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INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is August 7th, 2015. This oral history session is being conducted with John Charles in Houston, Texas, as part of the Johnson Space Center Oral History Project. Interviewer is Sandra Johnson. This is the third interview with Dr. Charles.

You mentioned in our last interview that simultaneously with the STS-107 mission preparation you were also the NASA life sciences liaison to the Mars Exploration Program, which required understanding of the design reference mission and its requirements for sending astronauts to Mars. Was that part of that early Bioastronautics Critical Path Roadmap? Or how did that fit into that?

CHARLES: Yes, it was. It was part of it. It was all linked together, and it was linked together in large part because I was the one doing it. I kept getting these assignments. I always said that my mail code and my job description never lined up. I was always either one mail code behind or one mail code ahead of what I was doing at the moment. That was the mid to late ’90s. I had established myself, not as the cardiovascular head anymore, but as the go-to guy for these off-the-wall projects.

The STS-95 NASA chief scientist, I was the guy for that, and then because of that, I became the [STS-]107 chief scientist, and because I was available and also interested, I became the liaison to the Mars planning organization, Doug [Douglas R.] Cooke’s group here at JSC, Bret [G.] Drake and [B.] Kent Joosten and John [F.] Connolly are names in that group.

Also because the requirement came up to identify the risks to the astronauts on long duration spaceflights beyond low-Earth orbit, I became one of the members of that. I'm never the first of anything, but I'm the cleanup hitter. Britt Walters led the risk planning activity for the first few weeks or months, and then he went off to do something else, and I was available and was asked to help do that. It was me and Lauren Leveton and Frank [M.] Sulzman from Headquarters on Joan Vernikos' staff.

The three of us, the three musketeers, were the ones that were trying to decide how to approach the risk assessment problem of bioastronautics. The perception internally and externally up until that point had been that bioastronautics and space and life sciences in general was an effort to see what was cool and groovy and fun to do in space from a biological perspective, but not really relevant to solving risks, solving problems of astronauts in spaceflight, either on [Space] Shuttle flights or on longer [International Space] Station flights or exploration class missions.

Our assignment was to understand what risks were really out there to be addressed and how close our program was to addressing those risks, and to have a tally. With a great deal of effort, we compiled a set of 55 risks to astronauts. That was after a great number of internal and even external discussions about what we should be focusing on. We decided that our job was to understand what I always called the worst case, what more politically correctly might be called the most challenging situation, which would be the piloted mission to Mars, including a landing.

My insights from the exploration community were that they were planning and working on a specific design reference mission. It's up to iteration 5 I think now. That was very simply the 6 months to Mars, 18 months on Mars, and 6 months back. So, it's a 30-month mission.

If we focused our bioastronautics research efforts on that mission scenario, we would identify, just going through the mission, all of the risks we were likely to encounter in the most challenging case. That became our scenario. Then the effort was to go back to our subject matter experts at that time, and that was still before the creation of the Human Research Program [HRP]. Bioastronautics was still being managed out of NASA Headquarters [Washington, DC] with obviously its largest contingent here at JSC.

The subject matter experts were for the most part here and it was a straightforward but not simple matter to essentially debrief them or interrogate them as to what the risks were. Any time somebody thought of a risk we wrote it down. There was very little filtering. It was really a collecting process. That's how we came up with 55, and it might even have been more originally. I'm forgetting the actual progression, but 55 sticks in my head.

After we had the list compiled then we tried looking for mixes and matches in between them, so if two different subject matter experts in two different disciplines identified something that sounded the same, then we would say, "That's really just one risk, and it satisfies two potential customers."

We did spend a lot of time doing that in the late '90s up through 2004. It had reached a steady state by the early 2000s. Like you said, that was in parallel with the 107 planning.

Frank Sulzman, Lauren Leveton, and I were the honchos for that and were briefing that and were—I guess the phrase is socializing that—telling people what we found and what they told us and what we heard them say, and these are the sets of risks. It reached a bit of a steady state. Then [NASA Administrator] Mike [Michael D.] Griffin came along and did the housecleaning effort at Headquarters, the ESAS [Exploration Systems Architecture Study, 2005] process early in the Mike Griffin era, after *Columbia* [STS-107 accident, February 1, 2003] and

after Sean O'Keefe left. He was really focused on the "next thing." He was not a big fan of the Space Shuttle or the Space Station, but he was willing to tolerate them because they were already in work.

He was really focused on exploration class missions. As far as I can tell from my place in the hole in the ground down here at JSC, he scrubbed the Headquarters staff pretty successfully to get rid of a lot of so-called extraneous personnel and expertise. He was responsible for the Human Research Program being created and for it being headquartered down here at JSC. It's still a NASA-wide function but it's embedded in what was the Space and Life Sciences Directorate, now the Human Health and Performance Directorate [HHPD], here, just because the same people would have been involved in both organizations. I get my paycheck from Jeff [Jeffrey R.] Davis, Director of HHPD, and I get my marching orders from my Program Manager, who gets them from [William H.] Gerstenmaier, who is now the head of Spaceflight [Human Exploration and Operations Mission Directorate].

At that time the effort really did focus on missions more. It became a more serious effort because Mr. Griffin essentially caused the Fundamental Space Biology Program to be eliminated, almost completely zeroed out, the Microgravity Sciences Program almost completely zeroed out. The story I hear is that he was on the way to do that to the Human Life Sciences, being advised by two of his astronaut colleagues that they really didn't see any value to this human life sciences stuff, because we got the Space Shuttle figured out and you're not going to need the Mars thing for 30 years, so surely you can go buy it when you need it. He was on his way to signing off, I imagine, on the disbandment of the Human Life Sciences Program. I have been told, I hope it's correct, that Jeff Davis was briefing him at one point and said, "You can't turn that back on. In 30 years if you want that it will not be there. NASA is the only customer

for human research leading to people going to Mars. Nobody else is doing that. You can't go find that somewhere else. We can't pull a book off the shelf and read it, because that book is not being written yet."

Griffin apparently, to his credit, said, "Oh. I didn't realize. That's not what I was hearing from my astronaut advisers. Thank you. We'll only give you a 50 percent cut instead of a 100 percent cut." The Human Research Program was then put in place. The Headquarters function became embedded at JSC in the life sciences organization. Because of the decreased resources and the increased scrutiny and the increased focus, we became even more diligent than before in scrubbing our list of risks, and it is now down to I think 33 risks, about 20 something of which are Human Research Program research-related risks, that is risks that are amenable to research.

Back in the 55-risk days we also included things like failure to provide adequate life support system, which is not really a risk, because if you don't have a life support system in your rocket ship you don't push the button that says "launch rocket." It's obviously something missing. That's a programmatic risk but it's not a human risk, and there's a difference there. The programmatic risk, how much is it going to cost to fix this deficit, versus the human risk, what's going to happen to the astronaut halfway to Mars when they suddenly realize they forgot their life support system, that's the kind of risk we dealt with.

Also going stream of consciousness here, I'm reminded that our pals the engineers, of whom Rick [Richard W.] Nygren was our in-house engineer expert—have you interviewed Rick Nygren?

JOHNSON: We have.

CHARLES: He is one of my best buddies, one of my best friends, and he has got such a diverse background. It was a real godsend to have him as part of our HRP initial staff.

He kept saying, "If you life sciences guys talk about risks, you're talking about these 1 percent chance risks and 0.1 percent as being serious. Every time the Shuttle launches with the turbopumps running, they've got a greater than 1 percent chance of the thing shredding itself and killing everybody and destroying the launch pad. Your risks really don't look like much to those engineers who are worried about life-and-death issues."

That led us to the discussion: should we just close up shop because our risks are so trivial? Or should we assume the astronaut are going to survive the launch, and then our risks become important? Because darn it, they survived almost all the launches, we really can't say that we're irrelevant, because after the main engines shut down and the turbopumps cool down, then we're the big risk. For the first eight minutes he's right, but for the next three years, it's our problem, not theirs.

We thought that was a good justification. We were pretty proud of ourselves when we came up with that justification, and we persisted. There are still some folks that toss that argument at us, and we obviously have a well rehearsed answer now.

JOHNSON: It makes sense because they have to survive after that eight minutes.

CHARLES: Should we just say, "Goodbye, good luck, you're on your own, let us know if your bones dissolve"? That was a big picture of what was going on. I think I've exhausted that train of thought for the moment.

JOHNSON: You mentioned that there were the 55 and then you pared it down to 30 plus. Once they were identified by those subject matter experts, were they categorized and then prioritized? How did that happen? What was that process?

CHARLES: You've said the magic word. Every manager loves to prioritize. They all have different ideas about what a priority really ought to be and how it really ought to be done. Yes, they were categorized. I'm good at categorizing things. I look for mixes and matches; I look for likes and not likes. It was pretty obvious. The bone guys were telling us the bone risks and the muscle guys were telling us the muscle risks. It came self-categorized, but there were some overlaps like bone and muscle overlap, and the cardiovascular system is in there too, and the neurosensory people, the sensorimotor people overlap with muscles. There's some of that.

Integration became one of our major efforts in those early days, because we were so terribly desperately stovepiped. The bone people were only interested in bone problems. Even the muscle people didn't worry about bone problems. They worried about muscle problems, even though bones don't exist without muscles and vice versa. Being a cardiovascular guy, I can say without fear of contradiction that we were the same way in the cardiovascular area, because it's cardio and vascular, and the heart people don't care about the plumbing, and the vascular people say, "The heart is just a pump, don't worry about it, it's always there, it pressurizes our cool blood vessels."

