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ORAL HISTORY TRANSCRIPT

LARRY E. BELL
INTERVIEWED BY KEVIN M. RUSNAK
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RUSNAK: Today is June 26, 2001. This oral history with Larry Bell is being conducted in the offices of the Signal Corporation, in Houston, Texas, for the Johnson Space Center Oral History Project. The interviewer is Kevin Rusnak, assisted by Kirk Freeman and Sandra Johnson.

Thank you for taking the time out today to spend a few hours with us.

BELL: Well, that's okay. This is my golf day, but I golfed this morning.

RUSNAK: Okay. Well, I'm glad we didn't keep you off the course then.

BELL: Getting too hot anyway.

RUSNAK: Why don't you go ahead and tell us then about your background.

BELL: Well, like I say, I was born as a farm boy back in South Dakota. Actually, my dad will tell you that's the only crop he raised that year because of the Depression in 1936. But grew up there in a rural town of 400 and went to high school there. As I mentioned earlier, I was taking on a farm project, raising a third of a quarter section for working hard one summer and a spring, getting a crop in, and lost $110, so my dad promised me that he'd send me to college if I promised to get off the farm and not come back, which I did.

Got my engineering degree from South Dakota State University there in Brooking, South Dakota, and applied for several jobs. The first one that I received an offer for and I took was the Corps of Engineers out of Omaha, Nebraska. It was in what they called a training program, so you went for six months in different areas of their office.

The first six months was what they called hydraulic design, where we were working on designing hydroelectric power plants and dams for the Pick-Sloane Project on the Missouri River. And then I went into military construction, which is where they were building missile sites, and I worked on the Atlas-Fs and Atlas-D missiles.

When that was finished, NASA was just starting up, basically. Had been the old NACA [National Advisory Committee for Aeronautics]. I applied to [Lewis Research Center] Cleveland, Ohio, and they notified me they had all their vacancies filled, but had sent my application to Langley [Research Center, Hampton], Virginia. And I was feeling bad, because several of my friends had gotten jobs at Cleveland and I was late getting my application in, but it ended up, they hired me at Langley, but I was to report to Houston after January 1, 1962. If I reported before that, I had to go to Langley. I didn't want to move twice, so I took vacation for two weeks in Nebraska and came down here.

Got here January 3, and was number twenty-four on the list. The first fourteen were personnel and relocation people, so I got an early start in the Lane Wells Building, which was a rented building down on Wayside. It was fun to watch all the people start coming in because I was here when John [H.] Glenn [Jr.] flew in January, and after his flight, quite a few of the people from Langley started to move to Houston because it was where we were going to have the then Manned Spacecraft Center, and so that started my career.

Worked a little bit of Mercury and then I was assigned to the Gemini and worked environmental control systems [ECS], primarily, and worked the Gemini Program. I was at the Cape [Canaveral, Florida] for Gus [Virgil I.] Grissom and John [W.] Young's flight. Took several days coming back. When I got here, they called. The phone was ringing and they said to come to work. The Russians had just done an extravehicular activity [EVA] and so we were to move out to try to do the similar thing on the very following mission, which was going to be in just a couple of months.

So we had a hectic sixty days, but we built the Ed [Edward H.] White [II.] EVA life support system. I was a project engineer on that. We got that hardware on board and flew that, so that kind of sent me down the road of extravehicular activities, and worked in that for quite a few years in Crew Systems [Division], headed up the EVA Development Branch and started the extravehicular hard suits and was head of the procurement for some of the later Apollo and then for the Shuttle space suits and Skylab in the middle.

I worked in Crew Systems Division [CSD] for over fourteen years and I was deputy division chief for Skylab when we did the Skylab Program, so I had an excellent opportunity to work all the parts of the life support including the clothing and entertainment equipment and EVA equipment and food and everything that we did for life support and human engineering on the Skylab Program, which was the first Space Station, if you can call it that, because we stayed there for months on end, 56-day missions.

It's interesting, because Jack [R.] Lousma, who was one of the first 56-day mission astronauts, was my next-door neighbor. One night we had a little storm, hurricane, that they had spotted, by the way, in the Gulf, coming in. His wife called me at home one night and said, "Jack was wondering if you could come over and help move up some furniture if the water comes up," and I said, "Jack? He's in orbit." She said, "Yes, he called down tonight on his personal phone call." Never dawned on me at that point that he was talking to her in the evening on a private conversation and he had asked me to come over and help, which I did.

Got to be good friends with quite a few of the astronauts in the early days, because there weren't that many of them. John Young and I still—I consider him a friend yet, and Ed White was a personal friend of mine, a tremendous loss. So I worked there in Crew Systems

Division until I was detailed to the Medical Directorate in 1975—actually, January '76—and I spent about a year there while Dick [Richard H.] Johnston was gone, and then he returned.

I went to the Engineering [and Development] Directorate [E&D] and was assigned to the Space Shuttle Program Office as the Engineering Directorate representative for payload integration and cargo integration, and stayed there until 1981. I became the cargo integration chief of the program office. Left E&D and stayed there at the program office, and finished my career there in 1994, after quite a few Shuttle flights.

So I always felt I had probably the best job in the Center, because working in the cargo engineering and the payload integration world, we got to meet customers from all over the world who wanted to fly their payloads and design hardware to fly them. Built the engineering drawings, got the hardware installed and verified, and saw it fly, so we got all aspects of the program and got to meet the customers from all over the world.

So it was very, very interesting and probably, if I had designed my career, I couldn't have designed a better scenario than the one I ended up falling into, so to speak, just because I wasn't hired at Cleveland. And I might add, all those friends of mine that went to Cleveland, within a year, applied down here, and I got them jobs in Houston and they all worked here later, so I ended up having the right application after all, even though I felt bad, I didn't get accepted at Cleveland. It turned out I was the fortuitous one of that group.

So that took me from 1962 till 1994. I retired under the effort that [NASA Administrator] Mr. [Daniel S.] Goldin had for the buy-outs to get rid of what he called the "too pale, too male, too stale" group, of which I was one, and I stayed fully retired for about a year and then came as a mentor for a young engineer with Boeing, and I've been working as a consultant part-time with Boeing since then, and have just activated some hardware that we had designed and built yesterday on orbit in Space Station, so I keep my finger in that way.

It's in my blood, I can't leave the space program entirely. I have two sons that work out here, and so it allows me to keep abreast of what's happening and have a little bit of influence, if not much, anyway. I've had a pretty rounded career in that regard.

I remember back in Apollo [13], when we heard about the explosion they'd had, without a phone call to anybody that I know of, those of us that worked in Crew Systems Division started to come to work that night because we knew they were going to have a lithium hydroxide problem. The command module, the lithium canisters did not fit the lunar module and so it was kind of surprising. Dick Johnston was division chief at the time. Ed [Robert E.] Smylie and a whole group of us just kind of formulated in the office out there and for the next couple, three days, worked on an idea of how to put cardboard and tape and plastic together to adapt them, and the way we made sure we could relay the messages to them on the telephone is we'd put a secretary or somebody who'd never worked in the program on the other end of the telephone and give them the cardboard and the hardware and then give them the instructions until they could figure out how to do it by telephone. Then we figured we had the instructions clarified so that we could tell the crew what to do in orbit, without a picture, because in those days we didn't have videos we could send up.

So we had some trying times, that being one of them. Apollo 204 incident, of course. I participated in some of the investigation on that, which was not enjoyable, but necessary.

And likewise, on the *Challenger* accident, I was leading the payload team to make sure that the cargo integration aspect had not played a role or contributed to that failure, and so participated at Cape Kennedy. Those were two sorrowful times, but we always learn, and I think we made improvements as a result of both of those incidences that will benefit the program in the future. Unfortunately, we had to learn it that way.

But other than that, it was all joyful. It used to be, people would complain about going to work and I couldn't understand it because other than the fact I liked vacations, I really enjoyed my work, and there's a real joy to that. I think if you can enjoy what you do, then they're almost paying you for having fun, in that respect.

I met wonderful people. Still know most of them. And that includes contractors and customers, because we used to deal with the payloads as customers. I was talking earlier about the Midwest. I found it interesting when we were working the DoD [Department of Defense] payloads. Due to the clearances that were required at one time, I had to take a lie detector test, which we all did, and there was one particular question they asked me that I knew when I answered it, I didn't answer it very clearly, and that was, "Have you ever done anything for which you could have been fired?"

Well, you know, you think back over your career of thirty-something years. And later on, he asked the same question again, and I answered it, and they disappeared and they come back in a while said, "Let me ask why you answered that the way you did," because it was getting a funny glitch.

And I said, "Well, I've got to tell you. I had only worked for the government about eight months when some friends of mine came to town to visit me in Omaha, and I didn't have any annual leave built up, so I called in sick and took sick leave that day. And if I'd have been found out, I guess I could have been fired for that." Which was a true answer. But the guy that was doing the test said, "Where were you raised? In the Midwest?" I said, "Yes." He said, "You know, I could ask that question of somebody from New York or most of the parts of the country, and it would have gone right over their head. I could figure that you came from the farm belt of the Midwest."

Well, I had, but I found it interesting that from that answer he could tell that I was raised in that kind of an environment. I know of a couple people that retired that I felt the best honor you could bestow on a person if they'd been outstanding was to say they were absolute integrity, and I always strived to reach that goal. I figured if I retired and people said that of me, then I'd been successful. I guess that went in line with the kind of question he asked, but I always felt like I'd give a day's work for a day's pay and if I couldn't get it, I'd go home.

But I enjoyed every day of it and it was very, very fortunate to have had the opportunity to have the career I did, and I couldn't have planned it, like I say. It happened. I still think NASA's a great agency, and the goals that they've set are certainly admirable ones. I hope they achieve them all.

RUSNAK: From this overview you've given us, you can see why you feel that you had a great job here. You touched on so many interesting and different things, from working on the EVA-related things early on to the payloads later. You covered a pretty wide spectrum. But if I can take you back to the very beginning, maybe we can talk about some of the details here. When you first came on board, how much involvement did you have with the Mercury Program? You said that John Glenn was just going up right after you came on board.

BELL: Well, the Mercury was pretty much already flying, of course. I worked for a guy by the name of Frank [H.] Samonski, who was the environmental control systems, ECS, manager at the time, and another gentleman by the name of H. J. [Harold Joseph] McMann. Joe McMann and I were the only two here at the time. It's kind of interesting that after the John Glenn flight, they called us and asked us to go to St. Louis [Missouri] for a post-flight review meeting, to which I felt real honored.

I didn't realize, I didn't know anything. I had read a book about what the ECS was, and they started to ask a question about why didn't the water-gas separator work like it was supposed to, and were we going to have an answer by this time, and I didn't know anything. Between Joe and I, we were running to the phone all day, calling people to get answers, and I felt so inadequate. As a result, we started working on a little project for an in-line water-gas separator because if you ever heard anything about the ECS in Mercury, they had that heat exchanger. Of course, water would condense and blow into the airstream and go right on into the suit but to keep that from happening, they had like a sponge in there that's similar to a sponge you'd use to clean your counter. And it would collect water in it and every so often they'd compress it and squeeze the water into a tank. That wasn't totally efficient and sometimes the water would come into the suit and get drops of water in the visor and there was concern about inhaling the water.

So we started working on a design of an inline water separator that was using a material called [unclear], which, when it's wet, it'll wick water through but it won't let air through, and you can just stick a hose to vacuum and it would suck the water off, but it would not let the air out and so it could stay pressurized. And we were using a design similar to that in a heat exchanger on Gemini, which I had just started working on, so we built a little in-suit hose water separator and took it down for [L.] Gordon Cooper's flight, which was the flight we first flew it on, and then put it in the suit hose.

In fact, I went out to the spacecraft and installed it myself. Gordo drove me out there in his Corvette to the pad and we put it in the hose. That was my primary contribution, really, to the Mercury, although I followed it closely because everything we did there was second generation into the Gemini, and we were patterning a lot of our hardware off the Mercury hardware. And Mercury was flying at the time we were developing the Gemini, so I would follow it closely, but my participation was pretty well limited to supporting my branch chief and building that water-gas separator, and other small hardware items for the Mercury.

RUSNAK: Well, as you've said, Mercury's flying and Gemini, you're getting in on the ground level, so tell us a little bit about developing this system from the very beginning.

BELL: In fact, Gemini started out being called a two-man Mark 2 Mercury, if you remember that, until they called it Gemini, because of the twin stars, but we used a lot of the same design concepts—lithium hydroxide for the CO_2 removal. But of course, the water-gas separator's emission had been a problem in Mercury so we went to a new design. We were building a radiator to reject the heat for the first time, which was going to be in the skirt around the back of the Gemini spacecraft.

