EIR Science & Technology

# Space research on the medical frontier

*In a Feb. 25 interview, astronaut David Wolf provides a first-hand report of life science and medical research on the Mir space station. Marsha Freeman reports.*

*Dr. David Wolf, 41, who recently spent 119 days in space as a member of a Russian Mir space station crew, is a medical doctor, inventor, research scientist, and career astronaut. He is a member of the Institute of Electrical and Electronics Engineers and the Aerospace Medical Association. Dr. Wolf has received 11 U.S. patents, and published over 40 technical papers.*

*In 1983, Dr. Wolf joined the Medical Sciences Division at the NASA Johnson Space Center, in Houston, and, three years later, was assigned to direct development of the bioreactor and associated tissue-engineering technology. He was selected as an astronaut in 1990, and served as a mission specialist aboard a Space Shuttle life sciences mission in 1993.*

*Dr. Wolf is described by NASA as an "active public speaker." He has also been willing to speak out. In December 1991, the FBI began an undercover operation called "Lightning Strike," to try to entrap NASA employees and industry contractors working in space life sciences projects into committing crimes. Operation Lightning Strike ended in December 1993, when Wolf, who had also been a target in the FBI sting, appeared on the NBC Nightly News and revealed the operation.*

*Dr. Wolf returned to Earth from his stay on Mir on Jan. 31, is undergoing rehabilitation to recover from the effects of microgravity, and is looking forward to working on the International Space Station (ISS).*

**EIR:** During your four and a half months on Mir, one of your primary responsibilities was the operation of a device called the Biotechnology Specimen Temperature Controller, or BSTC. It is my understanding that this is a cell incubator, and is part of the technology that is going to be needed to use a bioreactor in space to grow human tissue.

**Wolf:** The bioreactor is up there, right now.

**EIR:** Since you are one of the developers of the bioreactor concept, I thought you could explain the importance of being able to grow tissue in three dimensions in space, and how the bioreactor does this.

**Wolf:** I'd like to do that. First of all, everybody is interested in health and medicine. There is no question that there is a whole group of breakthroughs which will require research in space. One of those areas is tissue culture. We have already achieved a great number of breakthroughs in this area, and we're just getting started. I'm talking specifically about tissue culture in space, and whether you call it a specimen temperature controller or a bioreactor, really they all work on the same principle.

On the ground, tissue culture is very limited, to essentially two dimensions, because the cells fall to the bottom of whatever culture vessel we're working with, and they cannot grow in a three-dimensional arrangement, the way they grow in our bodies. All the tissues of our body are made up of three-dimensional arrangements of cells, and the function of our organs and tissues is totally dependent on this three-dimensional structure. It's become critical for cancer research, or developing the basis for tissue engineering in the future, to be able to culture cells and grow them into tissues in a way that they behave the way they do in the body. This requires three-dimensional tissue growth, where we control the spatial relationship between the different types of cells.

**EIR:** How does the bioreactor grow three-dimensional tissue?

**Wolf:** I worked for seven years before I was an astronaut, on a team that developed this technology, not just the specific

*Shuttle-Mir astronaut Dr. David Wolf.*

bioreactor machine. It actually happened when the Shuttle was grounded after the *Challenger* explosion. We were restricted to doing our research on the ground and we were attempting to simulate zero gravity. We took many wrong approaches, but finally, three of us came up with the approach to spin the culture, on the ground, in a cylinder of culture media, like blood, and build a machine that acted as a heart-lung machine, a kidney, a digestive system—essentially building a rudimentary artifical body to support the cells that were growing in this rotating, or spinning, cylinder.

By doing this, the cells would go around in the cylinder, mimicking the way they would grow in space. They would be suspended in the fluid without introducing mixing devices inside the vessel which, by nature, disrupts the culture. We achieved a three-dimensional suspension of cells with a very quiescent fluid dynamic environment. Most of our work is done on the ground. After something is well developed, we take it into space, when we think space can offer an advantage.

We got amazing results. We were able to grow human tissues, to limited size, in three dimensions. This became a breakthrough in tissue culture for ground-based use. In fact, a company has been formed by some of the people who left our laboratory, which sells this instrumentation to researchers all over the country, including the major cancer research centers. We found that cancer tumors could be grown in three dimensions, where they behave very accurately—as they would in the body. Therefore, we could do more valid studies of cancer genetics and the response of cancers to treatment. So, the issue of controlling gravity became important for cancer research. It generated a great deal of interest among the leading cancer researchers in the country, who now use the bioreactor.

