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JOHN B. CHARLES
INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is July 15, 2015. This oral history session is being conducted with John Charles in Houston, Texas, as part of the International Space Station Program Oral History Project. The interviewer is Sandra Johnson, assisted by Rebecca Wright. I want to thank you again for coming in to talk to us again today.

CHARLES: Glad to do it. Thanks for asking.

JOHNSON: We appreciate it. I want to begin today, as we talked about a few minutes ago, you've actually interviewed about your Shuttle-Mir [Program] experience. Since that was Phase One of the International Space Station, could you briefly describe how you first became involved with the International Space Station [ISS] Program? I know that you began with NASA in 1983 and then became a full-time NASA employee in 1985 and you started as a post-doctoral research associate. If we can talk about, from that beginning, how you became involved with ISS.

CHARLES: Okay. The beginning—I started a post-doctoral fellow in 1983 in the cardiovascular laboratory in historic old Building 37, formerly the Lunar Receiving Lab. After two years, I was able to get a civil service position in the cardiovascular lab, and shortly thereafter became the head of the cardiovascular lab. My mentor at that time, Mike [Michael M.] Bungo, became a branch chief and left that position open for me, the lab position. In the cardiovascular lab, I was responsible for understanding the effects of spaceflight, especially the deleterious effects of spaceflight from [Space] Shuttle flights on astronauts. It was mostly focused on protecting crew members during operational phases of their Shuttle missions, and the biggest risk we had identified at that time was the orthostatic intolerance after spaceflights.

One of the early Shuttle astronauts, Sonny [Manley L.] Carter, mentioned after his first and only flight that the hardest thing he had to do in the entire mission was to stand up after landing, because even after just a short flight—I think his first flight was four days—there is a lot of fluid loss, a lot of neuromuscular control change. They always say they're not calibrated for 1-G [force of gravity] after just a few days in weightlessness. That was all the incentive we needed to come up with a program that looked at orthostatic intolerance, that is the lightheadedness that comes after spaceflight, or after blood loss, or after deconditioning, in general.

That was the focus of my research in the cardiovascular lab. I was able to use the resources of NASA to develop techniques for monitoring blood pressure and heart rate, ECG [electrocardiogram], during reentry and landing, essentially a cardiovascular lab in a box, in a pocket. They actually added a pocket to the spacesuit for us in the post-[Space Shuttle] *Challenger* [accident] era, so we could get data during reentry and landing on astronauts during the actual first exposure to gravity after having been weightless for however long the Shuttle mission was.

I was also able to use the resources of NASA to develop a lower body negative pressure capability, LBNP, which had been used previously on Skylab, but had not been used subsequently. What LBNP is good for is actually to shift the body's fluids around as if the individual is standing up at 1-G; it gives us a chance to do a tilt test, a G-tolerance test, up to equivalent of 1-G, during weightlessness to understand how the progressive loss of cardiovascular function is changing the cardiovascular control during periods of weightlessness. We tried to understand the earliest phenomena that occurred in spaceflight, the earliest adaptations. We also did the operational stand test. Before and after flight, there was a medical requirement at that time for a clinical assessment of the crew member's ability to stand upright quietly for 10 minutes or so. We implemented that, and of course that became data for our laboratory to analyze, as well as being clinically relevant healthcare data.

With all of that going on, that was a busy time in the cardiovascular lab. We then got the opportunity to do similar measurements on the first Mir mission that an American astronaut flew, Norm [Norman E.] Thagard's flight in 1995, and we did many of those same investigations because he was launching on Soyuz, but they were landing on the Shuttle. We were able to implement some of the post-flight monitoring measurements and also the inflight lower body negative pressure experiment, using both our lower body negative pressure device, LBNP, in the Spacelab module and the Russian device called Chibis, which is obviously in the Russian vehicle. They have some differences in design, so we had to do some cross-calibration studies, and we acquired at that time a Chibis device from the Russian manufacturer.

After the first Mir mission, I was moved from research into management, and I became a Science Manager, now just about 20 years ago. So, for most of my career at NASA, I've been not a practicing scientist, not a useful scientist, but a science manager. At that time, I became the Mission Scientist for several of the missions of American astronauts to the Space Station Mir, the subsequent missions. I was there, I was a Mission Scientist for the—well, I forget now which ones; they're sort of a blur, and being the Mission Scientist or not was not really all that different in terms of interaction and responsibility, it just meant I got to do some public affairs weekly briefings on the status and the updates of the mission.

After that happened, after we finished up the Mir Program, I became the Chief Scientist for the second flight of John [H.] Glenn, John Glenn's return to space on the Shuttle Space Shuttle, STS-95. Then when that was winding down, I became the chief NASA scientist for the last flight of [Space Shuttle] *Columbia*, the STS-107 research mission. I moved out of the long-duration Space Station domain back into the short-duration domain utilizing Shuttle missions.

Simultaneously with that, though, I was also the NASA life sciences liaison to the Mars Exploration Program, which required understanding of the Design Reference Mission and its requirements on the life sciences for sending astronauts to Mars, and that is, by definition, one of the longest missions we're considering doing. I kept my familiarity with both things and was starting to see the value of the Space Station, in answering those questions and the value of the Space Station and continuing the work that we had started on the Space Shuttle.

After the [STS-]107 mission, I became involved in the Human Research Program, which was the movement of the life sciences management from [NASA] Headquarters [Washington, DC] down to the field Centers, in this case the Johnson Space Center during the administration of Mike [Michael D.] Griffin. After being the Deputy Chief Scientist, I became the Chief Scientist for the Human Research Program, responsible for understanding and making recommendations for the investigations that we needed to pursue specifically to prepare astronauts for long-duration flights to Mars. That's when the Space Station really comes into focus for our research.

After having done that for a while, I was promoted, or moved sideways, to becoming the Chief of the International Science Office of the Human Research Program, specifically to understand how to do the research that we need to solve the problems of spaceflight to Mars using international resources; that is, leveraging all of the resources available through all the partners on the Space Station. It is largely through that role, the International Science Office, that I became more fully involved with activities on the Space Station sort of from the other side, not from the domestic side, but from the international side, trying to see how we can use international resources to solve our problems and how quid pro quo we also apply our resources to the problems that the international partners have. That, in a nutshell, is how I got to be involved in the International Space Station Program. That's not much of a nutshell.

JOHNSON: That's a good summary. Just a couple of things. You mentioned that you became a Science Manager, and that was during Shuttle-Mir, and you made the statement you didn't do the real science. Maybe if you can explain a little bit more about what the duties of a science manager is—and I'm sure there's still science managers with the ISS—if you can just talk about the duties in that position.