We were using cryogenics instead of gaseous oxygen and hydrogen, and were flying fuel cells, which was the first flight of fuel cells. And in that particular system, the environmental control system, that I was working, also was responsible for the hydrogen and oxygen tankage. We didn't do the fuel cells but we had to provide the hydrogen and the pressure regulation for the hydrogen and oxygen for the fuel cells, as well as having it for breathing. So the tanks were sized and John Glenn kept asking, "What do mean by supercritical?" That was a mystery to John. And I indicated that if you take steam, supercritical steam, in college. Obviously, he took that in college. "Well, yeah, I didn't understand it then, either," John said.

I said, "Well, if you take a liquid and you heat it to the right pressure and temperature, it'll become a homogeneous dense fog, rather than gas liquid, that way, and zero gravity. You can draw it out as a dense vapor instead of gas or liquid. If you just pump liquid in there, it'll come out all gas or liquid. You won't get the supply you want." And that was a mystery. He really didn't understand that.

So, Garrett AiResearch, who, at the time was building the tank, has actually made a plexiglas sphere. They put freon and a light bulb underneath it, and you could heat it up, and you could see the liquid line move up, and then pretty soon it would become a homogeneous mixture. And so we had some firsts on that system, and one of them was the cryogenics, supercritical cryogenics, which we've obviously used since. Because it was the first time we flew it, we had heaters in there to—when we got ready to fly, we'd hit the heaters and drive the temperature up so that the pressure would come up.

We didn't realize it takes time for that to become homogeneous, so on Gemini II, which was unmanned, we hit the heaters just before launch and brought the pressure up to 950 psi, and said we were there and launched them. As soon as we got to zero gravity, the pressure dropped off and went back to two-phase liquid, and we realized we needed to have a mixer or somehow get that homogeneous before we launched. And so we decided we'd just start letting the heat leak going into the tank, because it's minus 200 degrees below zero. We just let the ambient heat days ahead bring it up that way we’d get homogeneous.

John Young kept saying, "How's it going to work?" and I said, "It'll be all right, John." So the day before launch, they came into Fat Boy's for lunch at the Cape and John asked, "What's the tank doing?" I said, "It's at about 900 psi, John. It'll be just fine." So when they launched, on the way up, all the gauges went to zero and John pops up and he says, "I told them it went to zero. There it goes. The pressure's gone to zero. The oxygen pressure's gone to zero." And Gus says, "But John, it says our suit pressure's zero, too. That can't be right."

And about then, Houston, who was control center, just following along at the time, came up and said they thought they'd lost the DC to DC converter. They switched to the backup and all the pressures came back up. For years and years, John will go by and he'll say, "What are you doing to me now, Bell?" because he figured I'd trapped him on that one. But we learned a lot.

It was supposed to set the stage for Apollo and while people will argue that those missions weren't necessary, we did do a rendezvous, which was one of the things we tried to achieve with the Agena. And a lot of the new systems, like I say, the radiator systems and the cryogenic tanks and fuel cells were all systems that we proved out in the Gemini Program, in preparation for Apollo, which were needed to get to the moon and back. So I think it was beneficial. We flew a lot of missions in a short period of time, if you look at when we launched. Gemini III was in '65 and we launched them all and were done in '67 with Gemini XII, so they were pretty fast and furious there for a while.

We did our first EVA on Gemini IV, which I'd mentioned earlier, with Ed White and [James A.] McDivitt on that flight. There was a certain secrecy around our efforts to get ready to fly EVA on Gemini IV, not because it was classified, but because if we couldn't get there in time, we didn't want to have a failure, so chose to do it under a disguise of a chamber test system. If you go look at the hardware that we flew with a chest pack, it's called a CVS, which stands for the chamber vent system.

[Thermal-vacuum test facility] Chamber A and Chamber B were just being finished at that time, so the scenario was, we were building escape systems to go in and rescue a crewman if he got in trouble while in the chambers, so the umbilical and the chest pack and space suit were really rescue equipment for the chamber vent, why it was called the chamber vent system. We would do our chamber tests and the like at night, after people went home.

About midnight, we'd fire the altitude chambers up and do all our chamber tests and stuff at night, and then in the morning when they came in they'd all be done, put away for the night. So that it was easier to keep that until we knew we had the hardware ready to fly. There was one, I think, about forty-eight hours, I never slept. Slept on my desk a few hours, trying to get that hardware to the Cape. It was successfully delivered and installed and then we went to Washington on the Gulfstream. [Robert R.] Gilruth, myself, Dick Johnston, an engineer by the name of Johnson, and several others. Briefed the associate administrator on the fact that we were ready to do an EVA. [Wernher] Von Braun was there from Huntsville.

When we got done briefing them, they went over and briefed the administrator and then twenty-four hours later they made a press release that we were going to do an EVA on the next mission. At that time, the old Nassau Bay Hotel used to be over here, and Channel 2 actually went up and built a studio up on the top of the Nassau Bay Hotel. I should say, NBC did, with a big picture window so they could do press coverage from up there. So it was a big deal back when we did the first EVA because, like I said, the Russians had just done that not too long before and they will tell you that isn't why we did it, and that's why we did it on that flight, I might add.

We were already planning on an extravehicular activity, but in all truthfulness, we moved it up to Gemini IV to get closer to the time the Russians had done it, because there was a still a race on in those days. Whether we admit it or not, we really were trying to beat the—not beat them, but appear to be on the same pace as they were. We had been working on some of the hardware, but we didn't use the chest pack. It wasn't far enough along. We did use the umbilical that was being developed. At that time, it was going to fly on Gemini VI and I used a valve and some tankage that was out of the environmental control system that we'd built for the spacecraft, dismounted the valve and did all the engineering work here at the Johnson Space Center, under the Engineering Division. Had the Technical Services [Division] build the hardware, and the major components came from our suppliers, and then we packaged it and put it together.

The people that built the hardware, Garrett AiResearch, did not know it was being used for an EVA. Didn't know about it till the press release came out, and were somewhat unhappy that their hardware was not going to be the first hardware to do an American EVA. I said, "Well, your hardware is the first hardware to do an EVA. It's just done in a little different package." The oxygen tanks that we were using were originally for an ejection seat, and the ejection seats were too thick, so they'd gone to a different design, so the bottles were available, so we used those for the emergency oxygen bottle in the chest pack.

The regulator was the environmental control system pressure suit regulator and the rest of it was built here, and put together here and tested in the chamber by Ed White, in the altitude chamber. Dick Johnston, in those days, had a policy. The engineer tried his hardware first, so the first person that took it to altitude was me, but I barely fit in the pressure suit. I had my neck crunched down. I never got up. I sat in a chair and they took me to altitude and then brought it down, and then Ed White was the second crewman to use it.

RUSNAK: How closely were you coordinating here with the people that were actually working on the suit, to get that specifically ready for an EVA on this flight?

BELL: The actual suit design was being handled by an engineer sitting next door to me, Elton [M.] Tucker at that time. David Clark [Company] was the manufacturer. And again, they had been working on an EVA suit, getting ready, because we were going to do it on Gemini VI, so we took the best of the designs they'd come up with, and flew those. Did micrometeoroid testing here at JSC. [R.] Bryan Erb and some of them did that, to verify that we were protected against micrometeoroids.

But again, the contractor himself did not know we was going to EVA on that flight until the press conference. We'd kept that pretty well away from all of the people. And that was, again, in case we couldn't make it for some reason, or did have a failure, we couldn't fly. We didn't want to have a reported failure in the press. It was all very successful and went very well.

RUSNAK: Who do you think was really pushing to include the EVA on this flight? Was it coming from the astronauts or the administrators, the engineering people?

BELL: It wasn't the administrator because he didn't know about it until we told him. I think it came in a senior staff meeting here at JSC. Dr. Gilruth was reluctant because he thought that was probably dangerous and we ought not try that until we were really sure. I'm sure the astronauts were ready, and Dick Johnston, our division chief, was convinced we could do that.

I think Ed White and McDivitt spoke up and said they were ready if we could get the hardware ready, so it was kind of a joint effort here at JSC. There were probably thirty or forty people in on the development while we were working on it. It only took us about four weeks by the time we started, and we were ready to announce that we were ready to go. Literally, the hardware was at Kennedy and installed in the spacecraft before we made the announcement that we were ready to go. And if you remember, they built a little hand-held maneuvering gun. Howard Johnson, the engineer, had done that, although we had helped him get—bought, again, the same bottles. I got those for him and we helped design them, but it was his project, and we got all that down there at the same time.

That was the first maneuvering unit that was used, and a very short duration, but enough to prove that you could, in fact, point yourself and propel yourself where you wanted to go. There was a lot of other discussions about trying to get static electricity discharge, or dielectric measurements between the Agena and the Gemini. That was abandoned on that flight because there was too much complexity they had at the last minute. Later on, they did go up and do a measurement of the Agena, and actually docked with one later. We were going to do a measurement of the last stage, but that never happened. We just went straight to the EVA. That was enough to do on that flight, we figured.

There was discussion of that with Von Braun up there about not touching it with a ten-foot pole. There was talk about building some kind of a measurement device that you could measure the potential between the two vehicles. That never was done on that flight. The EVA was successful and it made big headlines. I think it was a real boost to the agency about that time, because a lot of the Americans were still of the opinion that we were trailing the Russians a lot, and that kind of gave them a boost to think, "Hey, we did have a chance to get to the moon first." There really was a race in those days to get to the moon. Apollo, of course, was that project, but Gemini did lay some of the groundwork for that.

RUSNAK: Do you remember what you were doing when Ed White made his EVA?

BELL: Oh, yes. I was sitting in the control center. Chris [Christopher C.] Kraft [Jr.] had wanted us there in case a question or anything came up about it, or pre-breathing, because we had not done that before or anything. Although we're on pure oxygen. But the pressure suit checked out and all that, so I was kind of sitting at EECOM's [Environmental, Electrical, and Communication Officer] console at his beck and call, in case something came up. We also had people located in Hawaii and other stations to pick up in case we lost direct communications, that were familiar with the hardware that could do that. Norm [R. Norman] Prince and his wife had gone over there. So I was there and I remember that. That was an exciting moment.

RUSNAK: I bet.

BELL: I've got a picture at home signed by his wife that says, "Thanks for a good suit."

RUSNAK: That's great. Did everything perform as you had expected, on this first one?

BELL: Yes, it did. Our biggest concern was overheating. We didn't have any cooling system in that device. It was just using the dry oxygen, purging the suit and of course the perspiration evaporating was the only cooling we had. If he got excited or worked too hard, we knew we'd saturate the system.

The concern there would be that we were venting the gas overboard, it would turn to ice and could ice up and we didn't want that to happen, because you plug up the relief valve system. We had one backup to that and then an emergency, so we had three systems, but he didn't want to use those, so we didn't want him to overheat and we knew that EVA would be a high activity level, so our biggest concern was whether we could keep him within thermal balance, and that was probably the biggest success.

I mean, not that he wasn't warm—I'm sure he was, and he did exert himself—but we were able to keep all of it in balance, and his physiological measurements stayed in bounds, so that was probably the most worrisome I had about that hardware that worked well because ultimately we went, of course, to cooling systems in later suits.

But the Gemini system relied just on the dry oxygen purging the suit and evaporation to cool, so we were limited to about 1000 BTUs [British Thermal Units] peaks, with 750 average, and that's pretty low in a pressure suit. You can't have much activity. It's all right to float around, but when they start doing things and pushing around and shoving, you know they're working too hard. We had that problem a lot on a later flight, when they were trying to get the maneuvering unit back into the Gemini. He overheated and the visor started to fog up and he couldn't see and that gives you a certain degree of apprehension. So in the case of Ed, I was pleased that he maintained his biological, physiological rates such that we could keep a balance that worked.

RUSNAK: Well, since you brought it up, let's go ahead and stick on the Gemini EVA, and you were just talking about Gene [Eugene F.] Cernan and the problems he was having on Gemini IX. So tell us how—well, before, Gemini VIII was going to be the next EVA, but because of the problems they had onboard, they couldn't actually do it. So how did EVA preparation, either equipment or in terms of the crew, change between the first EVA, Ed White's, and then these later planned ones?

BELL: Well, in the Gemini IX, the EVA system was the same system we'd been working on to get ready, that we didn't have in time for Gemini IV, so we'd used a simpler system on Gemini IV. The primary difference in those two was longer duration. The one that we used on Gemini IX still used oxygen evaporation as the primary cooling system, but it also had what we called an injector, and recycled a lot—it's like a pump. Water pumps work that way. They inject high-pressure in the middle into a venturi and it'll circulate the gas, and it had a cooling chamber on it to recycle gas so it didn't take so much oxygen. We were just dumping it open-loop. We were bringing oxygen from the tanks on the Gemini, blowing it into the suit, and dumping it overboard. Gemini IX recycled the gas in the suit and then had an evaporator to cool it as it went around, and dumped about a third of it overboard all the time. Kept two-thirds recycling.

