The oral histories placed on this CD are from a few of the many people who worked together to meet the challenges of the Shuttle-Mir Program. The words that you will read are the transcripts from the audio-recorded, personal interviews conducted with each of these individuals.

In order to preserve the integrity of their audio record, these histories are presented with limited revisions and reflect the candid conversational style of the oral history format. Brackets or an ellipsis mark will indicate if the text has been annotated or edited to provide the reader a better understanding of the content.

Enjoy "hearing" these factual accountings from these people who were among those who were involved in the day-to-day activities of this historic partnership between the United States and Russia.

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JOHN URI

May 15, 1998

Interviewers: Rebecca Wright, Mark Davison

Wright: Today is May 15 [1998]. We are speaking with Dr. John Uri, who is Phase One mission scientist. This is part of the Shuttle-Mir Oral History Project, and interviewers are Rebecca Wright and Mark Davison. Good morning, Dr. Uri.

Uri: Good morning. And I go by "John," not "Dr."

Wright: Okay, John. We'll let you start by telling us some of your background and explaining some of your roles that you have with this program.

Uri: Okay. Well, I started in this program back in 1992, when the program itself started. In June of '92 is when the two governments signed the agreements between President [George] Bush and President [Boris] Yeltsin. Within a month, NASA administrator [Daniel] Goldin made a visit to Moscow and some of our folks here at JSC [Johnson Space Center] accompanied him on that. Dr. Carolyn Huntoon, who at that time was the director of Space and Life Sciences, headed up our delegation from life sciences. In fact, at that time, I was still working with a contractor, GE Government Services, which became Lockheed, which became Lockheed-Martin, whatever that progression was.

Anyway, at that point, our goal was, you know, the governments had made the agreement that we would cooperate in space. We wanted to put a little bit more meat on that agreement, kind of hammer out a program of what we wanted to do. At that point, we came up with the agreement that we would fly a cosmonaut on the shuttle, fly an astronaut on the Mir for a long-duration flight, and have a shuttle dock with the Mir. And so that was the program at its inception in 1992.

It was our task to come up with a scientific program for the cosmonaut on the shuttle and the astronaut on Mir to perform. Because we've had a long history working with the Russians at the level of data exchanges, mostly this was our life sciences people here at JSC. Our investigators here in house had that long history going back as far as 1971. Dr. Huntoon had made many trips to Russia between '71 and 1992 to work on these joint data exchanges, and we've had some of our PIs [principal investigators] take data on cosmonauts, particularly before- and after-flight bone and muscle measurements. So that had gone back a few years already. So even before the Shuttle-Mir program started, we had a fairly solid basis of working with the Russian counterparts in the life sciences area. We knew each other, we knew their PIs. Some of our PIs, our investigators, had worked with cosmonauts, so we had a fairly good relationship already established. So when this program started, we knew that it was going to be a crash course.

In July of '92, we made another trip to Russia. That was our first trip where we kind of outlined the bases and in a very general way said, "Okay, we want to do life sciences experiments on these joint missions." We went back a month later, I think, in late August of '92. At that point, we had already put together some of our proposals from our side as to what we would like to do. It was our first experience with long-duration space flights and Skylab in the early to mid-seventies, and so there were a lot of things we wanted to do.

So we went over there with a preliminary package in August to talk to the Russians about it. They were very supportive. All of these experiments were to be joint experiments. That is to say, we'd have a lead American and a lead Russian investigator on each experiment. I think we had something like twenty-six life sciences experiments we had identified that we wanted to do. So we had a general agreement in August that this is indeed what we wanted to do. We had six experiments identified for the cosmonaut on the shuttle, and then the twenty-six long-duration experiments for the long-duration flight.

Over the next several months, we had a few more joint meetings to hash out the details. Our investigators met with the Russian co-investigators. We came up with a very impressive program in a very short period of time. Usually this takes many more months, even a year or two, to come up with a solid program. So by early '93, we had a very strong program already outlined, and we kept working that for about a year.

I should add that when the joint program was first announced in the summer of '92, the expected long-duration flight would begin in September of '94, so we had two years to come up with a program. By comparison, when we fly a space lab mission, typically from experiment selection to flight is more on the order of four years, four to five years. So we had a very, very compressed schedule. That was one our first challenges.

Of course, our second challenge was that we were going to be flying on a vehicle that wasn't ours, that we didn't know much about. We had a vague idea of its characteristics, of its capabilities, you know, what science could we do. We weren't even certain what science hardware was on board.

So as we were progressing through this process, we learned a lot about the Mir, what its capabilities were, what life science hardware was already on board. Of course, because many of these investigations were continuations of what we had done on the shuttle, we wanted to take some of our own hardware with us to Mir. Of course, that was also a challenge.

The only way, at that point, we had to get hardware to Mir was by using the progress vehicles, which are relatively small. They can carry up towards, I think, 2,000 kilograms of hardware, but that includes all hardwares--food, water, Russian hardware--and we wanted a piece of that to get our life sciences hardware on there. So that was an additional challenge.

Of course, we had the language barrier. We had a very talented team of interpreters that had been working with us. Some of them went back to the Apollo-Soyuz days. They had been working with us for that length of time. So those were the challenges. Of course, we didn't know much about long-duration space flight and how to do science on that kind of a program, so we had a lot of learning to do. So that kind of got us through '93.

Then in late '93, the governments agreed that they would expand their program, a joint program with U.S. and Russian participation in shuttle and Mir. I think it was November when the governments agreed that there would be additional flights, shuttle flights, to Mir, as well as additional long-duration missions of U.S. astronauts on Mir. So the program went from something that was fairly small and self-contained to one that would be a multi-year program. We also invited other disciplines, other than life sciences, to participate. So, in scope, the program ballooned tremendously.

So as we are working to get the first flight under wraps and get the training done and the baseline data collection done, all of a sudden we're thrown this much larger task, so that was the additional challenge. So we had not even flown our first flight on Mir when they were asking us to fly, at that point, I think, it was four more, and up to nine additional shuttle flights was what was talked about back in late '93, early '94. This was still a year before we were going to fly Norm [Dr. Norman] Thagard on Mir, so we had a lot of parallel work going on. Very, very challenging.

So we kind of separated the teams. We had one team of people working Norm Thagard's mission, and for the life sciences project, that was Peggy Whitson. She was leading up that effort. Of course, she has now moved on to bigger and better things. She's one of our newest astronauts in the latest class. Then in, I think it was, March or April of '94, I was assigned the task of coordinating the activities, as part of this larger overall program, and this is where the designations of Phase One finally came into being.

So the early part, which was the cosmonaut flight on shuttle and the first astronaut on Mir, was called Phase One A, and then the rest of the program was called Phase One B. Of course, there were differences, in that Phase One A was not a contractual kind of agreement. Each side, each country, brought their resources to the table and there was no real exchange of funds or anything like that. Phase One B was the part that was under contract.

So this is through '94. As I said, we were bringing in all the other science disciplines, such as the microgravity and materials processing discipline, and that was managed out of Marshall. Of course, we were also continuing the life sciences, managed here out of Johnson. We had a fundamental biology group, managed out of Ames Research Center. We also had Earth observations, and that kind of fell into two categories. One was from here at JSC, from the solar system division.

So we had this more expanded program, where we had additional long-duration flights to Mir and we opened up two additional research disciplines to conduct some research aboard Mir. Of course, we continued our life sciences research, as managed here out of Johnson. We invited the microgravity world and materials processing to fly experiments. They were managed out of Marshall. Fundamental biology--we invited them and that's essentially the plant and animal work that we've done on Mir. Those experiments were managed out of Ames. We had the Earth observation, and that was split into two groups--one from JSC, here, from the solar system exploration division, and it's really the hand-held photography that we've been doing from shuttle over the years, of course, even going back further than that. We would continue that from Mir.

Another part, we would participate in what's called the international Priroda Program. At that point, in early '94, there was a plan to place international sensors on the Priroda module, which would be remote sensing kind of instruments and they'd be provided by European, by ESA [European Space Agency], by, I think, France and Germany, were the prime providers, as well as Russian instruments. We would participate in obtaining data as part of that program. It would be kind of melded into the Phase One Program as well.