CHARLES: Yes, they're called increment scientists now. They are responsible for making recommendations for the priority of investigations in all the disciplines. That was something that I was always pretty uncomfortable with because it required me as a NASA-designated Chief Scientist for the Glenn mission, or for the 107 mission, to decide which was more important if there was a time crunch, the crystal growth experiment or the flame investigation or the Earth observation or the medical experiment. Now, I did my darnedest to avoid being in that situation and let things sort themselves out, but that really is what the responsibility is, is to decide how best to use the limited resources and the perhaps very constrained resources in this or that mission to get the maximum benefit, and without unnecessarily causing damage or injury to the other investigations. The science manager, chief scientist or the increment scientist or the mission scientist has to have the broad perspective for all the payloads on the mission; has to have done the work ahead of time to become familiar with them, to understand the organizations that are sponsoring them, their needs and requirements and what they need to get out of this or that mission; and then be willing to take the blame for making a decision, or at least a recommendation, to the mission manager or the program manager, or whoever is in charge, for that particular set of priorities to be exercised.

I'm thinking in particular of one of the Mir missions, when we had several setbacks during the Jerry [M.] Linenger–Mike [C. Michael] Foale era—the fire on board which caused a revamping of the timeline, and especially the collision of the Progress vehicle, which cost us access to the Spectre module, which is where we had all of our research equipment. I will say this now on tape and on the record because I know that my Space Station colleagues will be hearing this: there is a natural tendency amongst the implementation folks to, when a problem happens, to stop everything and say, "Okay, well, let's shut everything down and then gradually turn it back on, when we know what the resources are that we have access to and can safely and gracefully turn things back on." My job as the Chief Scientist is to say, "Turn off the minimum things you have to turn off, but don't shut down the science program, which is your justification for being here in the first place."

There is a natural tension between those two perspectives, and we the scientists almost always lose because we don't control the resources, we don't control the need for the capabilities that the vehicle Station or the Shuttle or the Mir provide. When they're talking about resupply, or they're talking about priorities of repairs it's very hard to argue with a guy who says, "Okay

John, which is more important, your science or the oxygen supply?" That's an easy one to lose, and so there has to be a certain set of criteria and a certain perspective that the chief scientist or the mission scientist brings into that job to understand that you need to have a functional vehicle that's got the right conditions for science, but it doesn't need to be perfect before you resume the science.

JOHNSON: As you said, that in particular was with the fire and the collision. Have there been instances with the ISS Program since then that you've seen that same tension, or has the process been resolved as far as trying to work between the implementation and the scientists?

CHARLES: I think the Space Station Program has taken a huge step in that direction by refocusing on utilization after the construction phase was completed. I think they did exactly the right thing, and it became the Space Station Program's mission to utilize the Station effectively. There have been issues since then. For example, right now we're in a bit of a tight squeeze because the Space Station is being reconstructed. Modules are being moved around, and if supply vehicles don't make it—we've had three in a row now that didn't make it, and I guess the Progress just succeeded recently—that puts constraints on activities.

There's also, it appears to me, not being in the implementation business, there seems to be an endless supply of non-science activities that just need to be done, just absolutely positively have to be done right now. The number of hours that we have available for research purposes is, if you look at the total number of person-hours available on the Station, is pretty small. Again we come back to the position that isn't the Space Station being justified for the research, and especially for the human—I'll be very chauvinistic—for the human research that is going to be enabling for missions to Mars? Isn't that what we're told publicly the purpose of the Space Station is? How come we seem to get the smallest allotment of hours to do the research that we're told justifies the existence of the Space Station? Again the engineers say, well, the solar panels have to be working and the oxygen has to be on and the food has to be prepared and all of that, all the infrastructure things. Yes, that is all very true. But there is that kind of ongoing tension that says you don't have to have a perfect spaceship before you start doing useful research, and how much of that is enough and how much of this is enough?

To the Space Station Program's credit, they've designated Julie [A.] Robinson as the Chief Scientist for the Space Station, and she understands, I know, because we've had discussions with her that she is doing the job that I described earlier as the mission scientist had done in previous missions, where she's trying to weigh the requirements of all the users. We, of course, think our requirements are the most important. Julie is not allowed to agree with us on that position; she's got to weigh all the requirements she has on her plate. There is that kind of ongoing discussion, which is only compounded by the EVA [extravehicular activity] campaigns or the reconstruction campaigns when they move modules around, or the VIP flights that occur and derail your plan schedule, or any number of things that always seem to pop up when you least expect it.

Now, lest I sound unnecessarily negative, I will also say that we have just recently, the first week in June, succeeded far beyond my imagination, and certainly beyond my expectations, with the Fluid Shifts study. The Fluid Shifts Study is a major U.S.-Russian investigation to understand the actual effects of the headward fluid shift that I studied so intensively earlier in my career on a problem that we've identified in the last five or eight years on the Station, that is the visual acuity changes. There's a natural tendency to think that the flattening of the globe, the change in the shape of the eyeball, and the swelling of the optic nerve just absolutely must be due to the fluid shift that occurs in spaceflight, although we don't have any proof, any evidence of that. We just have an association, which is tempting to many people but is not rigorously supported yet by data.

One of the ways we're going to acquire data is by using the Russian Chibis device which I mentioned earlier, and a suite of American monitoring capabilities relocated into the Russian segment into the Zvezda module, and converting the Zvezda module into a cardiovascular lab, displacing the people—displacing the kitchen and the bedrooms and the thoroughfare the Russians need to go back and forth through there to get to their duty stations. This is an example of where we have seen the science requirements prioritized above the comfort and the activities of daily living for a very specific purpose. Full credit to the Space Station and to our Russian colleagues, and to the other NASA folks for persisting, for overcoming an almost infinite number of last-minute reasons not to do this thing and to succeed in implementing the set of investigations at least once in the Space Station, I hope several more times in the Space Station. It can be done, and as I say, full disclosure, it has been done, and I'm very glad to see it happen.

JOHNSON: As you said, the vision changes, that's a very important thing, because if you don't have vision, you can't necessarily do your work. I can see where that would become a priority.

CHARLES: It's a bit of a surprise, a bit of a surprise, too. We've gone through 20-plus years of spaceflight knowing that vision changes did occur, but not thinking they were very important. They just sort of were one of those things that happen in spaceflight, and it probably is going to get better afterwards, and everybody's vision changes when you get to be of a certain age anyhow, so what's the big deal? But after three or so months on the Station, several astronauts said, "You know, this is worse than I expected, and I haven't got enough prescriptive lenses on board to help me see my checklist anymore." And then post-flight analysis and post-flight measurements show the actual changes in the globe in the optic nerve that were not in family, not within the scope of previous experience.

So it was a bit of a surprise, it came out of nowhere. We still don't know exactly what causes it; we have several hypotheses, several possible contributing factors. If it continues unabated, then it will definitely be a problem on a long-duration Mars mission. Right now we're trying to understand whether it does level off after a few weeks or a few months or a year in spaceflight, or whether it continues to progressively impact the astronaut's visual acuity. If it does do that, then that is a problem that needs to be solved, and that's one of the things we're focusing on on our current one-year mission, and the other activities, the other experiments that will continue after that.