But they were similar in design, except the Gemini IX actually had a little more capacity than the one we had on Gemini IV, but not a lot, but it was similar design. But Gene Cernan, in wrestling, trying and fighting to get into the maneuvering unit in the back, just exceeded the capability of the system. It was designed to about 1100 BTUs and he obviously went up to fifteen or seventeen hundred back there, working. And when he did, the system couldn't remove enough of the moisture and started to fog the visor and that was the concern, the problem he had. His activity, metabolic rate stayed lower.

The system was working all right. It just couldn't handle the higher workload that he was giving it. So we aborted the maneuvering unit as a result. After he'd gotten out of there and then settled, the system did recover, but once you saturate the system, it takes a while. It's kind of like overheating your own body. It doesn't cool down immediately. It takes it a while before you gain back the heat sink that you lost.

So by the time he got back in, it was recovering, but it hadn't ever totally recovered like you wanted it to. It caused a lot of reinvestigation of what went wrong with the hardware. We really did not make any major changes in the hardware beyond—in the future Gemini missions. It was just a lot slower activity and a lot of things in the crew activity, plans that paced the crew a lot slower, and they still do that to this day.

If you read the crew activity plans, they plan out everything the crewman does, and they do simulation as to maintain their work rate so they don't get away from it like that, so quickly. So we learned from that, too. It was really more in the crew activity planning than it was in—also in simulations. Water tanks and other things came into play as a better way to simulate that EVA activity because it's one thing to do it in one G, to stick your foot in foot restraints and grab arm hooks and pull them out, but if you're floating free and trying to contain yourself, it gets to be a lot harder to do.

So air bearings and water tanks and other things became more of an instrument in training as a result of some of those activities that were like Gene Cernan's, when we problems. And if you remember later, and I think it was Dick [Richard F.] Gordon, we actually put a task panel out there, and had him try different things. Pulling Velcro apart, turning handles, and torque values to try to write a specification about what the right torque values and sizes of knobs and all that should be for EVA crewmen, and it went into kind of a design handbook, and it's been modified and added to for years since.

But it became apparent that we need to have some design criteria, what size handrails should be and how big handles ought to be and how much torque can you apply and what kind of restraints we needed and whether tethers on the waist would be adequate. A lot of things had to be defined and it started with a Dick Gordon task panel to do some of that. The flight crew ops [operations] people started fashioning test devices, if you want to call it that, to do that.

Even in Shuttle, we did a sample rail. You remember on one of the flights with Jerry [L.] Ross and them, where they took one of the rails planned for Space Station and ran it up and down the Shuttle and did some task work to verify we could everything they had planned for Space Station. The whole training process is probably an outcropping of some of the things we learned on Gemini, for starters. Even, a lot of times, what you call a failure has the most value in terms of learning, and successes don't always yield as much benefit.

RUSNAK: You've mentioned the astronaut maneuvering unit on Gemini. What sort of coordination did you have with the Air Force on including that in the missions?

BELL: Well, the one that the Air Force was working on, which was called, I think, M509, was the code number they had on it. The one we had built that was in the back of the Gemini IX spacecraft—or Gemini VIII, excuse me—we had built one just about like it, and Gemini VIII used the same back mold and the same shell. We were going to get some early maneuvering data using just cold gas. We just had nitrogen thrusters in one we'd built for Gemini VIII that we never ended up data out of.

The one they were flying for the Air Force had hydrogen peroxide thrusters and it was quite a bit more sophisticated, so to speak. And it had an attitude hold capability that we didn't have, so we were trying to get a stepping stone learning curve, from the little hand-held to—we had one—we were still using a hand-held device, but putting the backpacks on with a—you could get a lot more gas, so we were just kind of stepping up.

There was still a discussion about, you didn't need all this fancy thruster system. A hand-held device that you just point where you want to go, like a bicycle handlebar, would be adequate. And so we had built the backpack system that was on Gemini VIII just to hold a lot more gas, with the intent that we were going to evaluate the hand-held, and then the Air Force was going to do the one that was in Gemini IX and we would compare results and find out if you needed to have a fixed-base thruster system versus a hand-held device. So we purposely made it look just like the Air Force one, the same back shape and everything so that you'd have a one-to-one comparison—one being with fixed thrusters, with controllers, and another one with hand-held, just to see if we could do a good comparison.

We never got, of course, that comparison, but we ended up going with a fixed-base approach for the maneuvering unit for Shuttle, which I think everybody had a pretty good feel that would work. The question was, it was simpler to go hand-held, because you know where you want to go. You just keep pointing to where you're wanting to go, rather than have—theoretically, you could get better fuel efficiency if you got good at that, than having to cancel out this thrust. You've got too much of this, and you take out a little of that, and it's bang bang. They call it a bang bang approach versus just thrusting where you want to go.

I'm not an expert in orbital mechanics, but I just built the hardware for them. We did build that cold-gas backpack that we flew, but we didn't get to try that one. That was on Gemini VIII, that had the thruster problem. We might have run into exactly the same problem Gene Cernan did, just getting into it in the back of the spacecraft, because he used the same adapter system. We might have had trouble getting into that, too.

The later editions to maneuvering units went to full foot restraints that you get into and back in. I mean, there was a lot of modifications that came out of the experience of Gene Cernan's that we used even in the Shuttle maneuvering system to donning station. Some of that data, the learning curve was used in the design of that system.

In fact, Ed [Charles E.] Whitsett was the project engineer that worked after the Air Force, then worked for us in the EVA suit system, and then worked on the Shuttle design early on. We had cross-coupling between the design groups that were working the two concepts, and comparing notes. In fact, there was a lot of cooperation between the Air Force and us. The Air Force had an active space program in that time frame. It modified Gemini. We had a joint conference, a symposium one time in Las Vegas between us and the Air Force. I mean, there was a lot of—at the working level, at least—a lot of trading of information and cooperation.

RUSNAK: Did the Air Force, aside from the backpack, want any specific Gemini EVA technology there?

BELL: Pretty much. In an EVA sense, they were pretty well tracking our system, yes, the suits as well. They had gone to a modified space suit, but they were going to the same vendors that we were, and talking to the same people and using a lot of the same designs. And of course, we'd benefited most of our technology from the Navy. People laugh when I say the Navy, but actually, the Navy is where the submarines had done the closed-loop life support kind of work for lithium hydroxide and carbon dioxide removal of different types.

And also, the Mark IV pressure suit was a Navy pressure suit, which is the one we adapted for first Mercury and then modified for Gemini, with the pressure-sealing zippers and all that. So there was a lot of Navy to mass a transfer of technology. A lot of the people in our Space Suit Division, people that came out of—Ted [Edward L.] Hays and Jim [James V.] Correale and some of those that were in crew systems had come from the Air Force, so there was a lot of cross-coupling at that pressure suit and life support area. I think we feed off each other.

We got the information from the Navy and then later on, the Navy's getting data back from us, and the Air Force is getting data from us. And of course, the Shuttle ejection seats came out of an Air Force program, so at the life support, space suit, food, crew-provisioning areas, I think there was a lot of exchange of data, and trade of people sometimes. Personnel would actually transfer back and forth. The Air Force assigned people to NASA to work here, to, number one, glean from NASA our techniques, but at the same time, bring their contacts here for information if we needed it. So I've always felt there was good cooperation and exchange of data, particularly in those areas.

RUSNAK: Well, it seems logical, I guess, given the parallels, and in terms of the mission, and the crew makeups, that sort of thing.

BELL: Yes, and I think—I don't know if you remember back—the early Air Force and Navy suits were called partial pressure suits, where they used to just have capstans that pulled the fabric around the arm and give mechanical pressure. Of course, they'd get blood blisters in the joints and all that.

So the full pressure suit that the Navy came up with was a tremendous leap forward in the day that it was invented. That's one of the reasons we originally went with David Clark, because he was the company that had done a lot of work for the Navy, and then the Apollo suits were of course International Latex [Corporation], ILC. There were other people trying to or were into the pressure suit business. Litton Industries and Garrett AiResearch even bid, proposed a suit for us one time. The hard suit that was in my group when I was in the EVA Development Branch, we developed with Litton Industries.

Had a lot of that technology adapted to the current Shuttle suit, the hard torso ring, upper torso, and get rid of zippers and go to closure rings because zippers were the scariest part in EVA we ever did in those days, because zippers fail anyway, as a routine, and what those had is a mechanical zipper and then a pressure-sealing lip. And when you see astronauts doing kneebends and spreads and the zipper goes right through the middle, you just almost cringe, afraid they're going to tear them apart. So getting rid of zippers was an important thing, and we didn't really achieve that until we got to the Shuttle suit. And a lot of that technology for the bearings and the waist joint at least was originated with the hard suit, so that technology transferred over in some cases.

The pressure suit designs, one of the biggest problems is the work it takes to bend things. It's like bending a pipe. Especially the gloves are hard because they're so hard. They're articulated so well that it's hard to build a glove that fits where you can move it. It balloons out and then you can't bend it at all, so it's the hardest thing.

So designing what they call a constant volume joint, or as close to that as you can get, is extremely important, because if you could get a joint that when you bend it, has the same volume of gas that it did before you bent it, then there's no reason for it wanting to go back, spring back straight. To do that, you had to build rings and put cables and spacing down the middle and make them bend exactly around a bent radius. A lot of that, not totally, but to a large degree, that's been achieved in the more modern suits, so that the workload goes down to do things like that.

Of course, in Shuttle, most of the work is free-floating. There's not a lot of walking. In a lunar surface, that was very important, to get a suit that walking, minimize the amount of work you had to do to walk and bend down and pick up rocks and all that. The Apollo suit did a lot towards that end. It wasn't totally constant volume, but they had a lot of convoluted joints, they called them, which were probably the most complex thing about that ILC suit was the guy that dipped those. I used to accuse them of having a witch doctor up there because this one would work and that one wouldn't, but they actually would dip those in rubber and make those molded convolutes so that they'd have the minimum amount of pressure pumping so that they could bend and they worked very well, I'll have to admit.

Think of the amount of work they did on lunar surface. If you ever put on a pressure suit and try to bend it, you suddenly realize that pressurized cylinders want to go straight, and so if you bend them, they want to go straight again, so you're constantly fighting that unless you have a good constant-volume joint, and it'll stay put. So that was always a challenge. Gloves are still a challenge and always will be. I mean, they use like wires and forms and everything they can, but if you make them too—too many pieces are bulky and they can't grab anything. If you just build a glove it's going to balloon up, and you can't bend it, so it's a real complicated device from here down.

The hard upper torso and the closing ring makes it a lot more reliable. Metal rings and seals, they might leak but they're not more apt to come apart. We did a lot of work in trying to make sure the gas connectors had poppets on them and the like so that if you ever lost a hose, you wouldn't lose the pressure suit immediately. It would at least seal off. So we've had cases where there has been like diving equipment, there have been diving accidents or something. They've asked us to do an investigation.

It turns out a lot of the safety inhibits and lock locks and things that we have done in EVA space suits have been able to feed back into the diving industry and other places. Like lithium hydroxide canisters. When they have been used, they pop out so you can't put them back in. They had a little poppet that snaps out so you can't put a used one back in for a new one. A lot of that has been adapted into other industries as a result of the safety consciousness of the EVA systems that are applicable to other industries.

There's always a technology transfer out of these things. For whatever we do here, there's another application somewhere else—the auto industry or whatever that can benefit. Many, many times we only go looking for those answers when there's been a major mishap or some kind of a problem.

The one I meant, the thing about a diving incident, it happened, I think, off the California coast, where a guy put a spent lithium canister in his diving system and then died because he didn't have any CO_2 removal. Reading the accident report, it became evident that there is a way to preclude that, and it just hadn't been modified into their equipment. And so there's a transfer of technology constantly in that field. Portable hyperbaric chambers, something we thought about when we were building space suits. We used to say, why couldn't we just build a cylinder, and you could take it out on a diving rig or something, and you could pressurize it and have a portable diving bell, so to speak, or emergency hyperbaric chambers. Fabrics—We've looked at building pressurized tunnels for like transferring between vehicles in space.

Well, some of that's been adapted to like diving submarines, stuff where they can attach to other vehicles. I'm not sure they used our technology, but it's there. I mean, the same thought process gets you through that. To saw off some of the aluminum that was holding down the solar array on Skylab, we used a bone saw, which the physician told us about. One of the doctors over at NASA said, "If you need to saw that aluminum, you ought to go get you a bone saw. That thing will saw that." I said, "What's a bone saw?" He said, "Oh, when they do skulls or something, they'll put a wire cable through there that's got carbon in the grit or something, or diamond dust, I guess, and it'll saw the bone. That'll saw that."

