NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
ORAL HISTORY TRANSCRIPT

JACK KNIGHT
INTERVIEWED BY SANDRA JOHNSON
HOUSTON, TEXAS – 28 NOVEMBER 2007

The questions in this transcript were asked during an oral history session with Jack Knight. Mr. Knight has amended the answers for clarification purposes. As a result, this transcript does not exactly match the audio recording.

JOHNSON: Today is November 28th, 2007. This is the second interview with Jack Knight for the Johnson Space Center Oral History Project in Houston, Texas. The interviewer is Sandra Johnson, assisted by Jennifer Ross-Nazzal.

I want to thank you for coming back in today to talk to us again. At the end of the last interview you mentioned your move after the last Apollo mission to the Life Support Systems Section for Shuttle and then being picked up pretty quickly after that to work on Skylab as part of that fifth team under Don [Donald R.] Puddy as a biomedical officer. So if we could pick up there and start talking about that time period, and how that move came about and what your duties were as a biomedical officer.

KNIGHT: When Skylab was first started or they started to work on it Flight Operations had to decide how they were going to support it since it was going to be an extended 24/7 operation. Once you get into that and know that you're going to be in it and are committed to it, in order to maintain people's typical workweeks for an extended period of time when you're working a 24-hour-a-day, 7-day-a-week thing for extended periods of time, it really takes five groups of

people, and you're working three shifts. So that allows people to have some time off and average holidays. You can average roughly 40 hours a week over long periods of time.

Don Puddy had been pulled off Apollo. He had worked on Skylab in the preparation part of it, and he was the Flight Director for the Skylab 1, which was the unmanned launch. Of course, it had its problems going off, so it slowed things down for a couple of weeks or something like that; I think about 10 days or something like that they delayed the Skylab 2 flight, which was the first manned vehicle going up on a separate launch vehicle, to try to recover from what had happened on the Skylab 1.

After that Gene [Eugene F.] Kranz, who was head of the Directorate, said, "Okay, it looks like we've got this thing going now," and he wanted to have a fifth team. Like I said, I'd been reassigned to Shuttle after Apollo, just in its formative phases, and he was looking for people to get a fifth team up. So he went around and looked for people with some applicable skills. He picked some people out of the training group, because training was ramping down because they were no longer going to be training any more Skylab people after it got going, or they needed less people. Anyway, so he got me because I had life support experience and EVA [Extravehicular Activity] experience with people, and asked me to come do that. I said, "Fine."

Now, biomed [biomedical] was different [for me]; it was more of an experimental area. Skylab had four major areas of focus. Top priority was biomedical; learning how the body reacts over a long periods of time. The other was astrophysics, which was the telescope-pointing part. The third one was Earth resources, which points to the Earth so that one and the second one conflict with each other. The fourth one was corollaries, which is anything else you can think of to fit into the time available.

So I was in the biomedical area. That involved the medical personnel and people that were working the experiments, lower body negative pressure and some exercise physiology and a number of things like that. Our job was to acquire the data, make sure the flight plan was followed and the experiments were conducted in our area, and to fight for those things when you had conflicts going. A lot of the [biomed] data was essentially EKGs [electrocardiograms] that were downlinked, and we got that dumped off on tape and would send it over to the doctors, the surgeons' side of the fence, and then they would run it through all their evaluations.

Other things they were doing on board included the crew doing some sleep studies, where they would don these caps with electrodes, and they were doing food intake. So everything that went in had been calibrated to begin with, and the crew reported exactly what they ate by mass and numbers. Then everything that went out was captured and freeze-dried or frozen and put into containers and kept in a refrigerator and all brought back for analysis.

So essentially, because I got in late in the game, there were already four teams there that conducted the first Skylab [manned] flight, which was Pete [Charles C.] Conrad's flight. That was a relatively short one; that was 28 days, 26 days, something like that. So I just got in, and I was trying to go get myself qualified, at least well enough, and I'll tell you this, it's difficult to do in a short period of time, because if you start at the beginning, then you get to know all the people and you can learn the background of what you're doing, because a lot of that comes out in meetings and procedure development. So I came in late and didn't have the advantage of that. But I knew how to operate consoles. But you pick it up as you go.

But the first flight, the first manned flight, Conrad's, I worked in the back rooms and helped, because the ground data people didn't have it quite all together. They had it good

enough, but we worked quite a bit during those first several weeks of just getting things straightened out, so to speak. Anyway, we captured all the data.

Then the biomed position was not occupied between the manned parts, so when Conrad came down, there was a gap in there before the next crew went up. That was Alan [L.] Bean's crew, I think. Then the third crew was [Gerald P.] Carr, [William R.] Pogue, and [Edward G.] Gibson.

Anyway, for Bean's crew, things had settled out, and the systems people had figured out how to operate the vehicle. They had had the first failures that are going to—the infant mortality kind of things, and had fixed them as best they could, and then the next flight they brought up replacement parts. They essentially learned fairly quickly how to operate the thing for optimum return.

The other management part was the Flight Directors got tired fairly quickly of trying to prioritize between all these disparate groups, because there were project scientists out there, and they had contacts directly with the agency head and with the Center Director, and they would try to work around the system. So somewhere along in there the Flight Director said, "Look, you guys need to get your priority things together before you send it to us. You send us the priorities; we'll execute them."

So I think they appointed Dr. Bob [Robert A. R.] Parker, who was an astronaut, and he was to herd all these cats together, and "You get together your priorities for the next day or two or whatever it is, and then we'll go execute it." But they built ground rules over time. That's mostly observation and hearsay on my part, because I wasn't directly a part of it. But that's what went on, you could read that in the logs. So I assume that happened mostly during Conrad's or the first flight.

So anyway, things were fairly well run, managed, at the time Bean went up there. So Bean's crew did a really terrific job of getting just all kinds of things done and on time, but they got the majority of the good training, too. The next crew was the runt of the litter, so to speak. Even though they had the longest period of time, they really didn't get as good a set of training. And the ground crew could really move things through, so the last crew, they were inundated with just "Do this, do this, do this, do this," and they didn't have some of the background. So anyway, it was kind of interesting from that standpoint.

Then the other parts, from my perspective, were shift scheduling. They had essentially something like—I've forgotten how it worked, but they'd have three or four days on and two or three days off and then five days on. But you were always on a different shift, so it was like you have a day shift, a mid shift, and then a night shift. Well, in order to spread the misery, you'd get day shifts and then you'd move to the swing shift after a couple of days off, and then you'd go to the midnight shift. Well, one of them was called planning; the other was called execute; and the third one, I've forgotten what that name of that one was.

But anyway, this group would plan, and then the next group would muck around with it, and then the next group would execute it. [Aside—The Russians don't do it that way. They tend to do it that you're on for 24 hours, but you do the plan and the execution, and somewhere in there you get some sleep, I guess, but they didn't have as much coverage.]

But anyway, that's the way we did it, and I remember after Skylab was over they asked us to do lessons learned. So we'd sit there and write down things, and I said, "If you get another thing like this, I don't care if I'm on for 30 days straight." I was single at the time, well, until I got married right at the end of it. "But just leave me in that same shift so I can get used to it and can get fairly good at what I'm doing," because when you're just on five days and you're doing a

new thing, it takes a couple of days to get acclimated, especially when it's in a different shift at a different time of day, and the Circadian rhythms are all messed up. Well, they didn't do that, either, but those are the kind of things we did.

Well, as to getting married during Skylab: When Skylab was originally planned, it wasn't to go as long as it did, and so we had arranged the date to have the wedding, and then Skylab moved into it, and so we moved it. Well, you can't—it's harder today. You can't move those things around very easily, because other people have taken up the spaces and slots. So anyway, we found one and got married at the chapel at UH [University of Houston, Houston, Texas] during Skylab. So I just traded shifts with a guy for a couple of days and got married and got back on shift.

So we finished up Skylab, and after that we did the lessons learned and I went back into Shuttle. But then the ASTP [Apollo-Soyuz Test Project] came along.

JOHNSON: Since you were in Skylab and you went into that biomedical area, did you have any specialized training for that, since you were dealing with more medical issues?

KNIGHT: Well, I was not making any medical decisions, and the surgeon was sitting right next to us, so we were essentially managing experiments, and then getting the data for them. So if you're doing a lower body negative pressure, the astronaut, he's been trained to do it. He gets in the device, and he strapped on these devices, and you just say, "Are you getting data?" Well, I think they were recording on board, too.

But you're getting data, and then you go follow the protocol, which the crew was having to do on their own, because we weren't having continuous coverage during these years. We

didn't have TDRSS [Tracking and Data Relay Satellite System], so you were going site to site. Some periods you'd have a fairly decent amount per rev [revolution], and some periods of time you would go a whole rev without any data at all. So the crew had to follow the procedures that they had.

The thing was you were scheduling stuff. So, okay, it's time for Conrad to do this, or it's time for Bean to do that, or Pogue. They have the flight plan, and if they have any questions, you try to answer them, like if they're taking blood or something like that; well, where is this or where is that, alcohol wipes. That's what I'm supposed to know. Well, if the crew moves things around and they don't pass it on to the next crew, where are they. So those things go on.

I'm not sure I'm answering your question here.

JOHNSON: That's what I was just wondering, if you had any [additional training].