JOHNSON: As you mentioned during the Shuttle–Mir time, a lot of those experiments, those physiological experiments, were being done in the Spacelab. How much of it was being done on the Mir itself, compared to what you were doing in the Shuttle?

CHARLES: The Shuttle has always been a much more intensive venue for human research. The Russian philosophy on the Mir station was expressed to Norm Thagard by one of the cosmonauts he flew with, when the cosmonaut said, "Norm, why do they have you doing all this research? Don't they know Mir is not a research facility? It's an outpost." He was saying essentially, we're showing the flag in orbit, and all this idea of doing all this research, that's not what it's all about. Of course on the U.S. side, that was exactly what it was all about. We didn't build the Space Shuttle for that purpose, but we certainly used it to the fullest extent we were allowed to, and that was the justification for flying astronauts to the Mir station, is to get long-duration experience before we went on to the ISS. What is long-duration experience if not documentation of the effects of spaceflight on the human body?

There is that kind of intensive research that we took on the Mir station. We also had the benefit on the first flight of having the Spacelab module for a week's worth of post-long-duration data collection, including lower body negative pressure and exercise testing with American hardware so we could compare those results to previously-acquired Shuttle data. We didn't repeat that again, but the Space Station now fills that niche with U.S. and Russian and other hardware that allows us to make measurements in both segments. Sometimes we're able to make measurements on U.S. and Russian devices within a few days of each other to understand whether we're seeing a phenomenon that's related to specific peculiarities of hardware, or peculiarities of spaceflight, because we can compare the responses from several different items of hardware. That is something I had not expected was going to be available to us on the Station, but now in retrospect makes a lot of sense. But the purpose, as you mentioned, as far as we're concerned, is to understand the effects of spaceflight and use these venues and use the Space Station and the Mir and the Shuttle for that purpose.

JOHNSON: And before your current position, I think back in 2005, you were the Deputy Chief of the Bioastronautics Roadmap Project for the Space Life Sciences Directorate. That was preparing humans for flight.

CHARLES: Yes. Thank you for bringing that up. Everything we do has to be related to risk reduction. We are not the National Science Foundation, we're not the National Institutes of Health. We're not here to benefit life on Earth, we're not here to explore really cool things that we can do in spaceflight. Our purpose, our focus, especially in the Human Research Program, we are chartered specifically to solve the problems of astronauts going to Mars. We say long-duration spaceflight beyond low-Earth orbit, but that means Mars. We're talking risk reduction; that's specifically all about risk reduction. Like I like to say, and I do say in public, if we accidentally solve a problem that people have on Earth, well, that couldn't be avoided. But the purpose of our work, is specifically to benefit astronauts going to destinations like Mars.

We're not just playing in our sandbox. The justification is those missions will be so complex and so expensive that they have to be very productive. We cannot lose the productivity of the astronaut in situ—on Mars, for example—because of problems we could have anticipated and solved in previous venues in previous years. Our purpose is to deliver to Mars the most fit, most capable, most productive astronauts that we can because during their time on Mars, which will probably be on the order of 18 months, they had better be working harder than they've ever worked in their lives to justify the tremendous expense of those missions, scientifically and otherwise.

The purpose of the work that we're doing is risk reduction, and the Critical Path Roadmap was our first attempt at documenting the risks that would confront astronauts on long-duration flights, like to Mars. That was an effort that we executed in the late '90s, and tried to understand what those risks were, and that process continues to today. We have a set of 30-plus risks that we have vetted, and we continue to vet, because many of them are heritage risks, they're legacy risks, and the way they were written and the way they were practiced up until now, they probably are not as tightly focused as they need to be. We are still learning internally how to write risks, what the right way of expressing the thought is.

There are different ways of saying what the risk is, but they should lead to a question that can be answered and not just sort of a nebulous, free-floating concern that there's no obvious approach to the answer. That's the activity we're doing now. When you mentioned the Critical Path Roadmap, that is the forbearer of the set of risks that we are addressing right now that focus all of the work of the Human Research Program that the Chief Scientist has to be focused on. By that I mean the use of the resources of the Human Research Program to solve those problems identified in those risks, and at the end of the Space Station Program to deliver to the next program, whatever it may be, I imagine a nicely-bound document with a ribbon around it that says, here are all the problems you're going to find on your mission to Mars, and here are the solutions. Do with it as you will. We know how to solve these problems.

JOHNSON: And I imagine over the years, since Skylab, they found problems that they didn't expect, and with the Shuttle flights and Shuttle-Mir and on through ISS, are there any—you mentioned the eyesight and I know that was something that they knew happened. But how much of a problem it was, your group didn't really realize at first. Are there any other surprises as far as some of these risks and some of these things that you've found, especially since the ISS Program began? The duration is getting longer, around six months now, with astronauts.

CHARLES: I think the answer to that is no. I guess the big surprise is how much of what we're finding we should have anticipated. There have been surprises. For example, we have been surprised to learn during the Shuttle era that one of the phenomena that occurs in spaceflight, this headward fluid shift—and I always do this universal hand gesture when I talk about the fluid shift, the fluid shifting out of the lower body into the upper body, and it's really a redistribution and equilibration of a fluid throughout the body, which has a tendency to be a dislocation of fluid into the upper and away from the lower body.

In the upper body are your various pressure sensors and volume sensors which tell the brain whether you have enough blood volume on board or not. The natural response to this fluid shift is a decrease in fluid volume, which is one of the things we're talking about observing in spaceflight, but this fluid shift is implicated in this ocular change that I've described. One of the hypotheses, based on lots of research on the ground, was that there would be this fluid shift in the upper part of the body. Of course it is in the blood vessels, and it would distend the heart; specifically, the low pressure part of the heart, the left and right atria. By distending those parts of the heart, which is where the blood collects before it is then pumped out of the heart, it would stimulate nerve endings in the walls of the chambers of the heart which are stretched, and which signal to the brain that the heart volume has increased, and the brain knows from experience that that means there's too much blood volume in the heart.

We were expecting to be able to measure that with something called central venous pressure [CVP]. Central venous pressure involves putting a catheter into a vein and feeding it up the vein and into the heart so you can measure that, because on the Earth, people that are in cardiac failure, heart failure, that have increased heart size, have increased central venous pressure. It can be measured. We always thought, of course, all of the changes we're seeing in spaceflight are due to increased central venous pressure causing this distension, leading then to the reflex response that the brain is used to providing.

We measured CVP on several Shuttle missions and lo and behold, CVP was not increased. We have this phenomenon where the result is as predicted, but the predicted stimulation doesn't occur. That's a surprise. You asked about a surprise. That's one not from the Station Program, but from the Shuttle Program.

But it showed us what we should have known already, which is yes, of course the heart is expanded, those nerve endings are being stimulated, but the pressure inside of the heart is only a relative pressure. If the pressure outside of the heart changes, then it doesn't take the same pressure inside the heart to cause the same change; it's the transmural pressure, the pressure across the wall, that's important. If you have one atmosphere, like we have here, on the outside of the heart and then you have one atmosphere plus a few millimeters of mercury on the inside, it'll expand. If you have a vacuum around the heart, which you can't have, clearly, and you only have one or two millimeters of mercury inside the heart, it will cause the same expansion. It's the "delta," the change in pressure.

