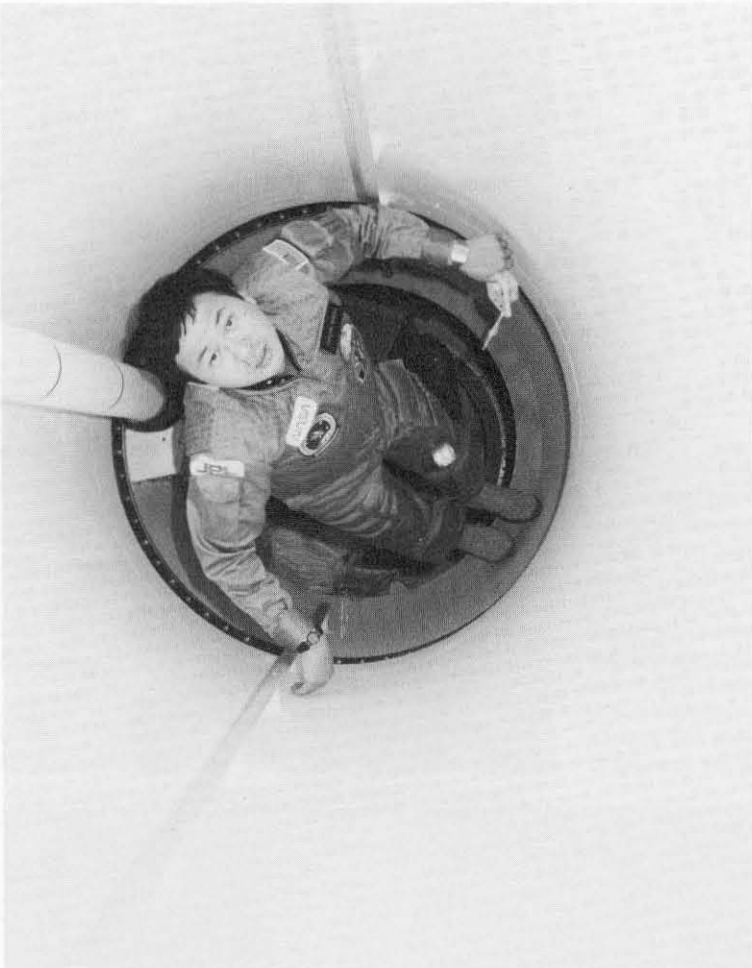
Survival training was the fourth category. Before launch the spacecraft is strapped to two of the biggest sticks of dynamite that this country ever built. And if those two sticks of dynamite don't work quite right, especially just before launch, there will be nothing left within 10 miles. And so just in case (they keep on emphasizing that point — "just in case") there's some malfunction, the rocket is about to go off, everybody else is long gone, and you are stuck inside the spacecraft, you will know what to do. Essentially what they want us to do is try to get the hell out of there. We're supposed to take a crowbar and pry open a panel above the pilot's seat, press a switch to blow out the window, releasing seven steel cables. We're supposed to climb out the window, grab onto the steel cable and slide all the way down (the spacecraft is about 10 stories high) and run like hell to a bunker 500 yards away. And if we can get into the bunker, we might survive. We've got to do all that in about 10 seconds flat. Well, they told us that we will probably be able to run a lot faster than normal in this situation.

Another aspect of survival training involves what happens if the spacecraft takes off properly but doesn't have enough thrust to go into orbit and has to ditch in the ocean. What do you do? You open the hatch and inflate the lifecraft underneath it, push it out, jump into it, and paddle away and watch the spacecraft (now literally a spaceship) sink. It's not really a spaceship, either, but a space-submarine, because when it gets on water, it dives like crazy. You have again about 10 seconds to do all this.

In September 1984 NASA finally picked the crew members for our particular flight. They included Bob Overmyer, commander of the flight, and Fred Gregory, the pilot. (Overmyer was really the pilot and Gregory the copilot, but in NASA everybody has higher titles.) The Spacelab engineer was Don Lind, and Norm Thagard was the space shuttle engineer. Bill Thornton was the physician, who doubled as zookeeper for the 12 rats and 2 monkeys on the flight. And Lodewijk van den Berg was the other payload specialist or astronaut scientist.