We also had the space science folks contribute some experiments. That's from Code S up at headquarters. Those were essentially cosmic dust collectors, is what that turned out to be. Very interesting science. And also from the commercial world, we invited them to fly some payloads to give them some long-duration experience prior to flying on space station.

So that was how we were scoping it out in early '94. To my knowledge, I don't think anyone's ever attempted that kind of a broad program, number one. Number two, trying that on somebody else's vehicle, working across nine time zones, working across a language barrier.

One thing I should add, as part of this enhanced program, we had agreed with the Russians that we would outfit two of their modules that had been planned to go to Mir, but were currently, at that time, were sitting on the ground, and that was Spektr and Priroda. Spektr would primarily be outfitted with life sciences hardware. All of a sudden, in this time frame, in '94, we were still a year away from flying Norm, so we thought, "Well, with all the life science hardware we had planned to launch on the small progress vehicles, let's put those in Spektr," which is a much larger, full-size module for Mir, and get all that hardware up there in time to support Norm Thagard's flight.

It was a great plan. Didn't exactly happen that way. There were delays in the launch of the module. Originally it was planned for, I think, late '94, and Norm's flight was early '95, so it looked like it was going to happen just perfectly. We get the module up there, hardware arrives before Norm. When he gets there, he's ready to go. Unfortunately, the module slipped. The launch of it slipped, and it didn't get there till well into Norm's flight, so we had to regroup again and put some of the hardware back on Progress to get them there in time for Norm.

So that was, I think, also a very good learning experience for station, that you always have to plan for unexpected things. They have a very well thought out program, but one little thing happens, and it upsets the apple cart, and you have to go back and replan. I think that's been the hallmark of Phase One that we've learned, you know, and I think Houston, these days, has this "expect the unexpected" slogan. Well, I think we should have come up with that first, because we dealt with that almost on a daily basis. I think that's just the way long-duration space flight is. I don't think that was unique to Phase One. We'll have to expect that in the ISS [International Space Station] Program as well.

So anyway, so we were outfitting Spektr. At this point, we had a whole team, headed up, at that point, by Charlie Stegemeoeller, who was getting the hardware on board Spektr, and the Progress, so that was going on in parallel. Peggy Whitson was doing the science program for Phase One A, and I, plus a whole team working with me, was trying to get ready for this additional program that was happening after Thagard's flight.

I mentioned there were two modules. We talked about Spektr. Priroda was the other one. The plan there was to outfit that with primarily microgravity hardware, facilities to support microgravity research. That was a glove box facility. We had flown on shuttle before in space labs, as well as a mid-deck version, and we were going to take that mid-deck version and put it in the Priroda to enable lots of experiments to be performed in the course of the program. The Canadians became part of this program. They provided some hardware. It was a microgravity isolation mount, which is a system that allows you to isolate experiments from the acceleration environment, or vibrations from the Mir, to achieve very stable acceleration environments for certain experiments that require that.

So we had another team that was working on outfitting Priroda. That was headed up by Gary Kitmacher. So we had lots of parallel efforts going on to try to get ready for all the really multiple programs, if you will.

So finally, in early 1995--well, let me back up a little bit. We got our first hardware up to Mir in August of 1994, and that was a very modest effort. We had three pieces of hardware going up on that progress flight. One was a TEPC. T-E-P-C is the acronym. It's a radiation counter. We wanted to evaluate the environment of Mir prior to our astronauts actually getting there in that particular orbit.

Then we also had the SAMS, which is the Acceleration Measurement System. We have flown that on shuttle. We had, at that point, flown that on a few shuttle flights, to measure, monitor, the acceleration environment of Mir, which is very important for a lot of the microgravity research. We also had a computer system, which was a computer link, essentially, between the experiments. It's a data system, so we could get data down to the ground. So we had those three items go up on the progress.

The MIPS--this was the MIPS-1 version, that's the computer system. The Mir Interface to Payload System is what the acronym stands for. We knew we were going to replace, eventually, with a MIPS-2, that was coming up on Spektr. We just needed it, in the interim, to get us through the first few months.

The TEPC was the first one we launched. We eventually replaced it with another unit, and I think we brought the first one home. The SAMS, I'm happy to say, is still on Mir today. It is the longest-lived U.S. hardware on Mir. Just as a side note, we've returned something like 40 gigabytes of data from that hardware alone, and we use it to monitor the acceleration environment of Mir during caisson periods, as well as during crew exercise periods, and also to measure what the little bumps are when shuttles and Soyuzs come to dock with the Mir. So, very important and it supports, I think, something like thirty-five or so--I'll have to verify that number--number of experiments on Mir during its course. And we are going to bring it home on [STS] 91, as our longest-lived item, and hopefully it'll take its place somewhere in a museum somewhere. It's unique hardware. Anyway, I digressed a little bit. I apologize.

Wright: Go right ahead.

Uri: But as we're going through, then we finally launched, and we had another Progress, I think, go up, just prior to Norm's flight in February, to preposition some of our life sciences hardware, the most critical items that Norm would need for his flight. I think that occurred in February. March 14th, Norm took his place inside the Soyuz with his crew commander and flight engineer. Had a perfect liftoff, and Norm was on his way to be the first American on Mir. Very exciting.

I happened to be in Russia at the time when the docking occurred two days later, and it was the biggest party I'd ever seen. No, it really was. It was a big international event. Everybody was just thrilled to have this program under way. The commander, typically, is the first one to cross into Mir, but he allowed Norm to be the first, as a sign of international friendship. From then on, Norm was under way and conducting his experiments on Mir.

We had another progress come up in April to deliver more supplies. Spektr finally showed up, I think, in May, which finally allowed Norm to essentially expand into his own, get some of that hardware done.

Then STS-71 was the first docking flight in late June of '95. It carried a space lab module in the cargo bay. We conducted more experiments after docking and hatch opening on the long-duration crew members within the space lab. After five dock days, there was a crew exchange as part of that. We were bringing up to Mir nineteen crew, the new cosmonauts to Mir, and we were returning Norm and his crewmates, were the Mir-18 crew, and we brought them back on STS-71, the first shuttle crew exchange that ever took place.

Then as far as flight operations, we kind of had a quiet spell for almost a year, as we were getting ready the next phase of the program. Then the next phase started with Shannon Lucid's flight in March of '96. Since then, we've had an astronaut on board ever since, continuously. I guess it's over two years now; twenty-four months. That will come to and end when Andy Thomas comes home, planned in mid-June right now.

As part of that program, we've conducted over 100 experiments in the various disciplines I talked about earlier. About seventy-five of those were actually done on Mir as part of the long-duration program. Additional ones were done on the shuttle.

Oh, and there's one team I did forget completely. I apologize. That's the space station risk mitigation team. One of the goals of the Phase One Program was to learn, on a space station, how to conduct science. We are still using it as a test bed for hardware and materials and things we plan to use for space stations, so we had a team called the risk mitigation group that were flying those kind of experiments to help us learn about space station, to make operation of space station easier and better, and just essentially learn our mistakes ahead of time. So that was a very productive group of experiments.

So that's where we are. It's been a very challenging program, very exciting program, one of the most difficult things I've ever had to do. Lots of trips to Russia. I think I'm up to about twenty. Some people have done more. There's a whole operations team that we've had in Russia. We have a consultants group resident at the Mission Control Center, commonly called TsUP, the Russian acronym for it, in Moscow. That's been staffed, essentially continuously, since Norm's flight, although when we had that caisson period on orbit, we were down to a skeleton crew, and as soon as we had a crewman go on board again, we fully staffed up. Although they don't staff twenty-four hours a day, they are available on call in Moscow twenty-four hours a day, when they're not in ESUP. And that's the team that supports the on-orbit activities.

Initially, our program concentrated mostly on just the science. Norm was essentially a cosmonaut researcher. He was there to do the science; we were there to support the science program. As the program progressed and our astronauts became more familiar with Mir systems, the Russians became more comfortable with having us aboard, not just as a researcher, but as a full flight engineer crew member.