What nobody had considered, and what many people still do not emotionally grasp yet is the hypothesis I favor, which is that spaceflight is the only time the thorax is completely unloaded. Anything you do on the Earth, anything you do under gravity, some part of your chest wall, your thorax, is compressed. When you're standing upright, it's compressed because all the ribs are pushing down. If you're laying on your back, it's compressed because the ribs are pushing this way. If you're sitting in a chair like I am, I'm pushing back against the back of the chair, and the gravity is pushing the front of my ribs. Only in weightlessness is the thorax allowed to expand, and people do comment on the barrel chest appearance of astronauts in space because there is nothing compressing the thorax in any direction. If you expand the volume, you're going to decrease the pressure inside. Decreasing the pressure outside the heart means you can have the same stretch on the walls of the heart without the same pressure inside the heart. The pressure increase is because of the change in the outside pressure, not the change on the inside pressure. Painfully obvious, pitifully obvious, and we did not see that before that happened.

The purpose of this long digression is to say that yes, we have been surprised by things, and in retrospect, almost all of those surprises should have been anticipated from day one. Why did we not think about this unloading of the chest wall before flight? As far as I know, nobody did, including me, and I would love to give myself credit for thinking of it ahead of time. Our ways of mimicking spaceflight on the ground are bedrest, head-down bedrest to try and push extra fluid in the upper part of the body. But you've always got this pressure on the thorax. You've always got this pressure pushing fluids to the upper part of the body. There's no convenient way to mimic spaceflight on the ground. There are convenient ways, but there's just no good convenient way to mimic it on the ground.

We do bedrest studies, we do water immersion studies, we do zero-G [gravity] airplane, we do off-loading using POGO [partial overhead gravity offset] devices to hold you up while you're walking at one sixth of a G [force of gravity], or whatever. Those all simulate parts of the spaceflight experience, but only in spaceflight do you get the whole integrated experience. That is where you get the baseline, the understanding of the physiological changes that occur in spaceflight, you can only get from spaceflight, which when you get them you realize you should have guessed what they were ahead of time. But there's an infinite number of possibilities on the ground. Spaceflight tells you which one of those possibilities is the correct one, and that way of course you should have guessed, but there is no way you could have guessed ahead of time.

There's a surprise that we got, an example of surprise. It's not the visual acuity change surprise that we got; it's a more fundamental understanding of what we didn't understand.

JOHNSON: Each time one of those surprises happened, does that change the way the researchers start looking at these problems on the ground? I know you said there was an infinite number of possibilities, but does that help narrow down those possibilities each time?

CHARLES: It does. It does shrink what we call the trade space. You know that it's more likely this one and not that one. Unfortunately, we are limited in the measurements we can make in spaceflight generally—I'm not talking about the heart now anymore, I'm talking about in general. We're limited in the number of test subjects we can acquire data on, so that we usually have fairly large uncertainties around our findings. We sort of have to agree that this finding means that thing, and we will progress in that direction. Right now we have agreed that spaceflight, long-duration spaceflight, does not cause serious structural and other changes to the cardiovascular system because that's been tested on the long-duration spaceflight.

Mike Bungo and Ben [Benjamin] Levine did an investigation called ICV, the Integrated Cardiovascular Study, and they did a repetition of the routine measurements, ultrasound and other kinds of things that we have done for decades on the Space Shuttle before that, and showed that the cardiovascular function of astronauts is maintained in spaceflight. That was one of the concerns that I had when I was doing my research back in my useful years: is there some effect of spaceflight that will cause this deconditioning of the cardiovascular system? Turns out the deconditioning is just what you would expect from the unloading, and Bungo and Levine are very careful in saying that as long as we continue doing the loading that we do, exercise on the

Station, then there's no problems, because we have appropriately replaced the loading due to gravity and working on the Earth with these very intense, acute exercise bouts in spaceflight.

The way we scientists phrase things is to be extremely constrained or constricted in how we describe something. So we say as long as the exercise and other countermeasures are the same, then okay, but if you take those other things away, then we don't know what the answer is. We assume that the sum of the things we're doing in flight equals the sum of the things that are done on the ground before flight and after flight. So there is some equivalence there. If you take some part of that away, then all bets are off. You may have this cardiovascular reconditioning that everybody was worried about since day one of spaceflight, and oh, goodness, what are you going to do then?

When we solve our problems, when we reduce these risks or mitigate these risks, we always have to stipulate how that was done. We can't say, "Okay, we've solved the cardiovascular problem," or we can't say, "We've solved the bone problem," without saying that we've done that by providing this countermeasure, or that treatment. We don't want future program managers to say, "Okay, we can go to Mars now because they've solved the bone problem," but not take the solution along with them. The bone problem may have been solved recently by this resistive exercise device; we're still trying to validate that. But the resistive exercise device takes up a module the size of this room, and a Mars mission will not have a module the size of this room to put the resistive exercise device in, so the program manager for the future Mars mission may say, "You know what? They solved that problem, let's go to Mars."

Then we'll say, "Wait a second, where's the module that has the hardware?"

And they'll say, "You never mentioned that before." We have to make sure that all of the stipulations are included in all of our recommendations so everybody understands that yes, you've solved it if you do this exercise, or that fluid loading, or this treatment, just to address those risks.

JOHNSON: That reminds me of when I was reading one of the interviews you gave, you were talking about engineers and those type of people, like you mentioned, they think, "Oh, we can go to Mars now." They want a yes-or-no answer and the scientist's answer is, "Maybe."

CHARLES: Yes, the scientists can never say, "Yes." It's always "Yes, if." We try not to say "No, because." We try to say, "Yes, if." Yes, we can go to Mars if you provide a resistive exercise device.

They'll say, "Great, how big is it?"

We'll say, "Right now, it's as big as a room. But you're the engineer, you can probably figure out a way to make it smaller." That's the task, but until we validate whatever you come up with, we're not going to sign off that you've solved that problem.

JOHNSON: A lot of the problems that you've looked at over the years, the neurovestibular system, you mentioned the cardiac, the nutrition, radiation effects and how that'll affect astronauts long-duration, changes in bone density, immune system. Also, there's the psychosocial effects. One of them that came up as early as Skylab was that you can't work people harder, because you have this amount of work that needs to be done in a short span of time, and expect them to be productive. That's something that's come up, I believe, with Shuttle-Mir and ISS also.

CHARLES: Repeatedly. That was one of the early lessons that the astronaut office tried to stress to everybody, including us. They thought it was important to stress it to us as well. We're natural allies, but they don't always see us that way. They would always compare Shuttle missions to Station missions and Mir missions and Station missions. They'd say Shuttles are sprints and Stations are marathons, and you run those two kinds of races differently. The Shuttles were sprint missions, and the people were worked as hard as could be worked.