KNIGHT: The additional training that I got essentially was to watch some videotapes and just then be aware. Well, we did some baseline [testing] of people on the ground, so in the months going up to the flight those guys would go over in the lab [laboratory] and we would go to another place and essentially they would do those exercises, the lower body negative pressure or something else, and we'd record it. So that becomes your baseline to compare when they get up there. So we'd do that sort of a thing.

But in general you've got a videotape or a workbook on the purpose of the experiment and what the equipment was and how it was used and what any constraints were. That was it. But no, you didn't go to medical school or anything like that, because again, you're essentially a tech [technician] making sure the equipment is there and it's scheduled and you're getting the

data and you're giving it to the right people. But it's having people that have practiced that and done that and know what the system is all about and knowing how the ground system works. That was what they were paying me to know, and knowing how to operate in that kind of an environment.

JOHNSON: Were the console positions the same as during Apollo as far as monitoring?

KNIGHT: The function was the same. The systems were different. You still had flight dynamics. You still had Retrofire Officers, Flight Director, surgeon, the network guy. Now, but because the Skylab systems were a little different, they called them something different, but essentially you're still—and there was a Command Module up there, so there they essentially—it was sort of dormant, and they would tell this position, "Okay, you're responsible for the—." There were only three measurements in which if they [the measurements] do this, then call somebody.

Or they probably had somebody there with the experience, anyway, like Gary [E.] Coen or somebody like that, that had come off the command module team. All these Flight Controllers, where they come from, they came from the guys who had done Apollo. There were very few just brand-new people in it, and hardly anybody just plain off the street, except there were probably some contractors that had come in that were Skylab-unique. And then there was [NASA] Marshall [Space Flight Center, Huntsville, Alabama], and the data was shipped to Marshall, too, and so they had land lines, and you'd communicate with them as well.

JOHNSON: Since you mentioned that you did come in a little later and you weren't as involved in the—

KNIGHT: The original planning itself.

JOHNSON: —maybe the handbooks and the mission rules.

KNIGHT: No, I was not [involved in the development of Skylab handbooks and mission rules].

JOHNSON: Were you involved, since you came in later, with SMEAT [Skylab Medical Experiments Altitude Test] at all, or were you aware of what was going on?

KNIGHT: SMEAT was the device that the biomeds use in their preflight training. There was apparently a 45-day SMEAT test, which was just like being on orbit, but that was before I came in, so that was over with by the time I got there. I think Bob [Robert L.] Crippen and the doctor, [William E.] Thornton were involved in that. The other [FCT] guys, John [T.] Cox and Bob [Robert H.] Heselmeyer and Bob [Robert] White and Lou [Louis A.] DeLuca, they were the other biomeds, and they were involved in that SMEAT testing. But, yes, it would have been very helpful to have been involved in that, in terms of being very familiar, having it internalized before you go into the flight. Without that it's sort of top level, and you have to refer to the books or something like that more often if you haven't internalized it.

JOHNSON: After Skylab you were appointed to the Mechanical and Support Systems Section.

KNIGHT: Yes, MOD [Mission Operations Directorate] was reorganized, and I think they merged with—let's see—we merged with FCOD [Flight Crew Operations Directorate], I believe. Anyway, they created branches that were more matched up with the Shuttle and what it was going to be, because we had a fairly decent idea by this time of its redundant systems, and because it had an aircraft role, which the other one [previous vehicles] did not, and had aerosurfaces and things like that. So, yes, it had other systems and more of them, so we were organized along those lines. That's where I was in the Mechanical Systems Branch at that time. Rod [Thomas Rodney] Loe was the Branch Chief, I believe, at the time.

[Here's an interesting aside. I don't know if it has anything to do with JSC history, but the Section Head that I had, because, again, we merged, and they brought in some of the Landing and Recovery people. Anyway, there's a guy named Dock [J.] Hudson, who turned out to be my Section Head. I'd never known him before at all. Turns out he brought me in and asked me one time who my dad was. I told him Jack Knight, and then he asked had he been in—well, it turns out Dock Hudson was my dad's copilot in World War II over in the China-Burma-India area. So it's just one of those, wow, coincidence kinds of things.]

Then I was lucky again. As the Shuttle Program was evolving people were looking at different aspects of it and what could we do to mitigate risk. This guy named [John W. Kiker], I think it was, came up with this idea as to how are we going to transport this Shuttle, if it lands at Edwards [Air Force Base, California], back to the Cape [Canaveral, Florida]. Well, you could put it on a truck or you could put it—well, that's a big sucker. So he came up with the idea of putting it on the back of the [modified Boeing] 747 [Shuttle Carrier Aircraft]. He built a model and demonstrated it. Well, once you've decided that, then he comes up with the idea, well, gee, we could do some testing of the glider function in the last parts of entry. So the Approach and

Landing Test was born, and Don Puddy was given the task of leading that from a Flight Control perspective.

I got asked to be on that team as the environmental control and mechanical systems guy. That was great, because it gave me a focus and it was an early part of the program. Somewhat simplified systems, but some of them were 100 percent what we ended up flying with. So it was great; gave us a great focus so we could build our handbook drawings and procedures and mission rules and things like that. It gets you into it early and gives you goal timelines.

That was a tremendous experience. Myself, Milt [J. Milton] Heflin, and a guy named Larry [E.] Bell, who's now deceased, and a lady, Ann [O.] Austin. I think she came in a little bit later, so I think it was me and Milt primarily, and then Larry Bell.

But we didn't use the word EECOM [Electrical, Environmental, Consumables Manager]. This was the period of time in the country when CB [Citizen Band] radio was a big deal and *Smokey and the Bandit* [movie] was a big deal. So my Branch Chief dreamed up a call sign—call signs are like EECOM, FDO [Flight Dynamics Officer], GNC [Guidance, Navigation, and Control]—of SMOKEE [phonetic]. You had to conjure up some things, but anyway, you could make them up. You could pick the letters out and make something of it. But anyway, so that was my call sign, mine and Milt's.

We developed requirements for the display system, and all the procedures, and then went off and executed the Approach and Landing Test Program. There were some captive active flights, and there were some free flights where they were dropped off the back of the 747. It didn't last very long. Once you'd dropped them off, it was I think about two minutes before they were on the ground, but then it was longer than that getting up there. We went through the whole process, simulations and planning and so on.

The crew had ejection seats at that time, so if something went really bad, they could eject. I think the very first time we separated, free flight one, one of the GPCs [General Purpose Computer] failed, which turned out to be interesting. The thing picked up and went okay, but we found out some things afterwards by the way we were configured that had certain other things failed would have engaged the BFS—backup flight system—which would have been really interesting if we'd had to do that the very first time. But we never did.

We learned a lot of things during that period. We developed procedures for APU [Auxiliary Power Unit] hot starts or restarts, and they [Sundstrand] did tests to demonstrate that they [procedures] worked or didn't work. So we did learn a lot of things in that particular area, more so than some areas. The propulsion guys got practically nothing out of it, because there was no propulsion systems. But the flight dynamics guys got some, and the GNCs and the INCOs [Instrumentation and Communications Officer] and us, environmental control.

JOHNSON: During those flights was the entire [Mission] Control Center manned for those?

KNIGHT: Well, there was a big debate, apparently, about whether it ought to be all conducted out at Edwards and whether they should move some people out there, and whatever went on behind the scenes, they decided not to do that but to use the Control Center. That made you work the com [communications] links, which was again a good thing, I think, and to help build up the ground systems and force that to happen a little sooner.

We had a room right off the side of one of the FCRs [Flight Control Room], and that's what we used, so it was a small room. It was off to the side. I think it's probably a storage room right now. So they set up some consoles there, and it seems like a little L-shaped room, maybe,

and some consoles, charts-boards and stuff, strip-chart recorders. Like I said, we did simulations and conducted the flights. It turned out to work real well.

JOHNSON: The Control Room itself, of course, that was off in another room. They were getting ready for the future Shuttle flights, and as you mentioned before, again the mission rules and that sort of thing having to be written for Shuttle. How involved were you in that process, and as far as the design of the actual Flight Control Rooms for Shuttle?

KNIGHT: The MOCR [Mission Operations Control Room], which is the one you see today on the third floor, it's in roughly the configuration for Apollo; it looks like it from a distance. But if you get down into the console, it's got stuff in it or on it that was developed through Skylab and through Shuttle, modified. Those were not changed appreciably. We just re-labeled the consoles, and people sat at them, and they put their requirements in. They might ask for more displays, because, again, you had a lot more parameters. We ended up having more front-room positions because the Shuttle was, again, more complicated. That was all being planned, and the Approach and Landing Test helped some of that.

What it essentially boils down to is what can a person cope with, how many parameters, how many systems, what level of responsibility, what level of interface? We tried certain things, and then over time evolved them, because we would combine certain things in one position, and then, "No, that's not working," so we moved them over to another position and re-evolved them. But we ended up with more front-room or more FCR positions, so where on a vehicle like CSM [Command and Service Module], on the systems area there was a GNC and a EECOM, so there was essentially two, and then an INCO, which did all the integrated comm.

When Shuttle came around there was an INCO just like there was a GNC; there was an EECOM, but then there was also an EGIL [Electrical Generation and Integrated Lighting Systems Engineer] and a PROP [Propulsion Engineer] and a BOOSTER [Booster Systems Engineer]. But there was a BOOSTER in Apollo, too, so that wasn't a difference. So, yes, there were a few more positions, a couple more positions added.