Sure enough, you buy this thing, it's got a metal ring on both ends, sawed right through that aluminum just like that. Later on, the auto industry used them to cut off tailpipes and stuff. The guy that sold us that realized he had something that would cut metal pipes. Well, he could sell that other places. All kinds of data like that that comes out of the—we built suits for, as you remember, the boy that couldn't get out of his biological protective shelter. They built him a suit over there in crew systems so that he could get out and at least walk about. "Bubble Boy" they called him. Biological garments.

There was a big concern when we first went to the moon about bringing back moon bugs, do you remember? So we had to build biological containment garments. They made them wear these stupid-looking masks and a green suit with a visor. But it was proven that you wouldn't get biological samples through it. In case there were anything on them, you'd get them into the containment trailer before the—well, then, years later, there was the green monkey disease broke out over in Africa and they took the lunar trailer that they had for the astronauts and the biological garments and flew them to Africa to get those guys that were suffering from that in to where they could do some samples and find out what they were suffering from.

That was from the Center—what do they call it—the CDC—the Communicable Disease Center, CDC [now known as the Center for Disease Control, Atlanta, Georgia]. Had heard about that and wanted to know if we had one, and they flew it out of here. So I think there's technology that I probably use everyday that one way or another was at least promoted by the space industry or accelerated maybe by the space industry, whether or not they were totally responsible. But in the life support space suit, biomedical data.

One of the systems that was in my group was the biomedical instrumentation data and Dr. Cooley one time—one of the guys who used to work here at JSC had gone to work for the Baylor College of Medicine downtown, supporting them on heart transplant pumps and research, and was telling them about some of our biomedical instrumentation here, and they had just done a heart transplant on an individual.

So we took down some of our biomedical instrumentation and put it on him and put a recorder so they could record the EKG [electrocardiogram] data, twenty-four hours a day. Up till then, they could only do it when they plugged him into one of these big boxes in the lab, and they'd do that a couple, three times a day. It was the first time Dr. Cooley had seen that clean an EKG. He says, "There's no wiggle in the middle." I said, "Well, that's 60-cycle noise. We filtered all that out."

So they started realizing that they could get a cleaner EKG signal if they just had their equipment modified a little bit. Plus, the portability. They could put this instrumentation on him and get twenty-four hours of data versus just periodic readings. And from that, between them and the Air Force high-altitude aircraft people's recorders, they started using twenty-four hour recorders, and of course, since then, other developers have developed all that equipment.

There was an individual who was a leading heart surgeon looking at some of our instrumentation and saying, "I have never seen a signal quite that clean," so there's a lot of that that came out of the human engineering aspects, I think. Of course, I worked in that area for quite a while, but there was a lot of transfer because a human's a human, whether they're in space or on the ground.

I think that's one reason there's a lot of—everything we learned in trying to minimize the size and weight of instrumentation and the like makes it beneficial then in the technology for people walking around with, be it an insulin pump or whatever. You know, the miniaturization of electronics in general has been a tremendous asset in that regard, and we were forced to it early just because we were flying minimum-lift vehicles, so everything had to be light and small.

So it would have happened without us maybe, but I think we accelerated the developments in the biomedical worlds at least, just because we were forced to have something they could keep inside the spacesuit, small and nonintrusive, so to speak, and yet, give good signal data that they could send so I felt that that was a very large area of technology transfer.

And then after I was out of the business, the medical director went out and put portable medical facilities for the Indians, through a lot of that technology that I didn't have anything to do with, but they did a lot of that, so I think that's an area where a lot of technology transfer could probably be traced, as well as materials from spacecraft and that sort of thing. The human aspect is the quickest to identify, just because they're almost immediately transferable. Anything we did on the human on space is immediately applicable to the ground as well. It's not unique to space, so it's probably easiest to relate to.

RUSNAK: It all goes back to these first few programs there that you worked on.

BELL: Yes, a lot of it I built that surely set the stage for a lot of that. Not to say there's not a lot of advances that have been made since then. Any one of us to go to the doctor these days and they do an EKG. They use those kind of sensors, you know that they used to sandpaper you and put alcohol, and nowadays they've got gels and stuff, but it's the same basic technique that we used back then.

Of course, we did the same technique they did in the labs, only we did it differently because trying to get it under the space suits. I think these go back and forth, is what I'm saying. One technology feeds from one and then the other goes. It's an exchange both ways. Technology advancements in the medical field can certainly be applicable to the space program as well, so it's a two-way street.

RUSNAK: From what you said, from some of these other areas, the military and such, where you get the technology transfer in the first place, so it's coming around, I guess.

BELL: Yes, and I'm sure that they have probably benefited in the other direction some, too. I know the Air Force has, and I suspect the Navy may have, too. I'm not sure.

RUSNAK: Well, we've talked more than a little bit about integrating life support for EVA, that sort of thing, but we didn't really talk about into the spacecraft itself in these missions, perhaps, that didn't have EVA on them during Gemini, the long duration ones. What did involvement did you have with the environmental control system that's just an inherent part of the capsule?

BELL: Well, I was what they called the subsystem manager for the Gemini, you see. It was not the Apollo. So working with the designers and the contractors, of course, we designed and developed and built the hardware. Also, we had a test system set up over in the old Crew Systems Division laboratories where we learned a lot about its performance characteristics.

When we lost an oxygen heater one time, the pressure started to fall real fast. There was a real concern about, would it continue to function properly. Well, we'd done enough testing to know that at a certain output level, it would continue to function even at a fraction of its original pressure, because what we had is oxygen pressure reference to hydrogen pressure reference to water pressure. We had a three-way reference, so as one went down, how did we know everything wouldn't immediately go right down with it?

Fortunately, by having experienced the actual hardware in the testing, we were able to answer those questions as it went, and allowed the mission to continue. We did power down so we'd get the power level down to where it worked. In fact, we had a real case about when would the pressure build back up and then eventually it'll vent. You know, there was a heat leak into the tank. We had a real bet going on over in the control center about when this tank was going to vent, and so they had a pool going, like a football pool.

Well, I should know this tank better than anybody, because I'd worked with it from the design up through the test, so I had predicted when it would vent, based on the heat leak. Other people were making their bets. I was tracking right down the line. It was just about going to go when I said it would, and the crew woke up early one morning, and as soon as they started to breathe more oxygen and get more active, it just leveled off all day long and didn't go off till that night.

One of the secretaries won it because she didn't have any idea when it was going to vent, but she won the pool. So we learn a lot about—and that's interesting, because from that change, and we knew the heat leak on the tank very carefully because we had tested it, so you almost predict exactly how hard the crew was working based on how fast or how slow the pressure changed. He could relate that right back to heat leak on the tank and say they're using so many pounds of oxygen per day, and so many pounds of oxygen relates to so much metabolic rate, so we learn a lot about behavior of systems and what demands—how they drive the system by their activity, and the interrelationship, I guess, is the right answer.

Well, John Young one time was complaining his eyes were burning and we thought it was lithium hydroxide, and when I was looking at the log later I realized he'd broken a bag of Tang, so we started looking into the ECS, taking it apart, and there's like yellow Jello all over inside the system. So I called up John. I said, "John, I figured out what was burning your eyes. It was that Tang." He said, "Oh, no. That happened at a different time." I said, "John, I found it in your underwear, in the neck of your suit." "Who else knows about this?" he said. But that's what it had been.

And what was funny is I had an individual who worked in my shop that had one bad ear and he said, "I'll bet that stuff would sting," so he threw a little in his eye, and oh, man, it burned something terrible, with that citric acid. But the fan had quit running on this ECS and that's why we took it apart, to have the fan brought in to find out why the suit compressor, we called them, didn't work. Well, it was full of Jello. I mean, this Tang had gotten sucked up in there, got wet, and just turned to Jello, and stopped the fan.

I told John, I said, "I think you used your suit hose as a vacuum," and what he'd done, that stuff was floating around, so he'd unhooked his suit hose and sucked it all up like a vacuum cleaner and it had gone right into the fan, and plugged it up. We could tell a lot by looking at the hardware what had really happened. John says, "I don't think so. I think it happened at a different time." I said, "No, come on, John. Let's go have a beer and tell me what really happened here. I think I know."

But the system worked pretty well. We had the radiator, and again, it was the first time we'd flown a heat-rejection radiator on a spacecraft, and the first time we flew it, it got too cold, way too cold. So there's was all kinds of suggestions on how to make it run warmer and the simplest one and what we ended up using was black tape. Somebody just ran strips of black tape down the radiator and of course, that warmed up those sections of the radiator and we put on the amount of tape we needed to match the heat load of the mission.

Analysis people will tell you that's a poor way to fix an overdesigned radiator, but it worked. In that case, we couldn't do much about the radiator because it was the structure for the vehicle, too. It was like a T-beam that had a tube in one end of it so that we actually used the structure that held the faring as the radiator, so we couldn't cut out tubes or anything. It was fixed in size. About all you could do was change the color or do something to cut its performance. The simplest one was to put black tape stripes on it and that worked pretty good, as a matter of fact. It wasn't my idea.

Then we went into Skylab, which was—I didn't do the environmental control system on Skylab. That was really coming out of the Huntsville [Alabama] Marshall Space Flight Center, and McDonnell Douglas, but we did have the crew equipment, which, again is the EVA and sleeping station and hygiene and entertainment systems and all that. That was kind of a funny one, too, because they decided they needed a fire hose, in case we had a fire in the electrical system somewhere, to get a water hose with a spray nozzle in it to fight the fire because we weren't in pure oxygen in Skylab. It was a mixed-gas atmosphere, seventy-thirty.

The Huntsville people had come up with a cost that Kenny [Kenneth S.] Kleinknecht, who was heading the program at that time, said was outrageously high. He said, "I'm going to get my guys over in crew systems to come up with a proposal. I know they can do it cheaper than that." So we got busy and put together a proposal on how to build this thing.

Well, it turned out it wasn't any cheaper. Just about as expensive as the one Huntsville come up with, and one of the guys sitting in my office one night, and it wasn't me, he said, "Why couldn't we just use a garden hose?" We kind of laughed. He said, "Oh, no, I mean it. Why couldn't we just use a good Sears and Roebuck or somebody's garden hose? That ought to work."

So we got to kind of laughing and thinking, why couldn't we, so he took off with some petty cash from the Hamilton Standard petty cash and went to the Pasadena Sears and Roebuck store and bought a $20, which was expensive, garden hose. It was 75-footers, in those days. Come back, and we cut the ends off, put fittings on them, wrapped them in beta cloth, put them under pressure tests and pumped them up to find out what pressure it took to blow one up, and then we put one on pressure and left it to sit, and took another one and cut the ends off, sent it out for a burn test to make sure you could or couldn't burn it, and toxilogical tests and all that, and about three days later we decided we had us a fire hose.

So we went to the big change board meeting over in [room] 602, I guess it is, up in Building One, the conference room where they had the change board, and I had these charts and we started presenting them about going to the hose manufacturer and it was going to be $60,000 or whatever it was for the mandrels and three hoses and the qualifications. It was going to be $160,000 and the Huntsville were saying, "I told you, Kenny. It's going to cost just as much as ours." I said, "Oh, you want the low-cost option? Give me backup chart number one."

And we go to talk about a Sears and Roebuck garden hose and we put this fittings on it, and I hear the people at Marshall saying, "I don't want to fly no Sears garden hose in my spacecraft," and Kenny says, "Keep quiet. We're going to hear this story."

Finally [unclear] said, "Well, how soon can you deliver one?" and a guy by the name of Roger [N.] Tanner reached under his chair and said, "We've got the training unit right here," and threw it on the desk. "Well, can you get it?" and it's all stamped off by quality and it's got these clean stamps and everything, and that's what we flew on the Skylab.

If you go look at the one over here in the Space Center [Houston], you can see it wrapped up around the water tanks up at the top. And it's nothing but a 75-foot garden hose that we cut off to sixty feet and the other ends of it were used for test samples. So some of those things became kind of fun. Same thing with the entertainment kits.

We had an outfit, people from California came in and they had studios making music for them and everything and the crew says, "Why don't we just pick the music we like the best? Why do we have to listen to this stuff?" I said, "I don't know. There isn't any reason why you can't."

So they just sent them downtown with petty cash and let them buy the number of tapes they wanted, bring them back, put them on there, and they went in the chamber and tested them and they sounded terrible because at the lower pressure, no bass, just real squeaky sounds. So they sent them over here to the labs and they just boosted up the bass till it sounded right at altitude and then that's what they did to them all and that's what they flew. They allowed seven inches high. That's all the volume we had. Buy whatever they want. We didn't care what it was.

Pete [Charles] Conrad [Jr.] took all maps. He wanted maps. He liked to look out the window and look at the ground and see where he was. So we just said, "You each have so many cubic inches of volume. Put anything you want in there." Give them the money and let them go buy it. It's a lot simpler and they liked what they had. Rather than going through all these studies about what kind of music and how they'd like this or that. Didn't need that.