We determined that there were limitations that were imposed by gravity, operating these systems on the ground, and we worked with the hypothesis that by going to zero gravity, we could grow larger and more complex tissues, which would then function even more like they do in the body. There's no question that one day humans will grow real organs for reimplantation, and we have shown that many of the secrets, or keys, to doing this can be learned by doing tissue culture in space. We've made very critical observations, as our bioreactors have flown in space now for a year or so. They have verfied that space is the absolutely ideal environment to unlock the secrets of the emerging field of tissue engineering.

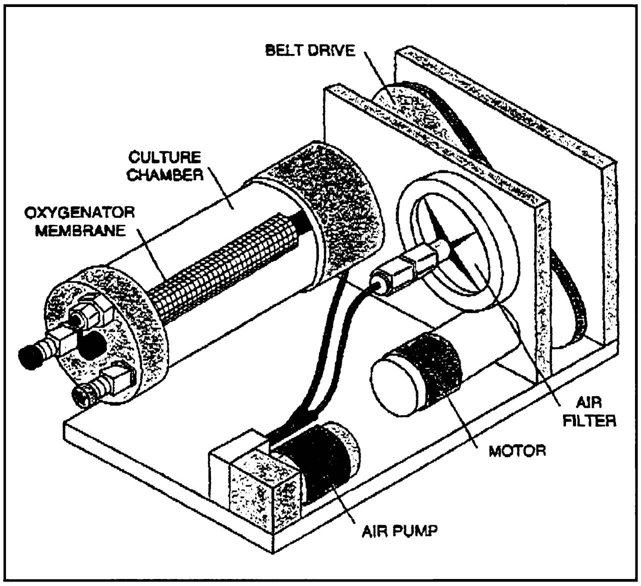
**EIR:** The experiment you were conducting on Mir was to see if there are changes in the cells as they replicate in zero-gravity conditions, and whether or not they develop all of the complex differentiation and other characteristics that they do on Earth. What were the results of the experiments that you were doing on the Mir?

**Wolf:** The biochemical results of differentiation are not analyzed yet; the samples were just brought back. But, we did definitely observe that the three-dimensional morphology of the growing tissues was much larger, and that much more delicate structures were allowed to form in a much more organized fashion than the best we can do on Earth. To me, this issue was of fundamental importance, and we clearly showed that our hypothesis was true, that we could do that. The biochemical—histology, and immuno-histology—and detailed analysis, are currently under way to verify that the cells are differentiated. I am very confident that we will see that they, in fact, did differentiate. You could not maintain that morphological structure without differentiation. The biochemistry at the cellular level is yet to be teased out and analyzed.

**EIR:** It seems that this would be important, because you would not want to introduce anomalies into the cell reproduction from either the device, or microgravity, itself. You would like to grow the cells without anything imposed from the outside environment.

**Wolf:** That's right. We'd like the advantage of microgravity for the organization of the tissue, while not interfering at the cellular level, of cell processes. There is no theoretical reason to think we would interfere with the cell processes, but we need to be absolutely sure that is the case, to make sure that our research is valid. That was an important goal of the work we did on my increment on Mir.

**EIR:** Astronaut Andy Thomas, who is on the Mir now, is continuing these studies in tissue growth with the Biotechnol-




*This schematic of the rotating wall vessel bioreactor shows the electric motor that rotates the culture vessel, the pump that draws air from the chamber through a filter and discharges it, the culture chamber where the tissue is grown, and the membrane covering the shaft of the cylinder, which feeds and removes waste from the tissue.*

*Astronauts Carl Walz and Jay Apt analyze a bovine cartilage sample during Space Shuttle mission STS-79. The astronauts activated the bioreactor experiment on the Shuttle and tested the sample tissue, before it was transferred, along with astronaut John Blaha, to Mir. See Figure 1.*

ogy Co-Culture experiment. He is growing two different types of cells in the reactor. What is he studying on his mission?
**Wolf:** We've been looking forward to this experiment for quite a while. Co-Cult simply means growing more than one cell type at the same time, together. We've taken this to a reasonably advanced level on the ground in a simulated microgravity system. The two types of cells he is growing are breast cancer cells and a fibroblast layer, made up of angiogenic cells, that is, a blood-vessel-forming type of cell. These are two types of cells whose relationship is very critical. A tumor attracts blood vessels just to feed its cells, and this is a key area of cancer research—why these tumors attract their own food supply.