Additional duties were taken on by both our astronauts and ESUP, in terms of Mir systems and operating Mir systems and us learning more about how the Mir systems operate--the environmental control system, the power, the thermal, everything else.

Some of the unfortunate events we had, such as the fire and the collision, made us become even more aware of how the Mir systems operate, and, of course, we became much more integrated into the Russian system on the ground, in terms of working these problems and other issues. The shuttles became very integral in maintaining the Mir, in terms of resupplying it with new hardware for hardware that had broken, resupplying water. We also tend to refill them with air during the docking phases.

So right now, the program is far more than just a research program. It's almost like the ISS is going to be. It's a very integrated, international, partner type of program. We know about their systems, they know about our shuttle systems, and that's the way it's going to be for the next twenty years as we fly ISS, so it's been an absolutely wonderful learning program from that standpoint as well.

As far as the science, what we've learned so far, as you can imagine, like any science program, the results don't happen overnight. The investigators have to get their data back and analyze the data tapes, or whatever data products they get back, analyze the blood samples of whatever we get from the crew members. Now all that takes time, compare it against other data they receive from other flights, or wait until we have enough subjects accumulated or enough samples processed that we can make some meaningful statements about the science.

Now that we've been at it for a couple, three years, we are getting some results come back in, and most of the investigators are just absolutely fascinated by what they're hearing. For many, it's the first time they've ever had a chance to perform experiments in a long-duration environment. Skylab was more than twenty years ago. Many of the PIs don't go back that far. I was in junior high when Skylab flew, so that puts it in perspective.

For many of the experiments, it was an extension of the work they'd done on space labs and shuttles before, but, again, as a stepping stone toward doing the long-duration science, they planned to do an ISS. Mir was just a perfect middle ground. We were able to test out hardware, make modifications as required for ISS, for the final hardware that goes up on ISS. It's a great learning experience from that standpoint, as well.

As I said, seventy-five experiments. Some of those are still in progress with Andy, so we don't have all the results back in. There's been some very fascinating things we've learned about biotechnology, about just the human body response to long-duration space flight, and there's so much more to learn in that arena. The Earth observations, the hand-held photography in particular, has just been fascinating. We've been tracking these events that happen on the ground. To put today's interview into perspective, we've had those fires in Mexico and Central America, with all the smoke actually coming across Texas, and Andy's been absorbing that real time, and taking, hopefully, lots of photographs for us, to be able to document that. We've also been tracking other fires over the last couple of years, such as the ones in Indonesia.

In some cases, the crew members were the first to report such incidents. We didn't even know about them on the ground. In relatively isolated areas of Mongolia, there were some fires two years ago that Shannon was the first to report those. We've captured volcanic eruptions. From a long-term tracking perspective, we're looking at tracking certain lakes and other areas in the world where the water level has been dropping due to irrigation use and pollution and so forth. Just absolutely fascinating data.

We've returned, so far, I think, over 20,000 photographs of the Earth, from Mir alone, giving us that vantage point of where we have a trained crew member that can track across seasons, and across years, even, the various events that are happening. El Nino was a big event the last year or so. We've had some very good tracking of both the dry and wet areas on the Earth, as a result of El Nino, and it's probably the best record we've ever had of an El Nino event. So that's been very, very fruitful.

I could go on and on. I don't know if you want me to, or you have specific questions you want to ask.

Wright: Before we get too much farther, tell us about the PIs. Since the program evolved from what you were originally told it was going to be, I imagine the PI pool did as well. Could you tell us how that happened, and give us some examples of some of the PIs and some of the things that they did?

Uri: Sure. Initially, when we were working just the first part of the program, when we only had the one long-duration flight, and we had very little time to get that program together, we relied on our investigators here at Johnson, who were into life sciences, to put that program together. So these were the in-house investigators we worked with for many years, and based on their experience on flying on the shuttle, they put together their program.

As the program expanded across the other disciplines and we had a little more time, we were able to actually go out and solicit outside investigators to submit proposals for experiments. We had probably hundreds of proposals that came in from the different disciplines, and the number may be higher, but I know it's at least in the hundreds. So those were, in many cases, investigators from universities across the country. In fact, many of them are international, from other countries, submit their proposals. Many of them we've worked with before on space lab flights.

So, again, there, too, they're relying on their shuttle and space lab experience, but wanted to see, "Okay, well, this is what happens over a fourteen-day period. What happens if I do that same experiment, but over four or six months? What kind of results will I see?" They wanted that comparative data. Many of these are well-renowned investigators in their own fields, the life sciences. Many of them are physicians, clinical researchers in cardiology and other areas. In the other sciences, they're also well-renowned researchers in their field, in combustion science, materials production, fluid physics and things like that. As I said, from multiple universities and also industries in the U.S.

We've had investigators from many other countries as well, not just from the U.S. Many Russian co-investigators and investigators on our science, and probably not an inclusive list, but let me rattle off some countries like Canada, Japan, United Kingdom, France, Germany, Hungary. Those are the ones that come to mind. A very, very international program. Again, that was also a challenge, incorporating their investigations from different countries. There was always a time difference, so that was a challenge. But it all worked out very well.

Wright: How were they selected? Was it your decision?

Uri: No, it was not. Just like it would normally be for a space lab mission, NASA puts out what they call a NASA Research Announcement which is an announcement that we're soliciting proposals for this particular program or this particular flight, and it's done differently in the different disciplines. In life sciences, they put out a specific one for Mir. In microgravity, they have more of a rolling admissions kind of thing, where they have quarterly announcements that go out into different disciplines, and investigators can submit proposals, and depending on what their proposal is, headquarters will then decide which platform it's more suitable for, whether it should be on shuttle, or on Mir, or on space station, or it should be a ground-based study or whatever. So those normal processes were used to select the investigators.

What happens is, the investigators submit their proposals to a point of contact at headquarters, and, of course, there's a cutoff date. All the proposals received by that date are then submitted to an external peer review process. So in other words, there's a group of scientists that get together in that particular field. They evaluate the proposals for scientific merit: "his is a good proposal. There's good science to be gained by doing this." They rate them accordingly and return those ratings back to NASA, who then essentially says, "Okay, anything above this rating, we can probably do this many experiments in this fiscal period."

Then we at the centers are given the task of evaluating those proposals for feasibility. It may be wonderful science, but it's impossible to do in space. Or, yes, it's great science, we can do it, and, yes, oh, we can do it. It's easy to do, we have the hardware, it's not that difficult to do in zero-G and so on. So that's the next phase, is we evaluate them for feasibility.

We also do kind of a technical, how much hardware will be required? Is the hardware available? Does it have to be built? Who provides the hardware? Things like that. And then we look at the proposal and essentially put it into a format where we can evaluate how to implement it in space. And then of course, at that point, headquarters makes a selection. "Okay, this is what we're going to go forward with. You will implement this set of experiments. Okay. Let's see, life sciences gives us seven, microgravity gives us six, or whatever the numbers are. Pull those together, and put that into a flight program."

Then we eventually generate a time line, a training plan, things like that. So it was fairly typical what you would do for a space lab mission. We used that same process for Mir as well.

Wright: I guess that was a little bit of a relief. You didn't have to recreate the wheel on that one.

Uri: Exactly. Exactly. It's not an easy process, and again, there, too, the template was very short. Normally, from when the NRA, the NASA Research Announcement, is released, the flight typically runs four years, five years. In the case of Neurolab we just flew last month, that NRA went out in July of '93, so it was almost five years for that process. For Mir, the NASA Research Announcement from life sciences went out in early '94. The first flight, at that point, was scheduled for December of '95. So we really had less than two years to get ready.

Wright: From the rate of responses, I take it the scientists were ready to do whatever they could.

Uri: They were ready to go. They were ready to go. There was a lot of interest in trying to do this. As I said, it's the first chance people have had to do research since Skylab, and it gave a lot of folks several years' lead time before they would do their experiments on ISS. So there was a lot of excitement and a lot of people were very much interested.