I get that. But, having the perspective that I had acquired at that time and I have continued to acquire, I'm also one of the people that argues for integration and for multidisciplinary approaches to things. That is such an obvious direction to go in a program like

ours when we're worried about reducing the risks to humans in spaceflight, and it has taken so much effort to break down the stovepipes amongst our own subject matter experts.

I tried futilely, that is with futility, early on at one of our annual life sciences meetings to gather all the subject matter experts together and to put all the risks up and say, "I'd just like all of us to take off our specialty hats and look at this risk list and decide collectively which ones are the biggest risks and which ones are not the biggest risks."

I could not have been more naive, because that is an ideal way to set people against each other. If you say that your risk is more important than my risk, that means you get more funding and have job security, and you're hanging me out to dry. Let's collude. I'll say yours is important and you'll say mine is important.

At the end of the exercise, which only lasted 45 minutes before it dissolved completely, every risk was at the top right-hand corner of the five-by-five risk matrix. They were all fatally impossibly difficult to do. Clearly I learned a lesson quickly that I couldn't rely on our subject matter experts to give a dispassionate answer to the question, because we didn't hire them to be dispassionate, but we hired them to be specialists. They are specialists, and they insist on being specialists. It's very hard to break that mindset if you go out and train scientists to be specialists in an area academically and then you bring them in and say, "You're a specialist in this area, but now focus on that area." Then you say, "Oh, by the way, what I just told you, don't focus on that area, give me a broader perspective." It's a recipe for schizophrenia, and I try not to be schizophrenic.

We've spent a lot of time at the management level trying to do the mixing and matching and trying to decide what the categories were and what the priorities were, and we're still struggling with that today. Bill [William H.] Paloski, who is our new Program Manager—for the

last two years—I guess he's not new anymore, but he's the Program Manager for the Human Research Program—was at NASA for a while, he left for several years, to the University of Houston as a tenured professor, and then got lured back to be the Program Manager. He does have the clarity of vision to help us to see when things are too stovepiped, and he has the academic credentials to call people's bluff and say, "No, you can't keep doing your thing. We're not going to do that thing anymore. We've solved that problem. You don't get to have a lifetime endowment to study a problem we don't have." We've got problems in the human life sciences area that need to be resolved before we can tell the engineers how to build the rocket ship. If we don't give them the answers that we want, they will make something up, and then the Mars vehicles will not solve our problems and cause other problems, and it'll be our fault because we weren't there with the right answer. We're doing an awful lot of focusing down.

The reason I reacted so intensely to the word prioritization is that every life sciences manager, and every other manager in NASA, cannot resist the lure, the siren call, of prioritization. Give me a list of things, and I'll tell you which ones are more important and which ones are least important. Then you say, "That's great. You put all your resources in the bone problems. Right now we've got carbon dioxide in the cabin and it's suffocating people. Are you cool with that?"

They'll say, "Oh. Well, no." They put carbon dioxide up there.

You say, "You've solved the carbon dioxide problem but now the food is all spoiled because we don't know how to protect it from radiation. Not a problem?"

They say, "Oh. Well, no." Everything gets to be the topmost risk again. They are all naively seduced by the idea of being the general, the admiral, and pointing fingers, and telling people how to go prioritize and you do this and you do that and when you fix your problem come

back and I'll give you a new assignment. There's a lot of subtlety that has to be beaten into people.

Recapping, we're still doing that. I like to say we're fighting the battle. We're still engaged in that process, and it is extremely difficult to do with smart good subject matter experts. The people we went out and hired to do this job because they're the right people to do this job are not good at doing this other job that we now decide is important.

That is probably going to be one of the things that takes the rest of my career and the rest of our management staff's time at NASA, just trying to make the program responsive to its actual customers, the engineers, who fully live the idea that better is the enemy of good, and if I can get you an 80 percent solution, don't hold out for the 95 percent solution or the 100 percent solution, because we can't afford it, and somebody else needs an 80 percent solution in the meantime.

We're trying to decide how far to go in those directions, but we are right now telling our subject matter experts that we're done with your discipline area. In my particular case, I work in the orthostatic intolerance and cardiovascular area. I am the one that tells the cardiovascular guys: we're done with this problem. If you faint when you stand up after a spaceflight, don't stand up, it's not that hard.

They say, "Yes, but the mechanisms are important. It's important to understand the mechanisms because you can't design the best countermeasure if you don't know what the mechanisms are. You can't fix the watch that's broken if you don't know the pieces that are broken."

I say, "That's not our job. Our job is to keep them conscious while they're landing on Mars and getting ready to go outside on Mars." We know how to do that. They land seated or

recumbent. It happens all the time on other rocket ships. You give them a G-suit [pressure suit] because you make them take the G-suit off when you do your orthostatic testing on them. Obviously it works, otherwise, you wouldn't make them take it off before you test them. When we test them, they take their G-suit off after a spaceflight, and make them stand up quietly or put them on a tilt table, and tilt them until they faint.

We say, "Don't move your legs because that constricts the blood vessels and gets the blood flowing back to the brain, and we're trying to avoid that." So, we've got ways to keep people from fainting. Keep them seated or recumbent, keep them in their G-suits. Don't let them stand still. All the things we do to them to understand the mechanisms of the cardiovascular system, that is the right way to do a mechanistic scientific study, but that's not what our job is. Our job is to keep them functional and conscious when they're on another planet. We know what to do. Let's not do this other stuff anymore. I'm not saying science is bad. I'm not saying understanding the mechanisms is bad. There may be a Nobel Prize in there for somebody, but that's not what we can spend our limited dollars on to solve problems for the Mars or for the exploration class missions. We got to focus.

It is very hard for me as a cardiovascular guy to convince my successors as cardiovascular guys that this is the right approach. They keep saying, "Oh, well, we don't know for sure that one-third of a G [force of gravity] on Mars will not cause them to faint. We don't know for sure whether the space radiation will cause vascular problems that will cause them to have other problems later on."

I'm saying, "Yes, we do. I will sign on the dotted line that that is not a risk anymore. I will be accountable in 30 years when the Mars astronauts all die because they fainted when they

stood up and the blood didn't flow to their head. I will take the blame for that. Let's move on to something else."

We have the same problem in the sensorimotor, the neurosensory area. Space motion sickness is extremely important. It goes away, sort of, in three days.

"Oh, well, it does, but we don't know if the nervous system is being restructured and rearchitected while they're in space, and then when they are exposed to another gravity field they may not respond the same way." That's all true. Nobel Prize material. Not part of our job description. Our job description is to help them land on Mars or another planet and successfully survive, stand up, be able to ambulate, do things, pick up rocks, discover life, discover ancient civilizations, whatever is on the planet. We don't have to understand every neuron in the vestibular system, how it got rewired during the six months of weightlessness. They're not going to be totally different. There's going to be some functionality. We know that because the astronauts coming back to Earth are still functional. Let's move on.

I call these mafias. The cardiovascular mafia and the sensorimotor mafia. That's tongue in cheek, but they're extremely internally focused. They really really think I'm wrong. They think it's unethical and immoral for me to be saying these things. It's really a matter of education and then at some point saying, "We're done, we can't focus on that anymore, I know you're unhappy about it, I know you're going to argue with me, I know you're going to file a dissenting report, but we have to move on."

That's the situation we're in in the cardiovascular area, the sensorimotor area. The bone area, we actually do seem to be having a countermeasure that is the Resistive Exercise Device, plus the bisphosphonate, the Fosamax, the alendronate does seem to protect bone density on six-

month missions and bone architecture. We'd like to get away from the pills, so we're now finishing up the study of the resistive exercise without the pills.

By accident when we started doing the study a decade ago, we assigned the same astronauts to do the exercise and the alendronate pills. Science 101, your first day in science school, is don't give two interventions to the same test subject. We seemed to think it was no problem. I don't know if I'm responsible for that decision or not. I don't know how we let it go, but we have this population of people that did the resistive exercise and the pills and now we're doing just the resistive exercise in a separate group of people to see what the differential effects are of the pills and the exercise.

Embarrassing. There it is. It happened, and we're recovering from it. But, we do have evidence that resistive exercise is going to be a big part of the solution to the bone architecture problem. By architecture I mean the internal structure of the bone, which is as important, or more important than the total bone density. We talk about losing calcium out of the bones, but it's important where it comes from, because the bone is just not a slab of bone, it's got architecture inside that is designed by the celestial committee on design to resist the loads that the bone is exposed to. It's beautifully engineered to do its job. By putting it in weightlessness we change that engineering, and then we bring it back to gravity and say, "Oh, you're back where you were before." The bones are saying, "Yes, but I don't have that capability anymore, what are we going to do about it?"

That's okay. We seem to have a solution, a big—a gross—that is a top level solution to that problem. When I say gross I mean not subtle, not elegant, but a functional solution to that problem. The bone people still are unhappy because they want to do the bone studies. We're saying, "Getting pretty close to having a solution. The best solution we've seen in a long time."

The immune folks are still in the rudimentary stages of collecting data and trying to determine really are there immune changes. There are immune changes, but they're trying to understand how significant and what direction they are and what the problems are. We have neglected the immune studies for a long long time, and now it's biting us on the backside. We're trying to learn what is important about the immune functions.

JOHNSON: What type of immune changes are there?

CHARLES: There are increased viral reactivations, they call it. That is, we all have viruses. Sometimes you get the sores in your mouth. Those are viruses that are being reactivated by stress or something you ate or something. We all carry those viruses around. You have outbreaks of these viruses in your body. They can be detected in your blood and your saliva.