It simplified the whole process sometimes. I find that to be challenging sometimes, to see how much can you simplify the whole process and still have a good product. I mean, there's nothing wrong with the product. The reason that garden hose would work is they didn't really care how flexible it was necessarily, as long it would move around where you needed it. Main thing is, it didn't want it to leak and one that would hold the pressure and last that long. Well, their most expensive garden hose will last you for years if you buy it right, so it was a good one.

RUSNAK: It probably outlasted Skylab.

BELL: It's still over there. The Skylab's on the ground.

RUSNAK: A couple of questions about Skylab since we're already on that. You were responsible for all the crew equipment in there, right?

BELL: Yes, I think what we referred to in those days was the human factor, or the habitability, I think it was called habitability hardware, and then the EVA hardware. Those were the two things that our group was in charge of. Clothing included in that, by the way.

RUSNAK: Here you've got people up for fifty or eighty some odd days, where they're almost in a regular shirt-sleeve environment, where they were working much different from Apollo or whatever. How did that approach change things from just looking at the very beginning, in terms of the kinds of the things they're going to need up there, and the differences in some of the basic stuff that was included on previous programs?

BELL: Well, there was a lot of—in fact, I think an outfit by the name of Raymond Loy [phonetic], out of Paris, did some human factor study for things like colors of the walls. You're in a confined space. Do colors affect you? And he got into the clothing, too, about colors of clothing, and we ruined all that by going to flame-retardant clothing. It was all kind of golden brown, and upset the human factors people, but it passed the criteria for not melting.

But we got into things like some astronauts like shorts. Some don't like shorts. Some like long sleeves, some like short sleeves. So they actually made them with zip-off sleeves and zip-off pant legs, with a little flap over it. That way, they were adaptable to the—it's amazing. Some people like to have a light jacket with a little elastic wristlet around the sleeve, and the next guy, no, he likes his loose. So we tried to build the Skylab clothing to allow for those changes without the basic design changing.

In other words, you take yours and you take off that cufflet if you didn't want it, or you take off the lower sleeve if you didn't like it, and that way, all of them were alike, but yet you could customize them without having to have a lot of different designs. Keep the cost minimized that way. Other things, like their undergarments, were just whatever their favorite brand. Go down and buy Fruit-of-the-Loom if that's what you like, and we would package them for them.

The biggest thing was to find out how often they had to change them because we couldn't pack as many as they might like so we had a duty cycle. They could wear outer garments for seven days, and undergarments for one, two days. I don't remember the numbers, but we had to go through and actually come up with the criteria to get it all fit into the lockers. And then to get it to fit, we'd vacuum-bag them. There would be a stack this high and it had to go in a little locker, so you'd put a bag around them and shrink them down and shove them in and then cut the bag. The crew's up there trying to pull these clothes out. I mean, they did complain about that, and I can understand why.

We got them in all right, but they had an awful time getting them out. The first couple garments, they'd almost dump the whole bag out getting them out. Eventually I could throw the dirty ones away and then move some over to another locker, but the first few guys had a real problem with that. But it was the only way we could get as many clothes as we wanted to into a given volume, and we were limited in weight and limited in volume, and clothing is mostly volume.

But we were able to accommodate most of their preferences. I wouldn't say personal desires, but preferences that way. And that was probably the first time that had happened because, like you say, in Gemini or Mercury or Apollo, it was almost all space suits or take those off and just wear a coverall or something. There was not a lot of different things. Whereas on Skylab, they actually did experiments and exercising and a lot of things where different types of clothing were desirable. We were able to accommodate it pretty well that way.

The entertainment kit had—I don't know how much they used these things, but it had like playing cards and a Velcro dart game that didn't work very well. Might as well—find out you take the tails off and just throw a Velcro ball over it just as good, but we tried to come up with some things to kill some time. They turned out, I think, more window-watching, taking pictures and reading books and listening to music. They had these little portable cassette players. They could either put one in the speaker system in the entertainment center or they could take a portable one and listen to it, and I think that's probably most of what they did.

They had some fire-proof playing cards. Probably the only deck of fire-proof playing cards in the world, but we had them anyway so they could have them to play, and I don't even know if they ever used them. But they went through a polling of astronauts to find out what kind of things they'd like for entertainment, and I think most of them wanted books, music, or something to pass the time like that, as opposed to games as such. Darts are an old pilots game. Everybody figured they had to have a dart game. Again, I don't know if they ever did it. You couldn't have a pointed dart. Poke a hole in a can. Velcro ones didn't fly very good.

RUSNAK: I guess you don't have to worry about them curving downward too much when you're throwing them in space.

BELL: No. Throw them that way, they go that way. That's true. I hadn't thought about that. Of course, that was a mission we were barely able to save. We tore the solar shield off on the way up, and it was a panicked thirteen days in May trying to get that thing to where we could save it.

So I think we rescued a good mission out of what was, at that point, a handicapped spacecraft. Popped the parasol out and that was one that—our division, not me. Well, I helped with it, but our division built that parasol that popped out to keep off that thing. We did work on some gas sensors. First entered to make sure we weren't getting poisonous gases because some of the insulation was concerned that they would generate cyanide or some other kind of gas, so when they first entered, they wore space masks and did gas samples on the way in, and we did fly those on, but everything was okay. We'd cooled it down ahead of time, too.

It was a different kind of a program and we had enough to move around for the first time and they had exercise equipment. I didn't, but the system did. And sleep stations where they could actually have their individual sleep compartments. Probably haven't had that again yet, even in the Space Station, at this point. Eventually, we might have. We're not quite there yet.

RUSNAK: Were you still paying attention to the EVA stuff?

BELL: Yes, that was still out of our division, the Crew System Division. At that time, I was at the division level, working Skylab, so we had people working space suits and the EVA and crew equipment and personal hygiene and all that. Until I left there and went over to Medical Directorate. That was about, let's see, it was '75 when we flew that, so it was that next January that I got transferred over to Medical Directorate.

We had just started getting ready for Shuttle. We had the space suit procurement just about ready to be released when I left. Well, in fact, we had released it. The proposal had come in the day that I was transferred over to the Medical Directorate, I think, about that time, so we were already busy working on the Shuttle space suit system—EVA system—when I transferred out of Crew Systems.

RUSNAK: Before Skylab, they used a slightly modified version of the Apollo suit, but I think they had looked at some other ones and even a more advanced one where some of the hard suit—

BELL: We looked at what we'd had at the time. In fact, when we started in the Skylab, we had a competition between three suit manufacturers, actually, or four, where we had competed a development of an advanced with, at that time, AiResearch, Litton Industries, and a joint venture with ILC, had all developed a proposed suit for use on Skylab.

The choice to go with the Apollo version at that time was primarily based on the fact that Skylab didn't require new developments, necessary new technology, and there was a desire to stay with something that we could pretty well rely on schedules and costs with, rather than a new development, because we weren't going to need a lot of mobility per se, necessarily, for those missions. So the choice was to stay with the new version or a modified version of the Apollo suit. And from the standpoint of, there wasn't a lot of time to develop a lot of new technology and have a risk that something would go wrong.

The new developments did pick up some pieces, like one of things we adapted was the bearings that we had developed in the AiResearch suit. They had a set of rotary bearings instead of just convoluted joints. You could use a set of bearings and get the mobility you wanted by rotating bearings, and some of that was incorporated. The bearing seals and rotary bearings were put in the shoulder, so some parts of the advanced suits were incorporated with a very limited number of parts. But pretty much it was the Apollo version, modified. And it was pretty easy to predict that it wouldn't be a schedule or cost issue to do that.

And at the time, of course, we were flying multiple Skylab missions, but a lot of this stuff we were sending one up on the first launch. There was just really the space suit. The EVA equipment was about the only thing we resupplied flight to flight. But the mission has been very much the Apollo Telescope Mount. At the time we designed the suit, all we really had for EVA activity was getting the films out of the Apollo Telescope Mount. Of course, all that business of fixing the solar array and all that wasn't intended when we started. So we had a fairly routine EVA, and taking current technology we were familiar with had a lot of advantages.

RUSNAK: So were you an intimate part of that decision process?

BELL: Yes. I'm not sure I totally agreed with it, but I was part of it, yes. Well, no, I had some reasons to want to go with some newer technology, but I understood the rationale, and, yes, we were part of that decision.

RUSNAK: One of the other things they worked on on Skylab were these prototypes for the manned maneuvering unit, the different kinds, inside rather than externally.

BELL: Yes. It was what I referred to as M508. It was an advanced version, if you want to call it that, of what the Air Force had started. Of course, no hydrogen, but it was adapted a lot from that design. The gentleman I mentioned earlier, Ed Whitsett, was our project engineer on that. Again, come out of our group over there. Inside, a controlled environment to fly around and make sure that—it had a stabilization system so you could stop and it would hold you in one fixed attitude, like a little gyroscope system. And that was the first time that had really been checked out with a crewman.

It paved the way for what we're flying, or can fly, I should say, in Shuttle. It hasn't flown recently, but there is one that has flown in Shuttle. It has that kind of capability and is really an application from the M508 experiment that flew on Skylab. It was very successful. I think most of the experiments that were tested on Skylab—we did away a couple to make room for the parasol. Some of, what they called the solar experiments that went out through the side of the wall, we used up their slot when we put the parasol out, so they didn't get all of the science that they wanted, but what they did do, I think came out, as far as I know, successfully.

We had to add a lot of Tabasco sauce for the second and third crews because they said their food didn't taste as well up there on orbit. So we put a lot of Tabasco sauce up, and every bottle that went up, before it went up, we'd put it in a little glovebox vacuum chamber and take it to altitude and open the cap and put the cap back on, so that it would be at five psi and not fifteen. And that glovebox stinks something terrible. Tabasco sauce when it evaporates does not smell good. I found that out. Like an old locker room. But every bottle that went up had been burped, as we called it, before it went up. And the crew said that helped a lot. Slopped a little Tabasco sauce on their food and made it taste better.

But that was one of the first times, too, they had food warmers where they could put the food in a warming tray and actually warm the food and prepare a hot meal as opposed to just cold meals. I wasn't responsible for the food, but I know that the crew were happy to be able to get some better food. To this day, they have a lot better food than they used to originally. Those toothpaste tubes full of stuff didn't taste too good. Ground-up meat in a slop that the Mercury guys had to squeeze out of a tube, I don't think were very appealing.

RUSNAK: Well, let's go ahead and move into Shuttle a little bit. You mentioned briefly some bits here and there, but let's talk about your first transition into Shuttle, putting Skylab beyond you. What's the first interaction you had with the Space Shuttle Program?

BELL: Again, in the same position within Crew Systems Division. We had several systems that we were responsible for—what they called the air revitalization system, the thermal control system, which is the radiators and the freon systems in the payload bay. Again, the EVA suits and life support system in general, were areas that that group that I was with were responsible for.

We started immediately on the design—I remember flying out to Rockwell [International, Inc.] when they first got told they had won the Shuttle contract, and it was literally given as a good news-bad news. You're the winners of the contract; the bad news is, you get half the money that you bid. And that's where we started and spent the first two weeks out there, pulling content out of the program and cutting technology proposals back, to be able to afford Shuttle, because it was more than we were allocated in the budget.

So I got in on it at that stage when they first got—there were two airplane loads of us. There was one in Continental and one in National. So I guess you'd call it getting in on the ground floor. I did not do the evaluation, the contract evaluation, but once they picked the contractor, I got involved in, started up the design for those subsystems, for which I mentioned.

So we followed those developments up through the preliminary design review. In fact, went out to Vehicle 101 [*Enterprise*], which is the air-drop system. Was assembled at Palmdale [California], and we went through some checkout testing on that while I was still at Crew Systems Division, before I got transferred to Life Sciences for that years.

So coming back to it in 1977, I guess, when I came back into the Shuttle Program, I was pretty familiar with all of the subsystems and the hardware. I had been away from it for a couple years. I took on a different role, but it was a familiar vehicle, and I knew a lot of the people from having worked at it. We had some early design issues, primarily the size of the crew and the mandate. When we started, it was strictly a seven-day—fourteen man days is what the vehicle was sized for. It could be at two men, seven days, or seven men—basically, two men, seven days.

And it became evident right away we were going to have as many as seven crewmen for multiple days, and we started talking about redoing our design criteria because we had a lithium hydroxide canister that had to be changed out on a certain frequency, that it was going to get to be to the point where regenerative systems would have made sense for the size of the crews and the time. But for where we were, we were already into the design and there wasn't enough weight and volume and money to afford all that.

So we are living with some of those—although they have since come up with a regenerative system design for the Shuttle, we did not get it in the first phase, had we started out with—now they're flying ten, twelve days with five or six crewmen. If we'd had a ten-day mission, seven-man crew criteria, we'd have designed a different system in a lot of cases, than we did. So it's just a little testimony for the fact to start with the right design statement.