Of course, at that point, there was some trepidation amongst ourselves and also the investigators, of, "Can we really do this? We don't know much about Mir. What is it like? What's the environment like? How much crew time are we going to have to carry out the experiments?" We were still in a learning curve at that point, and we guessed pretty well, because we got almost all--in fact, of the seventy-five or so experiments on Mir that we had set out to do, there's only one that I can think of that we never got done. All the other ones were either fully completed--in some cases, more than fully completed--or at least partially completed.

Wright: Out of those seventy-five, are there a few that really are outstanding in your mind for any special reason?

Uri: Well, they're all, of course, world-class science, because they were selected to be that. There were some, of course, that were continuations, and it was just filling in another data point. In several cases, we scored what you would call a "first" which had never been done in space before, whether Mir or shuttle or anywhere else. One of those areas was the plant growth experiments. On John Blaha's flight, we had a very successful plant growth experiment, the most successful one we had had up to that point, in terms of actually being able to grow a very large crop. A wheat crop is what we were growing. There's a little greenhouse in the Krystall module in Mir that we used for this. Not very big. It would fit on your desktop, basically. But space is very limited up there.

In previous experiments, both on shuttle and Mir, we were only partially successful at being able to grow any kind of plants, and so we were a little anxious about how this would happen. We had made improvements to the hardware, based on previous experience, improved the lighting and the ventilation and so on. Actually, it was a crew before John, the cosmonauts from Mir-21, that planted the seeds. Within days, they sprouted, and all of a sudden, they were just growing like gangbusters, and everybody was very, very excited.

If you've seen the pictures, it's a very full growth within that chamber. Nobody had ever seen that before on Mir or anywhere else, and so that was a first in terms of growing that large of a crop, that large of a plant system. We thought we were extremely successful. The videos and John's comments during the flight seemed to indicate that we were growing seeds and so on, and seed pods, and we were, in fact, growing the seed pods, but sadly, or unfortunately, because of--I'll have to get into why--but all the plants were sterile. They didn't produce any seeds, and so that was a disappointment after landing, when we got the plants back and the investigators were looking at them. They thought about it for a while, scratched their heads and put some other minds together on it, and finally realized that, well, there may be something else going on that's got nothing to do with space flight that may be causing this.

As it turns out, there's a gas called ethylene, which is present in minute amounts everywhere. It can be a plant hormone. It can be produced by fungi, it can be produced by off-gassing of different metals or materials. It turns out there are small quantities of that present aboard Mir. We're not sure what the source is, but incidentally, we had taken some atmospheric samples. We went back and looked at those and, sure enough, there was ethylene present in the atmospheres. Not harmful to people at all, but because it is a plant hormone, it can disrupt their growth.

The investigators went back to look at the samples, and they looked at the videos and said, "Well, you know, the plants really grew more than we expected." Well, if you have lots of ethylene in the air, that's what you see. The plants didn't grow seeds. Well, if you have ethylene in the system, that's what you see. So it's very likely that this little quirk bit us, and so if we have a way to scrub out the ethylene, we probably would have had an even more successful experiment.

But then, two flights later, on Mike [C. Michael] Foale's mission, we did another plant experiment with a different plant. The goal of this one was to plant seeds on orbit, let the plants grow and develop seeds, and take those seeds and plant them again in space. And if we were really lucky, we'd do that one more time during the mission.

Well, we were well under way to growing the plants, and then--boom--we had the collision. So we thought, "Well, how is this going to affect?" The power levels were dropping, we had temperature control problems, and all that resulting from the collision. But we as a program made the decision that, because this is a living experiment, that we'd keep it going, perhaps at the expense of others, if we had to, but we made that call.

As it turns out, even despite all the problems we had after the collision, the plants grew, they developed seeds, and we planted them, and they grew. And we did it again, so we got three plant cycles. That's never, ever been done in space before. So that was a big first.

Very optimistic that, looking down the road, we'll be able to do this on a larger scale, for several reasons. One, we can grow plants, whether on a space station or a trip to Mars, potentially, depending on the plant you grow, as a food source for the crew members. Two, plants generate oxygen, so you can include plants as part of your environmental control system. And three, the crew members we talked to that performed these experiments were gratified to have some living thing that they could tend aboard the spaceship. So psychologically, it was kind of a boost. It's more fun than pushing buttons or things like that, so the crew members really enjoy it. The plant growth experiments were very good firsts, if you will, from the program. When we started out, we had no guarantee that any of that would be successful, based on previous experience. In fact, some people were somewhat pessimistic, but I think we overcame the naysayers and showed that we can do this.

Wright: Great. Were there other firsts, other than that?

Uri: There were some other firsts. I don't know how much time we have, but we could go on. But one other one I would like to mention is the area of biotechnology, particularly the tissue culturing that we've done. We had had one experience in orbit.

Let me back up and talk a little bit about what the system is. We've done a lot of ground-based studies in growing tissue cultures, which is very difficult to do, just in flat plates, because, because of the force of gravity, when you try to culture the cells to form a tissue, rather than forming a three-dimensional structure, like they would in your body, in a petri or a test tube, they tend to form a flat surface, because gravity just pulls them apart, and does not allow them to form that structure.

The folks here at JSC developed a system, and, incidentally, David Wolf was one of the developers of that system, called a rotating bio-reactor. It's a drum, maybe about that big, six inches across or eight inches across, that rotates, and within it you suspend the cells in the media, and that rotation essentially almost mimics gravity, microgravity, or tries to minimize the effects of gravity that, if you suspend the cells, they won't be flattened out. You can grow more natural tissues. And you can on the ground, but you're still limited. There is still gravity; you haven't gotten rid of it. You've just tried to minimize its effects.

So the next step is to take that system and put it into space. You still need to suspend the cells, because you have to mix the tissues within the media, so it keeps getting fresh nutrients. But since you're in space, you've completely eliminated the force of gravity. We did that one time on a shuttle flight, a ten-day shuttle flight, and, of course, most tissues don't grow that fast, so you can't get very far with the experiment. So we thought this would be a great thing to do in space. We had plans to do that on ISS all along, and, of course, Mir came along, and this was a perfect opportunity to get ahead once again.

So we put the system on Priroda, and on John Blaha's flight we did our first experiment and we were growing cartilage cells, beef cartilage cells. We started with that. It's a very hearty cell. It's very hard to mess it up. It's very sturdy. It's slow-growing, so you can take your time with it. We started growing it, and despite the--we had some hardware problems with the instrumentation. We also had some bubbles that kept getting into the system. In microgravity, bubbles and fluids just don't get along.

We overcame those, and we were able to grow some very, very nice three-dimensional tissue cultures, which has never been done before. Compared to the ones that were grown in the ground unit simultaneously--we ran the experiments at the same time--the ones in the ground, as usual, kind of flattened and disc-shaped. The ones that came back from space were nice and full and spherical.

Now, there were other differences. We don't fully understand what they are, but because they're cartilage cells, they're used to taking loads. Like your knee, when you're walking, every step you take, the cartilage takes that load force from your bones. Even on the ground, in the tissue culture, there's that force of gravity, and the cells respond to that by building this matrix around them to strengthen them. Well, in space, you don't have that, so that matrix wasn't as strong in the space-grown cells, so there were differences that we hadn't really anticipated.

But again, looking downstream twenty-five, thirty years or whatever, you can grow tissues in space, in large quantities, which you cannot do on the ground. In a lot of cases, for instance, in cartilage, one of the applications might be cosmetic or orthopedic surgery, that you grow these tissues, then you can transplant them on the ground. Other cells that you might want to grow, for study in particular, like cancer cells, you can't really grow them in a test tube on the ground. You can almost have a farm growing these cells in space, bring them home and study how those cells grew in space. Kind of a manufacturing facility, if you will.

