CHILEAN MINERS RESCUE ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

JAMES D. POLK
INTERVIEWED BY REBECCA WRIGHT
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WRIGHT: Today is May 27, 2011. This oral history is being conducted with Dr. J.D. Polk in Houston, Texas, for the NASA Headquarters History Office. This interview is part of a series to capture knowledge about NASA's participation in the recent historic rescue of thirty-three Chilean miners. Interviewer is Rebecca Wright. Dr. Polk is the deputy chief medical officer for the NASA Johnson Space Center, and we are in his office today for this interview.

Thanks again for your time on your schedule.

POLK: My pleasure.

WRIGHT: You were one of four members of the NASA team who traveled in August 2010 to assist the country of Chile in the safe return of 33 miners who were trapped 2,300 feet underground. Explain to us how NASA first became involved with the rescue effort and then how you became involved.

POLK: I wasn't there at the initial onset, but I believe the Chilean Ambassador came to [NASA] Headquarters [Washington, DC] and asked for Headquarters' help for the rescue. At that time you had 33 people trapped about 2,400 feet below rock at 17 days. When you get out to the 19-, 20-day mark, that's the longest that anybody had survived in a mine, much less survived that deep in a mine and that many people in a mine. The Chilean president [Sebastián Piñera] is a

businessman by nature and entrepreneur, and he asked his folks to go and benchmark against who actually had people in a confined environment for any length of time, to see if they could get lessons learned to help get these folks extricated.

So as I understand, the Chilean ambassador came to Headquarters and asked for our help. Headquarters then turned to the Johnson Space Center because we have the bulk of medical assets here, but we also started to evolve a lot of the engineering discussions as well down here. Dr. Mike [J. Michael] Duncan, who at the time was the deputy chief medical officer, in the position that I'm in now, led that effort to begin to get a team together to see what areas that we felt we could contribute to.

Then as to my personal involvement, my background is emergency medicine. I'm board-certified in emergency medicine. I have a long history in disaster and crisis management in different roles, both as the chief of life flight when I was in Cleveland [Ohio], the state emergency medical services medical director for the state of Ohio, etc., so I'd had a long history of working in disaster and crisis management. Mike asked me to contribute—as well as my space flight knowledge from space medicine. That's how we got started.

WRIGHT: What was your first involvement as a team, before or while you were getting ready to talk with the Chileans?

POLK: I think our first involvement as a team probably was after a Skype [internet phone service] call to the Chilean Minister of Health. The Chilean Minister of Health laid out the problems and the gaps that they had and where they were in their current process in rescuing

these folks. You could tell from the conversation that it was a daunting task for him and overwhelming in its scope.

After that we talked as a team, both us gathering our psych [psychological] components with Dr. Al [Albert W.] Holland, myself, and Mike, starting to divide up what medical things would be needed, talking to NESC [NASA Engineering and Safety Center] with Clint [Clinton H.] Cragg on what engineering aspects would be needed, and putting all those together and discussing how would we convey the information to the Chileans. Would we need to go down, would we just converse by e-mail or Skype?

The Chilean Minister of Health actually asked that we come down. He felt that face-to-face was something that he needed. He also felt, quite frankly, that having us there would help the families, because the families knew that NASA was being invited. To have us there at the site and discussing with them, he felt would give them some degree of confidence and/or counsel. Then also, to give us a better idea of the challenges that he faced by actually seeing them for ourselves.

So we went down to Chile for the week very early on in the rescue process, and it was fairly interesting in that the folks that we were partnered up with, our counterparts, you couldn't have picked it better. Al Holland was paired up with another gentleman named Al who was a psychologist. They were of the same ilk. They had the same mindset, a lot of the same experiences. My counterpart was a gentleman from the Chilean Navy who was very vested in emergency medicine and trauma, and he and I had rotated at some of the same places in the United States and knew some of the same people, so we hit it off extremely well. Clint Cragg was paired up with a sub [submarine] commander who was from the Chilean Navy who was overseeing a lot of the logistical operations. And Cragg, aside from being an engineer with

NESC, happens to be a three-time commander for a Trident [Ohio class ballistic missile] submarine in the Navy. It was almost like gene splicing at that point in time, we really hit it off very well.