One goal is to reproduce breast cancer tumors in a fashion that even more accurately represents how these tumors grow in the body, including the blood-vessel-forming cells. It is not necessary for actual vessels to form; it is the interaction between the two cell types that is of great importance. We chose this pair of cells, because it takes us a good way down the path of studying breast cancer tumors, as well as helping us take the next step toward organ or tissue engineering. It's very clear that, in the end, there is no question that we will one day grow replacement organs for people, and space will unlock many of the secrets of how to do that. This is our first step in space, to move toward vascularizing tissue.

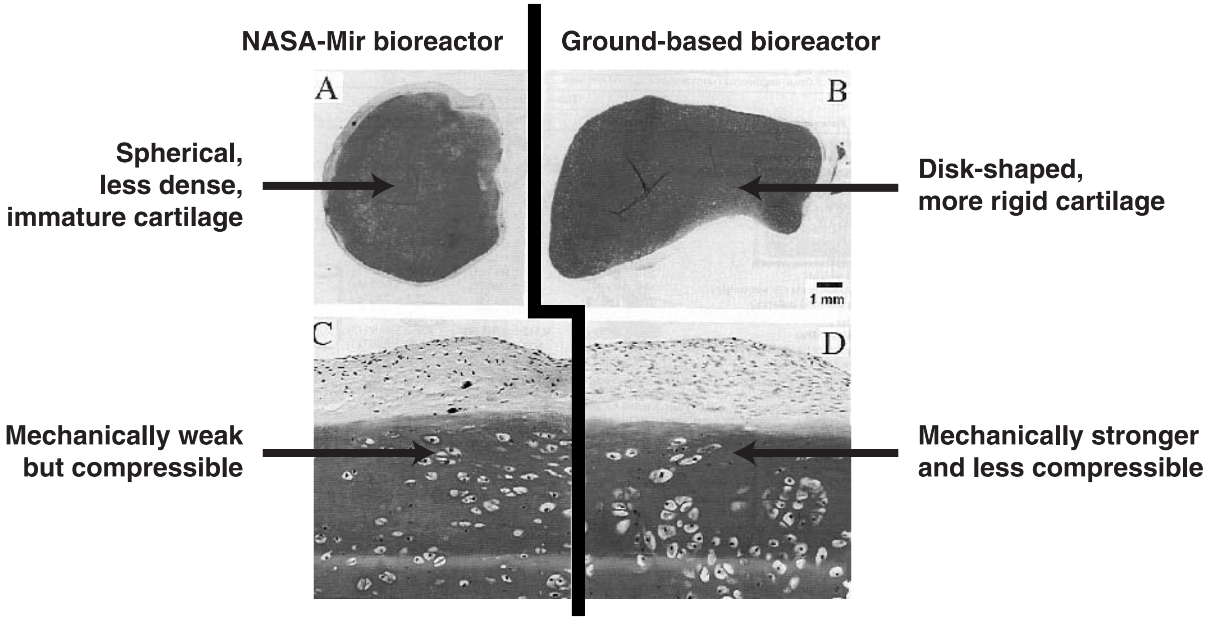
**EIR:** Would you have to be able to grow blood vessels in replacement organs created from tissue engineering?
**Wolf:** Absolutely. We picked a model system that will give us information in both directions. It happens to be a cancerous tumor whose vascularization we are looking at, but we are also interested in that as we move into normal tissue.

**EIR:** Do the cancer cells have some kind of mechanism for stimulating the growth of blood vessels?
**Wolf:** They clearly do. Tumors are in some way regulating blood vessel formation, and we want to understand that, so we can use it as a tool. In many respects, the tumor mimics the way normal tissue grows blood vessels, although it's a little out of control. It gives us a good way of studying the process.

**EIR:** If you understand what the relationship is, would this also work in reverse, to give you a way to stop tumors from growing, by preventing them from developing blood vessel systems to nourish themselves?
**Wolf:** Right. This would be wonderful. Once we understand the mechanism, the process, that gives us a directed target to be able to interfere with the process. This is one important strategy in fighting tumor growth.