JOHNSON: There was a long period of time, because it just kept getting postponed.

KNIGHT: I think the first launch was postponed, it was probably two years, slightly less than two years beyond what they thought it would be way back, but then that pretty well always happens. So we had the Approach and Landing Test.

We did a flight readiness firing, which was not originally planned, it's one of those things, "Wow, this would be a good thing to do." We learned something on that, too, that hadn't been thought of or considered, and that was when you light off the main engines, because they are offset from the place your solids [solid rocket boosters, SRB] are tied down, it moves the vehicle, so it goes like this and then back. [Gestures – slight back and forth motion] So that twang in there, nobody had thought about, and so the engineers when they saw that, they said, "Well, we better address it" So they retimed things so that when it moved over and then it came back, so that—and you could time that because of the structural dynamics were the way they were—you could time it so that the solids would light off when it came right straight vertical, so they readjusted the timing a little bit. You've got to let the mains come up to speed, and then when it comes back, boom, you fire off the solids and off it goes. That was impressive.

We also did a test—the software guys had to do a lot of work with this one—where the Orbiter was on the floor of the OPF [Orbiter Processing Facility], and I think they jacked it up in some way. But anyway, we did a simulated around-the-Earth flight, and the software guys had to build something to go in and make the IMUs [Inertial Measurement Units] think they were going around the Earth because you've got the gravity vector, and you have to characterize all of that. So that was another thing that was kind of added in as a "let's mitigate risk."

So we kept siming [simulating] and training and trying to think up new things. Every time you learn a little more; what if this, what if that, and you could do a lot of sim cases.

I think the other thing that we were paying more attention to than we did on early Apollo was the in-flight maintenance aspect of it. We ended up having a group whose job was just in-flight maintenance, which has to do with tool selection and technique development and photographic evidence and photographic background. So, anyway, they did a lot of work. They'd go down on the vehicle and look at what can you do, what kind of trouble is it going to be, and so on and so forth.

My recollection is a little fuzzy on that as to exactly when it started heavily, but we obviously had had our experiences with Apollo and Skylab on things that were going to need to be fixed. Now, the intent of Shuttle was that you wouldn't have to do that, because they had all this triple redundancy, and you would just, "Okay, well, it's gone; we'll just keep on going," and don't do anything.

Well, you could do that, but we were always reluctant to give up flexibility and redundancy, because some of the failure modes, if you did nothing, would take out stuff that was perfectly good, and you could get it back with certain procedures. We developed a lot of

procedures that would enable us to always maintain and always optimize. A lot of that went on early on, and then it continued as flights went on.

JOHNSON: During that time, too, and then 1978, the ’78 astronaut class came in, and of course, for the first time there were women and minorities involved in the astronaut corps. At the same time the same thing was happening to Flight Control. You may have been seeing more minority and female faces and that sort of thing coming in. How did that change affect Flight Control and that world?

KNIGHT: Well, I guess in the earliest days, it was again mostly an all-male enclave, and some of the early guys were military. So there were more beer parties, more smoking and all that. Well, over time and as these other things happened, but the culture was changing as well, so there was less of that. So now you see floating a keg, but not three kegs. I never drank, anyway, and I didn’t ever smoke, so for me it wasn’t a big deal, but over time you could see people were doing less of it. And, of course, the Surgeon General’s thing came out and people were just quitting, those that were smoking, like Puddy quit and some of the others did, too.

But I think the language mellowed out, and some of the jokes became more appropriate as females—mostly the females, not the minorities so much, but the females were added. Most of us of my age group were brought up to be nice with the girls. You never hit the girls. You don’t use curse words in front of girls. You don’t curse in front of your mother. So you have that, that sort of thing.

NASA did a pretty good job of selecting people. You didn’t just pick people off the street. You picked people that had gone to engineering school, so already you’re picking sort of

the top group of people. In order to get through a recognized engineering school and with a three-point GPA [grade point average] or something like that—this was before grade inflation—you were not a ditch digger. So you were already talking about people that were "smarter than the average bear," so to speak.

I guess the rest of the culture, they learned how to be polite and watched their language. Then the sports began to become mixed. So it depends on which time frame you're talking about, because it just grew, but early Shuttle was still most of the same guys, and it stayed that way for a while. Like Linda Hamm might have been one of the early ladies that came in, in PROP. I'd have to start thinking back. I'd have to go back and really look at phone books and org [organizational] charts to see when they started showing up and where.

Now, training had more of the females and minorities than, say, Flight Control did, but they had a larger turnover, and I think they were growing. They were expanding more, so they had more opportunity. I think maybe the females did feel more comfortable in that kind of thing, because training is nurturing; it's teaching. The traditional roles, like when my wife graduated from college, it was like you're a nurse or a teacher and she picked nursing. It takes time for more opportunities to show up.

So engineering was just not considered a big thing for girls. It took a while before it became that way, and so we'd get the—quote—"pioneers," if they wanted to come in that arena, and whether sometimes it's self-confidence and do you have it or not.

But I'd say training started out with a bigger female population, at least in sort of the MOD enclave, and then over time it—because Human Resources or Personnel, they got their orders, so they were only handing out offers until they met their goals, so it came up that way. So there were periods of time when, if you couldn't get the right mix, that you just didn't get

anybody until you got the right mix. [Or at least it sure seemed that way based on what I recall.] So those were kind of imposed from the top.

But in terms of how the culture went, that was my recollection of it; less smoking, less drinking, more appropriate language. Probably not as many "shouting matches" as you might have had in the old days. But that probably changed, anyway, just from the different people, even though it was males, because a lot of them coming out hadn't gone through the military and didn't get exposed to that kind of an environment. They came through that school process, so again, where are you coming from, that probably drove that.

JOHNSON: Those first flights, those first four flights and during STS-1, you served on console for Don Puddy.

KNIGHT: Yes, I did. The entry team.

JOHNSON: Can you talk about that experience and seeing the Shuttle fly for the first time?

KNIGHT: Oh yes. First of all, you have to say it was the first time that NASA had ever put men on a launch vehicle that launched the first time, so that was a step up of massive proportions. Every previous time you had to man-rate a vehicle by doing so many unmanned launches. Prior to the Saturn V it was ten when you're doing Atlases and Titans. Well, Saturn V was so massive they could have done ten, but, man, it would have taken a long time and been extremely expensive. So we put men on the fourth one and sent them to the Moon.

But Shuttle was another thing, and the cost business, because Shuttle almost didn't get approved. It got approved for a number of reasons, one of which was that it was going to be the only launch vehicle the United States would have, and it would serve the military and the NASA civilian role, and launching commercial stuff as well. But again cost, cost, cost, and so they decided they didn't want to put the money into making a completely automatic vehicle that would go up unmanned, do all its things, and come back, because man [a pilot] was integral to it. It was built that way, with a stick so the guys that were jet jockeys could fly it.

So they put John [W.] Young and [Robert L.] Crippen on there, and yes, they're sitting down there [on the shuttle stack]. We've done their flight readiness test, but we'd never fired off the solids, and the whole thing is going to be done in one event. I was the entry guy, but I was there for launch. We watched the countdown, and you watch this light off, and off she goes. Wow! Me, I just crossed my fingers the whole time, and [in a couple of minutes] it dumped the solids. At the time I don't believe any of us felt like the solids would ever be a problem. It was always the main engines [that were the concern].

Very, very sophisticated devices, those engines, so you say if you're going to have problems, you've got all this rotating machinery and so on, it's got to be the mains. So you cross your fingers, because you've got to watch those for eight and a half minutes. But they went off without a hitch, shut down, got onto orbit; opened up the payload bay doors, and then John Young's voice says, "Looks like we're missing some tile back there on the OMS [Orbital maneuvering System] pod."

I thought, "Uh-Oh." Because we'd simmed that kind of thing, because people were really [nervous]. [Aside—Chris [Christopher C.] Kraft once said that he'd get letters all the time from people, email, and he got some hate mail, and letters that say, "That tile is going to peel off the

Orbiter like corn off of a cob and you are going to kill everybody," blah, blah, blah.] Well, that [Young's comment] wasn't helpful to hear, because then you couldn't see the bottom. We couldn't see it from anything onboard.

Now, I think they had cut some deal with the DoD [Department of Defense], where they had some assets up there, and if you get the right pointing and lighting, their cameras could see some things maybe. I suppose that happened. I was never cleared for anything like that, so it was the Flight Directors and Kraft just a very few people, the DoD guys. So I suppose they did that, and nobody got excited about the bottom side at all, or I never heard anything about the bottom side, so that must have been somehow cleared.

But anyway, so you have this one on the top, and Engineering, they had done all their analyses and they, I guess, decided that—of course, there was nothing else at that time anybody could do about it—but decided that, okay, we don't have much choice. We're just going to come on back in with it after we've done our time on orbit in a couple of days. Anyway, so that was a worry, sort of a worry, but not that you could do anything at that time.

The rest of the flight went pretty well. So I did my shifts. Had the usual kind of things that occur the first time in orbit, the first time that you get to see the vehicle respond to the orbital environment, so what does the temperature profile look like? What are these pressures in the tanks? How does the cryogenic fuel cell supply system work? How do the heaters work? That vehicle was 102; it was very well instrumented. It had a lot of thermo-couples and strain gauges and stuff like that on it, most of which you didn't see till after you got on the ground. It was recorded on board, but Engineering, that was their baby.