From the time the crew was selected, the seven of us trained as a unit. We not only trained in the four categories mentioned earlier, refreshing them, but we also started to train as a unit to back each other up, just in case one or two of us became incapacitated. And we learned to live with each other's idiosyncrasies, since we would be living in very cramped quarters on the mission. Fortunately we got along well; at least we didn't have any open fights. During this nine-month period we saw each other more than we saw our families. After nine months we finally got tired of each other, and fortunately NASA got tired of us too and told us to go ahead with it.

For the last 10 days before the flight we were in the crew quarters, stuck together without seeing many other people. And we were watched and examined continuously. Just before launch we leave the crew quarters and go into what we call the "white room," right outside the spacecraft. Three volunteers are there — the only people besides us within 10 miles. This is the place to take care of last minute things — body functions, insurance payments, or religious services. And this is the place where, if you change your mind, you still have a chance to get off. But if you don't change your mind, they put this suit on you and send you off, and then they run like hell. Then you are inside, and they are gone; the towers have disappeared on you, and even if you want to change your mind, it's too late.



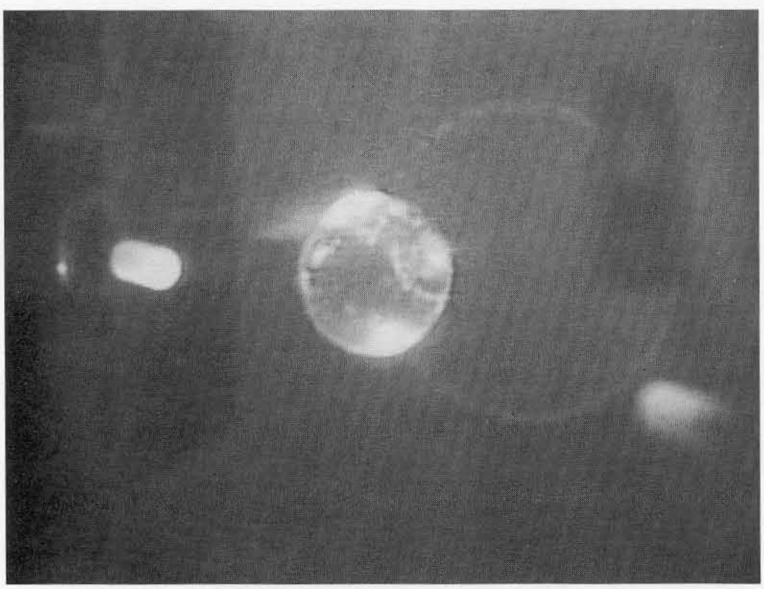
Wang floats through the tunnel connecting Spacelab 3's module to the mid deck of the shuttle.

Fortunately it was a very good launch. The countdown was smooth; there were no hangups or delays. It took about two hours for the spacecraft to get into stable orbit. When you first get in orbit and experience zero gravity, something very interesting happens. For the first time in your life your body says, "I don't need my legs." And so the brain says, "Since I have no need for the legs, let's shrink them." And your legs actually do shrink about an inch in diameter very quickly.

If your legs shrink, where does the excess go? It goes right to your face, and we all had this sort of chipmunk look. It's rather uncomfortable but of short duration, because the face is telling the brain, "I don't want this stuff either; would you get rid of it"? And what happens is that you start to discharge it outside your body. The only problem is that there are seven of us and only one waste management system.

It didn't take too long to adjust to zero gravity, and then we were ready to go into the Spacelab to start work. In the Spacelab

Right: Wang conducts an experiment involving a one-inch drop, visible in the chamber of the Drop Dynamics Module. The DDM uses sound to position and manipulate the drop without any physical contact. The image below is not actually a drop but a one-inch ball used for calibration of the instrument.



everything worked well except one thing — my experiment. I started to turn on the experiment the second day, and it didn't work. Normally when that happens you have to forfeit it, beause it's very difficult to repair an experiment in space. You can't take things apart and put them someplace, because there's no place to put them. And you don't have many tools; all I had was a voltmeter and a couple of screwdrivers. Also, you can't drive the spacecraft to some supply depot to pick up replacement parts.

Because we had a so-called payload specialist (me) on this flight, however, we were given the opportunity to try. Since I could not take the experiment out, the best way to do it was to go inside the experiment. So I lived inside that instrument for two and a half days. During that time all my colleagues could see of my anatomy was my leg. I took the whole instrument apart from the back, trouble shooting line by line, point by point. Although there wasn't a high probability of fixing it, with good support from my team on the ground we were able to discover the problem and find a way around it. We actually did a bypass surgery. Perhaps this provided a justification for NASA's decision to train scientists as astronauts; when experiments don't work out as expected, a trained scientist may be able to react to solve the problems.