**EIR:** Why did you choose breast cancer cells to grow? Does that type of tumor grow more easily?
**Wolf:** We have studied upwards of 15 different types, on the ground. We felt that breast cancer was a good model, from our observations on the ground. It grows in a glandular form, and we felt we were very well able to reproduce the gland formation on the ground. We just had to pick one, at some

FIGURE 1
**Cartilage grown in space and on Earth**




*Space cartilage is substantially different than mature native cartilage. The space and the ground-based bioreactor cartilage formation is superior to that from standard culture techniques. STS-79 Mir Increment 3.*

Source: NASA.

point. We found a researcher who put in a particularly good proposal for the [breast cancer] study. We had matured to that point, to put the breast cancer in space. Colon cancer is another one we are ready to study in space. We just haven't had a chance yet. In the end, we will study all of them. We've already put cartilage in space.

You have to realize that we've had extremely limited time in the laboratory in space, and we're trying to gather a database to help us direct and focus our research on the International Space Station, which we will begin launching later this year. At that point, we'll have more extensive facilities and continuous time for many years in the laboratory. This type of work takes a whole team of researchers many years in the laboratory, and what we have [now on Mir] is a small area of a small space station, with one astronaut, part time. We're really in our infancy.

We have to pick cells that are matched by our knowledge, during what I call the Shuttle-Mir pilot study phase. But, we do plan to up the level of effort on the International Space Station. And much of our work occurs on the ground in our laboratories, which is very complementary to our work in space. We work with major universities and medical centers throughout the country, with their laboratories also. So this is *not* just the work going on in space.

Space gives us certain key pieces of information, which, ideally, we'll be able to transfer to the ground, once we know how to do it in space. Three-dimensionality, vascularization—ideally, some day we can do it on the ground. Space is like cheating: We can take steps ahead in the three-dimensional organization before we know how to do it on the ground and get the information. We know it can be done on the ground, because a mother's womb does it every day. But we don't know all the secrets yet, and by doing it in space, we can leapfrog many of those details in space, and then backfill those details.

**EIR:** I noticed in the Feb. 20 update on the Mir mission, filed from Russian Mission Control, that the current resident astronaut on Mir, Andy Thomas, has had to troubleshoot the Co-Culture experiment, because bubbles had formed in the bioreactor and were interfering with the experiment. I understand that that had happened before, on a previous Mir mission.

**Wolf:** That happened with John Blaha's experiment [on Mir] also.

**EIR:** Has Thomas been able to solve the problem?

**Wolf:** It's not been a devastating problem to the culture, [although] we'd rather not have the bubbles. It appears that it is a completely different reason this time, from when John Blaha did it. It has been a problem, and Andy's been troubleshooting it and working with it, and we do need to solve that. Again, this is a key reason why we've taken these instruments up on the Shuttle-Mir, so we can get an early look at how these systems behave in space, so we can resolve those problems before ISS.

Really, it may seem like a problem up front, but it is a very new research tool in space, and you might say that this is our going through the initial testing. Luckily, the culture seems to be doing quite well, even though there are bubbles in it. It appears to be a problem of controlling some valves. I have a feeling it may be a more complex problem than that. We're trying to understand it.

**EIR:** You were not only a science investigator on Mir, but also a subject, in the study of the human body's adaptation to weightlessness. In your press conference last week, you described the process of readaptation that you are now going through. Could you summarize what the different stages are?
**Wolf:** There are clearly defined stages that I've noticed. Some of this has individual variability—or, all of it is highly dependent on the individual, but I think the stages are typical. I had about four days of serious balance problems, inner ear vestibular problems. It was classic. If I tilted my head to the right, I'd feel that my body was accelerating to the left. This is very explainable. It is the adaptation that the vestibular mechanism goes through in space. It makes it hard to turn corners, and when you go through a doorway, you get this overwhelming feeling that you're moving inwards due to the centrifugal force on your inner ear, and you tend to walk outwards. It makes you want to hit the wall and makes you tend to hit the doorway. You have to be very careful, and use your eyes very carefully, instead of your feeling.

Your eyes aren't stable at what you're looking at, because you're getting lied to by your inner ears on your motion. The position of your head with respect to gravity, gives you bad data. A lot of that data is used to stabilize your gaze with your eyes. This all tends to make you sick. You have nausea in the first day or two.

This is like what happens after a short Shuttle mission, somewhat more intense, but very similar. It resolves over about four or five days. I had a two-week Shuttle mission, and this was quite similar to what I felt after that mission. It resolves in the same amount of time, about four days, but was a little more intense, which tells us about the inner ear's adaptation time scale.