But we went through the flight plan. We executed the procedures. Things, in my recollection, seemed to go pretty well. The doors were open; got the doors closed and latches and all that latched up. APUs started, and they worked just beautifully.

But we didn't have TDRSS, either, at the time, so you're still working ground sites, and you have these periods of time when you don't have any coverage. It's a whole different world when you're that way, because you have to pay attention to what sites are coming up, because you have to make a call. You've got a short period of time to look at something, decide whether you need to do anything, and then make the call either before that one or make it for the next one. So before the next site comes up, you've got to convince the Flight Director, get your flight notes written.

Anyway, so [for entry] they got the APUs started; did deorbit burns. Everything looked real good. We still have these periods with no coverage, and then you know they're going to hit entry interface, and at that point the plasma sheet that comes all around blocks out the RF, radio frequency, to the ground sites, because we had no TDRSS. When you've got TDRSS, you can go [transmit] up, and then the plasma doesn't bother it so much. But going down, it does.

So you always had this, "Are they going to come out of blackout?" First time this has ever been done. I think John Young, he wanted to fly the needles, meaning he wanted to do it manually. Well, we all do it auto now, because the automatic does just fine; doesn't screw up. A guy can screw up, and the auto is going to—if it's targeted right. If it's not targeted right, he doesn't know, anyway, so there's not much he could do. Anyway, so the greatest thing was coming out of blackout. Wow!

At that point you're pretty sure you're going to make it, unless the crew screws up. So then they had the video of the Orbiter real high up; it was amazing what those telescopic cameras can pick up. But anyway, that was just—you're hugely elated.

Then my part from there on essentially is to remind them "You've got to drop the landing gear," because that was a manual procedure. You're watching the clock and the APU fuel and hydraulic temperatures. It all just worked very well. They got the gear down and came into Edwards and landed and rolled out.

It doesn't end there, because there's a lot of things that follow up. If you ever watch one of those landings, a whole bunch of trucks that come up there, and they put cooling back on it, because they never shut the vehicle down completely, although we could, because once you shut it down, you lose all insight into it.

So again we learned some things there that we incorporated into procedures later on to save ammonia; but there was a lot of things that had to happen. The water boiler goes off, and the ammonia boilers come on. The air data probes deploy, and then you've got to watch the altitude to remind the crew if they didn't; that you'd better get that gear down, because it just falls, and it takes a finite amount of time. [Aside: I think on STS-4 he [Pilot] was a little late, or he was sinking faster than he thought he was, and that gear was real late coming down. I think they went back afterwards, and it was locked a quarter of a second before it hit the ground.]

JOHNSON: Oh, my gosh.

KNIGHT: Now, it would have locked anyway, because it goes backwards, so as soon as the ground hit, it would have locked, even if it wasn't quite there. But that's really not good. So it

was an incredible feeling. I think Kraft said [after STS-1 landing], "We just became infinitely smarter," or some words to that effect or something; that's hearsay. He was up there in the back, so I don't know if he said that on a loop or I heard that afterwards. But anyway, it was just cheering, and everybody was—and John Young came down the ladder, and he was bouncing around, looking up at everything.

So, yes, it was a tremendous—what a great sense of accomplishment. Then we repeated it on STS-2. No, let's see; STS-2—the flights I did on Shuttle as a Flight Controller were 1, 2, 3, and 4. After that I was in management or technical assistant.

But STS-2, I think, was one where they had a fuel cell fail, and so we shortened the flight. I think that's where we really became more conscious of these folks' space adaptation syndrome, which means the crew hadn't adapted to microgravity, and when you bring them back, they're not very good shape, which is okay for an Apollo-type capsule, because you're just on your back flying down. But if you're supposed to be in charge of the vehicle and flying it and using your senses, well, that's not good.

So afterwards we modified the rules and invented this term called *minimum duration flight* or something like that. The objective, is if we get up there, if we at all possibly can, we need to stay at least 72-hours, or it was 96-hours, something, whatever it is. The rule is a little fuzzier than that, but it gives them [crew] a chance to stay [and adapt, even with certain failures].

Also, at least at the time, the flights [payloads] were deployables, and you could get something deployed in that period of time, so you could get your main goals, mission objectives, out of the way if you had a deployable. You get that up on the first day; the second day you can deploy it, get rid of it. Now you can come home, and you've done most of your mission, if that's

the kind of mission it is. I may have my timing a little bit off on that, but I'd have to go back and see how the rules evolved. But they did evolve over time, especially early on.

So I did [was a FCR flight controller on] STS-3. I did launch on one of the flights; I've forgotten which one that was now. I guess STS-4 was a military; it was a DoD flight. I think that one—did that one land at White Sands? One of them landed at White Sands, because again the other site was messed up, and we had to come down or something like that. Anyway, that's one where he came in a little hot—he had a PIO, pilot-induced oscillation after he got his wheels on the ground, but walked away from it, and the vehicle was okay.

That supposedly was the end of orbital flight test, and it was a mistake to call it that, as things later evolved. You get a different mindset when you claim it's operating. I don't think any of the Flight Controllers ever felt it was operational in the sense of an aircraft, of a commercial airline kind of a thing. No way it was ever that.

Eventually they took the ejection seats out and put more people on the flight deck. There were only two ejection seats. We were still flying 102, which had the ejection seats, and when you put the other two people on there, there was a question, "Well, are you going to leave the ejection seats hot so that at least two could get out?" There was some debate on that, and they decided no, we were not going to do that; it's an all or nothing kind of a thing.

So the seats were fixed so they wouldn't eject, and then eventually we just took them out and put lighter seats in there, because there's a lot of structure associated [with ejection]. Additionally, you have to blow the top off the cabin to eject them. So when that went away, you had no capability until after [STS] 51-L [Space Shuttle *Challenger* accident], and that's when they put in the where at least if you got to where you were flying level, you could blow off the side hatch, and then these guys could jump out on a pole.

JOHNSON: After those first four flights, as you said, you moved on into management at that point.

KNIGHT: Yes, I think somewhere in there I was a section head, and then Don Puddy was Systems Division Chief, and I came down to be his Technical Assistant. That was a fun job. I really enjoyed that. Somewhere in there I think he sent me off to—NASA has what they call a Management Education Program, which is a two-week session at [NASA] Wallops [Flight Facility, Wallops Island, Virginia], and he sent me off to that, which was really a very good experience for me at the time.

Afterwards I came back and, like I said, I really enjoyed being Technical Assistant, because I signed off on mission rules for the division, reviewed them and sent them on to that board. For the Crew Procedures Control Board, I reviewed all the procedures, Form 482 procedures that we submitted, and I was on that board and went to all the PRCBs [Program Requirements Control Board]. It was a lot of fun, a technical kind of thing. I didn't get to do console, except as SPAN [Spacecraft Analysis] or something like that. But it was a broadening experience.

Then I was selected as Branch Chief of one of the branches.

JOHNSON: Were you in that position as a Technical Assistant during the *Challenger* time period?

KNIGHT: No, I was a Branch Chief.

JOHNSON: Oh, you were already a Branch Chief then.

KNIGHT: I had gone down to be Branch Chief of the Data Processing Systems Branch, which is the INCOs and DPS [Data Processing Systems] guys and Spacelab computer guys.

JOHNSON: Where were you when the accident happened, the launch?

KNIGHT: I was in a meeting in my office, and then my secretary opened the door and said, "The *Challenger* just blew up." They had a closed-circuit TV down in the lobby, and I went down there. They were just replaying that over and over and over and over again. I honestly thought —because I wrote a letter to the branch--I said I think we'll be flying sooner rather than later, which turned out not to be so.

But just testing the waters, I remember asking a few people around the branch, I said, "Would you be willing to fly if we just put another one together and go with it kind of like it is?" This was pretty shortly after the event. And they, "Oh yes." Just to get a ride they'd be willing to go as is.

There was, you remember, the Rogers Commission [Presidential commission appointed to investigate the *Challenger* accident], and it had a number of people on it, one of which originally, I think, was Chuck [Charles E.] Yeager. There was some rumor that he went to the first meeting and kind of listened and watched that and listened to some of the first discussions —and he says, "Well, you guys, why don't you just fly when it's warm," and he walked out. He got off the committee. Because he said, "If it's a temperature thing, just wait till it's warm." In Florida most of the time you don't have those kind of freezing temperatures.

Well, okay, but that was not going to be the Rogers Commission's outcome, so they had the big investigation, and things drug on, and then it takes time to rebuild. Well, they got Congress to authorize another Orbiter, and that was two-year money to do that, and to redesign and rebuild the solids with that new seal design is not a two-week job, so by the time we had finally—it was two years almost before they got around to flying again. I was Branch Chief during all that time.

JOHNSON: How did the accident affect your position—

KNIGHT: Not much.

JOHNSON: —or your duties at that time?

KNIGHT: Well what we did was is when you have these periods like this, people go back and relook at everything, relook at all your documentation. So we did that. We did a systems review of all our systems, the ground systems, the flight systems, what recommendations should you make, what changes should you make, flight rules, ground procedures, onboard procedures, those sorts of things. We went back through; did exhaustive reviews.