Having worked for a long time in the payload world, I will say that if I were designing that for what it was designed to do, I'd put all of the frames in the payload bay the same spacing, but it wasn't done that way. It was done for the minimum weight, so that every one of them are different dimensions, so you've got to have a different set of hardware for every bay you're in—be it bay one, two, three, all the way through bay thirteen. Because those that were designing the vehicle had a statement at work that said, you will be within this weight bogey and you're going to fly the vehicle so many times. It never even mentioned payloads. And then had another group off looking at payloads that said, we need to have power and attached fittings and the like, and were told to make due with what they had.

So the problem statement was, a problem with Shuttle, we probably way overstated the number of flights per year to be able to sell the cost per flight. I think we could have had a higher rate and we do fly, but it was overstated in the beginning. And as the program settled down into the real project that was going to fly, we did not end up, in some cases, with what we'd call the optimum system. A very, very good system, but not necessarily the optimum. So it caused us some extra work and problems as a result, probably.

A lot of those things we tried to change as soon as we realized it, but you get these kind of developments going, and at a certain stage in the development time, you can't go back and fix it in the middle. You can do it later, but you can't do it when you need to. And that's the old story. You can go back and make it right later, but you can't fix it when you need to.

So we don't always write our problem statements quite right, but I'm not sure we knew how to write it when we started either. A lot of times we learn as we go. Things had been learned on Shuttle about what's a good biological clock time and then you don't fly a two-day mission. You have to get the biological clock set.

So I think about five days is probably the minimum mission you always want to fly, if you can afford to, because you get up early in the morning and you launch and you're going to fly in the day-night cycle to get around to where you're alert for entry takes a certain period of time, and I'm not totally familiar with that, but the whole idea, the manning of the Shuttle and the kind of missions we fly have expanded tremendously since we started the first statement of work.

Very, very capable vehicle. Think about all the things it's done. I mean, we've launched satellites out of there, and we've retrieved satellites from there, and docked when—I remember when we first looked at the Space Station statements of work for docking, you wondered if the Shuttle could make that soft a contact, and yet, you watch it and it just barely touches it. I mean, the crew has gotten so proficient, and that vehicle is very, very capable, but if you'd have told somebody—and they did.

When we first started working Space Station they said how slow we had to come into dock. They said, "You can't dock that Shuttle that softly." Well, they do it. So it's been a tremendous learning cycle as we went through this program. It's been with us now for twenty-something years, too. What, twenty years ago we flew the first Shuttle flight, 1981? I took over cargo engineering on the fifth flight, so I was there from basically '81, late '82, I guess.

RUSNAK: Well, before we get the details on that, if we can take a short break to change out our tape.

BELL: Sure.

RUSNAK: When we stopped, you had just mentioned getting into cargo integration and that sort of thing. Go ahead and fill us in a little bit on some of the details of what that job involves, what some of the complexities are, and how you meet the needs of all these different customers into one vehicle.

BELL: Yes. The way the program was set up, and I believe it still operates that way, is the orbiter was identified as one project office, and then of course, there was the solid state engines and the external tank, and then what they called systems engineering, that were responsible for the dynamics between all those vehicles. And we were given pretty much an empty, what I call the cargo bay, the Shuttle, and we had whatever it took as far as hardware, wiring, software, to integrate payloads into the payload bay and into the mid-deck aft flight deck, was our responsibility.

So if you picture behind the pilots' seats as just empty racks, with no instruments or switches in it, and the cargo bay totally empty, that's where we started and then we had sets of wires that came out of the back of the forward bulkhead. One side's power and the other one's command and data, and had like twenty-three twisted shielded pairs that some went out to aft to the tail zero, and so that, we allocated them. Basically, we assumed that we would typically allocate it four ways. That was just arbitrary. Because again, the vehicle was designed with not necessarily two or four or five of anything, so there was five PDIs [Payload Data Interleavers] and one power bus and so we divided it into four and pretty well made a division of four.

We had one extra PDI because there was five of them. And then we made wire harnesses that would reach the forward two sections and two aft sections, and they were segmented so that between vehicle flights, you could see what payloads were going to fly, and depending on what they were, you'd either have one big wire harness for one vehicle or you'd have three or four, and you'd take them all out and reposition them to where the next one will fly and tie them down and put the lids on and put them back in.

The Shuttle comes without any mechanical attachments, so they have what they call bridges that are a big metal frame to go between the frames on each orbiter, and that's where we mount the payload, in a bearing, as matter of fact. It's a clamp-on bearing, a pinion bearing, that a three-inch shaft goes through and that's what holds the payloads. We have three-trunion payloads and four-trunion payloads, five-trunion payloads, whatever you want. Most of them have a keel-bearing in the bottom and then two on either side of the top, so that they're stable on all axes. They won't go up or down, forward or aft, and the bottom keeps them from moving this way. Two of the top ones can slide and two can't, because thermal expansion and bending, you can't have them all pinned or they'll break something.

So it was our job then in cargo engineering to find out what payload—each payload would come in and they would negotiate certain services. They were so large and they needed so much power and so many wires for signal and so many for data, etc. And then we would allocate these services out, depending on—and try to keep them somewhat in fourths, if we could, or halves. If they were a big payload, they'd get half the capability. Something like a Spacelab used to take everything we had, so maybe they had a special set of services for Spacelab.

Then we would negotiate one payload at a time. You still don't know what the flight's going to have on it, and then they would mix them. We'd go through and fix them, based on when they were going to be able to fly and what orbit you're going to would dictate what vehicles would want to go on that flight, and then we'd fill it up with a secondary flight—GAS [Get-Away Specials] cans and side mount of payloads and build gas beams to mount them on and all that. We pictured it as a moving company going out to all the households to find out what furniture they had to move, and then loading the truck.

If we were going to New Jersey, it took a certain set of household. If we were going somewhere else, it takes—because if you go to fifty-seven degrees for science missions or twenty-eight and a half degrees for deployables, different kind of payloads wanting to go to different altitudes, different inclinations. So we would then start setting up the engineering, which was hardware drawings and schematic diagrams and wire harnesses and technical instructions on how to do all this work to configure the payload bay. They'd actually strip it clean and then put it back together for the next flight.

We had what we called an "up-down list" because if something didn't have to come off, if it was already in this location, you could use it again, then it would be on both the up and down list, so they'd only take out what had to come off and put back what had to go back on. And the same thing went on in the aft flight deck. You'd pull all the wire harnesses and reconfigure the switch panels to go to the different functions up there.

And then the mid-deck, we'd stow the mid-deck with all the lockers. We got involved in that because of the weight limitations, they had to be distributed for the structural elements of the cabin. So we would guarantee orbiter, we wouldn't put more than so much on the avionics bays up there, so we'd have to go through and weigh all those lockers and do a loads assessment and move them around to where we'd get within the capabilities of that.

We'd do a thermal analysis for—the attitude was going to fly against the time line and make the sure the payloads didn't exceed their limits. Because the payload might have a constraint that says I can't look at the Earth, or can't look at one attitude but so many hours. Well, then we'd have to make sure that the Flight Ops people knew the constraints, thermally or whatever it was, so that they would do their time line to maintain those constraints.

Of course, all of that was done by the Flight Operations, Mission Ops Group. But we'd work with them in our documentation. Like, if there was an engineering constraint, we would be sure and notify them so that they would do their attitude time lines to accommodate it. And so it was very much of a team effort, of which we had one element of the team. The other elements were obviously the Flight Ops people, the Mission Ops, and in those days, even the EVA people now were not in our group. Their activity was somewhere else. And they'd all come together and then review. It's called the cargo integration review, which I think there's one going on over in Regents Park One today.

For every flight they have, where all the payloads, Kennedy's launch center, and MOD [Mission Operations Directorate] people. Everybody come together and go through a review of the entire mission, design-wise, and make sure all the pieces fit. And then it starts getting bolted together. Literally, that happens at a point in time when the engineering drawings have just been released and the hardware's just getting ready to go to the Cape, so they've still got time to make some minor changes if you have to. It's kind of like the critical design review for the mission. Then the Kennedy takes all that engineering and they create a work paper and sent the technicians out to implement whatever we have.

And our job is to go back and review their paper to make sure they implemented our engineering correctly and then certify it, what's called a Certification of Flight Readiness [COFR]. So we would then sign a COFR statement for every flight that said that we designed it, analyzed it, verified it, and it's ready to fly safely. So it was mostly design, but we had some hardware. We helped deployment systems, for instance.

There was a system called a stabilized payload deployment system, which was a set of motorized arms. Roll a 50,000-pound payload out over the sill and release it. We designed electrical release umbilical systems that, when we got up there and wanted to deploy a payload, we could release the umbilical and let it go. Purge ducts. A thing you may have heard recall is a remotely-operated umbilical system, which mates and de-mates an umbilical arm to the payloads so that they can deploy and go out and be retrieved and brought and we can reconnect either hydraulics—there's a hydraulic version—or an electrical version.

So we had a lot of different kinds of hardware designs, as well as just engineering and analysis work to do. We had thermal people, structures people, avionics, and software. So it was kind of a mini program office within itself, even though we were dealing with the Shuttle vehicle. We didn't change it in any way. We had our own kind of a project office, so to speak, in the cargo world, dealing with customers all over the world. I worked under a gentleman called Leonard [S.] Nicholson at that time, for most of the time, who is now retired but was E&D for years after that.

Before the *Challenger* accident, we had a team of people who would go to aircraft companies and different people all over the world and negotiate transportation for their satellites to orbit. Had MexSat and Arabian satellites. We had Japanese, and we have flown those. But at the time of the *Challenger*, we pretty well got out of the commercial transportation business and stuck with Department of Defense and science, but at one time, we had a marketing group, so to speak, really looking at our cost.

In the area I was in, cargo engineering, we had optional services. For instance, a payload would come in and want to have some hardware built, or maybe he'd want us to do a loads analysis if we had a price catalog, where we'd price it for him and he could either go somewhere else and get it done or we could do it. So we had a little bit of fixed-price catalog business that we could do for—we've built so many different wire harnesses, thousands of them, that we could price that out based on the number of wire segments. If we had a ten-conductor wire harness, we didn't care if it was three feet or forty feet long, it didn't matter. It had the same amount of work to build it, basically.

So we could price those pretty accurately, and so some things were fixed price. Others were on a cost-plus basis. So we had a pretty good variety of activities from just pure analysis to what I would call meeting a customer, so to speak, and negotiating services within a set of constraints, all the way to building hardware, and then verification of the hardware. We used to a walk-down to the Cape, go down to do a visual walk-down. After *Challenger*, we decided we needed to do that and make sure there weren't any "don't fly" flags, and things that weren't going to fit or interfere and the like, and pat it on the head, and close the door. So it was kind of all aspects of—without getting into the basic vehicle.

I didn't do much with the basic vehicle, but we interfaced with it and utilized it. Tried to keep—the intent was to be separate from the Shuttle Program. Let them get their vehicle ready to fly and do the routine things. Occasionally we'd have to have what we called a nonstandard interface, like some particular payload had to have a special vent or something. Then we'd have to go and obviously work with the orbiter people to make sure they were in agreement with it, but if it was a standard interface, we had what we called the core ICD [Interface Control Document], which was standard services interface.

As long as we didn't go against any of those services the orbiter offered, and stayed within those constraints, then we were our own negotiator, so to speak, and we didn't have to really go back to the orbiter, unless we violated or deviated from those agreements. That still works that way, and that's a very effective way to do it.

RUSNAK: You mentioned the DoD payloads and you told us an interesting story about—it related to that earlier, but can you talk about any of those with us?

BELL: Not about what they were, no. But they were interesting in the respect of two things. One, they were leading the technology. When they flew a satellite, it was well in advance generally of the technology we knew existed in our day and age, because they always were looking for the newest technology for their activities. And it's always interesting to work [unclear]. Plus, they don't build many of those. I mean, one or two, you see, these kind of satellites, so they had lots of money for—if it looked like it could do a better job than whatever they were trying to do, they had the money to pay for it.

Consequently, they weren't beyond asking for a lot of things. I had one general call one time and wanted to know what it cost us to stretch the orbiter six feet. Obviously, it was too much, but they were very goal-oriented and they had a mission they wanted to go on, and they would do whatever it took to get there. So we did a lot of interesting, unique things for the Air Force that may or may not have been expensive, but helped them achieve their goal.

There's two things I didn't like about the job. I said I loved my job and I did. Two things I didn't like. There was lots of travel. My wife hated me to travel and I had to do a lot of it, and when I was doing a lot of that with those satellites, I couldn't always tell her even where I was going. So we had that little added complexity. Their payloads required a lot more interfaces, if I can call it that, because they operate through Aerospace [Corporation] and they usually had an independent verification contractor and a developer, so as a result, I made more trips supporting their flights than I would other flights, because there's a lot more entities involved in their activities.