It seems to be related to stress. Astronauts have increased stress responses even before they launch because they're so overwhelmed and overworked by the preparations for launch. Sometimes the stress levels and the viruses and the other indicators go back down in space and sometimes they don't, depending on the response, the characteristics of the mission. There are different kinds of immune function. There's the intrinsic, the innate, and then there's the adaptive, which is responding to stimulation, to the problems that activate the immune system. I'm not an immune expert. I just told you everything I know about it.

The point is there are many kinds of immune functions that we're trying to understand. There's also the evidence that some of the potential stressors like bacteria and viruses might be made stronger by being in space for some reason. Like *The Andromeda Strain* [book by Michael Crichton, and film], except not quite so dramatic.

JOHNSON: Let's hope not.

CHARLES: *E. coli* [Escherichia coli bacteria] and things like that seem to be expressing unfortunately more robust variants in spaceflight than they would on the ground. There's a lot of work amongst the microbiologists to understand what's going on with them and what about spaceflight is making them more robust and more of a problem for causing illness and disease amongst astronauts.

I haven't even talked about the psychological/psychosocial aspects of spaceflight. This is an area that we're putting effort into. We're focusing on this. My perception is that the psychological/psychosocial domain is able to judge its success by the ability to avoid psychological problems or if they occur by the ability to defuse them and to resolve them. The major work they're doing is developing metrics for understanding when these problems might occur in a crew in space and then understanding how to rectify the situation if there is a problem, like an open conflict. How do you go through conflict resolution, how do you build teams so they don't have conflict, what happens inside of a single person's head that might predispose that person to having psychological problems that can be related to spaceflight?

It's not weightlessness per se. It's the isolation, confinement, the distance from Earth, the autonomy, the small group of people, the same five other faces for two and a half years would probably make most people wacky. The small volume available, you can't go out for a walk, you can't really get too far away from somebody else, so how do you maintain distance. Guys like me would not do very well in the situation, because I don't like large numbers of people or even small numbers of people, and I don't like being confined like that so much.

There's selection criteria that need to be understood, and then especially the countermeasures. Psychological/psychosocial people, which we call behavioral health and performance, are interested in documenting problems in spaceflight. The last things astronauts will tell you about is any psychological problems they had in spaceflight, for a variety of reasons. Luckily we have ways of understanding through some simple testing cognitive changes, that is brain function changes, that may be occurring in spaceflight, which may be related to psychological or psychosocial problems.

We also have for a group of astronauts on the Space Station convinced them to let us read their diaries. It's a very walled-off investigation. Jack Stuster from out in California is the PI [Principal Investigator] for that. He proposed this, and we liked it so much, we keep renewing him and getting him new populations, because many astronauts keep diaries in space.

What he does is say, "If you keep a diary, let me read it. I will maintain it, protect it, nobody will ever see it again, I promise." We've tested that, and nobody else gets to see it. He gets to see it. Then he goes through and analyzes the content of the diary and categorizes the statements so that he will say that people—and he won't say who—but he'll say that 62 percent have problems with Mission Control, or 61 percent have problems with each other but they blame Mission Control, things like that. He gave us some very very good overall feedback about what happens that can be gleaned from diaries. That's an example of data that we get.

I like to say that when you look at the chart that I have of the changes that occur in the human body in spaceflight, many of the physiological parameters respond quickly to going into spaceflight, presumably respond quickly to weightlessness. Your fluid volume shifts and the corresponding line on the chart goes up. Then at some point your fluid volume is regulated and your nervous system responds appropriately, and so the line comes back down. Your vestibular

system responds to the absence of apparent gravity. After it figures that all out the stress comes back down. Bone loss continues for the time that you're in flight unless you're doing exercise. Muscle loss tracks bone lass because it responds to the exercise. Radiation exposure: the longer you're in space, the more radiation you get. So, that line continues to increase essentially indefinitely.

The psychological aspects of spaceflight may well be along the bottom axis of the chart: nothing, nothing, nothing, nothing, nothing, nothing, oh my God, disaster. There's not a line to it and there's not a response time to it. You can compensate as a group and as an individual until you can't compensate anymore, and now the specialists are trying to understand what are the markers for that, how do we know when somebody's getting close, how do we help that person stay compensated. We call those metrics and countermeasures.

The purpose of the research in that area is to understand that problem and most especially to develop, deliver, and validate those countermeasures, so that like the rest of us when a program decides to send astronauts to Mars, they can pull the book off the shelf that will have been written and open up the chapter that says, "Psychological/psychosocial and here are the countermeasures, here's what we're going to do to keep our people happy and healthy on the way to Mars."

It's difficult, as I said, to get astronauts to tell us about the problems they have unless they're keeping a diary, and then somebody knows about it. They just tell us indirectly in general terms what the problems were. The flight surgeons know but they can't tell us. The psychologists know but they really can't tell us. So, we're doing a lot of the work—this is a very long story, I'm getting to the point now—we do more and more of the psychological work in isolation facilities on the ground, where we can put people together in situations that we

wouldn't be able to do in spaceflight. Typically up until now they've been graduate students, or undergrads. We're trying to get more people like real astronauts in their forties and fifties and having done things in their lives, not academics. Engineers and whoever else, and putting them into isolation facilities.

We have the HERA [Human Exploration Research Analog] facility here at JSC. There's the NEEMO [NASA Extreme Environment Mission Operations] facility in the Florida Keys. There's the HI-SEAS [Hawaii Space Exploration Analog and Simulation] on the volcano in Hawaii which we have a funded investigator working in. There's a facility in Germany. There's a facility in Russia. There are others that we are not allowed to work on in China. People are doing this kind of work and we're trying to coordinate all that, or at least understand what everybody else is doing, so we know what's being done and what needs to be done and learn the lessons from what has been done.

We will take the work from especially our facilities that leads to a countermeasure and then try to validate—whatever that means—that countermeasure in spaceflight. We're not going to be doing these stressful situations on the Space Station. We'll be doing them in the analogue facility, the isolation—and Antarctica too, I forgot that, and there's some in the Arctic as well—then take the lessons learned, develop the countermeasures, and put them on the Space Station for use in case of a problem, but also try to figure out a way to validate them by causing small problems that hint at the issues and see if our countermeasures prevent them or correct them. Or if we're doing countermeasures that are preventing the problem, I guess we incorporate those. Is the absence of a problem evidence of our success, or is absence of a problem evidence that there was no problem to begin with? It's one of those dilemmas that we will have to figure out at some point.

This comes back to what I said earlier about the risks of spaceflight and the fact that we're looking for 80 percent solutions, because we will not be able to mimic every future Mars mission until we fly every future Mars mission. We have to use our best guess based on the insights of a lot of very smart dedicated people to decide what the problems really are likely to be and what the best solutions are likely to be. When I say likely in both those contexts that's not 100 percent. That's 60 or 70 or 80 percent times 60 or 70 or 80 percent. We're talking about a reasonable chance that we've missed the boat at some point in all that work we've been doing, but it's not because we're slackers. It's not because we're not trying our best. It's just because sometimes you don't know things until you know these things.

JOHNSON: It's like the eyesight problem that just popped up relatively recently.

CHARLES: But, was there all along.

JOHNSON: Yes. We talked about that before. It's difficult to figure out what all the problems are going to be when you don't know what all the problems are going to be.

CHARLES: Chuck [Charles A.] Berry, the Chief Flight Surgeon here at the Manned Spacecraft Center back in the '60s, used to tell Deke [Donald K.] Slayton and the other engineers, "Deke, you won't let me take any of your astronauts and test them to destruction, so I don't know what their breaking points are. You can do that with the hydraulic system or a rocket engine or a landing gear or parachute. You can take some off the assembly line and break them and know

what their characteristics are. But you'd get mad if I do that to your astronauts. So we have to do the best we can without that kind of definitive information."

That story is still true today, still correct now.

JOHNSON: There was a lot of unknowns early in spaceflight, so if you don't fly because you don't know, then you'll never know.

CHARLES: You never know. You just have to cross your fingers and say, "I'm pretty sure I got this figured out and I feel good about the risk we're taking and we'll learn something along the way." I think it's been a successful model globally up until now.

JOHNSON: I think so too. Going back to that 2005 time period, President George W. Bush's Vision for Space Exploration after the *Columbia* accident, and then the subsequent designation of the U.S. portion of the ISS as a U.S. National Lab. That's about the same time that the Human Research Program—as you talked about the change there. Talk about that time period as far as whether that designation as a National Lab—because the idea was to start the research coming from different places, not just NASA. You had mentioned before that prior to 107 science was the stepchild as far as NASA was concerned. Then you're in a process of trying to build the Space Station and having setbacks, but then they've designated this as a National Lab, so now science is becoming somewhat a priority, but you're still building a Space Station. Talk about that time period and just how much research was going on in your area on ISS in those early years.

CHARLES: In those early years we were the beneficiaries of that because even though it was designated as a national lab, it was not clear to us what that meant. I naively thought early on that that was good for us because obviously we're doing lab science, so that must mean that we have priority. I was wrong. It's non-NASA research and if I'd read the legislation or any of the descriptions more carefully or at all I would have seen that. But, it made no difference to us. We became the de facto dominant science because we take so much crew time for our biomedical research. A lot of other science can be done with minimal crew time because the astronauts set it up, turn it on, walk away or float away, and then come back later, and wonderful things have been accomplished in the meantime because of the design of the experiment and the design of the hardware.

Our stuff almost always requires continual attention and involvement of the crew members, so, we're the biggest crew time user. Up until the last couple of years, literally until the early 2010s, essentially we did not reach the limit of what was available for our human research. There was limitations on how much mass can be launched and scheduling, how much power and mass and volume. Up until the last couple of years, 2013-ish or so, we could accommodate pretty much anything we wanted to accommodate. We did a lot of self-regulation, self-censoring, so we were, for the Human Research Program, focused on risks that related to exploration class missions. We were not just throwing things willy-nilly at the Space Station astronauts but we were not bumping against any limits.