There were all kinds of other reviews going on. There was design certification review of the whole Orbiter systems. There was a review of the ground software; what's the pedigree of it, what's the requirements for it. Some of it was just built up over time, and you just had people doing stuff based upon scribbled notes. So if you had to go find the documentation for this, well, there wasn't any, or it was a few memos. So we ended up doing a more thorough job of

documenting things, documenting all the procedures, your ground procedures and the onboards. So yes, we did a lot of that.

But, again, maybe sometimes part of the reasons, bureaucratically, that you say, "Oh, we'll be going next week, or it will be a short period of time," is if you know you're going to be down for a long period of time, there's somebody saying, "Why are you keeping all these people around? They're just twiddling their thumbs." So the team pretty well stayed together and yes, whatever normal attrition you would have, you probably had.

We really looked at the manning. I think we started out, my recollection, if I remember, on the systems element of it, we had 36 people on an ascent team, and that was front room and back room, just for systems guys on STS-1. On STS-25 or 51-L we were down to 16. After we went back and re-evaluated, we said we'd gone too far, and I think we moved back up to about 19 and stayed there. So we had done a lot of evolution in reducing team size from STS-1 through 51-L, and then it leveled. But there was always that pressure [to reduce]. "Hey, this is operational. Why have you got so many people around?" and over and over.

JOHNSON: In '87 you were moved into a Deputy Chief for Systems Division.

KNIGHT: Yes. There was some kind of reorganization in MOD, and I think Don Puddy had moved up one notch or something like that, and [he was assigned to be Deputy Director at Ames Research Center] so Steve [Stephen G.] Bales, who was his Deputy, took his place, and then he—I was walking down the hall one day, and he said, "Why don't you come in here and let's talk."

I said, "About what?" I was a Branch Chief; he was a Deputy.

Then he said, "About being Deputy."

Usually you expect there's going to be a job announcement. Well, you're already the same GS [General Schedule] level, so in those cases you don't have to put an announcement out, because all it is is a lateral transfer.

So anyway, he chatted with me. A complete surprise to me, but we talked about it a while, and then he eventually said I was it. So I was flattered, and that turned out to work out really well.

JOHNSON: During that time period you wrote a Minimum Equipment List, a Mandatory Instrumentation List.

KNIGHT: Yes. That was one of the fallouts of 51-L. Bob Crippen was Program Manager at the time, and that was part of the launch commit criteria; well, [NASA] KSC [Kennedy Space Center, Florida] would disagree with this. But part of getting ready to launch is let's document, so we don't have to argue about it, what we need to launch. So we invented what was called the Minimum Equipment List and the Mandatory Instrumentation List, and I was assigned to pull all of that together, because it was mostly from our division. I wrote them up, summarized from a lot of people's inputs, formatted them, took them over to the [Shuttle] program and presented them, and they were accepted. So they became appendices to the launch commit criteria.

KSC never did like them, because they couldn't actually put them into the launch processing system. They wanted to automate everything. Well, these had some subjectivity to them. How many jets do you need, for example; and some of them you just simply couldn't detect at the time, but our rationale was if there were some way you knew that [a failure existed],

are you willing to launch or not launch without it, because it's a big deal to shut things down and start over. It costs a lot of money, and it ricochets downstream to lots of other things that go on, because we share TDRSs and things like that. But yes, I led that activity and got it through, and accepted up to the board.

But first before I got into that, I thought, "Okay, I think we need a letter from Mr. Crippen, because there's not a lot of people that are going to jump in and say, 'This is a great thing to do.'" So I wanted to short-circuit any resistance by saying, "This is from the top, so don't come around saying, 'Why are you doing this?' and so on." So we got a memo from Mr. Crippen saying he wanted this done, so I had license to go off and do it, and that worked out well.

It was really quite a good exercise, because what happens a lot of times is when you get down close to launch and they've gotten this thing tanked up and everybody's cranked up and so on, it's real hard to stop that train. So I wanted to put in those rules, that Minimum Equipment List and the Mandatory Instrumentation List, only the things that we were going to stand up and pound the table and say, "Absolutely not. Now, you can direct us, and we'll go support the best we can, but we are not going to cave in on these."

So I tried to put that kind of rigor into them, that it's something that MOD and our Flight Directors were going to stand behind, because when you get up into this world, the politics of it are such that managers, they want 100 percent agreement, 100 percent consensus. They don't like just to go with somebody saying no. They're a little better now; but there's always pressure there to go.

JOHNSON: That's true.

KNIGHT: If you're not willing to take a risk, you shouldn't be in the business. But the question is, is what level of risk.

JOHNSON: Then, of course, they launched in '88 in the Return to Flight. Do you have memories of that?

KNIGHT: Oh, that was Rick [Frederick H.] Hauck's flight, but to this day I still cross my fingers until the solids are gone, and yet the solids are probably the most reliable. In fact, it wasn't the solid. Yes, the solid seal failure allowed a super hot jet to impinge on the ET attach strut, but the actual structural failure was on the ET [external tank]. But I still do that [cross my fingers] just because, even though that seal now is virtually foolproof, knock on wood.

But the main engines are just like they were [more or less]. We did have a shutdown on one of the flights, STS-5 [actually STS-51G] or something; or it may have been one of those with funny names. But anyway, it was [C.] Gordon Fullerton's flight, and they had gotten past press to MECO [main engine cut off], fortunately, and it shut off. No, it wasn't Fullerton's flight, but anyway, this was one where the engine just shut down, but they kept on chugging on two engines and made it on into an orbit, and things came out all right. But the engines are highly dynamic in there. You've got 30,000-rpm turbines running,—big ones, not little ones—and things can go wrong.

JOHNSON: In '89 you moved into the Chief position for Systems Division.

KNIGHT: Yes. Yes, they had another reorganization, and S. Bales moved to another job, and I went over and said I was interested in that one, and so [Tommy W.] Holloway picked me.

JOHNSON: Also that same year the first President [George H. W.] Bush announced the beginning of the Space Exploration Initiative to build the Space Station, Freedom, and then to go back to the Moon and Mars. How was that announcement received and what changed, especially in your area, after that?

KNIGHT: Well, I don't remember a big deal about it. It was probably skepticism, to some degree, because we had seen—first of all, when this guy says go to Mars, people are saying, "How much?" And then you talk about these gigantic numbers, hundreds of billions of dollars, and I'm paying attention to what Congress is voting and where the money is and how it's being demanded by—there's all kinds of groups that want money. I just didn't see it happening unless you had some incredible technology breakthrough, which still hasn't happened. Space Station was doable. We'd done that already with Skylab.

Now, the question is, is how are you going to do it? So Freedom was the first incarnation; that was [President Ronald W.] Reagan's name for it. Well, see, Freedom was started under Reagan, and I think it—oh, gosh, again my—some of these fuzz together, because Freedom evolved into Space Station Alpha in the [President William J.] Clinton administration, but I think it was in that administration where it only survived by one vote, because again costs were going—people were playing the full-cost accounting game, and what rules are you—are you counting all the Shuttle flights as part of the cost of Station.

Of course, what had happened after 51-L was they changed the whole philosophy then, because DoD I don't think ever really wanted to be part of the Shuttle; they just accepted it, and fought it. They like their own rockets, because then they can declare national security when things do not go so well, they can hide it all and so on. But that Titan IV was a billion dollars a flight, which was twice what a Shuttle flight was, even fairly recently. So it's not cheap to do that. But nevertheless, they can dance to their own schedules, and they don't have to play with NASA, which has a more open environment, although we did set up parallel classified areas.

Freedom was collapsed for money projections and so on, a new administration. Then Clinton came along, and I'm not clear how it would have gone, except they had their geopolitical issues with the Russians after the USSR [United Soviet Socialist Republic] had collapsed. You had all these guys trying to survive economically, and they were selling missiles to other regimes, and they had a bunch of nukes [nuclear missiles] spread all around. So either him or Al [Albert A.] Gore [Jr.] dreamed up the "let's cooperate" and pick up on the ASTP [Apollo-Soyuz Test Project] thing. That also helped, on the premise that it would help keep them more controlled, because there were some economic advantages, too. Well, they had [Russian] Space Station Mir going up there, and we got involved in that.

JOHNSON: What was your involvement?

KNIGHT: Again, I was head of Systems Division. We were flying Shuttles, and the Shuttle went to Mir, so it was another flight. However, there was also some pressure to get some insight into how the Russians did business, and they wanted to have some Systems people go over there and at least try to talk to them and understand what's going on in the Mir. So I was partially

involved there; I just had no budget for it, and so you get into those kind of, "Well, if you want me to do it, budget."

"Well, we don't have the budget. Could you just do it?"

Well, I was probably not very sympathetic to it, frankly, because it looked like you were trying to do things with your hands tied behind your back. They weren't willing to give much, and you had no leverage, and you didn't speak the language, and they were very closed-in, so what's the point. You either trust them or you don't. If you don't trust them, don't go, because there was no way we were going to be in any position to do anything one way or another.

But there's management, and they wanted some insight, so my part of it was systems oriented. The Operations Division tried to provide some other insight into it. I think I ended up starting a little group to try to consolidate what we might know about the Russian Mir systems, but it was small.