Mike was of course liaisoning with the Chilean Minister of Health and with his position that he was working towards with Headquarters. Mike enjoys the politics and the overall scope of policy and how to attack some of these problems, and so they meshed very well as well. Mike's background is critical care and internal medicine, and this gentleman's background was internal medicine and nephrology. We were just partnered extremely well, couldn't have been better.

WRIGHT: Based on what you knew from the Skype call, from your discussions, how did you prepare to go down there? Did you go armed with materials or documents? Share some of the preparations that you put together before you left.

POLK: Yes, we looked at several things. Initially there were some things that we thought would be helpful and then, to be honest, as we got into the process there were many more things. For example, we knew the gentlemen were starving. They had been essentially eating a spoonful of tuna, a quarter of a canned peach, and an ounce of dried milk every other day. When you re-feed folks that have been starving, usually greater than five to seven days, that has to be done in a very methodic and purposeful manner. Otherwise you get into a horrible complication. History has taught us that. Back when we had prisoners in Auschwitz [Nazi concentration camp] and the US service members freed a lot of prisoners in Auschwitz, they were devastated by the horrible emaciated look of these folks and they gave them their C-rations, their Hershey [chocolate] bars

and their candy, etc. Unfortunately we ended up killing some folks because that carbohydrate load causes a complication.

We had already looked at something called re-feeding syndrome, and ironically it was for a different reason. The reason that we had looked at it was because with the Hubble [Space Telescope] mission, if Hubble had taken a strike to the [Space Shuttle's] wing-leading edge and needed to be rescued it could not get to the ISS [International Space Station]. It could not do what's called a plane change and a Hohmann transfer to get to the ISS for refuge. Essentially, the Shuttle would be its own safe harbor until a rescue mission was mounted, which would take several months. The Shuttle's only got so much volume so we were actually going to think about down-regulating the crew's calories down to about 1,000 a day and a certain type of calorie, what's called an RQ, respiratory quotient.

When you eat protein, carbohydrate, or fats, depending on the amount of that mix, depends on how much your body uses that fuel, and in addition then consumes oxygen or produces CO_2 [carbon dioxide]. For example, if you eat an RQ that's .85, which is mostly protein, you actually burn less oxygen and you produce less CO_2. That's important for us in a vehicle where it's an enclosed space, where the amount of CO_2 scrubbing capability was going to be limited over a two-month rescue mission, or the amount of oxygen might be limited in a rescue mission. Also, decreasing the calories itself decreases the amount of CO_2 consumed and CO_2 produced.

We'd worked through this, we'd worked through it in elaborate detail in [Microsoft] Excel spreadsheets and Access databases and figuring out what's called a Henderson–Hasselbalch equation as well as Harris-Benedict equations, in the typical NASA fashion of

looking at all of those things—knowing the weight of an astronaut, exactly how much oxygen that they would consume or CO_2 produce.

We took a lot of that information with us, potentially knowing that it might be helpful, but not knowing how much help it would be. Actually it was very helpful because when you're starving, you down-regulate your insulin and you use up what's called liver glycogen and your metabolism starts to slow down because your body realizes it's not getting enough calories and it wants to keep things like your brain and other things alive. Eventually you start to run off what is called ketones. Your body and your brain especially will run off of ketones, and you burn initially your fat and your subcutaneous fat, and then eventually you'll start to break down your own muscle to feed off of it. And that's kind of where they were.

We had talked to the Chileans, and of course they had talked to other academic centers and medical centers as well, but the fact that they were getting this constant message on re-feeding syndrome and the fact that NASA also said, "Well, not only do you have to be careful, here's all the equations and how you have to calculate this." We had an Access database that they could plug in the weights of the miners and actually be able to spit out exactly how much oxygen was going to be consumed, CO_2 produced, and where the protein-sparing diet would limit.

If you give someone too much carbohydrate initially, they get a surge of insulin, and also the food is fairly alkaline compared to their acidosis that they are in. What that causes is a profound hypophosphatemia, phosphate is driven into the cells. Your body works off of ATP, adenosine triphosphate, and that's how your cells have energy and use that substrate for energy. When you have no phosphate in your diet, your cell structures run dry. It's not unlike running shy of gasoline in a car. Then when suddenly you have a dietary load, especially if it's

carbohydrate and poor in phosphate, then the cells begin to burn that energy to consume that food to burn that for energy. But if the phosphate is still low you can get profound hypophosphatemia or low phosphate, and actually have cardiac failure.