I remember watching the STS-26 crew come in after their flight, and I think it was a four-day flight. It was a very short Return to Flight mission [after the STS-51L, *Challenger* accident]. They landed out at Edwards [Air Force Base, California], and I was in the clinic waiting for them to do a stand test. They landed and came out of the white room next to the Orbiter and waved the flag and walked around the Orbiter, very exuberant and happy. Then they walked into the clinic and they all sort of collapsed against the wall and the color drained out of their face. They were exhausted. That was just a four-day mission. You know that there was emotional tension, but also the workload, they kept them busy the entire time. I think on the Shuttle they gave them one day off a week or a half a day off a week on the routine missions, and on the longer missions maybe a little bit more. Only the commander and the pilot got to have dedicated exercise time, and the others sort of had to catch as catch can. Those were the lessons that were applied to the Space Station Program.

I think right now, sometimes in my darker moments, I think they have too much time off on the Space Station, because the important thing is to keep them healthy and productive for the entire time in flight. That's one of the reasons our research is what I think is too constrained, is because of all the other constraints, including time off. Now, in fairness to them, many of them work during their time off. They continue working in their after-hours and they work on weekends to do things that they're interested in, or things that they feel obligated to do. They do talk about it, but they really can't talk about it too much, because if there's too much notice about that, then the other side of the program will say, "We're supposed to be letting them rest, they should quit doing that," and then we lose that resource.

That's an interesting anecdote from Skylab. The third Skylab crew felt they were overworked because Mission Control was trying to schedule them at the work level of the second Skylab crew, which was composed of notorious over-achievers at the end of their mission, when they finally had everything figured out as they approached the end of their two-month mission. They knew how to do things efficiently in space, and apparently, I'm told, Mission Control just assumed that the third crew on their first day would be as efficient as the second crew was on their last day. The third crew tried mightily to be that efficient, then finally gave up and said, "No, we're not there yet, we need a little bit of time."

That was a lesson that should have been learned, and I'm not sure we're good at transferring those lessons between programs. I think the Shuttle Program did work the astronauts very hard. At one point, I became a believer actually in more rest time and less intense activities, because I was interested in the effects of spaceflight on the human body, not the effects of spaceflight plus physical exhaustion on the human body. When those guys came into the clinic and slumped against the wall, and then they came and did my stand test, what am I measuring? Am I measuring the effect of spaceflight or am I measuring the effect of physical exhaustion? If it's important to understand the effects of spaceflight, then you have to take care of your test subjects.

Which is why, getting back to the Mars thing, I endorsed the idea of not only appropriate activities and conditioning, but also appropriate conditions in the Mars vehicle. When the astronauts get to Mars, I want them to be in the best shape they've ever been in, not just physically but also emotionally and psychologically and in terms of performance. I want them to be as rested as they've ever been, because we have a lot of work for them to do on Mars. Astronauts don't always like to hear people say that, because it sounds like folks like me are endorsing sending Hilton Hotels to Mars instead of camper vans. Which is more likely to be funded and approved and sent to Mars? The minimum vehicle. But the minimum vehicle carrying minimum resources to maintain astronaut health and performance is not going to deliver the mission that you need to have to be able to endorse the second Mars mission and an on-going Mars program.

Again, there's one of these dynamic tensions where we need to make sure that the astronauts, even perhaps over their own objections, have the proper kinds of creature comforts to let them be well-rested, refreshed, and ready to go, physically and emotionally ready to go when they get to Mars. That's part of the work that we're doing in the Space Station as well is understanding what it takes to keep them motivated and functioning at high-performance levels for long periods of time in space.

JOHNSON: These psychosocial considerations, the different things that you've discovered through all this, it actually has affected the design of the Station as far as their areas that they sleep in being private?

CHARLES: Certainly private sleep compartments. The Russians did that on the Mir station, they had the "kayutas," the two permanent crew members had private sleep stations. I think that's just a real good idea. I think all of us need a little bit of privacy and a little bit of comfort, especially when it comes time to sleep. There were things like that in the Shuttle; those sleep stations when they had split shifts, when they had 24-hour operations. Half the crew at a time had access to those little phone booth-like things they could go into and sleep on certain Shuttle missions.

But yes, I think that's a very valid point, is that we need to be designing future vehicles to keep in mind, or in consideration of the performance requirements of the crew members, not just the life sustenance of the crew members. They need not only to be nourished and hydrated and exercised, but they needed to be appropriately rested and recharged and refreshed and be able to go do those important things that they're doing. That will be something that the Human Research Program specialists in human factors will be mindful of as future vehicles are being designed.

JOHNSON: You mentioned the area that was going to be designated as the cardiac area was the Russian module. Are there any other decisions related to the science that you can think of for ISS that have impacted the development or the cost, or the policies with the ISS Program?

CHARLES: Let's see, that's an interesting perspective. I must tell you that the reason that we're doing it in the Russian module is because we're using the Russian Chibis device, and the Russian Chibis device is affiliated with the Russian what is called Gamma unit, which is the medical monitoring hardware that the Russians need to monitor people in the Chibis, and it is hard-mounted in the Russian module. The Americans first proposed that we move the Chibis and the Gamma through the hatch into the U.S. segment, and make the Russians have to certify their hardware in the U.S. segment. The Russians said, “No, it’s bolted in, it doesn’t move. Your stuff is all portable. You bring yours over and we’ll worry about certification of your hardware in our module.”

I cannot think of any other examples where something like that has really been done. I think that’s right, because all the research that’s been done up until now has been done in specially-intended facilities, like glove boxes or the exercise facilities. I don’t think anybody’s ever relocated major suites of hardware throughout the Station for brief intervals like this. I’m pretty confident in saying that because there was so much gnashing of teeth and wailing and furrowed eyebrows as people tried to figure out how to do that that it seemed to be brand new to many people.

JOHNSON: Your position now, you’re dealing with international partners. You have that history with Shuttle-Mir where you dealt with the Russians, and from your previous interview, I know sometimes that was a challenge. It posed a challenge. Now you have your Russian partners as well as the other international partners that you’re dealing with. If you don’t mind, maybe talk about that for a moment, and how that affects the ISS. What are some of those lessons learned that you brought from Shuttle-Mir into ISS, and anything as far as the organization with the international partners that you can think of.

CHARLES: The Shuttle-Mir and the NASA Mir Program were instrumental in teaching folks like me how to work with international partners. I will tell you that the reason I have the international science job now for the Human Research Program is because I had the Russian experience in Phase One. Mike [Michael R.] Barratt, who was the program manager for the Human Research Program, saw the need for a more cross-participation between the U.S. and Russian segments, and engineered a collaborative program, and he identified me specifically as the person to help run the human research aspect of that collaborative program. He identified me because he and I both worked in Phase One together, and he knew that I had the background and the experience, and maybe even the temperament to work with our Russian colleagues, as well as our other international partner colleagues.