Now, afterwards, at the point that Space Station Alpha finally got going and they collapsed Freedom and re-divvied things up and finally got, I think—[Daniel S.] Goldin came along and he somehow browbeat Boeing into eventually taking the prime contractor role as Space Station Alpha lead after they had the teams up in Reston [Virginia]. Things began to solidify. Gene [Kranz] was still head of MOD, and he created another subdirectorate. There was subdirectorate for Systems and Ops [Operations] and Flight Dynamics, and there was a subdirectorate for Facilities. Then he created a third one for Space Station Alpha.

He pulled people out of the other areas, some people out of training, some people out of—nobody wanted to go, because they didn't trust it. We were one vote away—it only passed by one vote, and then it started to pick up again. But people were just reluctant to go over to something they had seen fail two or three times. But they did. They got some people over there.

So some people got promoted and got divisions. That went on for a while. Eventually they remerged things back, because I think Gene retired, and John [W.] O'Neill came back, and there were some other things on the Shuttle contracts. Goldin was trying to privatize the Shuttle and step one in that was to put all of the Shuttle [Program] under one contractor. Well, that never fully panned out, but they got KSC and a lot of JSC under one, the USA [United Space Alliance] contract. But pulling in Orbiter and pulling in ET and pulling in SRB and some of the [NASA] Marshall [Space Flight Center, Huntsville, Alabama] stuff never did really happen. Then they lost interest in it, I guess.

I didn't think it would ever work, anyway, because you're never going to privatize the Shuttle. You could spin it off like TVA, Tennessee Valley Authority, but it would still be a government-run thing, because there wasn't an economic reason in it. There wasn't moneymaking, so how are you going to privatize something if they're not going to make any money unless you're going to—in each case it's just still government-run.

So once Station got pretty well solidified and they cut the deal with the Russians, with Alpha, so that they [the Russians] would provide the first part and get them on board and use the Soyuzes [Russian spacecraft] and use the Progresses [unmanned expendable spacecraft] along with the Shuttle, then it became more a going thing. You had Boeing down here as a prime contractor and a program office and all that, and then George [W. S.] Abbey had a big role in it.

Eventually MOD remerged those divisions, those subdirectorates. We merged the Station Systems guys in with my guys in Shuttle into one big division, and they merged the Training Divisions, the Shuttle training.

I'd have to see exactly what the timing was, because I'm not remembering it exactly as to when—this was in the Goldin period. Whenever they did that contract change and put USA in

charge of all the Shuttle work, they also wanted—Goldin was really pressing to get the civil servants out of it, and people were resisting. But MOD turned training, Shuttle training, lock, stock, and barrel, over to USA and just left a couple of civil servants as contract monitors. And then moved some of the civil servants essentially into Station training, and some into other areas, including Systems Division.

In my division I think we turned over IFM, In-Flight Maintenance, and Photo/TV to the USA lock, stock, and barrel. But we kept a mix, a mix of civil servants and USA contractors in the other areas, and Flight Design did something similar. Operations did something similar. So we sort of complied, if we thought we could get away with it, with what Mr. Goldin wanted to do. KSC had similar issues that turned out eventually to cause some problems, but yes, that's the way we stayed for some time.

There was a period there where we also merged—this was in the late eighties sometime—merged the MCC [Mission Control Center] and trainer development organization, which was Mission Support Directorate, in with MOD. So MOD just absorbed that directorate. That was the time when Steve Bales went over to the Facilities sub-directorate, and a few other guys. They went over and began that subdirectorate, DA-3 part of MOD. Then eventually that became just a division.

JOHNSON: Eventually, the [International Space] Station did come to pass.

KNIGHT: Oh yes, Station came to pass, and then it became, except for the Hubble [Space Telescope] flights, about the only thing Shuttle did. Then we had the [STS-]107 [Space Shuttle *Columbia*] accident and shut down another two and some-odd years, and here we are. I was in

Systems Division until about ’96, and then I went and was Chief Engineer for the directorate for a year or thereabouts. Then I went over to take Bob [Robert K.] Holkan’s place in charge of the Space Station Trainer Project, and then eventually merged three small divisions into the one division, DV, which has now been renamed in the last couple of months.

JOHNSON: Well, as Chief of that Simulator Operations and Technology, what were some of the things that you worked on when you were in that position?

KNIGHT: Well, it was almost exclusively the Space Station Training Facility [SSTF].

JOHNSON: Was it developing the facility?

KNIGHT: Yes, and we were overseeing the SSTF development—[Aside: there was a real small group of [NASA] people, because when MSD, the Mission Support Directorate, merged in with MOD, NASA was going to this notion of contract monitors, essentially. In the early days the civil servants had a lot of detailed technical roles. They effectively had level-of-effort support, so they did almost day-by-day direction in where you’re going. Well, as we evolved, in the later years this became more of give the contractor some high-level direction about what you want and then let him go off and do it however he needs to do it. Then you have a contract performance monitor. Now, because of the history we still had some people that did understand that [technical system] stuff, and to the extent we could, we tried to keep our hands in it so we had some people that did understand Ada code and did understand the 1553 data buses and stuff like that.]

So I picked up a fairly small group of people, who had roles to keep their eye on what the contractor was doing. We had weekly statuses and monthly formal project reviews. So we essentially finished up that project, more or less. Anyway, we had a goal. We were going to get off this contractor, the development contractor, which tended to be expensive, and turn it over to the ops contractor, which was USA, by such and such a time. And we just finally focused on doing that, because otherwise these things can be dragging out and dragging out and dragging out, and it costs more money that way, which you could use for something else. So that worked out.

During the time before that was completed we merged that [Simulator] division with the MCC [Division], and another Division. Human Resources thought there were too few civil servants for that many divisions, so it would be better to have one division instead of three. So we did that.

JOHNSON: While you were Chief Engineer before that, you were also part of the Mishap Investigation Board.

KNIGHT: I led the Mishap Investigation Board for an incident that happened out in Building 350, I think it was they [Engineering] were doing a fuel cell test and were wrapping up the test. It [fuel cell] caught on fire, something like that. So Mr. Abbey wanted it looked into. He called it a mishap, so I got nominated to go lead that team, which I did, which was a great experience, as it turned out, for me.

JOHNSON: After that period of time and then after you were the chief of the simulator, you went in 2001 as Chief of Advanced Operations and Development Division.

KNIGHT: That was the division we formed.

JOHNSON: That was the one you formed from that.

KNIGHT: From the Simulator Development and from the current MCC, which George [W.] Bull was head of, and another one, which was Advanced Projects or something like that. Those three divisions were merged into one, and then I ended up with two branches and an office, because I knew the training facility was going to be turned over to another organization. So I just made that as an office, because it was easier to abolish an office than it was to abolish a branch. It turns out it's not that much different, but I thought it made sense at the time.

JOHNSON: Were you involved with the upgrade of the Mission Control Center during that time in 2001?

KNIGHT: Upgrade. A big upgrade—

JOHNSON: With the Compaq workstations. We found a press release.

KNIGHT: The MCC was a mainframe-based system up until the late nineties. John [F.] Muratore started that effort to go from a mainframe-based to a distributed-base system. I believe it was

about 1992 or [199]3 or thereabouts, and I was still Systems Division chief at that time. We all wanted to do that, we thought, because we would get control of our resources. We'd have color monitors and all that kind of thing. As it turned out, it did work out.

However, there were essentially three major parts [to the MCC involved]. One was trajectory; one was systems telemetry; and one was command, and they were all on the mainframe. So John essentially, by the time he left, he got all the physical infrastructure in, and he got the systems telemetry software converted off the mainframe. But the mainframe was still there for command and trajectory. Command we got off and trajectory we got off during my tenure. We finally retired the mainframe in 2002, so we got partially from a mainframe to a distributed system in the nineties before I got there.

So 1995 I think was the first flight that used a distributed system, partially used it for orbit. Then the next flight we did orbit and entry or something like that, and then the next flight we did all three phases. The mainframe was still there, but we were off those consoles, the old green consoles, and onto the new ones.

While I was there I put in a process by which we would—we called it the equipment replacement process, because some operating systems are no longer supported. [Aside: The first console computers were from DEC, the Digital Equipment Corporation, which gave us a good deal, and so we got their 64-bit operating system, which is Tru-64, but only DEC used it. As long as they were in business, that was okay until it comes time to upgrade, and then you don't have any choices. If you don't have any choices, then you're kind of at the mercy of the only guy that's in town, right? Well, over time DEC went out of business or was bought by Compaq. then Hewlett-Packard merged with Compaq. So the Tru-64 operating system they sustained for

a while, but they wanted to drop it eventually. Our contractor at the time [1999-2000], CSOC, replaced the older DEC models with new, faster HP models, still using the Tru-64 OS].

So I put in place a process by which we'd take the various elements of the Control Center and replace them, and try to do it over a relatively long period of time so that you didn't disrupt a lot of things. The amount of work is maybe about the same. You could try to concentrate it all in one year and disrupt everything and hope it all works, or you can do it slowly. But there's a lot of software that has to be rehosted, and that takes time. If you don't want to have to hire a whole bunch of new people to do it, well, then you do it slowly.

So that's essentially the process we have gone through, and so we have replaced the local area networks from a fiber—it's called fiber-distributed data system, which very few people are using anymore, with an Ethernet-based system. So we have essentially replaced the backbone. We're replacing the workstations now. We already did it with the integrated planning system. They had a process to do the voice system, the front end processor.