That was because CASIS [Center for the Advancement of Science in Space], the organization chartered to manage the National Lab aspect of the Station, which is 50 percent of all U.S. resources, was still getting off the ground. They did not have meaningful significant

investigations to put on the Space Station. We took up the slack. In the last couple of years now they've started coming forward and saying, "We want our 50 percent now."

We keep saying, "But we've already filled that 50 percent up."

The Station Program says, "Sorry, guys, they got dibs. You only got it because they weren't ready yet, but now they're ready."

We say, "Yes, but we're important, we're solving problems for going to Mars."

Everybody else says, "Well, that's true, except that's not the only thing we're using the Space Station for." It's a little bit of the "jilted lover" thing. You told me I was number one and now I'm not, and now you've got another boyfriend on the side and you don't want me to leave but you don't want me to be the only one either.

I may have mentioned this before. It's even more pointed than that because number one, we're not sure what it is the National Lab, what CASIS is doing. Much of what they do looks to us like frivolous. They defend it obviously as being very meaningful. Especially if it's commercially sponsored, the commercial folks don't want anybody to know what they're doing because there's intellectual property and there's corporate secrets. It's hard to defend something you can't really talk about.

We feel like our heavenly mandated charter to solve the problems for astronauts going to Mars really needs to be the most important one. Congress keeps telling us, "No, I'm sorry, you're not as important as you think you should be. It's important to develop the infrastructure that's going to keep space going, and that's going to require commercial investment. This is how we do that. We're giving them a chance to develop their capabilities so they have a future in space that will benefit all of us." I understand that.

Over the last couple of years—I keep saying last couple of years. It's really in the last year or so. We've really been constrained with cutting back on research that we're doing in space. We're focusing even more on the most critical risks, the highest priority work. The discussion we had earlier about categorization and prioritization activity, those really are current events for the Human Research Program, for HRP. We're still struggling with how much is enough to answer the question.

Rule of thumb for physiology in spaceflight at least is 10 or 12 crew member subjects all doing exactly the same thing is enough to even out the biological variability between people. Tall, short, fat, skinny, young, old, male, female. All those features and more caused slight differences in the way the body responds to a stimulus, a stress, a condition. But, you don't want to know what Fred's response is and what Susie's response is, you want to know what the human response is. The variation around that average is Fred and Susie and male, female, and old and young.

We say we need 8 to 12 crew members to do the exact same thing. We're probably not going to get 8 to 12 crew members in the new constrained era because the crew time is now being taken up by the National Lab activities. We have to really focus down and we have to go through some self-education processes. We have to decide since our 8 to 12 rule of thumb is really based on a diverse population, and astronauts are not diverse, they're carefully selected, they're screened, they're really almost all from the same cookie cutter. When you look at crew photos and you see the "moose" and you see the tiny little female you say, "They're not the same." There is some diversity but it's nothing like in the overall population.

On the Space Station they really are getting to be much more homogeneous. Can we reduce our requirement from 8 to 12 down to 6 or 5 or 4, based on the fact that these guys and women really are pretty much—they're much more alike than the general population?

Also, can we reduce the power of the statistical analysis? There are rules of thumb we all learn in science school: 0.05, 1 chance in 20 of a random variation. If it's less than 1 chance in 20, 0.05, then we'll call it significant. That'll be a meaningful difference due to whatever your brilliant intervention was. Maybe we don't need to have that kind of power in our statistics. Maybe we're looking for gross changes and not subtle changes.

If I put an astronaut in space and there are differences but they're not meaningful differences, well, then that's good enough. Again it gets back to that whole 80 percent solution problem. Yes, you're going to lose bone. Yes, you're going to lose muscle. But, you're not going to lose so much that you have a fracture risk, for example. We can live with that. That's not elegant. It's not beautiful. It's not Nobel Prize-winning, but it'll get you to Mars and back and you'll be functional there and back.

That's the education process we in the Human Research Program, both at management and at the scientist level, are going through now. Understanding with the help of some very clever statisticians that are largely writing the literature on what we call small *n* statistics, *n* being the number of people or subjects that are participating, small *n* being a small number, 2, 3, 4, 5, versus 10, 12, 100, 1,000. With that kind of guidance and that kind of sensitivity we are with difficulty making those adjustments. That allows us then to continue being useful on the Space Station even in the face of having seen 50 percent of the resources that we normally use now dedicated to the National Lab for the greater benefit.

JOHNSON: I was talking to Mike [Michael E.] Read. He mentioned that the addition of a seventh crew member is actually going to double from the average of 35 hours a week to approximately 70 hours a week of actual crew time. Is that then divided in half for you?

CHARLES: Yes, it will be. I will tell you now, digressing again, that that's a lovely story for them to tell us. "Oh, just wait till we get the seventh crew member on board. Then crew time is not going to be a problem anymore." When the Shuttle started flying there was two astronauts on board the first four flights. The story was always, "These guys are flying, you can't bother them, but when we put more people on board then there'll be time for science." Then they started flying four astronauts. One of them was the flight engineer, and then the other guy was the arm operator. The response then was, "It takes four to fly the Shuttle."

"Now wait a second. You told me it took two to fly the Shuttle, now I see four, now you're saying it takes four to fly the Shuttle."

"Yes, but when we put more people on in later flights there'll be plenty of people to do your science." Then they started putting five on. "It takes all five of these people to fly the Shuttle."

"Wait a second. It took two. Are there just not as good astronauts anymore? Because it took two guys back in the early '80s and now here in the late '80s, the '90s, you're telling me it takes five people to fly the Shuttle."

"Oh, well, they have a lot of important work to do, and it's not yours, but it's somebody else's work." Then the two payload specialists came along. "Those are your two guys." Sometimes they were not even scientists. Sometimes they were congressmen and Saudi princes, but they were our test subjects. Out of seven people on a crew we got one or two, nonscientists,

pretty much baffled by what we were asking them to do. But, they had the benefit of not being familiar enough with it to improve on it, so they would follow the checklist if they could.

Then after *Columbia*, no more payload specialists, except for Neurolab. Then it became seven people on the Space Shuttle routinely and none of them were ours, because it takes, say it with me, "Seven people to fly the Space Shuttle."

Now Space Station. Three people were on board. They're busy maintaining and scrubbing the walls and building and constructing. The Shuttle comes up. Yes, they're dropping stuff off and leaving stuff all over, and then these poor three schmucks on the Station have to put it all together and put it all away and get functional.

Then there's another Shuttle mission with another seven people kicking stuff and breaking stuff and dropping more stuff off. Then the three guys have to go do it again. "But when we get four on board, or when we get up to six, then it'll be good."

No, it's not good. I am quite anxious to see for the first time in the history of spaceflight the addition of the seventh person that will make our research suddenly just flow like milk and honey out of the River Jordan.

JOHNSON: It should be interesting to see, especially since now that it's moving from an assembly period into a utilization period, and as you mentioned with 50 percent of it dedicated to other than NASA research, and part of that being commercial. Of course that helps NASA. It also helps NASA in political ways because they have someone that can go to Congress and fight for them, and NASA doesn't have to necessarily do that. Now we have commercial interests that want to see the ISS succeed, and something to follow after ISS. You see the benefit of these

commercial partners, but at the same time NASA is still exploration and your area has to know what's happening.

CHARLES: Nobody has taken this responsibility away from us. Nobody has said, "You know what, we're more interested in commercial success than in preparation for exploration. Relax, HRP, the pressure is off, don't worry about it." Nobody has said that to us. Carolyn [L.] Huntoon, one of my early mentors here, when I used to feel this way, I used to feel just like this back when I was in the Cardiovascular Lab.

I'd go to Carolyn, because she hired me. I felt like I had entree to her. I'd say, "You've given us several things to do, all of which take 100 percent of the time. Which one is your priority?"

She'd say, "John, they're all first priority."

I'd say, "I get it. None of them are first priority. I get to choose which one is the first priority." It's the same way with the Space Station research we're doing. Our work is important and we're trying to fit into a box.

Gerstenmaier tells Paloski, "I'm not telling you to stop, I'm just telling you to go figure it out." He's saying, "You, Paloski, and [Michael T.] Suffredini, and [Gregory H.] Johnson, go figure it out. You're all smart boys. You were hired because you know how to do things, so go do this thing. I'm not taking the responsibility away from you. I'm not going to say HRP first, then commercial, then Space Station. I'm saying they all need to be done. They're all first priority. You're all smart. Figure it out."

JOHNSON: It should be interesting to see how it plays out here in the next couple years.

CHARLES: It should be. I'm very pleased to see, reading in the space press, that the last Space Station Research Conference was so well attended. People are so enthusiastic finally about the Space Station as a research venue.

JOHNSON: The one in July that just happened, that Research and Development conference?

CHARLES: Was it in Boston? I think it was in Boston in July.

JOHNSON: Yes.

CHARLES: Yes. I'd been to the first few of those, and they were lackluster, but apparently now it really looks like the potential customer community is getting enthusiastic. Not a moment too soon. You're right though that anything that keeps the space program vigorous and healthy and active is going to be good for all of us. A rising tide really will lift all boats and we will get more visibility and more credibility and have more responsibility. Not as much as we want, but more than we would have otherwise.

JOHNSON: Let's talk about the National Space Biomedical Research Institute [NSBRI] and that relationship. You mentioned it in one of the other oral histories. From what I've read, in '96 NASA, knowing that they didn't have the resources to deal with all the medical challenges, created a cooperative agreement with this nonprofit. Is it housed with Baylor [College of Medicine, Center for Space Medicine, Houston, Texas]?