So it added to my grief in the context of the number of flights and trips we had to make. Other than that, because they were stretching the envelope, so to speak, they were very interesting. We were doing some interesting things that I wouldn't have done otherwise, so I relished it, in that sense. I just didn't like the extra travel.

I didn't like the secretive part of it either very well. It has its reasons and I know why they do it, but they were interesting, and I think an essential part of our country's security and I would certainly endorse it but I would almost wish they'd come back and use the Shuttle because I think we did a lot of good for them. They don't currently use the Shuttle. They've been talking about coming back but right now the Shuttle is busy with Station anyway, so I don't think it'd make any difference. They had their own launch systems, of course, too, at Vandenberg [Air Force Base, California].

But the Shuttle brought them another opportunity, in some cases, especially if it required any man interface, which they didn't have. And so you could actually do EVA activity and do some things that would allow them some latitude they couldn't do on expendables. We also have a retrievable capability if something didn't work. We flew other military payloads that were not of a secure nature. I mean, the Navy flew, I think—I don't remember what the title of theirs was anymore, but it was a SynCom or one of those that we flew. It was a Navy satellite, but it was a communications type. They weren't all of a classified nature. So they were a good customer, really.

RUSNAK: In this pre-*Challenger* period, the Air Force was building their own launch facility to run the Shuttles out of there. What sort of interaction did you have with doing that?

BELL: Not a lot. Again, that was primarily with the people doing the launch systems. We did have some payload activity, obviously. We had hardware out there to support that. They had some things they called launch-on need. They wanted the capability, if they had a satellite that for some reason died in orbit, and they wanted another one up, they wanted to have the capability to call up an orbiter readily and launch it, which caused us to do some unique things because to be on a launch-on need sort of thing, we had to have their hardware all sitting in the bin, basically checked out, ready to go.

Going out of Vandenberg, that was more of a—we had the capability at the Cape, but it was even more so at Vandenberg because they're in that mode out there. I mean, they do that. So we had developed some unique hardware capability to be able to dedicate hardware to their missions. In other words, we trade a lot of commodities in the Shuttle, that we don't have enough bridges to put every orbiter, all bay, ten bridges, for instance. We swapped them from vehicle to vehicle, to keep them moving around because not all of them are flying the same time. Well, if you had a launch on need, you had to be guaranteed that those were available.

So we built them unique, attach hardware and unique wire harnesses, and put them in a bin, checked out, ready to go. So Vandenberg would have had more of that kind of an operation, so we were working in that arena, and accommodating the hardware and facility implementation for payload cargo integration out there, and that was about the only involvement I had, was really trying to accommodate the change in logistics as opposed to—but the vehicle looked the same as far as our engineering went.

RUSNAK: I was also wondering, how had you become involved with this whole area after having worked in Crew Systems for so long?

BELL: Well, I came out of—like I say, I went over to the Medical Directorate for a year or so on a detail, and then went over. Within E&D, Max [Maxime A.] Faget called me up one day after I had finished up that job on that detail and he says, "I see Glynn [S.] Lunney every day at lunch, and he keeps telling me our directorate's not supporting cargo integration. Would you go over—could I assign you over there to just keep him off my back? Get him whatever he needs. E&D will support him. Just find out what it is he needs."

So I went over on staff to Glynn Lunney, who at that time was Payload Integration—was not cargo integration. He was the Shuttle operations and payloads. So I kind of sat in his office complex and got him engineering support from the thermal people and structures people and crew systems and everybody in E&D. I'd get them to support whatever they had to, to get the Shuttle going. So I worked over there and then supported a guy by the name of Larry [G.] Williams, who had the cargo engineering office, in establishing interface documents and negotiating with the payloads for thermal control and all of these things E&D provided.

And so when Larry Williams moved up, they picked me to take over that organization. It was an engineering organization. I'd come out of engineering, so that's how

I got into it. I spent almost fourteen years, thirteen years in that job. It was probably the highlight, from the satisfaction of a broad-scope type job, it was one of the better career jobs out there, in my opinion. I passed up an opportunity to go do something else one time. I said, "I'd do you more good here, I think, than I can on the other job," which probably would have been a promotion, but I said, "I'm high enough. I'm going to stay where I'm at, and do what I'm doing."

I had good people, and some of them are still there and they're still good people. Went by and talked to them yesterday a little bit. Pretty much doing the same thing, although when they transferred to USA [United Space Alliance], they were supposed to pick up a lot of that activity that NASA had been doing and have, I guess. I think NASA's still in the requirement section and still oversees that, but a lot of the things we do are now pretty well that of USA.

And the other thing was, they were going to combine all of that under one contract, and we had ours under separate contracts, and I understand why they want to do it. It's a good thing to do. Because we had what they call original orbiter contract B and then they had a Schedule C, which was the cargo integration had added on, and then we had system engineering, which was Schedule D. So the contracts were coming to a close and they were going to put them all under one contract and integrate them, and I wasn't anxious to involve myself. I mean, the timing was right for me to retire when I did. That was before they even talked to USA. Everything was right at the right time.

RUSNAK: You mentioned earlier some of the involvement you had with the investigation on the *Challenger* accident. I was wondering if you could elaborate a little bit on that.

BELL: Yes, when that happened, of course, immediately they put together the investigative team, and they divided us into groups and pretty much by discipline and for instance, all of that that had to do—did the payload come loose, for instance? Go look at everything on the payload that you guys did in the cargo integration and payload world and see if you can verify any abnormalities or anything that would have contributed to this accident.

So we went back, and what limited data we had, we went through all that and analyzed it all and went back through all of the installation records to make sure that all the bolts had been torqued to the right values and everything was where it was supposed to be, and re-reviewed all of the activities that transpired. And then we actually investigated—went and inspected the hardware as it came back to see if there were any clues of what might have gone—or how the accident contributed to it, or how it may have contributed to the accident—either way. Of course, on that flight we had a big IUS [Inertial Upper Stage] TDRS [Tracking and Data Relay Satellite], which is an upper stage for the telecommunications relay satellite on the other end of it, and so we were primarily getting those pieces back and looking at it.

The engine on the IUS was, of course, still a hot engine when it went—I mean, it had powder in it when it went in, so they had to take it over and take the propellants out of it. So we were looking at the hardware pieces and trying to establish any failures that may have preceded the accident and what had recurred as a result of the *Challenger* accident.

We found nothing in the engineering or payload world that had contributed to the accident. We found some minor errors we'd made in torque values or something, but none of those contributed. We did, were able, by looking at the hardware pieces, contribute some degree in adding to the logic of how the sequence of events had occurred, because we could see where the bottom of the payload bay had pushed the payload out of its trunion. It had come pushed out from underneath, which fell in line with the sequence of events of everything else, to the tank and the airstream catching the orbiter and everything.

And then we'd go back and reviewed the films and watched the IMAX to see—they had different ones. We were going to see if we could see any of the previous launches that were in the IMAX film to see if we could see any puffs of smoke. So I just supported the team in that regard and then wrote a report on everything we found in the cargo payload world.

We did go back and modify some of the analysis models we had for loads. Not that it had anything to do with the accident but in doing some detailed analysis, what they called shock spectra, of the previous flights, including that one. We decided we had underestimated in some degrees and some frequency content the amount of loads payloads might experience, so we went back and we modified the model enough to cover those, so that we had no areas uncovered, and we always exceeded anything we'd ever seen, probably almost too conservative to the point that some payloads complained that we were shaking them to death, when we didn't need to. But we were sure this covered all that data. We hadn't found a few minor places that we had not predicted this high a loads as we were going to get.

So we did some changing in how we did our analysis. We also changed how we did follow-up, closed-loop engineering. I will say that in the cargo world, we were already doing what I call verification. As I mentioned earlier, we'd send the engineering to the Cape. They would process paperwork to do the installation and then we would review that to make they'd done the right torque values and all that.

So we were pretty well into that process. The only thing is, we didn't always have all that done before we launched, so we changed our process. That became part of our COFR process, that we had finished all that before we'd sign a certification for flight. The whole program took on what they called more of the same thing, close-loop engineering, after that, because we were doing more of that than some elements of the program were, but it was decided we needed to do more check and balances because prior to that the thought had been, we don't need to look overlook everybody else's shoulder. You send the right engineering down there, you trust them to do it right, because we got to get the cost down on the program a little bit.

And again, I don't know if that contributed at all, but we went back and recovered some of that follow-up, closed-loop engineering as a result of the *Challenger* accident, and went into more detail of what they call COFR process. It's just to make sure you don't overlook something. That's what it's all about. And a little more cross-communications as to what's happened. Again, I don't think any of that directly related to the Challenger, but it was things that came out of that investigation that we probably ought to do.

RUSNAK: Yes, it seems right in line with the general sense of things going on after *Challenger*, and it seems to be the same direction that all the other areas were going as well.

BELL: And it was probably the right thing to do. I don't argue that. In fact, I had been a proponent of what I call the closed-loop engineering anyway, and I always felt—of course, I grew up in that era. In Mercury, Gemini, and even Apollo, we used to do what we called a pre-shipping inspection. We'd do a detailed checkout of hardware and inspection. You'd ship it somewhere and then you had a receiving inspection. You'd go through it all over again. And we had cut a lot of that out, for money reasons. You ship it and the person on the other end is responsible to make sure it's in the right state. So we went back and reinstituted some of that, and probably appropriate.

RUSNAK: While you take a little drink there, I don't know if there are any other comments you want to make on Shuttle before I—I've got some other kind of follow-up questions from earlier, I guess, but I don't think I had anything else on Shuttle unless there are other comments that you wanted to make.

BELL: I just think that the Shuttle is a testimony to one tremendous vehicle, when you think about it. For its time, when we designed and built that, to be the first re-entry re-use vehicle, people will criticize, it takes too long to turn around, too expensive. It may be true, but it's a marvelous vehicle, when you think about it. And if you've never had the pleasure of just crawling up in one and looking at it, it's a massive vehicle.

The first time I ever walked under one when it was sitting in the hangar, it's not like a drawing. It looks big under there. I mean, that is one big wing up there. I get a shake every time I watch one launch, I still do, but what a graceful thing to land in. I mean, it's gorgeous. I think we can be, as an American, proud of that vehicle, I really can.

RUSNAK: Unfortunately, I've never had the privilege to go crawl up in one or underneath one.

BELL: Well, you'll have to make a trip to the Cape some time and see if you can do that.

RUSNAK: I saw one on the pad for one of the launches.

BELL: If nothing else, when they bring one through Ellington some time, at least go out and watch, to see it sitting on top of the carrier.

RUSNAK: Absolutely.

BELL: It's huge. Bigger than a DC-9, and that's a pretty good-sized airplane. But the delta wing makes it look even bigger. Definitely proud of it.

RUSNAK: And certainly a lot of the people who we've talked to are very proud of it and get a good sense of the challenges that were involved in creating this thing, and once you hear all that, you realize what an achievement that this Shuttle really is.

BELL: I guess I would have said back when I heard all of this—I used to sit in the meeting and hear the discussion about all the constraints to a launch, and the landing sites overseas, and the TAL [Transatlantic Abort Landing] sites and the weather at the Cape, and the weather at Edwards [Air Force Base, California, and the weather here, and the ten thousands of parts that have all got to click in a split second. I said, "We'll never get one of these off the ground. I mean, it'll never launch. There's no way we can get all these millions of things to come together, click at the right moment, and all the weather to be right."

And we do it remarkably well. It amazes me how many times we get off on time. I used to sit there and say, "They'll never launch this thing. There ain't no way." I mean, you'd hear all the stories. Every subsystem. Well, we've got these parameters—Oh, my word. To get all that stuff to click and be in limits and ready to go, but it does. That, to me, is fascinating as anything, that it all works. Too many variables to make it all come off and on time. Although we have launched some in less than optimum conditions, without hardly realizing it.

The night we launched STS-36, which happened to be one of those DoD flights, by the way, it launched into a different inclination than they typically do and scared the people on Long Island half to death, because they could see that thing flying off the coast of Long Island, which they don't normally do. But that particular night, we were between rain clouds, and they were on hold for lightning within ten miles, which is one of the things you wait for, and all of a sudden, they had an opening in the rain and they picked up the count.

Well, while they were doing the count, I'm sitting there looking at the camera out on the pad and there was rain going by the Shuttle and we launched, because the nine minutes between the time we picked up the count, a storm blew through and so we launched right in the middle of a rainstorm. You only knew it because you were looking at the cameras out on the pad. By the time you get inside the start sequence for the engines and everything, you're not about to stop then, or even the APUs [Auxiliary Power Units], once they kick over and start, you're into a recycle if you don't launch then. I mean, that's just go for it, and that's what we did.