So anyway, we said there's various segments [of the MCC/IPS] that logically you could do together, and we put a process in place to do the planning and the systems design and the execution, and do that at a level-loaded budget rather than having these [budget profiles]. Some people, I guess, especially those that don't really have a lot of insight into these kind of things, seem to think that you can go in and just build it once, and then you stay with it forever. It's like you buy your car, and then you can drive it for the next fifteen years and just put gas in the tank.

Well, you can do that with a car, but with a system like the MCC where you're constantly dealing with things that change, it's not so easy. A simple thing is if you want to replace a printer, a new printer—say your printers are ten years old—well, your new printer might not work with your old system, because you don't have a driver for it. If you don't have a driver for

it, that printer is just nothing, just a piece of iron or plastic, whatever they make them out of. So you have to keep upgrading.

Then if you're buying commercial software, operating systems and things like that, they don't sit still, either. Once we went to a commercial environment like that, then we become somewhat prisoners of that technology and how fast it goes and whatever you're willing to pay for or not and whatever you can keep up with. Then if you're interfacing with a lot of other people, you have to maintain standards and live with those standards.

Some things at a low level, you can keep for a while as long as they run. Now, if they ever break, you can't find parts anymore. So that's why you have to keep things up and going for a while or keep things to a relatively close level to what the current technology is if you're going to use current technology. You can do it other ways, but it tends to be more expensive to do it other ways.

So what I did was, along with my Branch Chief, we put a process in place where we would do periodic replacements of various elements, so there were five or six or seven elements, and then you sort of leapfrog these along the way. So any one of them would have a life cycle of eight, nine years, maybe, but you offset when you replace them so that you can keep things level loaded. So that's what I did up until essentially the time I retired.

JOHNSON: You were still with NASA at the time of the *Columbia* accident?

KNIGHT: Oh yes.

JOHNSON: Where were you when that happened?

KNIGHT: I was running the Control Center environment. What I did at the time it went down is just thought, "Well, we've still got Station up there, so we can't just let everything stop." When *Challenger* happened, everything [in the MCC] stopped. You freeze everything and just wait until somebody—well, we couldn't do that, because we were supporting Station, so we had another operation ongoing.

We had to isolate what we needed [for the investigation], because under the ground rules certain things have to be frozen. So the documentation on console at the time, that's boxed up and kept under somebody's oversight. You can get it out, but you have to sign for it. It's like forensic evidence.

Then [as time goes by] you have a Return-to-Flight environment where you've got the program, Shuttle Program, "We want a new this. We want that. We have a new MER [Mission Evaluation Room] concept, and we want this and we want this." So we had to build all of that in there [the MCC environment] while we're doing an ongoing operation and not disrupt the one with the other.

So that was what I was doing just trying to keep the shop going, and while all this other stuff is going on around us, and try to not get hung up too much. I went to the Center [management] to say, "We need to release this because of this reason, that reason. We can't keep the software frozen because of this reason or that reason. So we need an approval," and I went through the rationale as to why that was okay.

JOHNSON: When did you retire?

KNIGHT: January of 2006.

JOHNSON: What led to your retirement at that time?

KNIGHT: Well, there's personal reasons on that. But I'd been there 40 and a half years. I wasn't that old, and every once in a while—the number of funerals had started to increase, and I'd known some guys that had died while still in office. Well, if you do that [die in office], you never have much opportunity to enjoy what you've worked for. I enjoyed work. I couldn't ask for a greater career. It was just wonderful. But there's those people at home.

Well, let's see, Jon [C.] Harpold. He and I were the same age, and we get a call one Sunday, and he had a heart attack. Boy, that can happen real fast, and is it stress related and so on? Who knows, but just a combination of things, and frankly, there were things going on at NASA with Mr. [Sean] O'Keefe's administration and some other things that I just—you know, why am I doing this? So I decided this was a good time.

MOD had a new Director, because Alan Flynt had come on. New guys, they come in. Maybe they are entitled to pick their own team and not get stuck with the guys that were there before. So who knows? Just a lot of things, but it just seemed like it was the right time to do it.

JOHNSON: Throughout those 40 years you've worked with a lot of different managers in your career. Who would you say was an influence on your own management style?

KNIGHT: Don Puddy is probably the most influential. But Gene Kranz, clearly; everybody that you're probably doing a direct report to, and then you make observations. S. Bales had an

influence. But Don was probably the most influential; that management education program also. They have a couple of guys up there, one named Jerry Harvey; he's been doing it—at the time I went there in '83 or'84 or whenever it was, I think he had been there for 20 years then.

He's the guy who developed the Abilene Paradox, and to me it was a very influential little session that he had with us about how you treat people and ought to treat people. I think he has since put that in a book along with some other things. I think he's still up there, George Washington University [Washington, D.C.]. So that was pretty influential. They did something they call red/blue games. I had read about some of that before, but that and just reading.

Down here some years later, they would go into this quality process, and the Safety and Quality Assurance organization brought down W. Edwards Deming, Dr. Deming. He wrote the book *Out of the Crisis* and a number of other books, and he was the guy that was big on what's called statistical process control. He had some management theories, and he had exercised them in Japan. That's essentially where they got their quality control. They just led them to essentially—that's why my wife drives a Honda and people think Toyota is the best car around, although their quality has fallen off a little bit; but the quality process. His book and his seminar—that was later, nineties sometime—I thought were quite good.

Some of the other stuff, risk management, I had a little course in that, and that was, I thought, pretty good. Some of the stuff I think is overblown, culture surveys, for instance.

JOHNSON: Well, what would you say was your most significant accomplishment during your career with NASA?

KNIGHT: Well do you ask that as a personal accomplishment or team accomplishment?

JOHNSON: Either one.

KNIGHT: The team one, I don't know how anybody could say anything other than Apollo, the Apollo Program. I was on all the manned Apollo flights—or all that had a Lunar Module on it, so all the landings. STS-1 was also a huge thing. Those are the ones that stand out as just incredible.

Now, there's your team kind of things, but I contributed a lot for my part of it, I thought, and I think Don Puddy thought a lot of me, too, because he kept asking me to be on it, support his team. As far as I know, all the Flight Directors tended to be happy with my performance that way.

I did propose some design changes to the vehicle. One of them was essentially pushed by the crew. Originally the Shuttle Orbiter, once it's down on landing and rollout, its aerodynamic control for left and right directional motion doesn't work so much because it gets too slow. So they put differential braking in to do that, and most aircraft have that. Well, on almost all those systems if you try to use the brakes when it's going too fast, you'll burn them up.

So the original design of the Orbiter was such that you couldn't engage differential braking until the nose wheel was on the ground. Well, while the nose wheel was in the air, that means you've got no differential braking, and therefore if you have crosswinds—the Orbiter has such a large side profile that if you have a significant crosswind—well, you're not supposed to land in those crosswinds, anyway, but if you did, it might drift over.

So John Young, being the kind of guy he was, wanted—and Crippen, but I suppose it was John mostly—they wanted differential braking to work when they got the mains on the ground

even before the nose wheel got on the ground. So they talked me into taking forward a proposal to take the nose wheel [Weight on Wheels (WOW)] inhibit, out of the circuit. So I took that forward and the board signed off on it and it was taken off.

Then later on they found a design [situation], the way the Orbiter buses were designed and the way the APUs were designed and how they were wired up, there were two failures that would take everything out, three systems out. It was just an artifact of the way they designed it. So I took that forward and said, "You need to find a third way to power these particular buses." I think this was after 51-L, but they were receptive to that kind of thing at that time, and they did redesign, and they powered the control buses from a third source. So that was a design change that was put in place.

That was probably, if you're asking about those kinds of things, those are the ones I remember. But I'm pretty well proud of everything, just about, that I did and was involved in. Significance is in the eye of the beholder so I don't know [what others might think].

JOHNSON: If you don't mind, I'm going to ask Jennifer if she has any questions before we end today.

KNIGHT: Sure.

ROSS-NAZZAL: One of the things that I'm always curious about is gauging what people think about the Johnson Space Center's impact on this area, and I was curious—you've worked here for over 40 years. What sort of changes have you seen over the years?

KNIGHT: Well, I think the space center location here is huge. If you were here before it was here, it [nearly the whole area] was part of the ranch.

JOHNSON: The West Ranch.

KNIGHT: Jim West Ranch. He had the house over there, and in fact, they had a bunkhouse over in Nassau Bay [Texas]. It was still there when I first got here. There wasn't much around. Webster [Texas] was a sleepy little town. So this Johnson Space Center has been a huge draw to this area.

Now, since then, because it got things started and was a catalyst, a lot of people—of course, there's the water, so you have these places along where people put their boats, a yacht club and this and that, and now South Shore Harbor. So it's drawn a lot of people here to begin with, but then so have the [Houston] ship channel industries and the bay port and all those chemical complexes and stuff like that. It's a community that people like because it's near the water; I think a lot of people just like to live here.

So they've grown up. League City [Texas] has grown up. Dickinson [Texas] has grown up. Webster has grown up. The Gulf Freeway [Interstate Highway 45 South] just keeps getting wider, and then they put the malls out here. When I got here, the closest mall was Gulf Gate out there where 610 [Loop] [intersects I-45]. When I first got here, I'd go downtown shopping to Foley's [department store] or something; anyway, they had the big downtown store. No way would I ever do that now—but then the Almeda Mall and then this mall [Baybrook Mall] and Mall of the Mainland [were built].