There was also a profound weakness, due to muscle atrophy and not being used to using many of the muscles, such as the muscles that control posture and balance, that are just not used in space. The whole neurological circuitry and the muscles themselves are atrophied. You have this profound weakness and poor control of your posture and balance. This starts right in the beginning, of course, when you get back to Earth.

After about three or four days I got into a phase, for another week or two, of muscle soreness: profound muscle soreness, as though you'd worked out very heavily. But the heavy workout in my case was rolling over in bed, was the strain on my back, bending over to pick up a coin, getting down and back up. Just walking and doing normal activity, taking a shower, led to rather severe muscle soreness over my whole body. These muscles had been accustomed to working without gravity, and now, this was a high load on the muscles. They responded as they would to any heavy exercise, and in this case, just normal activity was heavy exercise. Lying in bed in gravity, and rolling over or raising your legs up, is more exercise than we got working in space.

And all through this, we were doing physical rehabilitation. We still are, half a day, every day. We started off with stretching and just walking around in the water and working with extremely light weights, just to get these muscles accustomed again to working with gravity. That lasted for the first two weeks. The muscle soreness didn't come up for three or four days, but in the first two weeks, it was there, along with the weakness, which was slowly getting better. And now, after three weeks on the ground, I'm in a phase where my muscles don't hurt any more very much, and we're working with physical rehabilitation with a professional trainer, who is working with weights. We're running now, and swimming, and weight lifting of different kinds, special exercises that rehabilitation people know about, to bring back strength. Our hypothesis also is that along with the muscle strength should come bone mineral density. I lost 10% or so of the bone mineral density of a number of bones.

**EIR:** It is my impression that it is the bone mineralization that takes the longest to recover after a space flight. Is that so?
**Wolf:** I think that's true. I expect that it will take six months or so, if I work hard at it.

**EIR:** Knowing that, I was surprised when you said in your press conference last week that you thought that in the future it would be important for astronauts to be able to make multiple long-duration flights in space. You mentioned that one of your crewmates on Mir, Anatoly Solovyev, had made five such long flights. For the sake of safety, wouldn't you want a certain amount of recovery time between flights of that length?
**Wolf:** Exactly right, and Anatoly has had that. I don't think he repeated a mission in shorter than maybe a year and a half, two years, I'd estimate.

**EIR:** He would certainly be a very fascinating person to study, in terms of bone density recovery. Do you think the bone density does come all the way back up to normal levels? Or is that not necessary?
**Wolf:** Perhaps it's not necessary. We will see where it goes. I think one of our [Mir] astronauts has gotten back to very close to normal. I can't give out private medical data; it will all be reported in the research documents. But indications are

that if you work hard at it, you can get back. When we collect the data on all seven [Mir long-term astronauts], as we get some time behind us, hopefully we will get an indication of what it takes to get it back.

And we're interested in what it takes to not lose it, in space; to minimize this loss. Our approach is exercise and strength training in space. This is a key area of our research, so we can conduct exploration of other planets, and so we can work on a space station and prevent these rather serious degrading effects.

**EIR:** If there were a way of mitigating the effects during the mission, you would be in a position to decide that people could stay for six months, or even a year or longer, on the International Space Station?

**Wolf:** Even after three months, we could have them come back and not suffer these great losses. I have a feeling that we'll be able to do better, but you can't reproduce the details of a gravity load [in space]. It's a very complex interaction with the human body. We probably won't get to a complete countermeasure, but we certainly can do much, much better. It's important that we do not spend all the time exercising up there. We need to pick the right exercises and the right equipment. After all, our job is not to go up there and exercise.