But after all those constraints, you said, "Well, we got that one kind of close." Not lightning, however. Just rain. Overall, it just blows my mind, actually, that we can get that thing off as many times as we do, that close to the planned launch time. And part of that comes from knowing all of the stuff that I do from back—all these things that have to go ticky-to at the right time, but it just amazes me that it happens.

RUSNAK: Well, as they found out on Apollo 12, even launching when there is no lightning, but in rain, you can have some problems.

BELL: Yes. Well, again, like I say, the weatherman said we had a window here of so many minutes or something. Well, we did, but by the time we picked up and kind of got going, that thing moved a little faster than they planned. They just happened to get there just as we launched.

RUSNAK: Well, you know, we haven't talked a whole lot about the Apollo Program. Here we went from Gemini to Skylab, and now Shuttle.

BELL: I wasn't that as involved in Apollo personally. That's probably why. Gemini overlapped, if you'll remember, the beginning of Apollo, and we started working Skylab in that end time frame. I was working EVA spacesuits. I did involved ourselves in some of the science experiments. I assisted in life support systems. We were doing advanced life support. But the Apollo office was up and running in crew systems parallel to the Gemini, so

I wasn't as heavily involved in Apollo, so that's probably I didn't talk about it much. It was a tremendous program, but I watched it go by more than I did the others.

RUSNAK: One of the other topics I wanted to ask you about. Through the various programs, the kinds of testing and qualification going on, from the beginning of Gemini through Shuttle and cargo and crew systems, do you remember any significant events from either qualification testing or perhaps design testing, that kind of thing, that really comes to mind?

BELL: There were several. A gentleman—I mentioned his name earlier—Joe McMann and I were working on two different designs of a 14-day spacesuit for Gemini that was going to be easier to doff inside the minimum cabin and everything, and we had two different designs. We decided to test them in an altitude chamber for a 14-day long-term test.

Brooks Air Force Base [San Antonio, Texas] had, at that time, the best small-man chamber to run in. So he and I had gone over and we'd built ourselves a little cooling system for the spacesuit, using Little Joe heat exchangers and Mercury suit fans. In fact, I went down to the Gulfgate Shopping Center, crawled into the Mercury spacecraft and took a fan out for that thing. We took it around and ran that test and received a terrible phone call on the twelfth day, on a Sunday, that there had been a fire, and two guys by the name of Fletcher and Smith were in the hospital in critical condition. They were our test subjects in that test.

Went over that afternoon, the two of us flew over there, and that was a ghastly opinion to look into that cabin and see what had happened. Fortunately, our hardware, fortunately, hadn't been involved, but on the way over, I had remembered that that heat exchanger that we got out of Little Joe had some magnesium in it, and I thought, oh, word. Magnesium burns like a torch. So I was all the way over, nervous as I could be that I'd get over and find that thing had contributed, and it hadn't. We had it all wrapped in insulation and it was in good shape. Very, very bad day in my life, but I found it also interesting that, because at that time, the Air Force was somewhat trying to get into the space program, that they made very little of the fact NASA was even associated with that test.

It was an Air Force test, Air Force subjects, and I was willing to let them go along with that. I didn't want any more publicity than we had to over that. But we were fortunate that our contribution to that didn't have anything to do with the fire. We learned something from it that got me thinking about burning wire, because what they had decided in looking at that—they had a panel that they'd take out quite often, and they had flexed the wire harness to where the fuse never blew, and yet it caught fire because they broke the strands in the wire down to where they had one or two strands and it acted like a fuse and lit it.

So we started taking wire harnesses that we had, and doing burn tests to try to find out what wire was self-extinguishing and what wire was not self-extinguishing, and found out that what we thought was fire-proof wiring was not, and pure oxygen, it burned pretty bad. To the point that we canceled the last Mercury flight, partially because of that data. It gave us a lot of insight into what we needed to do, even in the Gemini spacecraft, and certainly Apollo, that, as bad as Apollo may have been, it would have probably been worse if we hadn't done a lot of that testing on the wiring that we had done, and changed out a lot of that wiring and gone to Teflon wiring and some of the others that don't burn.

And the reason was, the national standard for determining self-extinguishing wire is what they had tested to, and that used to be a horizontal wire, and you'd start it in the middle and it had to go out before it got to the end. Well, that's fine in one G in open air, but hang it up vertically in pure oxygen, it's just like an explosion, and all you had left was burnt ember of wire, and so we were a little concerned.

So it contributed in a remote way. I mean, while that fire at Brooks had nothing to do with any of our hardware, it got us thinking about how safe we thought we were by putting fuses in a wire harness and relying on the fuse when the fuse would never go and the wire catches fire.

So the next question was, how are you going to guarantee we'll have wire that doesn't burn? That's the best thing you can get. And we found out ours did, so it contributed in the sense that it led the way for better wiring, which we've used since. So that's one test that didn't meet its goal, but probably had a long-range effect in a good sense.

Both Fletcher and Smith, by the way, survived, and we're glad of that, but it was touch and go for a while.

Another one I thought was interesting was doing the early Gemini tankage for the oxygen-hydrogen tank, one of the tests was supposed to pass based on some military code was be pierced with a bullet because, of course, airplanes and stuff get shot. So we had one pumped up out there in the test range at China Lake one time, and shot a bullet into it and that thing went into a million pieces. Blew all apart. We finally realized, we don't really have to be safe against that. Plus, I think we used too drastic a test, so we had to go back and modify our test criteria a little bit.

And one other time, we had a pad emergency air pack that I had built when I was over in Crew Systems. I had one built in Crew Systems, which was two little pressure bottles in a chestpack, with a neck ring, and it was designed for a crew that got out of the Apollo, to throw it over their neck, plug it into the spacesuit, and go down the slide wire. Called a pad emergency air pack—PEAP. It was supposed to have leak before burst criteria. In other words, what they call fracture mechanics.

Well, nobody could determine if they did or not because they're what they call cryogenically-formed tanks. They stretch them under cryogenic temperatures. So we decided we'd run a test over in the Thermochemical Test Area, and we put a scratch in one on purpose, hooked it up, and hooked up a 6,000-pound pressure vessel and blew them up. Man, I mean, we blew that thing all to pieces. There was nothing left. Decided that wasn't a very good test. The shock wave blew it up. Should have built the pressure up gradually.

So the test we finally ran was we pumped two of them up and threw them off the top of a two-story building and bounced them off the sidewalk. We said if they survived that we thought they were all right. When we went back and did the fracture analysis, the guy said, "You were crazy to run that test." It taught me a lesson. Don't run a test unless you can explain the failure. The test is what blew the bottle up, because we had this huge tank outdoors and this big line, and we just hit it with a bullet coming in, basically. We should have built the pressure up gradually. I mean, it blew them all to pieces, nothing left. The fiberglass was gone, it smashed the camera and everything. That was a test we shouldn't have run.

One of the concerns I mentioned earlier I think, discharging water into space is a concern. You've got to do it a certain way or it'll ice up. You've heard of that over the years. Certain experiments, we've had icicles. And you can do that by heating a nozzle and by coming off a nozzle. What proved that, we had a chamber over there one time, and we used to take collections in the restrooms. We'd call them "uricicles."

We'd drop these things in there and test them in that chamber, and nobody wanted the job of cleaning that chamber out when it was done, but it had to be done. You could do that for hours and hours, it worked fine, and all of a sudden, you'd see one of these icicles starting to form, and it'd grow just like a worm coming out of there, until we perfected how you could keep those things from—if you watch how they do it these days, if they dump liquids, they'll usually have like a rubber spot and a nozzle in the middle, and that's all heated so that it—first of all, it's a nonstick surface, like Teflon, and it's hot so that you get it away from there before it turns to ice because as soon as you drop water out in space, it turns to ice.

The way we used to cool the Mercury astronauts or the Gemini on orbit, to some degree, till the radiators would cool down, and the EVA people, is with boiling water. Now, people say, well, boiling water? Boils at forty degrees in a vacuum, so it's an excellent coolant, as long as you can control the boiling rate. So we've used water boilers, different designs, but basically sublimations, what they use on the life support system, the EVA life support system, where it goes directly from a liquid to gas. But basically, by evaporating water, you can get 1,000 BTUs per pound. It's an excellent coolant, and it does it right at forty degrees in a vacuum.

I had to laugh. Talking about testing one time, we got a comment from some person out there in the public, who wrote us a letter about, he had some protective gloves for us when we were out there, to work around these steam ducts because the hot temperatures would burn their hands. He was thinking steam, water steam. So he was designing these gloves he would sell us. He wanted them for the crewmen to be able to touch these hot steam ducts.

He didn't realize it, and most people don't, that water boils at forty degrees. If you've driven up to High Mountain, Pike's Peak, with the old cars, before the days of good thermostats, they used to all boil over on the way up because the water boiled at 120, 130 degrees up there, but it gets cooler and cooler as it goes up. We had a lot of those kind of little things that came along.

RUSNAK: Well, I think that's all the questions that I had. I was looking over my list, but I did want to give Kirk and Sandra a chance to ask some if they came up with any as we were going along. Kirk?

RUSNAK: During the Apollo Program, didn't you help a little bit on the PLSS [Portable Life Support System] system? I was just wondering what your perspectives were on that.

BELL: Yes, the portable suit to a little bit. We worked on some of the suit bearings, I mentioned earlier, and the portable life support system, in the initial design, and then again, when we had some problems at one time with an oxygen regulator. I got on the investigative team to help work that. Hamilton-Standard was the manufacturer of the portable life support system and went on several of the design reviews to Hamilton-Standard for that. I just wasn't the primary lead. I was assisting, as opposed to taking the lead.

But yes, I did help with it, but I didn't, I don't think contributed a whole lot. Now, the sublimation cooling system we were talking about earlier, I participated a little bit in that, because we had had the water boiler system—evaporators with, I mentioned earlier, the water-gas separators. And that had a higher volume than they had room for on the portable life support system, so Hamilton-Standard proposed the sublimator, which was a thin plate, and it goes straight to the gas, like I said earlier, as opposed to going to through a vapor stage. So I helped do a lot of testing on that, but that was their design. I didn't do that. For the most part, I was assisting, as opposed to taking any leads in Apollo.

Elton Tucker, who was my suit engineer, did a lot of the work on some of the thermal garments for the space suit. All the biomedical instrumentation we used was out of my group, and the portable radio, the radio communication systems, we worked on, but I wasn't a big player in the Apollo system. The EVA hardware, mostly. They had an investigation on an ECS fire they had in a test apparatus at Garrett AiResearch in the early Apollo and I went out and participated in that review and made some design changes and inputs to that.

I also testified to the Apollo 204 investigative board on recommended changes for the Apollo ECS, but that's about the limit of my Apollo that I did. I don't consider that I was the primary design engineer or project engineer. I assisted and was brought in several times on several things, but pretty much it was an assisting role. Or to bring experiences I'd had one of the other programs to bear on a problem of one type or another.

For instance, some of the portable tool devices and the like that they used on the lunar surface, we helped develop those in my group. Used to have the human factors group in my EVA branch. Martin Debrovner, and they did a lot of work with the—we also did some of the medical experiments. Of course, we had the biomedical group. For the most part, we were in a support role.

RUSNAK: Anything else? Well, I want to give you a chance to make any final remarks. Anything else you want to say, any other stories that come to mind, or any other people you wanted to mention before we close up?

BELL: Well, there's a lot of people. It's hard to name them all, but certainly George [M.] Low and Dr. Gilruth, Max Faget. All of them were a tremendous influence on my career.

I'll always have a warm spot in my heart for Richard Johnston, who was my division chief for a long time. And the reason for that is, the way he managed. I took a lot from that and tried to follow that lead, and I used to call him a "rally around the flag" manager, and by that, I meant he didn't tell you how to do it, but he had a way of bringing you into his office. "If we've got a problem, I want you guys to solve it because I know you can," and just pumped your ego up to where you went out and worked like crazy to get it done.

If you've got good people around you and they're motivated, you don't have to do much, and so I tried to follow his lead in that way out through the rest of my career. I'd get good people and then if they had a problem, come and ask me if I could help them, but I don't want to answer your problems for you. If I can be of aid, let me know. Otherwise, you've got the problem. Go work it and tell me what you think. I learned a lot of that from Dick and so I always had a nice warm spot for him.

But everybody I've worked with has been so good. It's just hard to name them all, but those have all been great influences. John Young, who still sits over there. I had a lot of hours, I had lot of fun with him. Ed White was—I was touched very close to Ed. He and I got to be pretty good friends during the EVA development for Gemini IV, so I've met a lot of them, but those people are particularly, I think, influential in my—whatever I did right in that career, I did a lot of it because they taught me how to do it, I think.

RUSNAK: Well, I think that's a good note to end on, so I'd like to thank you again for taking out the time this afternoon.

[End of interview]