There are differences in degree of insight that is required, depending on the partner and depending on the circumstance. Clearly the one-year mission that we're engaged in right now is largely bilateral. It really is like Phase One all over again; it really is U.S. and Russians. We have made sure to include the other international partners as much as possible, just so it's not so blatantly bilateral. When I make public presentations and my presentations to program managers, I can say it's a multilateral effort. My goal is to have multilateral human research on the Station for the purposes of this risk reduction. The one-year mission is largely bilateral, but our purpose on the one-year mission, in addition to acquiring the one-year experience, is to pioneer, or otherwise identify the processes that will allow us to do it on future increments, with all partners participating. The lessons we're learning on the one-year mission are applicable to all future increments and all future investigations.

My goal is to have not a single investigation, like this Fluid Shifts Study, which is the most complex that's ever been done in the Station. I want to have seven of those, on every increment, of the most complex thing that's ever been done on the Space Station. That involves moving hardware and people and resources back and forth across the segments, and answering important questions that could only be answered on the Station, using resources that we have on the Station. This is a lesson learning opportunity, and it's a way of demonstrating, in a very visible manner, that we've learned those lessons, we know how to apply them in the future, and now if you, the program managers of the Station Program, really want to have world-class research in the human physiology area done in your Station, this is what it's going to take. Please tell your people that when we call them and ask for this and that resource, it's okay, they can talk to us and they can actually give us those resources, and if not, they can help us figure out another way of doing it. It really is complex and it's painful, but by repetition, it should be if not less complex, then at least less painful in the future. It should be something that we can do more and more of in the future.

The experience with the international partners has been more of the same with the Russians, again learning lessons that we should have remembered from Phase One, then also understanding the specific requirements of the other partners. A lot of that is personality-driven. Sometimes it depends on who you're dealing with from the other partner that dictates what kind of speed you make, what kind of progress you make. Part of that problem is the fact that NASA alone seems to have more people than tasks. There are many people. NASA has 10,000 civil service employees and tens of thousands of contractors working for it. Those manpower levels are unheard of in other space agencies.

When you talk to the Canadians or the Japanese or the Europeans, you may be talking to the same person for this purpose, this teleconference, as your colleague talks to for another telecon, and as another colleague talks to for another telecon. They are all very, very overbooked. There are allowances that we have to make because just because I have the luxury of focusing only on my activity doesn't mean that my counterpart has that luxury. When I ask my counterpart for data or feedback or reviews or something, my counterpart may be hearing the same request from three or four other NASA people, and there's only so many hours in the day.

That really is one of the eye-opening experiences in my work with the international partners through the Space Station international science activities is how much—NASA does a lot, NASA initiates and sustains a lot of effort. If we try to make it apparently more seemingly equitable, we may be doing ourselves a disservice, because our partners just don't have the resources to do that, and they really will contribute more if we can nurture and support their activities as we go along. We've done that in the area of the Human Research Program. The European life sciences or European human research activities take advantage of the infrastructure we've built.

The NASA folks may do some of the documentation that otherwise the Europeans would be required to do, just to make sure that it gets done on schedule so it doesn't impact the overall flow of things. We schedule their informed consent briefings with the astronauts, just because you don't want to have astronauts approached by the American informed consent specialists and the Europeans and the Japanese and the Canadians, because after a while, the astronauts say, "Wait a second, who are all these people? Why are they calling me up?" It's better to have a single point of contact, and we have taken that burden on ourselves as a way of facilitating the work that gets to be done. It facilitates the work of the international partners, and it also makes our own lives easier, so it really is a win-win.

That's the kind of lessons I think we've learned from the international collaboration on the Space Station that can benefit future Space Station work and future international activities elsewhere in mission planning as well as research.

JOHNSON: The scientific community is global as far as researchers from all over the world, and on the ISS with the partners themselves, and what you mentioned is they're using the facilities and the infrastructure that's already there. What I'm going back to is the statement you made earlier, as far as the Russians on Mir said this is an outpost, this isn't a scientific experiment. As far as the human research, is that something that all of the partners are interested in now? The effects of spaceflight? Or is that something that the U.S. is more interested in?

CHARLES: All of the partners are interested in the effects of spaceflight on the human body. The U.S. is interested primarily in risk reduction. The other partners are interested in benefits to life on Earth as well as risk reduction. As I mentioned earlier, the HRP charter does not mention that. In fact, our charter almost excludes that from us. We have the separate organization CASIS, the Center for Advanced Studies in Space, which is focused only on benefits to life on Earth. If they dare cross the line into benefitting astronauts in spaceflight, we in the Human Research Program get really mad, and we have words, because that's our charter, not theirs. If we dare to benefit life on Earth, that's their charter, not ours. That sounds bizarre to the rest of the world. How can you possibly separate those topics? The answer is, you can't, but we do anyhow.

In Russia, the Russian investigations are designed to understand the effects of spaceflight on the human body according to the protocols and the methodologies they've developed over their decades of scientific work, and a lot of the work that they do doesn't have the obvious applicability to spaceflight that we would look for. But their decision-making authorities and their funding agencies say this is what we need to be doing on the Space Station.

Same thing for the CSA [Canadian Space Agency] and for the Japanese and the Europeans; their taxpayers, their stakeholders and shareholders are looking for benefits to life on Earth. They don't care if the Americans want to go to Mars. They're looking for how is this huge cost of the Space Station make life better for Frenchmen or Japanese or Canadians? If you happen to benefit astronauts going to Mars, well okay, that's good, too.

There is this difference in approach, a difference in philosophy. We are focused on risk reduction. My job as the International Science Office coordinator for this, and as the co-chairman, along with my Russian counterpart, for a panel that recommends research for the Station, is to try to get all of the partners' resources applied to solving our problems. It is very—I keep saying "chauvinistic," I hope that is the right word. It really is very greedy on our part. I want to use the Japanese resources and the European resources and the Russian resources to solve problems that we've identified, even if they don't think those are the important problems, because my boss and his boss have told me those are the important problems. But quid pro quo, the Japanese say, "We're helping you with this thing, maybe you can help us with that thing." We say yes, of course that's a fair trade, because again helping them helps us, and it's win-win. There are those differences in philosophy.

When I talk about the work we are doing, I will always say that we, the partners, have agreed on these risks, because we have agreed on these risks. The interpretation of those risks is different. I use the interpretation I like best and say, "The Japanese and the Europeans and the Russians and the Canadians agree with me on that."

They say, "Sort of." I guess they turn around and say, "The Americans agree with us on this interpretation" when they're talking to their funding agency.

But there are also differences, and I think I mentioned this in my Phase One interview, there are differences of understanding of understanding; that is, there are differences in knowing when you've got enough data. The rest of the world seems to be pretty happy with what we call onesies and twosies. If you get data on one astronaut or two astronauts or three astronauts, what else do you need? They sort of feel like they understand that phenomenon in people. On the U.S. side, we are nuts about statistics, and statistics require sample size. We have a rule of thumb that if you don't get meaningful data on 10 astronauts doing more or less the same thing, then you really haven't finished the task. Ten astronauts is three or four or five studies to everybody else in the world, but not to us. To be successful on the U.S. side, I have to recommend and foster repetitions of investigations to that extent, I'd have to draw the international partners in in support of that kind of activity.