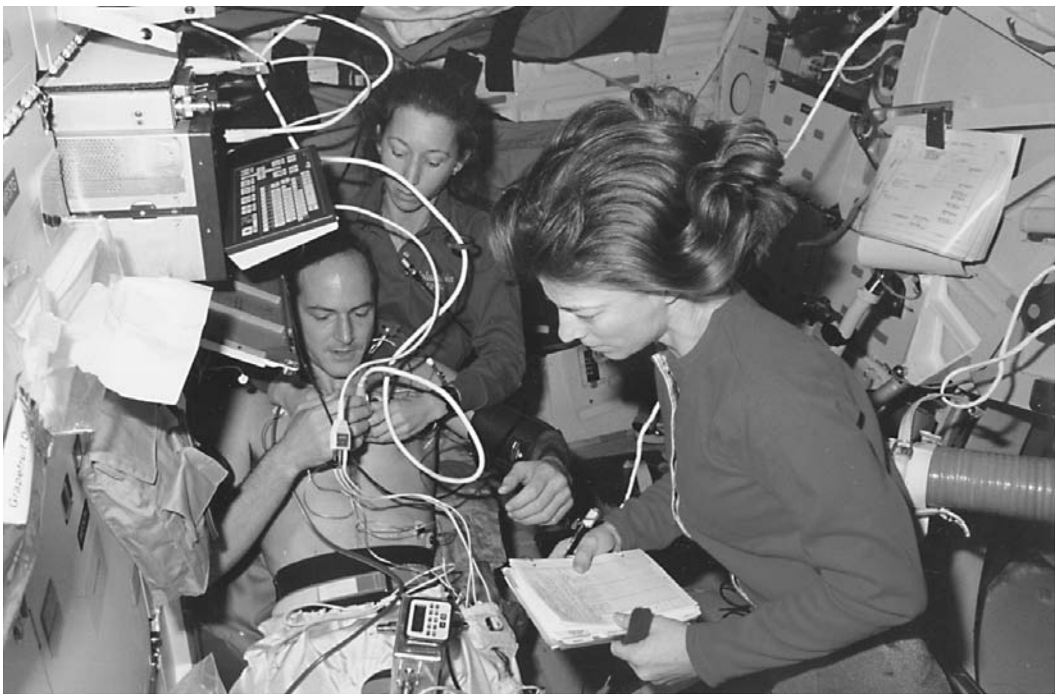
**EIR:** The flight by John Glenn coming up in October is very exciting, because adaptation to space flight has been described as similar to an acceleration of the aging process. Beside the one or two specific experiments that he will be a subject for on that mission, all of his other health parameters will be monitored, the way they are for any other astronaut. Do you have thoughts on what might be the most interesting aspects of the relationship between space adaptation and aging?

**Wolf:** Of course, we will get information on the effects of zero gravity on older people. But you're talking about the reverse: How can that give us information on aging itself, by flying an older person? The way I look at it, is that aging is something that happens at different rates, at different points in our lives. He's going to be at a different stage in life, and going to be responding differently to the zero gravity and to readaptation [than younger astronauts]. If we can understand the difference in his response and how it's related to his age, I think this may open secrets to us—it's another parameter, another variable we can introduce, that hopefully will elucidate some of these mechanisms of how space is affecting humans.

He's older, and may come back without any strength loss, or with more strength loss. This will shed a great deal of light on how we can develop countermeasures. We can look at his physiology and the differences and use those as key aids to research.

**EIR:** I know Senator Glenn's flight is only a ten-day Shuttle mission, so it's not as if his experiences and responses would be comparable to yours after four and a half months. But even on such a short flight, do you think there are specific areas where his adaptation will produce new data? He won't be there long enough to see long-term effects of bone demineralization, but are there some areas where we will see some change?

**Wolf:** We don't know that. He may show the demineralization. We don't know yet. That's assuming the answer before we go. We have a great database on people who have been up



*While Dr. Wolf was in the Medical Sciences Division at JSC, he was responsible for the development of the American Flight Echocardiograph to help ensure the health of the crew. It is seen here in use by STS-32 astronauts David Low, Marsha Ivins, and Bonnie Dunbar (taking notes), in January 1990.*

in space approximately ten days, and they do show many of the effects that we're talking about, in terms of strength loss, muscle atrophy. Many of these things are visible. It's a first step with him, and I think we need to be cautious in our first step. Just as in the bioreactor, we're not doing every experiment we would like to up there right now, but we had to get started somewhere.

**EIR:** To finish our interview discussing the bioreactor, where we started: You were asked last week at the press conference, about astronauts who have left the space program after long-term flights on Mir, and you said you were in the program to stay. I assume from your answer that you are looking forward to spending time on the ISS, to continue these experiments with the bioreactor. What do you see as the next steps in the tissue culture area?

**Wolf:** I am very excited about where we're going in space and having very capable laboratory facilities in space to do research. We're going to achieve that on the space station. I am in it for the long run and, before you called, I was discussing what we are going to do up in space *this afternoon,* with Andy. I basically consult [with him] every day on what he's doing up there [on Mir]. You realize, this was originally the mission I was supposed to do. [Wolf took the place of astronaut Wendy Lawrence, doing his mission on Mir one increment earlier than originally planned.]