That's what we're doing on Andy's flight right now. We're flying some human breast cancer cells, and endothelial, or blood vessel cells, in the same system. What we're hoping is happening right now is that those cells are coming together like they would in the body. When a tumor grows, it either tracks or in some way encourages the growth of blood vessels to keep it supplied with nutrients. We're hoping that in this experiment, which has not been done in space before, that these two tissue types are coming together and forming this one functional tissue, if you will. As a first step in being able to study how we can do that for future studies of growing these tissues, bringing them home, studying their structure, their DNA, their other molecular structures within the cells.

Again, on this mission, we had some challenges with the hardware not working exactly as we had anticipated, and despite those problems, those bubbles came back again. We thought we had it fixed, but they're still there. Despite those problems, it looks like the cells are growing very well. We won't know till after the flight whether we've actually got that functional tissue, but we're very hopeful.

Wright: You were talking earlier about "expect the unexpected." I guess with the collision, and with Mike Foale being up there, you had to regroup.

Uri: We did, indeed.

Wright: Would you like to tell us some of the challenges you had in putting everything back together again?

Uri: Well, it's funny. I was thinking back to the press conference that we had here on Monday, and one of the reporters asked Frank Culbertson what were his low points and high points in the program. I was not asked the question, but mentally I was going through what my answer would have been. My answer would have been, the low point is that it's coming to an end, because it's been a lot of fun. It's been tough, it's been challenging, I grew a lot of gray hairs, but it's been a fun program.

The high point, I think, was right after the collision, where everybody came together, on our side, on the Russian side, worked together to overcome that very serious problem. From a science perspective, we were practically dead in the water right after the collision. We had no power, we had lost the module where our life sciences hardware was. Some of our samples are still there in that freezer that was stuck in Spektr. We'll probably never get those back. And all of a sudden, we said, "Well, this is Mike's flight. We've got two more after him. If we continue the program, we'd better figure how to work around him. How are we going to get through and finish the program as successfully as we want?"

So we all got together on our side and with the Russians. There was a progress already scheduled to launch ten days after the Spektr collision occurred, and usually, if you want to fly hardware on there, it's a week's, if not longer, process to get it there and get it launched and so on.

The Russians were very accommodating. Within ten days, we had hardware on that Progress heading to Mir, that we had not anticipated ever putting on that Progress, primarily to help Mike out. He had lost some personal belongings and things like that, personal hygiene items. And we had those on the Progress within ten days. We had the collision, we called back here, we said, "What do you want?" They said, "This is what we want." They shipped it to Russia, the Russians shipped it to Baikonur, put it on the Progress, it was on its way to Mir. Unprecedented, as far as I can tell.

Of course, we had the longer-range problem of, well, do we replace the hardware we lost in Spektr? If so, how much of it? Again, there, the Russians were very accommodating. They made room on several progresses for us to launch replacement hardware. We had lost a centrifuge. That went up on a Progress. We replaced it. On the shuttle side, they were accommodating. We were able to get hardware on 86 and 89 shuttles, to get replacement hardware up there. Our freezer, in particular, we needed that one. Not to minimize; we did lose some science, because of the collision, obviously. Some of the experiments we could not continue during Mike's flight, or they were reduced in scope. We had to replan some of Dave Wolf's flight because the hardware simply wasn't there yet, the replacement hardware. And some of it we're still feeling even now, but we're probably back to about 95 percent, if not more, capability, even with Spektr still being closed off. It was a long summer.

Wright: I bet.

Uri: Summer of '97 was a long summer.

Wright: A triumph over the unexpected though, wasn't it?

Uri: But we got through it. I think the lesson there is, just like after the fire the previous February, that these things will happen. They may not be as dramatic as a fire or as a collision. Things always happen, and you can't predict them, and you have to be ready to respond to it. We're ready. We've passed the lessons on to the ISS folks. Many of us are actually working over to work station programs in one capacity or another, so hopefully that experience will be transferred over. Hopefully, we won't have anything as serious or as dramatic, or things will be even smoother, but you never know. You have to be prepared for it, and I think we know how to respond in those kind of cases.

Wright: The proof is there. Did you have problems after the fire as well, with the science area?

Uri: Only that the crew were so busy dealing with the fire and its aftermath, that we had to reschedule a lot of activities. So, again there, too, it was on that mission that we had one experiment not get done, but that was mainly for scheduling reasons.

There was an EVA scheduled for fairly late in the flight, and for one reason or another, it kept getting delayed, and we had time-lined that one experiment to occur after the EVA, and it just kept getting pushed out to the right, and then we just ran out of mission. We kept it on board, hoping to get it done during the next flight. Of course, we had the collision, so that regrouped all of our thoughts again. Finally, we just said, "Hey, we tried, and it just couldn't happen."

Wright: Tell us about how the EVA in science worked. You mentioned that a little bit in the press conference the other day.

Uri: Yes, we did have some experiments that were actually tied to EVAs, because they're mounted externally to the vehicle. We had the first two that went out exterior. Actually, the Mir-21 cosmonauts took it out for us. Those were the two cosmic-dust collectors from the space science division at headquarters. They were outside for almost a year, essentially collecting particles. Well, I say "cosmic dust." That's too generic. One was primarily looking at those kind of cosmic dust kind of particles, or interplanetary dust, that does come near the Earth. The other one was more looking at any kind of particles that may be in the low Earth orbit that may potentially be harmful to vehicles that are in that orbit.

So they were outside for, I guess, almost a year. We brought them back, and we had some unexpected results from that, in that the number of small particles was actually higher than we anticipated. These are like dust-grain sizes, so you don't see them, you can't track them with radar, but they're there. Some of these particles swarm in clouds, for instance, particularly if they come from a spent rocket stage. We knew the rocket stage was there. We had no idea the cloud of particles was following that rocket stage. That's one example.

We also had some radiation equipment, and we wanted to mount a radiation decimeter on the outside of Mir and have one on the inside, to determine what the shielding is by the vehicle. I think Jerry and Mike--Jerry took it out and Mike brought it back in. We also had some from the risk-mitigation folks that were looking at essentially putting a variety of samples outside, to look at what the impact of being outside, because of solar and temperature variations, the atomic oxygen that's in that orbit and things like that. So Jerry put that one out, and the Mir-24 cosmonauts brought it back in. It was out for almost a year.

Then we also had some that were taken out by shuttle astronauts during the 76 dock phase and brought in during the 86 dock phase. Those were also mostly orbital debris kind of measurement devices, and also materials exposure kind of devices. So we got a lot of science, and because they had to be mounted externally, EVA was the only way you're going to get there and back.

Wright: The program evolved from where it started. How did your relationships internationally evolve? Did you see a growth between trust and relationships and working environments between the Russians and the Americans?

Uri: Absolutely. Maybe to clarify a comment I made early on, our relationship that goes back to the 1970s was really among our scientists here and scientists in Russia, most of whom work for the Institute of Biomedical Problems. When we started this joint program, we, of course, realized that they were not the only organization in Russia that did the space program. But we were not familiar with the overall structure of what the different organizations were. Some of us had heard about a company called Energia, and they're the ones that actually built the Mir and operate the Mir, but we didn't have many contacts there at all. As we started the program, we then became aware of what they actually did, who the people were, and those were the people we started interfacing with, in addition to the scientists we had worked with before. So we had to develop brand-new relationships. Of course, you know, when you only meet for a week or two at a time, every three or four months, it's kind of difficult to do that, in any environment.

But over the years, yes, indeed, we developed very strong relationships. I feel comfortable with several people in Russia that I can call at home any time of day or night if a problem occurs. And likewise, if they needed to, they could contact me at home. So we've exchanged home phone numbers and we've gone to each other's houses on visits and so on, so that relationship has improved, both professionally as well as personally.

As far as other international partners, one of the things we wanted to do as we started working with the Russians is talk to other international partners, like the French and the Europeans and the Germans, who have independently worked with the Russians, so, kind of, "Well, okay, we're doing this but somebody else has done a similar thing. How did they do it? Can we learn something from them?" In that regard, we got closer with them as well.

All of this, of course, is good for the ISS, where all of us will be working together. In fact, there was at least one trip when I was at ISA, I ran into some of my Russian colleagues there, and, of course, we had a little party and all that ensued. We ended up meeting each other in various places. The amount of back and forth traffic between U.S. and Russia is nothing like it was when the program started. I mean, it's probably at least tenfold greater now, if not more.