For example, I mentioned this Fluid Shifts Study that we did in the first part of June. It is, like I say, the most complex thing we've seen done on the Station, and we expect to do it more times, at least twice more on this mission, the one-year mission, and on subsequent missions to get a sample size that is statistically valid. There are those that say, "Great, you've done it. What's next?"

We say, "No, no, no, we're only getting started. Now we know how to do it, now we can do it enough to make sense of the data."

There are others in the world that say, "No, wait a second, it's time for a new challenge; you've finished this one." There are these differences in philosophy that we have to try and meld together. I like to say that I may not be a scientist anymore, but apparently I get these jobs because of my charm and persuasive abilities. I'm supposedly able to convince others to see our point of view, even if it doesn't match their own benefits. Of course, there has to be this balance of interests between the parties who are contributing. But a great deal of international work on the Space Station is to find the common ground and to find the things that people can agree on and then to maximize the productivity of those kind of things. The Fluid Shifts Study is an example of that. Hopefully only the first example of that.

JOHNSON: As you said, that's part of your job, to make those recommendations. Are there any examples you can think of where you made these recommendations or recommendations for research, and the answer has just been no, we're not doing that?

CHARLES: I'm not very far along in that process. Up until now, we've done it for the one-year mission, and that's been largely bilateral, and I'm overwhelmed how many of the recommendations I made for that were accepted. I think we recommended 17 investigations for this one-year mission, and I was really going to be happy if we got one or two. Darn it, we got 17. Somehow that worked. I did surprise a few of the folks that were working with me when I told them, "If we get the Fluid Shifts Study and the Field Test Study, which is a pre and post-flight study, when we get good data on those, I'm going to call this a victory. All those other investigations we have, those are nice to have." I'm pretty sure nobody will ever read this oral history, so I'm safe saying that to you all.

The recommendations going forward now will be based on applying the lessons learned from the one-year mission to future increments, all the future increments. We're in the midst of formulating those recommendations; we're in the midst of bringing the international partners into what has been a bilateral activity, and making it the truly multilateral activity, which was, initially, a bilateral negotiation between me and my counterpart. Here are my investigations, and here are his investigations. Well, these seem to look like each other, let's blend those together. These are different, so we'll make those part of your national program and you do those and we'll do these, and we'll talk about them later. Now I'm to the point this summer of doing that with all the other partners. I'm not sure how to do that yet; this five-way negotiation process is going to be a challenge, using, again, all my charm and persuasive abilities. I'm just understanding what needs to be done. Luckily, we've been doing it low-key up until now, so we have an idea of what the puts and takes will probably be.

We also have an idea of where we will not succeed. For example, there's an American ultrasound device on the Space Station. It is used by the USOS, the U.S. [Orbital] segment. The Russians don't really have any need for ultrasound at this time, but if they needed it, they would use it. There's a replacement ultrasound being proposed by the French space agency through ESA [European Space Agency]. We did a comparison and said, "Okay, we can upgrade the current one, or you can fly your new one. We, NASA, recommend upgrading the current one because it will do almost everything you need, and it's already there, and it's a smaller effort."

The Europeans say, "No, you misunderstand. We want to fly our ultrasound device." The bottom line is probably we're going to quit upgrading the American one and wait for the French one to show up as a successor, then upgrade the American one later on when the French one is out of date. Because, it's not just the data that are important, it is also the fostering of the industry in each of the partner agencies' countries. You want to make sure that they all get a chance to say, "As Used on the International Space Station" for their hardware or their techniques or their technologies.

It's part of the infrastructure, it's part of keeping a healthy Space Station, it's part of keeping everybody interested and engaged in the Space Station. You can't just all be, "Here's the finding that the Europeans came up with using the American hardware, and here's the finding the Japanese came up with using the American hardware." Because their hardware people say, "You know, we're good too, we build hardware. We deserve a chance, and we'd like some of that publicity." There's that kind of negotiation process.

One of the reasons that I'm in this job and one of the reasons that my job exists is because supposedly, apocryphally at one point an astronaut woke up one day and checked his to-do list and found out he had to put on three ECG recorders for three separate investigations. I'm pointing at these devices on the table [microphone receivers, the size of a deck of cards], because that's about how big they are. Did it really make sense for that one person to put on three sets of electrodes and carry around three boxes of electronics, answering ostensibly the same question for three separate investigators? "Don't these guys talk to each other? Why is this a good idea?" That's always the example I wave around; my job is to keep that from happening ever again.

But sometimes you need to have two Holter recorders because this PI [Principal Investigator] has a need for a certain format of data that is incompatible with what that other device provides, and the other device has a PI that needs a different format of data. Sometimes on some days, my job is to tell the crew member, "No, seriously, you've got to put on these two recorders, and yes they look the same on the outside, but believe me, they're different on the inside."

Obviously, the hardware, the product from this country or that country, has different design criteria that have gone into it and different specifications that are based on what the investigator from that country wants or needs to do his or her job. But that investigator also comes up with those requirements based on what technology is available to that person in that country. It's sort of a vicious circle; the investigator insists on this set of requirements because that's what his country provides. Well, if the investigator insists on it, then that's what the investigator should be getting from the program. It's not just a matter of synergies of the science; it's a matter of the understanding of the greater sense of requirements, the hardware and other requirements that allow the science to be done on the Space Station.

JOHNSON: You mentioned CASIS before and how they do what's applicable to Earth. Do you work on panels together? How do you negotiate that with them, as far as the science on the ISS?

CHARLES: I have not been involved with CASIS up until now. I may be more involved coming up in the future as responsibilities shift within the Human Research Program. A lot of that integration is done through Julie Robinson in the Space Station Program Science Office. If CASIS comes forward about a medical investigation that involves people at all, then Julie will send it to us to review to see if it steps on our turf. I think she probably makes other arrangements for other fiefdoms, other domains that have specific responsibilities. If it does, we either work out a deal whereby we collaborate, or we take it over ourselves, or we tell them that it steps on our turf, but we don't care, we're not interested, and you can't do it, either.

We try not to do that last one too often, it's not really conducive to future cooperation. Really, it's more a matter of finding collaborations, or putting our stamp on it to make it useful to us. Up until now, that's been done through Julie Robinson. I do have colleagues in the Human Research Program that sit on her advisory panels.

JOHNSON: We've talked about some of the challenges you've had in your career in the last hour. Is there any significant challenge that you would consider to be the most significant challenge or the most difficult thing as far as ISS Program is concerned, that you've worked on or that you've had to deal with?