The second thing that you can have is hypokalemia, which is low potassium. Again, because of the surge of insulin, if you have too much carbohydrate the alkaline nature of food is compared to the acidosis of the bloodstream, and that profound drop in potassium can cause cardiac dysrhythmias, which can be fatal. So, literally, re-feeding folks has to be done in a very methodical manner so that you don't kill them.

You had different factions down at the mine. You had the engineers and the miners themselves who wanted, "Hey, let's just start shoving food down this hole," and the Minister of Health, who had listened to our counsel and had listened to different academic centers, knew he had to do this is a very methodical manner. The typical rule is to go low and slow, so they went at 500 calories, then 1,000, then 1,200, then 1,500, and to do it with a particular amount of substrate. At the time they were using Ensure Plus, which is a nutritional supplement that has several things in it, potassium, phosphate, but it's also fairly protein balanced, has a little bit of carbohydrate. It also has thiamin, which is another important B vitamin that your body burns up when you're starving. If you don't have thiamin and you get glucose, you can get what's called Wernicke-Korsakoff syndrome, which is a neurological syndrome with horrible ataxia [loss of muscle coordination] and other things.

So it was paramount that when they were re-fed, that they were re-fed in a low and slow process, but also that they got a huge amount of phosphate and potassium and thiamin as substrates to prevent the medical complications. They did that in textbook fashion, and because

they did that in textbook fashion, out of the thirty-three miners they had not a single complication.

That was probably actually the second time they had saved them. The miners had saved themselves, they were kind of the masters of their own fate and destiny in that they had dug wells in the mine. What most folks didn't realize is that there were a couple things that we were fortunate in. First, this was a copper and gold mine, not a coal mine. In the US, unfortunately, we do body recovery in mine accidents more so than we do rescues because it's methane explosion that occurs and then very often the miners asphyxiate. Between the trauma and the lack of oxygen and the methane, it's a very poor outcome. Whereas in a gold and copper mine, especially an old 100-year-old mine that had a lot of different airshafts and substrates, it didn't have methane gas and so their breathing air was good.

The other thing being that the miners were themselves at sea level. The entrance to the mine was at 2,400 feet above. Most people mistakenly thought the entrance to the mine was at sea level and that wasn't the case, it was actually at a higher altitude. Where that was an advantage is that the miners themselves, since they were at sea level, were able to dig wells to find water. I think they dug three wells. Several were not potable, when the miners drank the water out of those they had gotten sick or ill. But one was; one no one got sick with. They were able to then with supplies continue to treat it, with bleach if needed, until they were able to get the bottled water down there. Their ability, their shift leader's leadership in having them dig those wells allowed them to survive. Otherwise they would have had severe dehydration and had compromise from that as well.

So by the time they'd re-fed them, that's twice that they've been saved. One from having water, the second by re-feeding, and then there was a third thing that came up very quickly. The

Minister of Health asked us what labs [laboratory medical tests] he should send down. At the time there was only a four-inch-round tube called a paloma tube [Spanish for dove]. It's like PVC [polyvinyl chloride] pipe that is not perfectly straight because it's going through solid rock so it wavers a little bit. You can only send down about a six-foot-long torpedo of things, whether it's water, food, etc. It was taking a great deal of time to get something all the way down and all the way back up, and the Minister wanted to know what he could put in this torpedo as a medical test. What lab work should he do, what things should he do?

On the International Space Station we very often use very simplistic lab tests, one of them being the urine test strip. You'd think, what kind of information can you really get from a urine test strip? You can get specific gravity, which tells you whether or not someone is dehydrated or not, which is good because then you knew what miners needed more fluids. It also can test for ketones, so you know who is still starving or not. You can see protein in the urine. And it has one problem, which is a problem that we use to our advantage.