Wright: Do you find a comfortable exchange of information between the scientists?

Uri: Yes. Not to say that there aren't instances when the sharing of information is not complete. I think partly because of the language barrier, there may still be some misunderstandings of well: we asked for this, but they thought we asked for something else. And so we get the wrong information back or not as complete as we would like. Then you kind of just go back and forth until you get the information sorted out.

I think partly because of just the years and years of Soviet-style management over there, there may still be some level of hesitancy to share some data. There's still a big infrastructure about secrecy over there. A lot of documents are still considered classified when we consider that, well, that's, you know, it's common knowledge here. So sometimes you have to overcome that as well, and the Russians understand it, and they tell us, "Look, you know, we'd love to give this to you, but I have to work it through this level of management before it's approved that I can give it to you." So that delays exchange of information sometimes.

But in the end, I think we've gotten what we've asked for. In particular, when we've had the significant events on Mir, it's like the doors fly open, and we go to their meetings and sit in meetings that a few years ago we would have been completely off limits. We have visited facilities that a few years before we didn't even know existed. The CIA might have known about them, but we didn't. Even within the Russian society, they're considered very closed. And we have seen things that a few years ago we would have never been able to see. So they've really opened up.

Wright: I'm sure they'll continue on that as well.

Uri: Well, if we're going to continue working as international partners, that's part of the process. Share and share alike.

Wright: We talked about experiments that were a first and that were memorable. Do you have an overall increment? Was there a long duration that proved to be more successful or is outstanding in your mind?

Uri: No, I think in each, in their own way, each increment had their highlights. We've learned a lot from each one. The first kind of faltering steps as we're still feeling our way through the system, then we got more mature, and then we had the challenges of the collisions and then, of course, the learning was in a different arena, not so much in the scientific so much as, well, how do you do the science? How do you recover from something like this to keep your science going?

Then we recovered, and we had Dave and Andy, essentially, compared to other missions, essentially trouble-free, relatively, and just going through the steps and getting it done, which is hopefully what station will be like. But it's been very successful overall. As I said, we've had seventy-five or so investigations. We're just now at the point where publications are coming out from some of the earlier science. That's a process that I think a lot of people underestimate how long it takes to get through that process. Just to walk through it briefly, the investigator gets the results back, and somebody comes back during the flight, but the real stuff comes back with the samples and the real data tapes and everything else after the mission. They don't get it right when the shuttle ends; there's still some delay period. Some of the stuff comes out that day, some of it not for a few weeks, and then it has to be sent to the investigator. This is not the only thing they're doing, so there may be other activities they're working on. They're college professors; they have teaching responsibilities, things like that. So it may not be the first thing they get to, although typically it is, because it's very unique and very exciting, and they want to get the data analyzed as fast as possible.

But then they have to go through the analysis process, and in some cases that's rapid and in other cases it takes a long time. It runs through several tiers sometimes. They go through the first analysis and they say, "Well, preliminarily, this is what we can say, but we need to do more." In some cases, they want to do additional ground-based studies. For instance, I was talking about the plant growth and how we found out about the ethylene. We didn't know that right away when we got the samples back. The investigators suspected it might be ethylene, so they wanted to run some ground tests. They grew some plants in a chamber, where they introduced ethylene at known concentrations, and then the plants grew exactly like the plants on Mir. So they said, "Aha! I think we've got something." But that took more weeks.

So, anyway, by the time they're ready to write up a manuscript and submit it for publication, it's been anywhere from months to maybe a year after the flight ended, and then you submit your manuscript to a particular journal of your interest, and that can take another several weeks or months. That goes through a review process. They may come back and say, "This is good, but please change this," or, "Add this." So it goes through an iteration or two. Then it's accepted for publication and then it's finally published. That's another several more weeks or months. So it could be two or three years in some cases, between when the flight ended and when the publication hits the streets.

Some of the experiments, like the life sciences one in particular, the investigators won't publish anything until all of the subjects have been completed, all the post-flight data collection is complete, and then they can look at all subjects from the whole program, as a whole; otherwise it's not really meaningful to publish bits and pieces of that. So it may be years.

Having said that, it's gratifying that there's at least fifteen publications that I know of that have already gone out and have been published, and I know of probably twenty more that are in various stages of preparation. Some have been submitted; they're waiting for that review process. Some have been accepted but not yet published. So I think within the next year or two, we'll probably see dozens more come out as the investigators finish up their analysis and their writing and reviews and all that.

So what the final number will be, I can't say, but maybe fifty, maybe more. Probably at least one from each investigation. In some cases, I know the greenhouse one in particular, they're looking at many publications resulting from that one experiment, because they're looking at different aspects of the plant growth, the respiration of the plants and all that. So I keep asking people to be patient. Science doesn't happen overnight; it takes time. It will happen. I know it, and I will see it in the next year or two.

What impact that'll have on other investigators? I do know that even before they publish, investigators do go out and go to scientific meetings and present preliminary results, so other investigators are aware of it. In many cases, these are investigators that are planning similar science on space station, or they're investigators that are looking at very different kinds of things, things that are happening here on Earth. That space experiment may have applications here on the ground.

For instance, one of the things we're looking at in three different experiments we've flown, there's a group of substances called colloids, which are basically solids that are suspended in a liquid. There are very common examples such as paint or milk or some cosmetics that fall into that category. There are other categories like liquid crystals that are essentially colloids and there are a lot of applications from what we've done in space to what everyday people use all the time here on the ground to make some of those industrial products better.

In space, you can do some of those things that you cannot do on the ground, because gravity just interferes with the process of crystallization. There's sedimentation between different components that in space you don't have to worry about. Again, that takes time. What we've done on Mir in a lot of cases is just these pioneering steps to look at what's open, what can we do later on? When we have a larger facility, we can do multiple experiments.

So Mir, Phase One, was really, in many cases, a testing ground, kind of knocking on the door saying, "What's back there?" We've also tried some furnaces on Mir to make alloys of metals that we can't really do very well on the ground, or if we can make them, they're full of impurities. And so if you try to produce something out of that alloy, because of the impurities, it's not as strong as it could be. It breaks, it doesn't last as long.

One, in particular, is looking at the metal, the types of metals that you're looking at in the process, we use here on the ground in industrial processes to make the actual dyes that make other things, but on the ground, to make those dyes very strong is hard to do, because there are these impurities which, hopefully, when you make those metals in space, you won't have those impurities. The dyes are stronger, they can last longer, ultimately save money, because you don't have to replace them as frequently. We have that application.

The other one that's sometimes overlooked is, we have our astronauts looking down on the ground and catching things. As I said, the volcanic eruptions and the fires that, when we're sitting here or even from an airplane, you don't get that global view. You know that there's this smoke heading your way, or a volcanic eruption, you can kind of see where it's headed. You can evacuate people much more easily. Yes, we have weather satellites, but they don't do the same thing that we can do from Mir or from ISS, with crew members looking down on the ground. They're designed for different purposes, looking at weather systems. I'm talking about other events that can happen.

Also, in terms of long-term climatic changes, we can monitor that from Mir or from ISS. Looking at the land use, for instance, around cities. You compare a photograph of Houston taken from space in the seventies versus today, you can tell there's lots of differences. And other cities as well, that perhaps lakes that are around those cities are now smaller because they're irrigating and you have to worry about that. Climatic changes caused by El Nino effects, whether locally or globally, those need to be monitored.

So, those are the very real impacts to people on the ground on a daily basis, and the important thing to make sure is that that information gets out there, that we don't just keep it within NASA. So we encourage all of our investigators to participate in scientific meetings and exchanges, to talk to other investigators in their field, who may not be doing space research, but the data or results generated from the space experiments can then be transferred to scientists on the ground. In particular, we're making good use of the Internet, particularly the Earth observation photographs. Those are put on the Internet, and anyone can have access to them. So we're trying to get the message out.