CHARLES: Yes.

JOHNSON: Could you talk about that relationship as far as with the Human Research Program, since it sounds to me like it's more in line with what you're trying to do? How does NASA work with them?

CHARLES: The National Space Biomedical Research Institute was chartered in '97 and they got a 20-year charter with 5-year interim reviews. We're now in the last couple of years of that charter, and HRP is now considering how to reinitiate that process for the 21st century.

NSBRI as it currently exists will cease to function as it currently functions in 2017, but something will follow. There will be another organization with a slightly different target because things have changed. What has changed is partly perception. At least in my perception it's partly perception. In the late '90s there was the appearance of lots of these external organizations through cooperative agreements. The Space Telescope Institute, the Astrobiology Institute. All these institutes. This one was expected to be something along the same lines, that is it would provide the in-depth subject matter expertise that NASA would not be expected to provide in these biomedical areas.

I have told people, and I have been corrected, but my recollection was that the expectation was that NASA would continue to provide the project management expertise but the real intellect, the scientific expertise, would be in the NSBRI. I don't think I was wrong, even though I've been corrected, because they populated themselves accordingly. They populated

themselves with mostly world-class scientists from the U.S. primarily in all the different topic areas that NASA identified.

Along the way, NASA started to shift some personnel, especially contractor personnel, from the support contract to the cooperative agreement. Some of the in-house scientists that were contractors moved from Wyle or Krug or whatever it was at that time to NSBRI. Some also moved to USRA [Universities Space Research Association]. USRA has another cooperative agreement that supports NASA in a slightly different way.

Over the course of the 20 years it became clear that having a separate management structure and a separate organization—which had a separate charter and separate marching orders—was not going to be the best way to solve the near term problems that NASA Human Research Program had identified. NASA did not divest itself of its internal civil service science cadre, which might have been the case. NASA might have delegated or IPAed [Intergovernmental Personnel Act] or something the internal scientists to these other organizations, USRA or NSBRI, but we didn't. We kept an internal cadre. They were the favored children. They were the more beloved of the children.

The NSBRI folks were the less beloved of the children because obviously familiarity and exposure and also the fact that the internal folks were familiar with the problems of spaceflight, whereas many but not all of the external folks were new to spaceflight and needed to be educated to our very peculiar functions and institutions. Clearly there's an advantage to having new blood, but there's also an efficiency that's lost if everybody is new and doesn't know what it is, which part of the rocket goes up, and what happens in space.

Over the course of let's say the first 10 years or so, NSBRI was functioning as essentially an independent research institution, solving problems that NASA didn't really have, because

they were interesting problems, and that was what their charter said to do. With HRP becoming chartered itself and then rising to preeminence in the internal human research area, we began providing more specific direction to NSBRI. NSBRI in their various management manifestations resisted, because that was not what they were told to do, that's not what they were populated to do, that's not what they were chartered to do. It looked like a bad idea to them. It looked like these folks on the inside who were just worried about their own paychecks and their own cushy jobs were trying to get rid of the competition.

Not saying that wasn't true, but I am saying that that was not completely true and that with the acknowledgment that the NSBRI could not go away within the 20 years, a bit of an uneasy truce was established, which has become I think more comfortable and easier now, with a lot more interaction between the organizations at the management level and a lot more interaction between the organizations within the structure of the organizations themselves. To the point now where some of the civil service scientists are team leads for the discipline teams at NSBRI and where there is some travel back and forth between the organizations. Well, not as much as there might have been, but there's some exchange in personnel between the organizations.

There's also more responsibilities being offered to the NSBRI folks in the space and the HRP planning process. We're bringing some of their expertise in house at the management level so they understand what it is that we're doing and understand how it needs to be done. The NSBRI has evolved I think to becoming a "less different" organization than it started out to be. It's now appropriate for the charter to be revised to reflect the current realities and the current requirements of our reality.

They have come through their five-year reviews in very good condition. They always review well. We're involved in the reviews as part of the explanation to the external reviewers what it is we're expecting from NSBRI. Then NSBRI will say, "Yes. You heard what NASA expects from us and here's how we respond or don't respond and here are the reasons why we do or don't respond." NSBRI also has the advantage, I think you mentioned earlier about CASIS as well, that they can go to Congress and they can testify to Congress about needs and problems, whereas we really can't.

Gerstenmaier goes to Congress and talks about the big problems, hardware and funding, and might have a sentence or two in there about oh yes, biomedical problems as well. NSBRI has developed over the decades some political connections, especially here in Texas with our senators. Kay Bailey Hutchison, who has retired now, but when she was the senior senator from Texas she was well connected with NSBRI. Charlie [Charles F.] Bolden was on the board of directors before he became the NASA Administrator. Obviously he's not on the board of directors anymore, but he's familiar with NSBRI and he's a good friend in general of life sciences even as Administrator within the limits of his capabilities.

I think with the turnover in the political leadership and the fact that the cooperative agreement is now reaching its final couple years, it'll be important to come up with a different model for the extramural participation. I think NSBRI has demonstrated great strength and great value in having that extramural capability, the ability to go out and find expertise for a problem that pops up, and then when that problem is resolved not to have to maintain that expertise internally as a civil servant or retirement plans.

HRP's problems have also evolved since the late '90s. We now think we have solutions to problems, whereas we really didn't at that time. Now it's more a matter of translation, of

incorporation, what we call transition to operations and transition to—writing the book that we're going to put on the shelf. I keep using that metaphor, but the idea is there will be answers in that book and now we need to get the operators, the flight surgeons, the astronauts, the mission controllers, aware of these solutions so they can incorporate them, and the vehicle designers, so they can design vehicles that don't cause problems to astronauts based on the research we've been doing. It's time for a revamping of NSBRI and USRA and HRP to meet the needs going forward in the next few decades of the 21st century.

JOHNSON: I think that clears that up for me, because I wasn't sure about that relationship and exactly how it worked.

CHARLES: Yes. It was rough for a little while, but we're all dedicated and mature individuals. Nobody liked it being adversarial, and we've moved beyond that.

JOHNSON: That's good. You mentioned that the move from building the Space Station, the assembly mentality to the utilization mentality—

CHARLES: Right. I didn't repeat that, but for the record, that's a big deal. Going from the construction phase to the utilization phase really has changed the way the Space Station is regarded and is used. I give full credit to Mike Suffredini and his group and Julie Robinson for embracing that change in paradigm and really doing whatever they can to make utilization the priority on the Station, even though I'm unhappy that we're not the most important utilization aspect of that process.

JOHNSON: They have that Revolutionize ISS for Science and Exploration team, the RISE team. Have you been involved in any of that?

CHARLES: No. I hear about things like that but I really have enough other things to do. I'm delighted when somebody else takes on those responsibilities.

JOHNSON: Let's talk about the one-year mission and some of those aspects of what's going on in research with the one-year mission. You've been involved in some of that. If you want to talk about your involvement in it. You mentioned before that the one-year mission—and because of your current position it's interesting—is like going back to Phase I with the Shuttle-Mir [Program] because of our relationship with Russia and that cooperation. If you want to talk about that mission and what the hope is, the research that's going to be done, and then of course with the twins and the twin research that's going on because of that.

CHARLES: The one-year mission evolved over the last two and a half years. The collaborative effort was really initiated in the latter part of 2012. That was what I call the Mike [Michael R.] Barratt era. Mike Barratt was our interim program manager after Dennis Grounds left. Barratt was appointed by Bill Gerstenmaier to be our program manager for about a year to help bring us around, the Human Research Program, to focus us on the capabilities that we need to really be focused on for exploration risk resolution.

That was simultaneously with the Space Station refocusing from construction to utilization. Mike Barratt did a very good job of asking everybody what problems they had and

what solutions they might envision to get their research work done. One of the recurring themes was that we didn't have enough astronaut participants. I mentioned before the small *n* problem. Barratt, having flown on the Space Station himself and having worked with the internationals and especially the Russians and having a very tight connection with the Russians, having been the lead flight surgeon for Norm [Norman E.] Thagard back in Phase I, he has a strong insight into the Russian/Ukrainian/Slavic universe. And on the Space Station having noticed that the Russian cosmonauts were not always fully occupied for reasons programmatically on their side, he wondered why we were suffering from a shortage of warm bodies of astronauts when in fact we were only using half the crew members available.

Now about the same time there was interest on the Russian side with flying a one-year mission. I don't know, I was not privy to all of the deliberations. Along about the second half of 2012 the Space Station Program managers appointed themselves a committee of the whole, the ISS Experts Working Group to attack several different problems. I don't know how many teams they formed themselves into to address the future of the Space Station.

The teams included things like deorbiting the Space Station when its lifetime was over. How do you do that safely? Keeping the Space Station functioning as long as you can. How do you do that safely? There was a few others. One of them was using the Space Station to prepare for Mars missions, essentially code for using it to simulate going to Mars. Another one was something along the lines of facilitating international collaboration so that you don't have redundant requirements and redundant resources required on the Space Station.

The example there is some astronaut in the deep dark past checked his daily worksheet and found out he had to put on a Holter recorder, an ECG [electrocardiogram] recorder, for an American investigator, and a different one for a Japanese investigator, and a different one for a

European investigator, perhaps, and obviously asked the question, "Why can't you guys all get together and get your data from one recorder?"

Turns out there's very good reasons why there are three different kind of recorders. They just looked the same to the guy but they were really different. They had different requirements. The timeliners just said, "Well, they're all Holters and they're all using electrodes and he's got plenty of room on his chest for all these different electrodes. Let's just schedule them all the same day."