In the emergency department, it's somewhat frustrating with the urine test strips because they can't tell the difference between hemoglobin, which is blood, and myoglobin, which is a protein byproduct of muscle breakdown. It'll test positive for blood when really it's myoglobin. If we were to go to the gym and work out vigorously on our muscles, you get some myoglobin spilling into the blood. If you had a urine test right afterwards it would look like you were positive for blood. That's somewhat frustrating for emergency physicians. However, we used that to our advantage in this case. We assumed that all thirty-three miners were not having kidney stones, so if anybody tested positive for blood we knew it was going to be myoglobin and we knew they were breaking down their muscle.

The problem with that is when you break down your muscle, either because you're starving and feeding off your muscle, or, in their case, because they were sleeping on hot rock—there were no cots or beds in the mine so they were literally laying on the rock to sleep—you start to break down your muscle and those breakdown products of myoglobin bombard the kidney. They're very large molecules, and it can cause what's called acute tubular necrosis, or the beginning stages of kidney failure. Eventually, if you have enough myoglobin bombard the kidney, which is called rhabdomyolysis, then you can go into frank kidney failure.

They sent down the urine test strips, and sixteen out of thirty-three of the miners tested positive for high myoglobin. They were in the early stages and throes of kidney failure, so they did two things. First, they targeted those folks for higher water consumption to get their urine output greater than 100 CCs [cubic centimeters] an hour. And the second thing they did, which was ingenious on the part of the Chileans, is put out through their press wire essentially an innovation challenge that said, "Hey, we need cots for these folks to sleep on, and, oh, by the way, they're cots that have to fit in a four-inch round tube that's six feet long."

The industry responded, and within days they had prototypes from different companies and they started sending down the cots. They only had to send down fifteen or sixteen cots because the miners were in shifts so you didn't need the full thirty-three cots. People would hot rack, or bunk, as they needed to. By getting them off the hot rock in the ground and by increasing their hydration greater to the point where they had urine output that was 100 CCs an hour, they actually saved them from renal failure. All of the urine cleared on all of the sixteen.

Now you're not even a month into this rescue and they've saved them three times. One from the initial dehydration, second from re-feeding, and third from renal failure. Then they continued to feed the folks, and as they got another supply line, or paloma, and a third paloma—

the more tubes they were able to get down and then get more supplies down to them, the better they did obviously, and they started to eventually send them regular food.

We could tell that the miners were in much better shape when one day they sent food back. We had one miner that did not want—I think it was apple crisp or peach cobbler or something for dessert—and he didn't want that, he wanted something else. That's kind of the hallmark. You know when we're starting to get choosy on the menu that you've reached a certain threshold that you're no longer in survival mode.

One other thing I think was very important for the Chilean government is that we broke it down into segments, into bite-size chunks. The Minister of Health himself knew that and had broken things down into three or four different segments, but we expanded that a little bit for him. We're used to that in missions. We have preflight things that we do, then we have the flight team, and then we have the post-flight things that we do. Typically there are different teams that handle those things that all come together in a larger, greater mission that a flight director and program manager oversee at a much higher level. They needed to do the same thing, because it was clear when we were down in Chile that the Minister of Health was overwhelmed.

We broke it down into, first, you have the initial incident. Then you have the survival phase, then you have a sustainment phase, then you have a rescue phase, and then you have a convalescence and rehab phase. The initial incident, you worry about trauma or about asphyxiation and all those things, and fortunately they'd gotten past that. The survival phase was the re-feeding and the hydration. Then the sustainment phase is making sure they're well fed with a normal diet, but also the psychological support and making sure that you start to change their mindset from a sprint to a marathon.

The first estimates were that it was going to be December [2010] before they would get them out, which was four months or more. Fortunately it wasn't that long, it was much faster due to different drilling techniques. But we had to change their mindset greatly. First they were in a horrible mindset of despair, they thought they were going to die before they were rescued. They weren't horribly sure they were going to survive even after the first contact with them by the Chileans on the surface. Their mindset at that point, at that seventeen-day mark, they were literally wondering, "If this guy dies, will we eat him?" It's kind of hard to get your head around that kind of mentality, but shifting them from that to, "All right, now we've got work to do to clear the rock from the drilling. We've got this, we've got these things we've got to set up." Giving them meaningful work was extremely important.