CHARLES: Yes. All of them. They're all challenges. I don't mean to be glib or dismissive, but there's the limitation of crew time; I've mentioned earlier that the Space Station exists, at least in my mind, to allow human research for risk reduction for long-duration flights beyond low-Earth orbit. But we're not getting as much crew time as we think we need. We have to fit into a very small crew time box. Part of that crew time is because NASA's allotment of crew time and other resources is split 50/50 with CASIS. CASIS is supposed to be bringing benefits to life on Earth, and we think that's ducky, but that's not what we're here for.

There are other things, like the Space Station Program just recently came to us and asked for an endorsement of a certain position between the U.S. and the Russian sides, and could we get it to them quickly? So we drafted the memo for my signature and my Russian counterpart's signature and we sent it off to be translated, but we're told no, the Russians are supposed to translate from English into Russian. We only translate from Russian into English. That's a contractual stipulation that makes a lot of sense overall, because the Space Station Program does not want to be supporting the Russian infrastructure by doing translations the Russian side should be doing. But if we're asking the Russians to do us a favor by signing this memo, it doesn't seem very nice for us to say, "Oh by the way, here's a version you can't read. If you want to read it, go get it translated yourself." We lost that argument.

So, we're simultaneously being asked to provide the support for this position, and to get Russian support, but we're not making it easy for the Russians to support it. That's just an example of the kind of things. They happen at the global level. When a tourist gets assigned to a Soyuz mission, that displaces some kinds of research that you want to do. That's at the programmatic level. When this country or that country invades another country, then that affects the partnership, and that's at the global level. At the more mundane level, if this document or that document needs to be translated or needs to be signed, or doesn't need to exist in the first place, why are you bothering me with this stuff, and why are you making it difficult for me to help you do this thing?

Lots of challenges. I don't want to put my finger on any single challenge. I will tell you, though, that since I brought up the international relationship thing, the Space Station Program is exempt from any of the problems between the U.S. and the Russian side. Our work has progressed largely unimpeded, despite any political issues at higher levels. That's not true for the rest of NASA, but it is true for the international work that I'm doing specifically and for the ISS work in general. We've had good relations with our Russian colleagues, even in the face of dire news stories on both U.S. and Russian newscasts every evening.

JOHNSON: On the flip side of that, is there anything that you consider your most significant accomplishment, or anything most memorable that you can think of for ISS?

CHARLES: Well, yes. This one-year mission, of course, is the major effort that I've engaged in for quite a while, and it's probably my career-capping activity. I was invited by the Space Station as a guest to watch the [Soyuz] launch in Baikonur in March, and that was spectacular.

Any launch is spectacular, but this was good because we were, I think, three times closer than you are for a Shuttle launch. It's equally dramatic. Even though the rocket is not as powerful, you're a lot closer to it, and you can almost feel the heat coming off of it. Having being escorted around and being shown all of the facilities of Baikonur and being treated very well by the Station Program really was a spectacular experience.

But that was part of this involvement in this one-year mission, and this one-year mission is almost like it was intended specifically to capitalize on the skills that I should have developed by now through NASA's efforts on my part, to allow me to give back and to make something happen. In the context of all that, the Fluid Shifts Study that we're doing, this most complex, highly-integrated investigation ever on the Space Station is sort of the epitome of that international collaboration. I keep saying it's an example of what we want to do more routinely in the future, but I might not be around long enough to see it happen routinely in the future.

Having been involved in getting it done the first time, the example has been very gratifying. It's doubly gratifying because it involves an area of my own interest, the area that I worked on as a scientist, although I was not involved in the investigation except as a mentor to foster it, and to try to help it happen programmatically. It's very gratifying to be able to see the activities and hopefully soon to see the results from the investigation and know what they mean based on my own previous experience. If I had to pick one investigation, that would be the one that would be the example. I'm glad it was this one.

JOHNSON: In a previous interview that I was reading, you mentioned that you cannot imagine sending people out into the universe without the Space Station. We've talked about the plan, the

Mars missions, but if you want to just for a moment tell us what you meant by that statement and what you feel will be the legacy of ISS.

CHARLES: There was a cartoon by Tom Toles back in 2003, an editorial cartoon, and I use it in all my public presentations. He drew a picture of a Space Station orbiting the Earth, and the little word balloons say, "The Space Station is important to understand the effects of the spaceflight on the human body, without which we cannot do the Space Station to understand the effects of spaceflight on the human body." And I say he was being sarcastic, he was saying it's what some people call a self-eating watermelon, playing in your own sandbox. But my position is yes, that is exactly right. That's why we have the Space Station, is to understand the effects of spaceflight on the human body so we can have spaceflight.

I believe it is critically, vitally important to have humans in space, not just robots, but humans in situ in space to do the challenging things that robots can't do or can't do efficiently, and to make the decisions on the spot that robots can't make without calling home. The only way we can send humans into space for the long term, and by that I mean repeatedly, is to have an understanding of the effects of spaceflight, specifically weightlessness and radiation and isolation, on the human body. The only way we're going to acquire that is by doing that kind of work on a Space Station.

We've been given the International Space Station that's been outfitted very well in some regards as a world-class research facility and it's incumbent on us to use it to the fullest extent, so we can then enable those future missions beyond low Earth orbit to take this pile of answers that I've tied this ribbon around at the end of the Space Station era, giving it to the next program manager and say, "Here, go forth, do your missions. Here's what you need to know to keep people healthy, happy, functioning, and effective in long-duration spaceflight. Now go and do something with it, show us why it's a good idea to put humans on Mars, or to send people to asteroids, what they can do that only people can do in those situations, not what robots can do as well or equally."

Yes, my philosophy, and I'm not bashful about it, is that thank goodness for the Space Station. Anybody that says we should have moved on, the Space Station's a dead end, it's a diversion, it's a backwater, that tells me that they are not thinking about people in space, and they're not thinking about usefulness in space. If your understanding of the future of spaceflight involves people in situ in space, beyond low-Earth orbit, you need the ISS or something like it to do the basic work. I say we're doing our homework, and we're not allowed to finish, to go on to the next grade, the next level, until we've finished our homework here. I think we'll be hard-pressed to finish our homework by 2024, but if that's as long as the school's open, then that's the answer.

There will inevitably be additional research that NASA sponsors on other space stations, perhaps the commercial space stations, perhaps the Russian one, maybe even the Chinese one someday; who knows, maybe we'll be doing investigations there as well. This is our chance to acquire the full set, the fullest possible set of answers for future exploration. When I said that I could not imagine going off into the universe without the Space Station, I really meant that. To do so will be foolhardy, will be suicidal, will be asking for failure.

Does that clarify?

JOHNSON: That does clarify.

CHARLES: Does it emphasize it enough? Because I could go on at great length if you'd like me to.

JOHNSON: No, that's a good answer. Is there anything we haven't mentioned, talking about Space Station, that you'd like to mention?

CHARLES: No, I think I've dabbled in all the points that I wanted to, and maybe even offended a few people. This is probably good enough for now.

JOHNSON: Okay. I appreciate you coming in today and talking to us. Thank you.

CHARLES: Oh, I'm delighted. Thanks for asking me.

[End of interview]