There was some naive scheduling involved as well as naivete on the part of the proposers, the scientists and everybody else. That became the rule of thumb for the purpose of international collaboration, so that nobody ever has to do three Holter recorders anymore, it became that specific. No more three cardiovascular recorders on the same guy on the same day.

That has become my dogma in my job as the International Collaboration Manager for the Human Research Program. These expert teams met. Mike Barratt and Barbara [J.] Corbin from the Human Research Program were part of Team 5. Team 5 was this multinational collaboration. Team 6 was the one that dealt with using the Space Station to simulate aspects of going to Mars. They included in that a one-year mission scenario.

The Russians may have proposed the one-year mission scenario, but NASA was very enthusiastic about it at the management level. The Russians also coincidentally saw an opportunity for more tourist flights on the Soyuz, because if an astronaut goes to the Station for one year and the Soyuzes have a six-month lifetime, that astronaut is not coming back when the Soyuz comes back. A fresh Soyuz has to go up to replace the stale one. "Oh, look, there's an empty seat going up and back in the space of a few days or a few weeks, and there's this backlog

of people that are willing to pay $60 million to do that, so perhaps we can find a happy way to satisfy both the one-year mission and the tourist opportunity."

I'm not saying those two are cause and effect. I'm just saying simultaneously we had the One-Year Mission and the tourism opportunity. The tourism opportunity does not and did not interest me, but the One-Year Mission was part of Team 6. At some point then Barratt and Barbara Corbin had done the preliminary setup work. Once again, being the cleanup hitter, I was asked to assume chairmanship of Team 5.

When the IEWG, this ISS Experts Working Group, the self-appointed subcommittee of the whole of the Station Program Managers self-assigned charter expired, our Team 5 was chartered by the Space Station program managers as the Multilateral Human Research Panel for Exploration. Each word is significant in there. We go by MHRPE. I tried to get it MURPHY at first, but the p's and the h's were in the wrong place.

I chair the MHRPE with my Russian co-chair, Valeri [V.] Bogomolov from IBMP [Institute of Biomedical Problems], and with the representatives from ESA [European Space Agency], JAXA [Japan Aerospace Exploration Agency], and Canada [Canadian Space Agency (CSA)]. The first thing I did as the co-chair of MHRPE was to petition to bring that one-year mission into the Team 5, into MHRPE, instead of in the Mars simulation working group, because I could tell, and we all could tell, that that was going to be a heavily biomedical activity. I didn't want a bunch of people that were not interested in biomedical trying to manage the flagship biomedical mission on the ISS. I thought that was part and parcel of our assignment. The Station Program Managers agreed and the One-Year Mission became part of MHRPE's charter. It became foremost in MHRPE's activities. It became the example of how we would do

collaboration in the future, the pioneering example, because it has the visibility and the time priority.

It was going to happen on a certain calendar date, and we had better be ready for it, so people couldn't say, "Nice idea, come back later." We'd say, "No, the one-year mission is launching in 18 months, and we have to have things in place. So, you program managers and you engineers and you timeliners need to answer our phone calls and help us work this out, because we don't know what we're doing, and it's going to happen."

The one-year mission became, as I said, the prime example of how we're going to be doing collaboration in the future. It was primarily between the U.S. and Russia because it was a bilateral activity, one U.S. astronaut, one Russian cosmonaut on the Station for a year. Coincidentally freeing up two seats on that Soyuz mission, in case anybody was interested.

Within the space of a few weeks or even just a couple of months in late 2012 and early 2013, we came up with a list of investigations that needed to be done in this one-year mission. Mike Barratt gave me my marching orders as the chairman of this committee. He said, "Do what you got to do. Work with everybody, but the deal is we're going to compare the six-month database we have with the one-year database that we're going to acquire on this one-year mission. We're going to do it multilaterally, that is with the U.S. and Russians. We'd like to have the U.S. and Russians working together on this to double your *n* from one to two. If you can get the other partners involved, so much the better." In fact the program managers through their control board called the SSCB, the Space Station Control Board, essentially charged us with having a bilateral—that is a two-party—mission – "but don't forget the other partners."

Again these beautifully contradictory instructions. "It's all about you and the Russians. But it's not all about you and the Russians. Don't forget there's other partners involved as well."

My recollection is that I had the plan in mind, but I waited to see who they were going to assign as the crew member. Of course they didn't ask us what experiments were going to be done first, then pick a crew member appropriate to that. They said, "Here's the guy that's going to fly your One-Year Mission. You'll be doing your research on him. We sure hope he's amenable." Because astronauts always have the right to withdraw or not to participate from biomedical investigations. That's just ethical and legal.

As soon as Scott [J.] Kelly was assigned, I asked our mission planners within the Human Research Program, "Tell me what he did on his last six-month mission, because if I'm going to compare six months and one year with a set of investigations, they ought to be the same investigations. He's already done a six-month mission. Let's ask him to do the same things or something very much like them again on the one-year mission." They gave me the list of things. His last mission, his six-month mission, included a lot of investigations that we were not doing anymore. We had reached their termination point on many of them. All of them, I think.

I call those the zombie experiments. I brought those back from the dead. The PIs, the investigators, were writing them up to publish them, and then I came along and say, "Oh, by the way, I would like to have you stop finishing your work, and continue it for one more data set, which is going to be one or maybe two more people that are not going to be the same as what you got before. They're going to be a different population. They're going to fly for 12 months versus 6 months."

Many of the PIs said, "That will do serious damage to my experimental design. I'm not interested."

I said, "Guess what, you are interested, because we're funding you, and we still have dibs on this. We can do it ourselves if you don't want to do it for us, but I really recommend you do

it for us, because you'll get the data, you'll have access to the one-year mission, you'll be a hero, and we're going to do it anyway." They saw the wisdom of that approach.

Other investigators were very very happy. In fact most of them were very happy to be involved, because they see this as the next shiny thing, and more NASA money is always better than less NASA money. We're going to keep their contracts open for a couple more years.

We also had a new set of investigations that seemed to be starting at about that same time to answer new questions, or the second iteration, the second version, of the old questions, because, parenthetically, we're allowed to get smarter. We finished up one set of investigations. We understand what they taught us, then we ask the next set of questions. Lead us to the next set of investigations.

In that population we have such investigations as the Fluid Shifts Study, which I described previously. We also have the Field Test, which is a continuation of some early work we've been doing to try to understand how astronauts are able to function immediately after a six-month spaceflight. We would apply that then to the 12-month astronauts as well. We came up with a set of investigations of—I think it was about 17 investigations, old and new, for Scott Kelly. We asked the Russians did they have any investigations that corresponded to these, because it'd be lovely to have the same investigation on the U.S. and the Russian side so they can solve two problems for two separate space agencies, two separate investigators, using two crew members simultaneously.

They said, "Well, no, not really, but we have another set of investigations that we're trying to do." So I and my colleagues tried to find matches between these fairly disparate sets, and found a few, and came up with some approaches.

One of the approaches we came up with was categorization again. The categorization would be the set of investigations were either what I call joint—that is there's an American and a Russian co-principal investigator for the same investigation—or there's something that I called cross-participation, that we have two investigations, one U.S., one Russian, that are not the same, but similar. We would ask the American to do the American investigation and the Russian investigation. We'd ask the Russian to do the Russian investigation and the American investigation. We'd ask the principal investigators to share the data, so they would each get twice as many subjects of one-year crew members as they would have otherwise.

Then we have another that we call data exchange. There's an American investigation. The American astronaut is doing it. There's a Russian investigation. The Russian astronaut is doing it. They are sort of similar, they may have some parameters in common, but we're not going to ask the American to do the Russian. We're not going to ask the Russian to do the American. We're just going to ask the PIs to e-mail or communicate relevant data exchange. So, there's joint, cross-participation, and data exchange. There's only a couple, two or three, depending on how you parse it, joint, and half a dozen cross-participation, and then the rest of them are data exchange.

We also involved ESA, JAXA, and the Canadian Space Agency in this. Mostly the data exchange process. There are third party investigations that seem to match one or the other, the U.S. or the Russian ones. We asked them to be involved, thereby making this a multilateral mission, at least in name, when in fact it was primarily bilateral.

That is the set of investigations we're proceeding with now. The Russian did not agree to do all the American investigations. The American did agree to do all the Russian investigations. Along the way over the course of the two and a half years of planning that gave me many

opportunities to be interrogated by the SSCB on how things were going and why wasn't I doing better at preparing, one of the things the Russians in particular kept coming back to is, "Why aren't you doing more joint investigations?"

Now to me they were all joint. It was an ambiguous word that I chose. I did assign this co-principal investigator category, I assigned it the name of joint. When they said, "Why aren't you doing more joint investigations?" they were thinking of those. But, I was thinking they're all joint, because they're all multilateral. I don't think the Russian guy is as sophisticated with my terminology as I am, so I'm guessing what he means is why aren't we doing more overall collaboration?

I kept saying, "We are doing a lot of overall collaboration. We're doing as much as you guys will allow us to do. How are you asking me to do more when in fact then I turn around to your people and they say you're doing too much?"

They would look at me like I had a hole in my head. "Oh, you don't get it at all." I finally realized that they were looking for what I call the joint studies, the co-principal investigators, because that way you solve two problems with one investigation. I finally realized—it took me, I'm embarrassed to say, a year and a half or two years to have the epiphany talking to Julie Robinson and to the people in the Space Station Program. They would try to explain to me as simply, using fifth grade language, as they could. I just didn't get it, but I finally realized that my cross-participation studies were exactly the worst thing I could be doing, because that doubled the crew time. The American was doing the American study and the Russian study, the Russian was doing the Russian and the American study.