It's something we've learned from space flight—and something we've learned from sea voyages in the past, the Arctic Passage [19th-century expedition], things of that nature. People that are busy and have meaningful work are not sitting there depressed, worried about the outcome. Because the drilling up above has a pilot hole, bits and pieces of the rock would fall down the pilot hole and start to accumulate in the mine so they had to clear that. They had the constant up and down of the supply palomas coming with the water and the food that they had to do. They were working in shifts doing all these things, and it was very helpful. Splitting them into shifts and giving them some sort of circadian rhythm was also important.

We had lots of folks e-mail us, trying to be helpful, with suggestions like, "You should send them iPods [digital music players]." Well, that's nice on the surface. Most of us, when we go to the gym like to listen to our music and the whole works, and have pictures of our kids or what have you on the iPod. But in a survival situation you don't want somebody going off by themselves to where they can get depressed. They need to eat as a group, work as a group, sleep,

everything as a group. Everyone takes care of each other, and no one goes off by themselves. If somebody becomes quiet and starts to isolate themselves, you bring them out of that and engage them in the group. It was extremely important to do that. Plus, mine safety. You didn't want to have somebody yell, "Look out!" or, "Rock!" and have you sitting there with 70 amps [amperes] of Foo Fighters [rock music group] in your ear. That was something we had to contemplate as well.

Al did a great job on also making sure that the amount of communication from the surface to the mine was appropriate. There was essentially a planning meeting every day between the surface and the miners so that they knew what was going on on the surface. They knew how far the drill had gotten, they knew if there were any setbacks, a bit breaking, etc. Then, talking to the families. We'd start to send down personal items, keep them connected to their family and above, but also that fine line of too much comm [communication] from the family. People have problems and worries on the surface, but you don't want to translate those into the mine. They have their own problems and worries in the mine.

We've learned that in long-duration space flight. We've got the IP [internet protocol] phone and we thought, "Oh, isn't this great? They'll talk to their families every day, what a great thing that is." Well, it is and it's not. It's a double-edged sword. If you've been working all day in space and you've had on the task list everything that you had to do by this hour, and the ground wants these pictures down, and you finally get to your pre-sleep period where you can take a breath a little bit and you call on the IP phone and your spouse says, "Hey, I thought you were going to take care of that roofing before you left, you need to call the roofer. Johnny got a D on his math test, and you talk to him because you're the one who usually helps him with math." All of a sudden now it's not just your problems that you're dealing with, you're dealing

with the other problems. There's a fine line between support from the family and from the surface, and taking on the ownership and onerous responsibilities from the surface and the family. We parlayed those lessons from space flight into the mine as well, and with the Chilean authorities.

Then of course we had to start thinking about the rescue portion. The rescue was fairly interesting from a NASA standpoint in that we used our engineering and design expertise. Clint Cragg was the leader of that area through NESC. Designing the capsule wasn't just, "Well, I'll make a metal cage and bring them up." There were different things that we had to consider. First of all, it's a 2,400-foot journey, and you're limited by the size of the drill bit at 26 inches. Somebody standing essentially at attention [military posture] in a cramped metal cage of 26 inches, just like an 18-or 19-year-old out on a parade ground. A healthy, vigorous, athletic 19-year-old soldier stands there with his knees locked and after five minutes will pass out on the parade ground. The problem with the miners was unlike the 19-year-old soldier who passes out and then becomes flat and then has blood return back to his heart and brain, if you're in a cage where you cannot lie flat, you get what's called orthostatic hypotension. You're not getting enough contractility of your legs, your blood is beginning to pool in your lower extremities, your blood pressure drops and you're not getting enough blood back to the right heart and you pass out. Eventually when you don't get enough blood to the right heart and you can't lie down, you're in danger of dying. That's one thing that we had to worry about, how are we going to combat that?

Also, how are we going to monitor the folks on the way up? Whether they were going to panic, whether we could see if they were breathing or not, whether they had enough oxygen. If the cage got stuck because of rock, you only had the oxygen above you and below you. You

were going to have metal above and below you in the cage, so that small volume of oxygen or the small volume of CO_2 that you would produce, we had to worry about all of those things.