Wright: Sounds good. They rely so much on the crew members to conduct these experiments. Explain to us what you do, or what the program does for the crew members to get them ready to be scientists in space.

Uri: That's a good question, and it's probably a long answer, because when we started the program, we thought we knew how to do that, based on our shuttle and space lab experience. How do you train a crew member to get ready to do your experiment? But we were training them for a ten- or fourteen-day mission. We had two years of training so we could train every little bit of it, and their last training would be right before flight, or when they actually do the experiment.

However, in a long-duration flight, your training templates are somewhat different. Also, we were training them mostly in Russia, on Russian systems. They would come back here to do some science training here in the U.S., but in many cases, that would be weeks, usually months, before they actually do the activity on orbit, so how do you make sure that they still retain what they trained in January when they're doing the activity in August, for instance? So that was a challenge.

We realized we had the cultural differences between us and the Russians, but we also had a cultural difference in how do you do short-duration versus long-duration space flight? And that dawned on us that there are significant differences. You don't train the crew members the same way. For shuttle or space lab one, we had a dedicated payload crew of usually four, three or four astronauts, who did nothing but, or essentially, just the science. On Mir, we started that way, but then it involved that our astronauts also got involved in Mir, so they had that additional training involved. And then we had the training--well, you know, we only have this amount of hours and it's so far removed from their actual experiment. How do we ensure that they do it? You can't train them for every single thing that they're going to do in a particular day, so you do more broad-based kind of training, more generic-skills-based, as opposed to specific tasks. That was quite a learning experience.

Again, that's something we've transferred over to the station guys that says, "Okay, you guys, I hope you're aware of this, and hope you're training your crew members for this as opposed to how we've been doing it for shuttle and for space lab missions." So far, all the crew members have done very well. They've gone through the training program with a lot of interest, a lot of enthusiasm. They want to know as much as possible.

We've also developed some systems whereby they can get refresher training on orbit. We have a system called COSS, the Crew on Orbit Support System. It's basically an IBM laptop computer with an optical drive, and what we do is put training lessons on the optical disks. In a lot of cases, we videotape their last training session, where they've asked the questions, and the hardware's there, they're actually operating them. We videotape it, transfer that to the optical disk, put it on the system, so when they're on orbit and they haven't seen this hardware for three months or haven't trained on it, they can review the procedures all they want, but they can plug this CD in, and they watch themselves operate the experiment. So that's a perfect refresher. That's something I think that's proved very useful. In fact, we time-line these activities now, that, "Okay, on Tuesday you're going to do the experiment, but on Monday, we want you to watch the video so by the time you get to the experiment, you know what you're doing."

Wright: Is it psychologically comforting for them to know that they've already done it once and they see themselves doing it?

Uri: Oh, yes. Very much it helps them. They feel comfortable. Sometimes even seeing the hardware brings a lot of that back, but when they have the procedures and they're reading that and they're watching what they've done, it just all comes back. And that's proved very useful. But that was a learning--we didn't come up with that automatically up front. That's something we had to learn through the process. In many cases, it's not as simple as, "Okay, you push button A, then push button B, and you flip this thing." They have to understand the science behind it, because sometimes something happens that's unexpected, and it's maybe not in the procedure in the cookbook, and they have to think about how to respond.

On Mir, in particular, we had relatively limited communication between the ground and the crew member, and so they have to respond real time to something that might have happened, and that can only be done if you understand what the experiment is, what the purpose is. So we try to instill that in the crew members as well that, "Okay, you're not just flipping switches, you're doing it because this is what's happening, and this is what we want to get out of the experiment." That's been very productive and useful as well, very successful.

Wright: How do the crew members like doing the science? Is that something they enjoy doing? You mentioned earlier, it gave them something to do while they were there.

Uri: Exactly. And that's a very important factor psychologically. Most of them have been the mission scientist or mission specialist class of astronauts, except for Blaha, who was actually a commander astronaut. All of them picked up very well on the science. They understood the rationale behind it, the objectives. They enjoyed doing it.

As I said earlier, the ones that did the ones where we had living things growing, whether it be plants or the tissue cultures, took a particular interest in those, because it's not just pushing buttons. You're actually doing something, you're seeing the results real time. You're growing something, your tissues are growing, your plants are growing, they're germinating, they're forming flowers. So you've done that. You feel comfortable. You feel very proud of yourself that you've accomplished that in a very difficult environment. So they've enjoyed those.

Typically, what we've heard from the crew members is, "Don't give us things where all we have to do is push buttons. You can train a monkey to do that. We want something where we have to think about what we're doing." So we've tried to design experiments like that. Of course, some of them are just so simple that that's really all you need to do, and you do that. You have to balance that in their program with things that keep them interested, keep them occupied, keep their minds challenged. I think we've managed to do that on every flight so far. Again, a good lesson to learn for people designing the science program for ISS.

Wright: Were you involved in creating the daily checklist and the time-lines that they use doing the experiments?

Uri: In some cases, yes, but mostly a lot of that gets done up front. We're involved in generating the time-line we produce before the mission: "From launch to landing we want to accomplish this amount of science." We know very well when we develop that time-line, things are going to change, things are going to move around. Something you planned to do on flight day forty-seven, you'll probably do on fifty-two, because something else happened. But you keep that big picture in mind as you're going through the mission, to make sure things don't fall off at the end. Like I said, it did happen that one time.

As far as the dailies, we do have that team in TsUP, that has a daily interaction with the Russian time-line group. To generate the daily time-lines, there's a form that goes up to the crew each day that says, "Okay, tomorrow, here's your list of activities." Kind of a daily time-line. Depending on how the commander wants to do that, it's done by time, but some of the activities are not time-critical. We'll just say, "Just get it done tomorrow. We don't care if it's morning, afternoon, evening." Other things are very specifically timed. "You must do this right after you wake up, right after exercise." So those have to be done at that particular time. It's typically up to the commander who decides how he wants to run his mission. We do have interaction in that back here, and on some missions I've been more closely involved than others in actually saying, "Okay, well, we had wanted to do this tomorrow, but we know next week something else is coming up, so let's move it there," or something like that, so it's almost a daily kind of give and take, but always keeping that big picture in mind, that we make sure we get everything done, so we don't slip too much further out into the mission.

It's not an easy thing. It gets very complicated. You're weighing different science priorities. You have multiple experiments going on simultaneously. What is important to get done today versus, "Well, okay, we can slip this to next week," or, "We were going to do that next week, but let's do it today instead."

Of course, there are realities of limited communication with the crew member and telling him, "Okay, we changed our mind. I know it's on the form, but could you please do it tomorrow instead?" He may have already done it. So that happens once in a while. Usually it's not bad, it's just then, "Okay, well, then we regroup again." So, as I said, it's "expect the unexpected" almost on a daily basis.

Wright: You must have had a great group of people working with you, to get all this done.

Uri: I have. I had a great group supporting me over at Lockheed-Martin, in the Mission Science Office. The operations engineers also, mostly from Lockheed, were just excellent, very dedicated. Many of them spent a long time in Moscow, usually on a six-week rotation basis. Our operations lead would be there for the whole mission, so four to six months, in Moscow. And some have families. Some took their families with them, some didn't, so there are challenges there as well, on a personal level. Just the daily--it's long hours over there. It's not easy. Of course, if they're there in the wintertime, they have to deal with the climate.

Wright: Long, cold hours.

Uri: Yes. Long, cold hours. Lot of dark hours outside. So it's been a challenge all around.

Wright: And for you, all that you had to coordinate and implement and develop. You must have caught yourself coming and going a couple of times.

Uri: There were some days, yes. I wasn't sure if I ever got any sleep on some days. So, yes, it was very challenging. As I said, the early part of the program, when we were trying to put the program together and we really didn't know what our resource envelopes were going to be, "Now, how much can we do? How much should we ask that we can do?" Kind of working in the dark a little bit, and that sort of gradually progressed to putting a real mission together. As we were doing some of the missions, we had the fire and the accident that caused us to regroup. There are very, very few slow days.