So I think it's been very, very influential as being a catalyst out here. U of H [University of Houston] put itself out here, [University of Houston-]Clear Lake, because of the Johnson Space Center. It wouldn't have been here if it wasn't for JSC.

You can see the housing when they had that period after the *Challenger* accident, housing just froze out here. Prices dropped like—somebody catty-corner from my house over in Oak Brook West, they'd just bought that house at a fairly elevated price. It was an elderly couple, I think. But anyway, right after that I think was *Challenger*; and the prices dropped, but they wouldn't sell. I'm not sure they ever lived in it, and it just sat there and deteriorated until they passed away, and then finally somebody, I guess their estate sold it off.

But yes, there was that period, and so that's what happens when people are scared something bad is going to happen, and you have layoffs. So, yes, I think it's had a big influence.

Now I think it's somewhat less so because of the other stuff that's come out here, but if JSC were to close down, I think you'd see the area—I don't know if it would completely collapse, but—well, you saw what happened when Ellington [Air Force Base, Ellington Field, Houston, Texas] was turned over. The city tried to pick it up, and they've done a few things out there, but it hasn't grown significantly.

I guess UPS [United Parcel Service] lands out there. The Texas Air National Guard, I think, is pulling out or going to, and if NASA can't justify that little air force they've got out there—and that's going to shrink when Shuttle goes away, because there's just no way you need that many astronauts anymore. But Ellington, they'll probably go out there, and the Department of Homeland Security, they may fly their little drones from out there, but it's not going to be as big a deal for that. They haven't been able to totally commercialize it. They've tried to get some tenants there, but so far I don't think they've gotten that many.

ROSS-NAZZAL: So you settled here in Clear Lake. You bought a house in Oak Brook West?

KNIGHT: Yes.

ROSS-NAZZAL: Did you have any involvement in local community affairs or anything like that?

KNIGHT: Well, when I got here, I was looking for apartments on Red Bluff [Road] and so on, and I found one over in Portofino Apartments in Nassau Bay. There was some guy who had a two-bedroom, and his buddy or whoever he was sharing it with left, and so they were looking for somebody to share. So I rented it, half of the apartment, so to speak. We hardly ever saw each other, as I remember. I was there for about six months, and then he left, and then I ended up going down to Dickinson and lived down there for about a year, again with some other buddies, and one of them got married.

Then I came back to Nassau Bay and lived in the Bay House [Apartments] for several years. Then my future wife found this house over in Oak Brook West in 1973, and so I bought it in ’73 before we were married. Then we got married in January of ’74, and I’ve lived there ever since. So that’s sort of the story of my moves.

Clear Lake was not a part of Houston at the beginning. In fact, we fought that, so we had a community association. I was never really part of that; I didn’t run for anything like that. I was focused on the job here.

Then after we got married, we had a child, and my wife left her job eventually and took over full time raising him. She got involved with the schools a little bit, and she got the

symphony to come out here for the first time, and essentially monitored the schools and took him into a lab [laboratory] school over at UH when they had it—that's since shut down—and essentially helped out at the schools and whatnot. I got into Boy Scouts and was Assistant Scoutmaster for some years and things like that. Soccer; coached soccer; coached baseball—or coached with somebody on baseball, and YMCA basketball.

ROSS-NAZZAL: Sounds like you kept pretty busy.

KNIGHT: With my son, yes.

ROSS-NAZZAL: I'm curious, how has JSC changed since you started working there until you retired? Can you give us an overall sense of what your feelings are?

KNIGHT: Early on as the Manned Spacecraft Center, it was again engineering, very engineering oriented; get the Apollo Project done and program done and so on. Afterwards we're engineering oriented, project, program oriented. It always has been that way.

What has changed, and you alluded to it earlier, is after the sixties and after the Vietnam War and after we got in the feminist movement and more women in engineering, and the administrations come along and they want to show progress. And Human Resources change; Personnel became Human Resources. You got into diversity training. That's where the evolution has come about, and it's probably accelerated for the political correctness over the last several years.

Then the other thing that's happened from my perspective is the notion of program management, cost control, earned value type systems, risk management. There's a lot of what I call the management guru stuff that came in, and they think they can—in my judgment it looks like they think they can come in and they can have programs run by accountants and lawyers, and engineering is just a resource. Then you have an accident, and then you'll have the politicians, "Oh, we've got to have more safety," and the culture improvements, Sean O'Keefe's thing. So that has been an evolution.

Now they've got what I would call—which you can understand, since you see who's been trying to run the show—the military mentality, where management comes in, and they'll stay someplace for two or three years, and then they'll move on someplace else. I refer to that as a hummingbird approach; other people call it "hit and run management."

But if you don't stay very long—in the military you can do that. This is just my opinion, okay? You can do that because they have a huge infrastructure, and it's a hugely expensive infrastructure, but they have field manuals and manuals on how to do this and manuals on how to do that and manuals on this and manuals on that. So their generals and admirals move around frequently.

That was what they were doing with NASA—got to get somebody to spend time at [NASA] Ames [Research Center, Moffett Field, California] and somebody to spend time at Marshall, and move these guys around from Center to Center. That has a value to it. Mostly it's in who you get to know, so who your buddies are. But what does it do for you technically? I have yet to see any substantive evidence that it is useful. In fact, somebody can argue that it is not useful; that it causes you to lose your technology edge.

When Sean O'Keefe was there, who did he put in charge of the Centers? Jefferson [D.] Howell [Jr.] was a really nice guy, but he's a General from the Marines, and he was a poli sci [political science] major at UT [University of Texas, Austin, Texas]. Where is his technical background? Now, some managers think, "Well, you just hire that." Well, maybe, but then if you're going to sit on this board, what good is your decision? What's your background? Or are you just guessing on which guy makes the better case?

So when Mike [Michael D.] Griffin came in, the first thing he did was essentially replace most of the Center Directors that O'Keefe put in place, and he's replaced them with somebody that at least has some background. Mike [Michael L.] Coats was an astronaut, and he is a longtime JSC guy, so he at least has some background with technical history. You've got to look at the other Center Directors as to who he's put in place there, and who has moved on since then. But at least Mike Griffin has embedded his own knowledge —he's very technically oriented. But there's other politics going around, and the politicians have an effect on that.

So at the NASA level those are the kind of changes they are trying to put in place, and who knows? We'll see whether it works. There seems to be a notion, like in the Constellation Program, that you can write all these requirements and fill all these squares, and then just say go, and bingo, it will spit out an Orion module, and it will be wonderful. There will be no cost overruns, and it will all be done by earned value. I think that's run by people who don't understand technology, if you're trying to push the edge of the envelope.

If you're not trying to push the edge of the envelope, like what I was doing at the Control Center, we were using commercial technology. So it was clear; I am not pushing the edge. I do not want to be on the bleeding edge of technology, because I can't afford it. It would be fun, and if I had a lot of money like DoD does; they have DARPA [The Defense Advanced Research

Projects Agency]. Look at what DoD does. They'll start a project and spend billions and billions and billions of dollars on it, and drop it. Okay, it's just money.

Well, NASA doesn't have that kind of margin to do it, so if you stay on the non-bleeding-edge side of technology, you could probably do those kinds of things. In Apollo we did not have that option. In Shuttle, sort of; a lot of Shuttle was semiconventional. It had basis in—the air frame was an aluminum air frame. So all of the aerodynamics was reasonably well understood. Tiles were new. Fly-by-wire flight control system, most of the development of that was done under DoD. But they [NASA and Rockwell] implemented it, and they did a bang-up job of it. Main engines were fairly—you just don't have a lot of other places to do that, so those were really pretty high-tech development.

So here we are today, and I think there is a notion that they can do project management as if you're not pushing technology. But we'll see how it works out.

JOHNSON: Well, is there anything we haven't talked about that you wanted to mention?

KNIGHT: Well, the last part of all of this, probably this last half-hour has been my opinions on things. They're grounded in observation and opinion, and a lot of other people could disagree with that, and obviously do, because they're doing things that I wouldn't have done.

MOD was essentially run by people that grew up in it until—well, no, there were little periods of time when somebody else came in from the outside. They didn't stay very long. Kenny [Kenneth S.] Kleinknecht was there for a short period of time—I think it was sometime in the Skylab era—and he left. I have a vague recollection that there was a General Kirby or

something like that who popped down here for a short, very short, period of time, and then it went back to Abbey and Kranz.

So both those guys, George Abbey came in with Kraft at the time, and he worked for him, but he ended up running MOD for a while. But then it's Kranz and O'Neill. Those guys—Jon Harpold and Randy Stone, all those guys grew up in MOD, so they had it internalized, you know. Then you've got Mr. Flynt who came in from the outside. We'll see. And he's reorganized it [MOD] to a degree, so we'll see how well that works as it plays out, because he's left now. So we'll see how it works. MOD will probably be okay, but it may deviate from what he started out to do. We'll see over time. So there's a long time to go.

JOHNSON: We appreciate you coming in again and doing this for us.

KNIGHT: Well, it's been enjoyable. I'll be interested to read the transcripts.

JOHNSON: Okay.

[End of transcript]