If the rock that was loose up at the top of the mine fell down and actually pinned the cage, you wouldn't want some guy stuck in a very narrow tube for a day and a half. First of all, physiologically he probably wouldn't tolerate it. He could get the orthostatic hypotension and potentially die. But second, he would burn up his oxygen and produce too much CO_2, so we had to figure out a way that they could escape, even if they were in the cage.

All of those things went into design requirements. Initially we wondered should we build the cage, should we build the capsule? The Chilean Minister of Health, I thought, was also ingenious in how they attacked this. I think part of it was for PR [public relations] reasons, they needed something to show that the Chilean government was helping to do this, that they weren't just turning it over to folks. He asked me, "Actually what I need you to do is give me all the requirements for this." So, much like when we build a space capsule, we built the requirements. What are the physiological requirements, the medical requirements, the cage requirements? Should we do a fault tolerant with this, that, or another? Should it have levers for an escape for the bottom to drop out? Should we do this, should we do that?

We had pages and pages of requirements written in typical NASA fashion. We wrote these in very short order after we went down to the mine, and the teams worked very diligently on it. Engineering even had concepts, they used the students that they had in engineering to help build conceptual vehicles out of PVC pipe. And we had the small—it's a laser kind of putty cutting, much like they use in the auto industry to make models of cars. We have the same thing for space vehicles, where we can take our requirements and our dimensions and make a three-dimensional model of the vehicle. The engineers even had several three-dimensional models for

us to show the Chileans as to how this would look, which I think helped. They took the requirements and they gave them out to the industry and other places, and, again, used competition and innovation and said, "All right. Here's the requirements. Bring us your best models."

Several companies responded, as did the military, as did other different industries, and they had several working prototypes brought to them. The Chilean Navy actually had the best design, and so that's what they went with, the Chilean Navy design, but it was based on NASA requirements. The Chilean Navy did tweak some things and made some upgrades and had some interesting ideas as well that were parlayed, a lot of our different requirements. It worked very well.

One of the things that we do for the Shuttle and the ISS is before the astronauts come home, because they are at a loss of fluid volume because of the fluid shift on orbit, we do what's called a preload or a salt load. They usually take a certain amount of salt tablets and a certain amount of an electrolyte fluid. What that does is increase what's called preload in the venous capacitance of the body so that your blood pressure doesn't drop. That way when astronauts go from zero-G [gravity] to 1-G, their blood pressure doesn't drop and they don't pass out while they're trying to pilot the Shuttle or the [Russian] Soyuz [spacecraft]. That fluid load is also augmented by a garment that gives pressure to the lower extremities and pushes blood up to the heart and brain. We also use exercise, the pilot and commander and these returning Soyuz crew, to increase the muscle contractility in the lower extremities. Your muscles also add tone to the venous system to allow that blood to come back to your heart and brain.

We used the same thing on the Chileans. They did exercise prior to their rescue, they did the same fluid load as we use on the Shuttle and the Soyuz, and they had a garment that was not

a pressure garment, it's called a Jobst garment. It's a tight garment underneath their clothes that pushed a little bit of the fluid and allowed the fluid not to puddle in their lower extremities, pushes the fluid back up into the heart and brain. That allowed them to prevent orthostatic hypotension while the guys are in the capsule.

They monitored the folks and their vital signs on the way up the capsule. The other thing that they had, if you noticed in the pictures, the miners all had harnesses on. They weren't hanging in the capsule itself, the harness was in case the capsule got stuck. They had a separate cable that went through the capsule, and there were two levers that would allow the bottom of the capsule to drop out so that the miners could be lowered back into the safety of the mine in case the capsule got stuck. That's why they had the harness on. We had thought about those things.

The miners themselves had not been exposed to ultraviolet radiation and sunlight for months, so, again, the Chilean health authorities had lots of competition and innovation. The Oakley [Inc.] company responded, so they had really nice Oakley sunglasses. They met the requirements of blocking UVA [ultraviolet-A] and UVB [ultraviolet-B], but also were temper-resistant so that falling rock or debris—they were also safety glasses.

They just did an outstanding job, and as you could tell when they got to the surface they looked like rock stars. Coming out, they were chanting and running around. But even then, one of the things that we asked the Chileans to do was to treat them in what's called a Six Sigma fashion. They should not be lulled into a false sense of security. When the folks get up and they get to the top of the mine, they're cheering and they look great, because they're running on adrenalin. Very often the blood pressure and/or pneumonia and/or whatever problem that miner might have, once the adrenalin had worn off, would take hold.