I doubled the crew time, and we don't have enough crew time to do the work that we need to do. Why did I think it was a good idea to double the crew time? So, they were wanting

more joint and less of the cross-participation type, but they never told me that in language that I could understand.

I get it now and now that is my new dogma. It's all about joint investigations. So only too late. We're stuck with what it is for the one-year mission. Everybody's making their best efforts to do what it is I originally asked them to do. They're putting a happy face on. They're doing as much as they possibly can. I think so far it's turning out to be spectacularly successful. I also told some people—and since this is not going to be published for a long time—I told people that my criteria for success are extremely low.

We have these two joint investigations, the Fluid Shifts and the Field Test. If we get those done I'm going to declare 100 percent success. All the other stuff is icing on the cake. Since we're going to get much of the other stuff done, I'm going to declare 110 percent success. But I didn't say that until the very end of the process, and only to a small number of people until this obviously gets published.

The important thing was exactly what the programs wanted, which was to have these two major investigations. I think in a previous interview I discussed the Fluid Shifts Study, and I described it then as the most complex biomedical investigation that we've ever done on the Station and possibly ever been done in space, with the possible exception of work that was done on Neurolab or maybe the space and life sciences Spacelabs. I still think that. It is more complex than those because it requires resources from the U.S. and the Russian segment on the Space Station, which is not currently configured to facilitate that kind of resource exchange. That was one of the assignments for Team 5, to break down the barriers between the two segments.

People don't realize that the Space Station is really two Space Stations joined at the docking node. They both have different management characteristics and different requirements. Much of those management characteristics are intended specifically to keep the others out. What we had to do to use the Russian lower body negative pressure device called Chibis was to move American monitoring hardware into the Russian module, essentially take over the Russian habitation module, and convert it into a cardiovascular laboratory with wires and hardware. People couldn't go to their dining table or get to the bathrooms because we were taking it over, and we had to do that several times during the course of this one-year mission.

It takes several days to get it configured and deconfigured. You do it at several-month intervals, not monthly, but several-month intervals, so that it's not a constant impediment, but it's a frequent impediment. It's significant when it's in place.

That is the model that I am still hopeful of seeing on future collaborative missions. I said that the one-year mission is the pioneering example, but the rest of my assignment was to do this on all future Space Station missions, whether they're one-year missions or not. I'm using the one-year mission as the pioneer, as the stalking horse, as the scenario that identifies the problems for future collaborative investigations. Then just in the last few months when the Space Station Control Board asked me to give a report, I said, "We've prepared for this one-year mission. It is going well. It is now up to you program managers to make it possible to do this in the future, because we are doing a lot of things in the least efficient possible way on this mission, and you will not allow us to do it this way again. If you really want joint work as you say you do, then each of you, Mr. Suffredini, Mr. [Alexei] Krasnov, and all the other program managers, need to talk to your people about streamlining your processes."

There was a bit of consternation because each of them thought that I would cause the other to streamline their processes without actually causing each of them to streamline their own processes. I said no dice on that because nobody is innocent in this game. The Russians refused to acknowledge this problem until literally Christmastime of 2014 when suddenly it became a major problem on the Russian side: "how are we going to implement this mission in three months?"

The Americans have known about it for years but didn't do anything about it. They just kept laying more processes on us. Now this is my biased perspective obviously. I said, "Nobody's innocent in this and you both have to fix this. The way I recommend doing that is that you both send your experts off into a room or retreat someplace. Everybody spell out what their process is to get from experiment arrival to implementation to orbit. All the steps that need to be implemented, all the documents that need to be written by people on my staff or in my group. Tell us ahead of time so we can get those done before you need that information. Don't wait until you need the information and ask us to go write a book. Then you on the Russian side, please don't delay until six weeks before a launch, then come to us with a set of requirements that no two of you agree on."

The Russians seemed to be making requirements up at the last minute. They seemed to be saying, "Oh my God, something has to happen. We don't routinely do this because we don't work with the Americans on life sciences. What do you think we ought to do?"

One group would say, "Well, we need this document."

Another group would say, "Well, we need such a document."

Then they'd get together in meetings and they'd say, "Well, we have this document we need." The other ones would say, "Well, so do we, we have a different document. Okay, let's

ask the Americans to do these documents." It's Christmas break and it's springtime in 2015 and we're getting all these requests for documents.

We say no, and then the Russians say, "Well, we'll ask other Russians to do this." The Russians come to us and say, "Well, what information should we put in here?"

We say, "I don't know. It's your document. We never saw it before." Bottom line. The Russians don't seem to have an established process for what we're talking about. The Americans don't seem to have an established process, but the Americans have plenty of processes, and they can figure one out that's going to be very cumbersome.

I asked the two program managers to assign their people to come up with a consolidated plan that's doable by scientists like us, science organizations, that will satisfy both of their requirements. They were a little bit consternated. They were a little bit concerned because they were not expecting to get homework from me. They were expecting for me to tell them the answer, not ask them the question.

As we left that SSCB meeting, people on their staffs did have those assignments. Now sitting here in August of 2015, I'm anxious to hear back from them about how successful they've been. I don't know the answer to that. I do know that the planning for future missions is being impeded because we don't have these consolidated processes. I am right now missing deadlines that they charged me with meeting in part because I don't have these processes that I need to do my job.

The other part is I still haven't figured out how to do other things that's not their responsibility. But I'm at least partially delayed because of their inability to tell me the right way to do things.

JOHNSON: The studies that are being done up there and with Scott Kelly and then his brother Mark [E. Kelly] being on Earth.

CHARLES: The Twins Study.

JOHNSON: The Twins Study. I'm just assuming as a nonscientist that Mark is the control and then the changes will be studied after that. Just what exactly are you looking for?

CHARLES: The story of the Twins Study is interesting because after Scott Kelly was named as the one-year mission crew member, Julie Robinson and I were sitting with him in an office over in [Building] 4 South. I think his brother was there as well. I think Scott and Mark were there. He was getting ready for his first press conference, and so Julie and I were walking him through the set of investigations that we envisioned for him to be doing in the biomedical area. Julie would talk about the other investigations.

As we essentially stood up to leave, Scott said, "They're going to ask me if we're doing anything about the twins, because I've got a twin brother." Julie looked at me with a little bit of a deer in the headlight look.

I said, "No, we're not. That's a stunt. We're not going to do that." I was thinking but didn't say, "You've both been astronauts for several years now. You've been twins for most of that time. We didn't ask you anything up until now. Why would we start now in this most difficult of circumstances?" The hardest thing we've ever tried to do. Why would we make it even harder by doing this?

I went back. I think Barratt was still the Program Manager at that time. He said, "How'd it go?"

I said, "Well, it went very well. Julie and I walked through everything, and as we started to leave Scott said, 'How about us as twins?' and I said, 'No, of course not.'"

Barratt, as I recall said, "Not so fast, John. This is an opportunity perhaps we shouldn't be so quick to dismiss." I don't recall exactly what I said, but I'm pretty sure I didn't say what I was thinking, which is you got to be kidding me, because that's going to be very difficult to do, and it's going to be a stunt. I keep using this word "stunt" in politically indelicate situations. But, we will not learn anything of value from this, having one astronaut who's a twin in space and one astronaut who's a retired astronaut twin on the ground. What possible benefit will this have?

Cooler heads prevailed. They convinced me, and I think convincing me was part of the thought process as well, that we are in the 21st century and genetic aspects of biology are becoming more refined and more informative and NASA is doing very little of that. Here's almost a special case delivered to us for us to get into the genomics business, and these guys are interested and willing. I don't know if I went back to Scott or maybe Barratt did because they're friends and essentially said, "You know how I told you we didn't want to do anything with the twins? Well, we do want to do something with the twins."

Scott and Mark said, "Great, okay, let's talk about that." So we came up with a plan. I think it's not nice to say I was opposed to it all along, but I was trying to be dispassionate about it. Having gone through the setup process for the set of investigations for the one-year mission, I did not want to see that derailed for what I kept calling a stunt until somebody finally told me to quit saying that.

I was the lead scientist for that as the lead scientist for the one-year mission until we were able to assign Craig [E.] Kundrot from our staff as the project scientist for the Twins Study and Graham [B.] Scott from NSBRI as the deputy project scientist. They did an excellent job of coming up with a set of investigations which are going to be informative and illuminating and also not disrupt the one-year mission set of investigations.

I helped write the solicitation. We actually went out and solicited, with a very quick turnaround, extramural scientists to help us do genomic studies on these twins. I made sure that the solicitation that we drafted, that got sent out, essentially said, "What can you do with no crew time, no samples, and no funding?" That was moderated a little bit so there's a small amount of sample and a small amount of crew time, mostly incorporated in the ongoing one-year work, blood draws and other tests that were being done on Scott that could be done then on Mark.

The funding was not exactly zero. There was a small amount of funding but it's not enough to pay for the expenses of the scientists. We had 40 responses from world-class scientists who saw this—and I finally realized at that point that I was the one that was out of sync because this is the 21st century. This is the new wave of investigations. Thank goodness my management didn't listen to me, and they persisted with this approach, because I think we had 40 responses, of which we selected 10 to cover the entire omics spectrum, from the gene all the way up to the whole organism, the whole astronaut, including the psychological aspects.