Wright: As the program comes to a close the next couple of weeks, I know your job's not going to be over. It's going to continue, but it'll take a different pace. As you look over the whole program, from what you've told us for the last hour or so, I have to assume that it far exceeded the expectations that you had hoped.

Uri: Yes, it did. Well, number one, one thing I didn't mention is, somewhere along the way, we had only started with five missions and then they added two more long-duration flights. This happened probably in late '95. In fact, it was about two weeks after the birth of my daughter, so there was that to juggle as well.

Wright: You worked that in? That was good.

Uri: Somehow, you know. It was one of those welcome-home ceremonies from Russia or something. Anyway, so we had that to deal with. Of course, then we had to develop a program for two missions. As we were getting ready to fly, really, our first one in this program, we were already adding more to the tail end of things.

So, yes, it was very challenging, and I think it did exceed all my expectations, in particular because of the things that happened that we didn't anticipate. That really pushed us, it challenged us. It made us look at the program in a different way and look at how ISS may happen in a different way, made us think that there may be more to this. Like I said before, other things will happen, and we have to be ready for that.

From a science perspective, I think we did very, very well. Early in the program, before we started flying, there were people that didn't think Mir was a good enough environment to do some of the science. Turns out that was not the case. It's a very stable environment for doing the microgravity type of experiments that require the minimal bumping and vibrations and so on. Turns out the results we got were excellent. So I'm not sure what people based that early belief on, but that proved to be not the case. We did more experiments overall in the whole program than we had anticipated, partly because of the extension. I think the results that are coming in now are very, very exciting, and there's, I think, a lot more to come.

Wright: So the benefits will be long-lasting?

Uri: They'll be long-lasting and a lot of this will be wrapped into the ISS research, to make it better, so I think the return from ISS will be better because of having done Phase One. We won't waste a lot of time on ISS doing things that we know are maybe not the right way to do it or not suitable for doing things on a space station platform. We can redirect that to other channels. All in all, I think, just having had the experience will make developing station a lot better, a lot easier, and save money, I think.

Wright: How about yourself? Something you learned about yourself or about your stamina, if nothing else?

Uri: Well, I certainly learned that.

Wright: Or as a scientist?

Uri: Well, I certainly learned about my stamina and my patience. I mean, I was amazed at what we had to endure in some cases. Maybe in an earlier time, I would have just said, "Look, you know, King's X. I'm outta here. I've had enough. This is too much." And after a while, you just said, "Okay, well there's another thing we have to deal with, and we're just going to do it," and we did it.

From a scientific perspective, most of my background was in life sciences, and then all of a sudden, as this job came along and this program expanded, I had to learn all about microgravity, all about some of the biological things, about the earth sciences and learn what all that science means and why we're doing it, and some of the physics that I had to understand, which I never did in college, but I finally got forced into me. So that certainly broadened my horizons about, gee, there's a lot more we can do here in space than just looking at what happens to crew members that I was not aware of before. That certainly expanded my horizons. So I have a better understanding of what we're trying to do on station as well.

Wright: And you'll be moving toward that? Is that what you mentioned earlier?

Uri: Yes, I'm going to be focusing on the life sciences experiments back again, so this was kind of a blip on my career, if you will. It was kind of an oddity, if you will. But because of that, now I know how to do this, but I also understand why other people are doing other science, and why that's just as important. It's not, "Oh, that's all that other stuff." It's like, "Okay, I've been there. I know why we're doing this, too." So it puts everything into better perspective.

Wright: And that it all kind of melds together at some point.

Uri: It all melds together. We can learn from them, they can learn from us. It may be a totally unrelated experiment, and yet because of the way they did it, I can learn something from that and how to do this science better. We've had a couple of symposiums where we get the investigators together and report on their findings, and we typically do it, okay, here's the biomedical investigators that give their talks and then the other group gives their talks. Initially, only those interested in life sciences showed up for their session and then vice versa. Then people realized, "Well, you know we just sit through this just for grins," and then they're the ones that start asking questions. So there's a cross-feed of knowledge and expertise and experience that goes outside that single discipline, and that was really gratifying. So everybody can learn from everybody else. Nobody's isolated in their field.

Wright: When we've talked to other people, so much emphasis is on what we've learned from the Russians or what the Russians have learned from us, but I guess in your case we've learned from each other, within our own discipline.

Uri: We did, indeed, and I know we've learned a lot from the Russians. They've been doing this long-duration stuff for twenty-five years, and for us to think they don't know how to do it is ludicrous. So we did open our eyes and ears and we learned from them and we're still learning from them, as well as from ourselves as to how we take our knowledge that we learn from them and apply it toward station.

Station won't be identical, but there's a lot of similarities between Mir and what we're going to do on station, that a lot of that is applicable, I think. But we have learned a lot from ourselves, about ourselves. I've met a lot of wonderful people in this program that I wouldn't have had a chance to meet otherwise, from other centers. It gave me a chance to visit other centers I probably wouldn't have gone to otherwise and just learn about what it is that they do. I've learned more about the Agency, how it operates. It's been a great learning experience.

Wright: Someone might want to tap into your brain about that part, as well.

Uri: It may be a scary part. [Laughter]

Wright: Mark, do you have some questions?

Davison: You just mentioned that you got to meet people in other [NASA] centers. Can you talk about some of the experiments that other centers brought? Say, Marshall or Ames, or somebody else?

Uri: Marshall brought mostly the microgravity experiments. They provided one large facility, which was the glove box, where we performed a lot of experiments. Some of the things I talked about, I didn't tell you where we did it, but a lot of them were done in that glove box facility. It's in a closed facility. You can conduct even controlled combustion experiments and so on, and that's proven to be one of the hallmarks of this program.

I should have said not just the agency, but also other international partners. We've had a chance to meet with them and visit their facilities in France and Canada and other places. So it's broadened that horizon as well.

The Ames people were the ones that brought the greenhouse experiments, the plant-growth experiments. They also did some of the radiation work, and we also did an experiment in embryology, where we grew some quail eggs, to see how they developed in space. Also very, very successful. The most successful were done like that on Mir. The Russians have tried that before, and in this program, we just had a lot of success, learned a lot about that.

Of course, Lewis [Research Center] was also involved. They provided some of the experiments for microgravity. So it went Lewis, Marshall, and then they provided it to the program. And then other non-NASA centers provided experiments, such as some of the industries. Commercial ones, in particular. Commercial development centers that provided experiments in hardware. I knew very little about that before I started this program.

Davison: Another follow-on to the Ames research you talked about. Was there any animal research, similar to what we do on the shuttle, that we tried to do long term on the Mir? Similar, I guess, like trying to get a centrifuge on station. Was there any type of work that would develop into that?

Uri: No, the only two animal experiments that we did was, one was this quail egg. I'm going to call it "incubator" for short, because we used an incubator system on board the Mir, and that was only about a seventeen-day experiment because that's the time of gestation for the quail eggs. We didn't actually hatch them on orbit. We didn't want birds flying around. We were just really strictly looking at how does the embryo genesis within an egg develop over that course of seventeen days. Again, since seventeen days is about the maximum for a shuttle flight, that would have been very difficult to carry out on shuttle. We wanted to have that pad on either side that we could do the experiment fully.

We also had one experiment that actually utilized beetles we got from central Asia. And that was more of a circadian rhythm kind of experiment, looking at how we altered the light and dark cycles, and how do the beetles respond in terms of activity levels and things like that. But in terms of other animal experiments, we did not do those on Mir. We didn't try a centrifuge facility. I think, number one, we didn't have the resources or the capability to fly a large enough centrifuge on Mir that would not have disrupted the whole system itself.

Wright: That's all I have. You have anything else you'd like to add at the end?

Uri: No. I think we've pretty much covered it all. I think, just to wrap up, as I said, it's been probably one of the most challenging things I've ever done over the last six years or so.

Wright: Been a full six years.

Uri: Been a very full six years.

Wright: Or maybe a ten-year span in a six-year block.

Uri: It feels like ten years some days.

Wright: We wish you luck in your ISS adventures.

Uri: Thank you.

Wright: And I thank you again.

Uri: My pleasure.

[End of interview]