If you noticed, the Chilean health authorities, after the guys were done hugging their spouses and their kids, etc., laid them all on a cot in the same fashion, took them to the triage tent and examined them and did treatment on them, made sure they all had thiamin and other multivitamins and fluids, in that treatment area. They were all treated in that same fashion, regardless of how they looked, and that was actually very helpful because several of the folks were still ill. They had pneumonia in one, several were still fairly dehydrated. One was a diabetic that they needed to pay attention to as well. By doing that very standard Six Sigma, not letting their guard down, they were able to combat and prevent anyone having untoward sequelae afterwards.

They then took them by helicopter, which is another recommendation of ours, to the hospital and put them through the evaluations and checks. That helped for a couple reasons. It helped, first of all, that because of all the medical testing they were not overwhelmed by family and friends. They got to introduce themselves back to family and friends in chunks to allow them to get used to being back on the surface. It allowed them to treat things and make sure that they were healthy, but also allowed us to start telling them to get into the mindset of rehabilitation and convalescence.

I think that's the hardest part. We warned the Chilean health authorities that once they get to the surface it's not over. Typically what we've learned in space flight is we treat and/or rehab [rehabilitate] our folks for two times the length of confinement. There's psychological aspects, returning to your family. This was a traumatic event. The potential for post-traumatic stress disorder, the potential for nightmares, depression is very real. It doesn't show up right away in the first thirty, forty-five days; it shows up usually after that. We forewarned them about those things, that they were going to have to be diligent on those things. Health

consequences, virus reactivation, especially herpes viruses or Epstein-Barr viruses, still occur after very stressful events like that. And silicosis and/or lung problems, because they were in a mine with fine dust from the mining and the drilling, could still be a problem. They embarked on those.

I think, though, that the American public, the Chilean public, and probably to some degree the Chilean government started to get a false sense of security when the miners came out. One's going and running the Boston Marathon, one's on [*Late Night with David*] *Letterman* [television program], they're going to [Walt] Disney World [amusement/theme park]. You think, wow, post traumatic stress? They're going to Disney World, they're on *Letterman*. They're not having post traumatic stress. But we've gotten word since then that they are having problems and they are having nightmares and there are folks with suicidal ideation. The things that we knew would occur, they don't usually occur in the first day or two that you're up, or the first week or two while you've got the spotlight on you. It's usually after all the press goes away and all the attention goes away and it's just you and your thoughts at night, and your own demons, that those things occur.

So I think, at least from our standpoint, a lot of the lessons from space flight—whether it was the fluid loading, whether it was lessons that we've learned from orthostatic hypotension from our labs and other places, whether it was how to re-feed folks that might be starving due to Shuttle/Hubble missions—all of those things came into play—the psychological aspects that we've learned on ISS, probably more so than we even anticipated in our first conversation or two. And, fortunately for us, a very positive outcome with the thirty-three people surviving.

But typical of our lessons learned, we still feel that mission's ongoing. Whereas most folks would say that once the thirty-third guy was up the mission was over and that's great, we

still have the mindset that until we get about a year away from this the treatment for depression and post traumatic stress and the psychological aspects are still paramount in our mind to treat those folks. Those are things that we've learned from exploration and from tragic events as well.

Even [Space Shuttle] *Columbia* [STS-107 accident] and [Space Shuttle] *Challenger* [STS 51-L accident] have taught us. Because of our own tragedies and stressful events, treating those folks and the survivors on the ground, how long it took for folks to recover from that, even those lessons learned—which I think Rick [D.] Husband and the crew would probably be grateful that at least there was something to be gained even from tragedy at NASA—could be applied to this Chilean mine rescue. I'm sure in Al's [psychologist] mindset he's still thinking that it's still going on. It'll be every bit of a year or more before those folks are stable at least psychologically and not at great risk for suicide or depression.

WRIGHT: Listening to it, it sounds like so much of what you needed to assist them fell into place. But what were some of the challenges that you faced, especially at the onset, of being able to gather the information and/or get the resources you need to be able to help them?