I'd like to emphasize the teamwork on these missions. There were about 300 individuals at the Johnson Space Center in Houston supporting our flight. And I had nine people just on my experiment team, working all the time I was working and working even when I got to rest. Arvid Croonquist and Eugene Trinh deserve a lot of credit. I don't think they slept the entire time, to be sure to be there when I needed help.

The best time of the flight for me was when I started to do my experiment. Normally we are supposed to work only 12 hours a day, but in reality we worked about 15-16 hours. Time is such a precious thing in flight that every single second counts. You can always do other things later. So even though I lost two and a half days, I was able to recoup most of the things that I wanted to do by working longer hours.

What the experiment did was spin out a drop, bifurcate, and then become axysymmetric again, and bifurcate again, and so on, again and again to confirm the theory. As I mentioned earlier, this theory has been around for many years, and we didn't expect anything to deviate from the calculations of the bifurcation point, because that's essentially a universal given. And in the axysymmetric shape region it behaved very nicely. But once it actually got to the bifurcation point, it deviated from the theory quite a bit. This was a surprise to us; we didn't think this was in dispute. In fact, when we took it further, to the fission point, we found that the fission point does agree with theory, but the shapes are quite different. Now, I always like this sort of outcome, because I can tell my theoretician friends that they're not as good as they think they are.

People always ask the question: what is it like in space? For one thing, there's no up and no down. So you can live on any of the six surfaces. When we started out, the spacecraft was pretty cramped for all seven of us. But once you get into space, you find that you don't have to live on the floor; you can live off the ceiling, or you can live off the wall, so the spacecraft becomes very spacious. I picked the ceiling for my home base since I spent two and a half days working upside down anyway and was used to it.

In space you can really fly. If you want to go someplace, you don't walk, you just tap your finger in one place and you fly over. Not everything is positive; for example, writing is difficult, but you learn to adjust to these things. The human body is a very adaptive system, and it takes only about a day or two to adjust to the space environment. From that point on you feel quite comfortable in space.

What do we eat in space? A typical menu would consist of dehydrated meat and vegetables. This is a meal you could eat if you had a good appetite. But in space, even if you're not sick, you really don't feel that great. So most of us didn't really eat the whole thing. I brought some Chinese tea along, and that's the one thing that kept me going most of the time — a cup of tea and some nuts. When I came home I had lost about four and a half lbs., and that's quite typical. (We also gain about one and a half inches in height.) One person on our flight, however, had a great appetite. Whatever the rest of us didn't eat, he finished. And when he came back, he had actually gained five lbs. That made NASA history.

How do we eat in space? There are two ways. If you want to do it the way you would usually eat on earth, you have to move the food toward your mouth at a very slow pace, so the food won't leave the spoon or fork and land someplace that you don't want it to. Or, rather than bringing the food to your mouth, you can leave the food in midair and take your mouth to it. That works pretty well unless a colleague gets his mouth to your food before you do.

Putting on clothes in space is also different from on earth. You don't put them on one foot at a time, but two feet at a time, two arms at a time. Because the clothes spring out and take their own form, you don't really put them on at all; you just wiggle yourself in.

When you sleep, you don't lie on something — you just float. So when you're tired you just close your eyes and you can go to sleep wherever you want to. It's very comfortable. The only trouble is that sometimes you float too far and drift into your friends.

At the end of the sixth day and the seventh day, when the experiments were all done, we closed the laboratory and for the first time had time to be tourists. We were given about six hours to look out the window and see the earth and take pictures. Flying at a speed of Mach 25, we went around the earth every 90 minutes. Every 45 minutes we got a sunrise; every 45 minutes we got a sunset. We flew over familiar places and some not so familiar. I especially enjoyed seeing San Francisco, Los Angeles, and Shanghai, where I grew up. Viewing the earth from this perspective gave us a strange feeling. From space we can see that the earth is very beautiful and that all of us are very fragile.

When the tourist season was over, we had to come home. After flying around the earth 110 times (2.5 million miles), we landed at Edwards Air Force Base, and the pilot (the commander) put his front wheel right on the yellow line of the runway. We were quite pleased with ourselves. We had a very good flight and accomplished what we set out to do. □