Craig and Graham melded those 10 investigators into a single team. I won't say seamless but very darn well integrated. They are making progress in understanding the effects of this one example of spaceflight on these two individuals. Not because they think they will gain renown or insights that will solve problems, but because it's the first of what we think will be a future of omics-based research perhaps even displacing the kind of things that I'm more familiar with, the

older physiological and biomedical models. This might be the way to get the answers to the questions we need in the 21st century within the constraints that we're being faced with, like the crew time that I mentioned before. If we can get data from blood draws and genetic analysis of body fluid samples, that tells us most of what we need to know about bones and muscles and cardiovascular systems, then we don't have to do lower body negative pressures and postflight activities once we get these calibrated.

Right now my hope is that that does turn out to be the model, that from the genetic-based analysis we will be able to understand much of what we need to know, and at least focus our other efforts more specifically on things that we can acquire through that pathway and the guarantee of a great deal of additional insight into the integrated organism, that is the astronauts, from the genetic aspects that we couldn't acquire by any other technique.

Again like the one-year mission, this is another trial, another pioneering opportunity. Our 10 investigators have thrown in wholeheartedly because they want to be part of the new wave. They want to be part of the first effort by NASA to do this. They're not getting a lot of funding. They're spending some of their other grant money on NASA work, and we don't mind that they do that. They're also going to have credit and credibility when it comes to defining how things get done in the future. They'll also be able to claim credit for having been there at the very beginning of what I think is the new approach to doing life sciences research.

Since Craig has moved off to Headquarters for a new job, I am now the project scientist again for the twins study. Having diligently ignored it for the last year and a half or two, I'm now learning about it again. I'm very impressed at how well it's organized and how productive it is and it will be, despite my efforts to put the kybosh on it at the beginning.

JOHNSON: I wasn't sure when Scott was chosen, if he was chosen because he was a twin, or—it's interesting that that came almost as an afterthought.

CHARLES: It's incidental. In fact Scott was chosen after six or so other astronauts were chosen and then unchosen. The Astronaut Office, I am told—I was not part of the discussion, but I am told—went through a large number of individuals. We would periodically hear this name or that name as, "Okay, here's your one-year crew member."

I started asking around, "What experiments did that person do before? How can I make comparisons?"

Then we'd hear, "No, that's not the person after all, something came up in the medical record. We're still looking. Stand by." That's why Scott came in fairly late in the process, because we had been expecting to have somebody assigned in the summer of '12. He was assigned in November of '12. There were several months of false starts before the crew member was assigned.

There's a small number of astronauts that are eligible for the one-year missions if we have more, because of their medical character. Radiation exposure for example. The longer you go between flights, the better your radiation picture is. But, the shorter you go between flights, the less new training you have to do, because theoretically you're still qualified from your previous flight for a lot of stuff. Then there's a staleness factor. If you wait too long, then you got to repeat more training. Imagine there's two curves that cross, and there's a sweet spot where biomedically or medically you're getting more qualified in terms of radiation exposure, but trainingwise you're getting less qualified because you're forgetting things you learned before your last mission.

There was some characteristics of several individuals. I don't know who made the final decision. It was obviously the Astronaut Office with all their managers, and the flight surgeons with all their managers, and program management at Headquarters with all of their involvement had to go through the set of names, and then wait to see if anybody else objected. There was apparently several protests that came along from one source or another after so-and-so was tentatively identified. Somebody would say, "Well, that person isn't good with the robot arm, or that person's radiation dose is still higher than we like," or something like that.

Scott was not chosen because he was a twin. Scott was chosen because he was the last man standing essentially. Just lucky for us in the 21st century medical approach to things, he has a twin. We can take advantage of it.

JOHNSON: You've got to take advantage of it while you have it. It'll be interesting to come back in a year from now and talk to you again about the mission and everything that you've learned from it at that point, or beginning to learn. I know a lot of this isn't going to be for a while, especially with that.

CHARLES: I mentioned more one-year missions because I will tell you also that after I kept using the word stunt so much for both twins and the one-year mission, the Human Research Program management, Bill Paloski by this time, didn't really agree with me that the single iteration was a stunt. But, as a scientist he realized that this *n* problem—if you have one or two one-year crew members, you really are not answering anything definitively about the population. You can't generalize to a large population. So, the position that we came up with was that we would endorse this one-year mission if there was a plan for more one-year missions, so we had a

reasonable expectation of getting a sample size of 6 or 12 one-year crew members that we could then compare with our six-month database. The Space Station Program concurred. The Russians never actually concurred or didn't, but we thought we had a deal. That's what swayed me. It's not a stunt if you have multiple flights.

Now here we are in 2015 and we're saying, "It's time to start planning the next one-year mission." The Station Program, the American program, says, "Well, okay, let's talk to the Russians."

The Russians say, "We never agreed to that." The Russians are saying things like, "Well, let's wait and see how this one goes." According to our plan, the next one was going to be getting prepped now. We don't wait until this one is finished, which is another six months from now, before we start planning for the next one, because it takes several years to plan. We want to solicit investigations from the scientific community, fresh new investigations to do on future missions. That takes a certain amount of time before we can even start training the astronauts in what they're going to be doing in flight and building the hardware. There's a lead time in there. We were expecting that clock to start last month, July of '15. But now we're waiting until at least March of '16. I'm sure there'll be time after that before everybody says, "We're ready to consider this again."

It's looking more like a stunt again because it may just be a onesy.

JOHNSON: That's what I was wondering. If you go from one-year mission to 18-month mission to two. Is there a thought of building it up to that three years so that you know you have that to go before you go to Mars?

CHARLES: There is no requirement to have a three-year mission before a three-year Mars mission that I'm aware of. That is the advice. What you described is the program that the [Thomas P.] Stafford Commission keeps recommending. They kept saying, "Why are you not doing any longer missions? Why are you doing all these six-month missions?"

I would argue that the six-month missions were teaching us much, but not all, of what we needed to know for longer missions. Again because the early adaptation of the physiology and the fact that it reaches an adapted state or an acclimatized state within a few weeks or a few months means that as far as this or that organ system is concerned whether you're in space for two and a half years or one year or six months you're qualitatively the same. If we can get a countermeasure, a treatment that works for you after six months, I would feel pretty good about that after two and a half years.

Not all systems. Obviously radiation, obviously the psychological/psychosocial aspects, those require longer exposure, but we have ways of doing that. We do those on the ground. Radiation in beam facilities on the ground. The psychological ones in isolation facilities on the ground. I still say in my public presentations that I would not have been reluctant to certify for a Mars mission based on a good database of six-month missions, because I think we understand much, not all, but much, of what we need to understand.

But, if you're Tom Stafford and you're a military test pilot and you're an engineer, you don't buy that argument. You'd rather see one one-year mission, one one-and-a-half-year mission, one two-year mission, one two-and-a-half-year mission. When I say, "You can't do that because of statistics," he'd say, "Why do you care about statistics? If they survive then it was okay. If they don't survive, well, then we figure that out later, because that's how we did Gemini." Which is true.

Then I would say things like, "This is not Gemini and you can't expect scientists to sign off on that. That's not ethical or realistic."

So far we've been winning, with the six-month population. Overall we win, because we may not get any more one-year missions. Stafford is still unhappy with the fact that we're not doing longer missions. In fact sometimes the Russians now say, "Well, let's do a different kind of one-year mission."

I keep saying, "No. Let's do more of the same because we don't know anything yet about one-year missions." There's a sense that I get that some of these senior managers are more looking for the next interesting thing than they are the next statistically valid thing. If you've done a one-year mission, let's do a one-and-a-half-year mission. "No. We're not there yet."

"Let's do a mission where maybe they land halfway, then launch again, to simulate going to Mars—landing on Mars and getting back into space."

I say, "Oh my goodness. That's going to complicate things incredibly."

They say, "Well, let's just think about that."

The idea of agreeing to future one-year missions is contingent on these other things. This time next year if we chat, maybe I'll have more information on the planning, the thought processes, and my gradual acceptance of these ideas.

JOHNSON: Not calling them stunts anymore?

CHARLES: No. I got to quit saying that. I did that. Rice University [Houston] has this International Space Medicine Summit every spring. George [W.S.] Abbey is one of the organizers of it. Bobby [R.] Alford from Baylor College of Medicine is a co-organizer. They

had a breakout session. Gerstenmaier was chairing it. He asked the question in one of the breakout sessions, "How about this mission scenario where we have six months, then we land for a few weeks, and we launch again and pretend we're coming back from Mars?"

I said, "No. That's a stunt." Of course I'm essentially criticizing the idea of the AA [Associate Administrator] for Spaceflight in front of lots and lots of very well renowned experts.

He said, "Okay, well, we've got to work with John on his ability to express his thoughts without calling his boss's boss's boss's ideas a stunt. We understand there's a little bit of refinement required."

I do tell people though that I've reached the point in my career where I am within a few years of retiring. Who knows? If they decide that perhaps I should retire sooner than that, it wouldn't be all that bad a thing. My restraint might be a little bit less than they would like.

JOHNSON: Looking back over everything, is there anything you can think of that we haven't talked about?

CHARLES: Oh my gosh, I hope not, because we've talked on topics that I hadn't really expected to talk on. I think we've done good so far. If we think of more we can always reconvene.

JOHNSON: Yes, we can. If there's anything you can think of, just let me know. But I appreciate you coming in again.

CHARLES: Another topic, in case we want to do it in the future, is about history, space history. I'm a big space history aficionado. One of the reasons I like it here and want to put off

retirement is because I can feel the waves of history at JSC. I can walk on paths and know that [Robert R.] Gilruth walked those same paths when he was contemplating Apollo. There's lots of archives. Avocationally I'm a space historian. I talked to Rebecca [Wright] about Building 37, which is just a slight manifestation of that. But, maybe sometime in the future when workloads permit we can talk about space history too.

JOHNSON: That would be great. Thanks.

[End of interview]