POLK: Actually, not many. To be honest, the Chileans were extremely forthcoming, which is, in and of itself, different. You think about when the United States or the Russians have a submarine that is stranded or we have Hurricane Katrina even. Other countries offered to help us. "Oh, no, we got it." There's a little bit of ego there, there's a little bit of you don't want to be the most powerful country and relent to someone else's help. The Chileans looked at it totally differently, in a different mindset. They're like, "Hey, we're still in charge. Bring all your ideas.

We'll look at all the ideas, and we'll pick the best stuff out of everything, and we'll do whatever we can from an innovation standpoint to apply your lessons to get these folks out."

It was not this, "Nope, we got it. Thanks, love you," kind of egotistic or egocentric type of mentality. It was totally opposite. They were extremely grateful for the information and the insight. They were still in charge, obviously. They were going to decide whether or not they were going to implement your advice or your counsel, but they were very forthcoming with what their needs were, what their gaps were. If we needed any information on the mine or what type of drill or this or how fast, we got that information right away.

And likewise at NASA, although our primary purpose is space flight and space flight missions, we had no problem getting folks to help us and/or pay attention to this. Engineering, for example, building the models. We were careful that we were not going to use taxpayer or government resources in areas that we were not authorized to do, but to theorize and/or to use the science and engineering background of the agency for folks to say, "Here's an idea. Have you thought about this for the design of the escape pod?"

It was remarkable as to how much information we could get and come to bear. Even, to some extent, our international partners—the Soyuz fluid-loading protocol, in addition to our Shuttle fluid-loading protocol, see which was best. But little things. I'm sitting in my living room with my laptop, and I'd gotten an e-mail from one of the Chilean docs [doctors] who said, "How fast can this pod go up? We don't want their blood pressure to drop if somebody pulls it up too fast. Is there a standard?"

Well, in talking with my international partners and other folks, all on e-mail going back and forth, or Skypeing, there is an ISO standard [International Organization for Standardization]. ISO is typically a European standard agency. There's an ISO standard for the speed of an

elevator. They had done a great deal of study to make sure that when an elevator starts to go up, people's blood pressure don't all drop and you end up with unconscious people in an elevator. Within probably seven minutes of him asking the question, we've had a conversation on about four continents by either e-mail or Skype or the electrons, and I sent him the ISO documents and standards. Then we theorized, well, if they start slow and the first two seconds work up to the speed that a typical elevator would go to at a meter per second, then they should be fine.

It's interesting what a small and global community it's become. One, because of the networking that we have from the International Space Station. If I needed something, I could reach out and touch the Japanese flight surgeon, the ESA [European Space Agency] flight surgeon, the Canadian flight surgeon, the Russian flight surgeon. We are a global network. Also that technology has allowed us to e-mail, Skype, and/or sit there with your pajamas on and your iPad 2 [electronic tablet computer] and hold that kind of conversation.

WRIGHT: That's a good way to do business. Our time is up for now, and a good way of closing it is the fact that you're preparing for a trip to return. Of course it'll be a little different from the last time you went, can you give me an idea of what your expectations are or what you're hoping to gain from going back and talking with the people?

POLK: Most folks would assume that it's a one-way conversation, that we're going to down to see what worked, what didn't work for the Chilean mine. It's actually a two-way conversation. Not only do we obviously want to debrief what worked well, what didn't work well, what did they use, why did they decide not to take this requirement or use this requirement, but also what things we can bring back to long-duration space flight. A lot of the things that we used from

space flight were applicable to this situation that we never would have dreamed of. It probably works that way in reverse as well, that there are lessons learned and things that they learned—from the physiologic standpoint, medical standpoint, psychological standpoint, leadership development, business-type lessons, innovation lessons, not just necessarily things that live in the medical house—that might be applicable back to our space flight. Especially as we go and embark down the road for commercial space flight, where our mindset has to change somewhat from the way we've done business for the last fifty years. Their entrepreneurial and innovative spirit and how they attacked this is something that is probably a good lesson learned for us coming back, especially as we embark on commercial space flight, to see are those lessons learned we can apply there.

WRIGHT: I hope when you come back we'll have a chance to visit.

POLK: I hope so too.

WRIGHT: Yes, thank you.

[End of interview]