**EIR:** I know. It must have been very disappointing.

**Wolf:** We had pretty good [tissue] culture facilities up there anyway, and a lot going on, during my mission. In some ways it was easier to do photography on the tissue with the equipment that I had. Even easier than with what Andy has. There were some advantages, but I consider the full-up rotating reactor the real machine here.

When you talk about the next step on the station, I'm still talking about the next step this afternoon. On the International Space Station, we will be able to do the research more like we do it on the ground—consult with our colleagues, and adapt day by day. A lot depends on what we learn on this mission with Andy, and what we learn in the ensuing time on the ground, and the analyses from the samples I brought back. We will formulate a plan based on all that information and choose our experiments on ISS.

Ideally, I think we should go toward continuing cancer research using other cancer models and types. We need to also move toward tissue engineering in terms of shaping tissue and functionally vascularizing it. I'd like to see us move into neural regeneration.

I have a friend who had a broken neck, one of the best pilots I've ever known, and there are a lot of people like him we need to help. I consider that a high priority. We had nerve cells on my mission, and they showed an excellent ability to reproduce in zero gravity. You'll be awed by some of the pictures when they're published.

**EIR:** These are pictures you took on your Mir mission?

**Wolf:** Yes, of neural cells growing—not just cells, but large groups of neurons.

**EIR:** Is this a hard effect to produce?

**Wolf:** We thought that we could preserve them and bring them back, but even when I fixed them and brought them back, I'm told that they didn't withstand the reentry. We need to have the type of research facilities to do the analyses on orbit. We also weren't able to use all the fixatives we might, and I didn't have an electron microscope up there. I didn't even have a very good microscope, but it's still obvious [from the photographs].

**EIR:** When Shannon Lucid came back from her mission to Mir, she said that she really enjoyed the opportunity to work again in a scientific laboratory.

**Wolf:** I felt the same thing.

**EIR:** As long as Mir is running without needing a lot of intervention, in terms of repair, you have some peace and quiet to work in a laboratory, which I'm sure astronauts do not have time for otherwise.

**Wolf:** That's right. Most of us came from working in laboratories, and once you're an astronaut, it's a different environment. I did feel exactly what Shannon felt, that is was a real pleasure to get back in the lab and do my work. But it was hard to do this at the same time as working with the Mir systems. I had a lot of responsibility for helping with the repair work, and this knowledge of how to conduct the research, concurrent with the mission operations, is critical, and that's being fed into our operations. How do we schedule people and let them work?

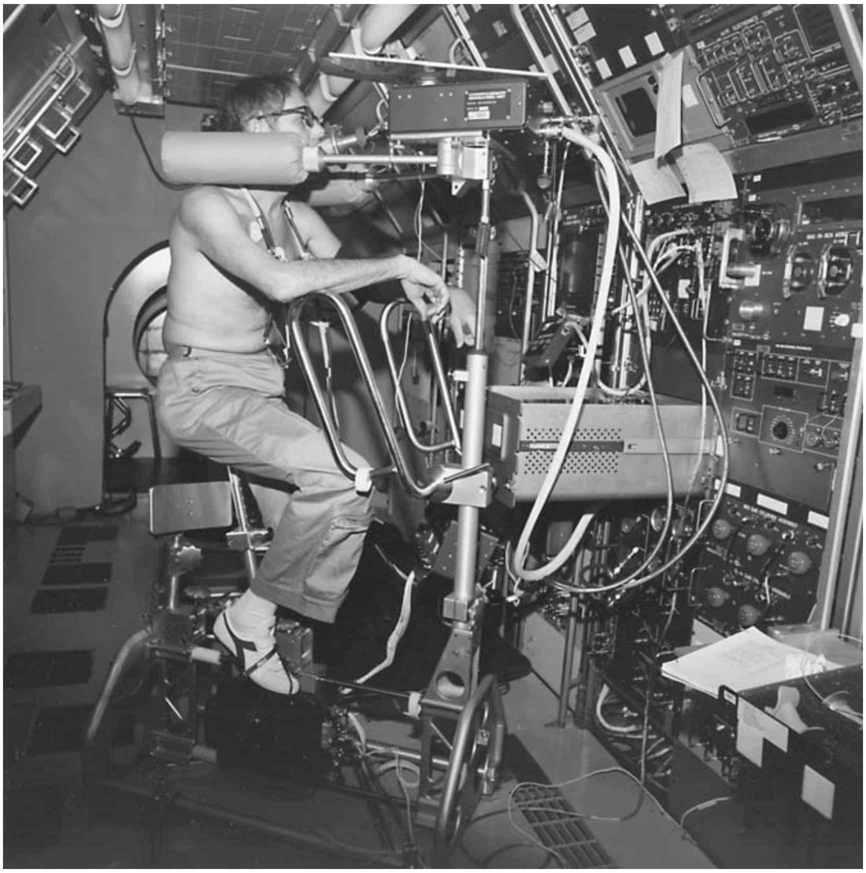
An example: There was a time a month and a half into the mission, when I knew that, to ideally image what I was seeing in the culture, I needed to set up another whole instrument from another experiment—a video microscope—but that would have taken a few days, just to get it out and set it up, and there wasn't room, at the time. I would have liked to call down and say, "Look, we need to change course here, completely change course, and take a few days out to document what we've got here." But we couldn't do that, because we had other experiments coming on line, and we had a schedule to keep.

A key part of my debriefing [was to say] that if we're going to work as we do on Earth, we need to have the flexibility. Very few discoveries come on schedule. We need to let discoveries happen. We need to have a flexible schedule, and optimal use of the human that is up there making judgments and observations.

**EIR:** There aren't too many Earth-based laboratories that work on a time line.

**Wolf:** That's right. This was taken to heart by our schedulers, by our people who are operators and controllers. We're working towards allowing that type of research to occur on the International Space Station.

You realize that [now], if we make a plan of what we want to conduct and it's somewhat ambitious, if we don't do it all, and we just don't go through the motions of doing it all, we get criticized as a failure, or for not completing the mission. On the other hand, if I make the judgment that we need to proceed with *this* work at the expense of others, you can imagine the uproar there would be from the others! This is a challenge for us, how to get this kind of flexibility into the program and also—people have done many years of preparation and we need to do their experiments also. But we don't want to plan non-ambitiously.



*It is important to find new countermeasures to space adaptation, because astronauts are not sent into space to do exercise, as Dr. Wolf stresses. Here, STS-40 astronaut Dr. Robert Ward Phillips participates in a cardiovascular deconditioning experiment, atop the exercise bicycle.*

**EIR:** This must also require a lot of coordination with the ground. ISS will be more automated than Mir, but it will still require coordination with Mission Control and also scientists on the ground. Will that requirement impinge upon flexibility?

**Wolf:** You raise a critical issue. I raised it also in my debrief. We do need access to talk to the most knowledgeable scientists involved in the work on the ground, ideally, directly, one-to-one, and our communications systems need to be designed to accommodate that. I agree, it's not just the astronaut up there working, it's him working in conjunction with the scientists on the ground.

This happened on my mission. There were many decisions that had to be made on the tissue culture, based on what was happening in the systems on the ground. I sent down photographs and images in a very limited fashion, to help them understand what was happening in space. I would describe what was happening, but due to limitations of the infrastructure up there right now, it might be days until I got a response, so I had to work more independently. But ISS should be much better at including the ground-based scientists in the day-to-day, or even hour-by-hour, decisions. This will be a great advantage for us.

I hope the public realizes that we take it step by step in space, and it's rare to have that "Eureka!" discovery, but it's really made up of step-by-step, small observations that eventually lead to a discovery that's important. That's the difference between stepping on the Moon and operating a laboratory in space. I hope that we capture the interest of America with our step-by-step scientific research as much as we did by stepping on the Moon.

**EIR:** When do you think the results and material from the tissue culture experiment on your flight will be available?

**Wolf:** That's unfortunately not my business. That data goes to the investigators.

To me, it is important to stress that NASA has a unique ability to put together teams that are hard to find anywhere else. And that was the kind of team I got to work with on this, and it currently exists at NASA. It extends out to academia, and it was really fulfilling for me to have equipment up there, and work with the team that developed it. I guess it's rare that an astronaut gets to do that. I'm really proud of that team. It's an amazing multi-disciplinary team of scientists, engineers, technicians, and biologists. It takes that multi-disciplinary approach in these days, to come up with important discoveries, in many cases. I know we can contribute immensely to this emerging field of tissue engineering.

It's a great team, and we get to do it in space, too. It's fantastic!