ORAL HISTORY TRANSCRIPT

EDWARD L. PAVELKA, JR.
INTERVIEWED BY CAROL BUTLER
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BUTLER: Today is April 26th, 2001. This oral history with Ed Pavelka is being conducted for the Johnson Space Center Oral History Project, in the office of the Signal Corporation in Houston, Texas. Carol Butler is the interviewer, and is assisted by Kevin Rusnak and Tim Farrell.

Thank you very much for joining us this morning.

PAVELKA: It's my pleasure.

BUTLER: To begin with, if you could just tell us about how you became interested in aviation aerospace, what kind of guided your career and led you towards NASA.

PAVELKA: As a very young boy, my father always encouraged me to get into engineering. At that point in my life I had no idea what engineering was, but I always remembered that he encouraged me to do that. He was a very mechanically inclined person, so he, my father, was my main encourager to go in that direction. As it turned out, when I got older, my interests in math and through high school and into college, math and science supported that.

So when I graduated from high school, I looked for a college that I could go to where I could study aerospace engineering. It was called aeronautical engineering when I began, but as I went through school, the curriculum changed and they added courses and it became aerospace engineering. So my father was really my main supporter and inspiration.

BUTLER: It's good to have that family support.

PAVELKA: It was.

BUTLER: How did you then learn about the opportunity at NASA? Did you move right into that after college?

PAVELKA: It was my first job straight out of college, and I guess, you know, President [John F.] Kennedy had inspired the country, and that was sort of like a star that was shining. I was not smart enough to know at the time that that's exactly what I wanted to do, but it was like a dream. When I came to time for graduation from college, it really was a seller's market at that time. I received like thirteen job offers, and the very last one I got, very late, was from NASA, and it was very lowest paying. I didn't hesitate, I accepted it, because, for one, I'm a native Houstonian. I sort of liked to come back to the Houston area. But number two, I was, of course, interested in NASA. Again, it was like a dream that I wanted to fulfill. So it all worked out.

BUTLER: Certainly seems to have.

PAVELKA: It was wonderful, and it was such a right time, too. I could not have known it at the time, but it was a very glorious time to get into the space business. It was my first job, so I had nothing to compare it with, and I would go to work every day and do things that people would say, "Wow! What are you doing out there?" And I just thought that's what everybody did. I didn't know any better.

BUTLER: That certainly seems to—It's a similar story to what we've heard before, even though it was a low offer and didn't know the extent of how challenging it was, or was going to get over time. What was then your first job that you moved into when you came to them?

PAVELKA: I came in early 1964. Glynn [S.] Lunney was my first supervisor, and my first assignment was in the flight dynamics. I was a flight dynamics officer. They called us FIDOs. That was a fairly small group of people when I first joined the organization. There were only three or four people that were doing that type work. Glynn Lunney, Cliff [Clifford E.] Charlesworth were doing Gemini work at that time. We had another couple of people that were beginning to work more in the systems area, the telemetry part.

But our area was trajectory, where we would learn how to determine the trajectory of a spacecraft from launch on into orbit. There were orbiting satellites, and so there was a little bit known about Earth orbit at that time, but the technology for the radars and how you could put various radar data together to make a good solid trajectory was still being developed. So that was a challenge for us to make sure we knew where the vehicle was, because our job was to create the maneuvers that would do whatever you needed to do, whether that was raise the orbit, lower the orbit, get it ready for landing, provide a maneuver that would land you at a certain point.

Of course, in Gemini we landed in the water with a parachute, so there was a boat out there that wanted you to be close to them. Most of the time we did pretty good. But my first job then was in the trajectory area.

BUTLER: How did you learn all of these techniques, the procedures, how to plot these trajectories? What was the process that you went through?

PAVELKA: It was very much what you'd call on-the-job training. Our mentors, I guess, were Lunney and Charlesworth. They were the guys that had been doing it, and Chris [Christopher C.] Kraft [Jr.] before them a little bit, and then Carl [R.] Huss was in the trajectory area, also from the retrofire standpoint. He was a retrofire officer.

It was that you studied books. The first book that I studied was one on the Mercury launch trajectory data system. You had to learn about how the data flowed so that you knew how to tell the people to switch trajectory sources, because we had the traffic sites for the launch all the way out to Bermuda. We knew things about—some of them got noisy under these conditions. We had to know that.

So we also would get memos that would come through the office. In those days, there wasn't so much paperwork as there is today. You could fill many rooms like this with paper. In those days, there was precious little paper. The people that got it were the guys like Cliff Charlesworth and Glynn Lunney. So it was our job to watch for when new paper came in and we would try to get a copy of it.

Ken [Kenneth W.] Russell, a friend of mine, that had just entered the workplace before me, he and I shared this one book that we had on the trajectory data system, and we would find memos and stuff and get to work early in the morning, copy the memo, because nobody thought of, "Let's make copies of this and give it to all the people so they'll know what's going on." You had to look out for yourself. It wasn't that they were keeping it from you, although to us it kind of seemed that way, but it was that they were so busy carving new ways to go.

So Russell and I, and then several years later, Steve [Stephen G.] Bales joined us. We were the first wave of new-hire people out of college that had joined the space program. I guess I was really the first new hire, or fresh out, from University of Texas that joined Lunney's organization. We studied and studied, and then we began in the, like for the Gemini II mission, that was pretty well set up and planned before I joined NASA. Although it had not occurred yet. So I was able to watch the Gemini II mission from the Mercury Control Center at the Cape [Canaveral, Florida].

But then for Gemini III and IV, we were bringing the new control center along here in Houston, so I was on the blue team with John [D.] Hodge, and so we simulated and simulated and simulated, and the group of people who put the training on, and we call it simulations, their job was to make it look as lifelike as possible. And it really did, although in the beginning we didn't know it was going to be looking lifelike, because we didn't know what a real one looked like. But they did an excellent job. So a few pieces of paper, a lot of training and simulations, and a lot of conversations with folks like Lunney, Charlesworth and Kraft.

Then, of course, in those days before we opened up the control center here, everyone would gather together, pack their bag, go off to the control center at the Cape, and you sort of lived together down there in a motel. You'd get together in the evening and you'd swap ideas and stories and they would debrief problems. Then you'd all go out to eat. And so a lot of it rubbed off on you by osmosis, that here were the guys that knew what you were supposed to do.

For the Gemini III we were at the Cape, and Lunney and Charlesworth and [John S.] Llewellyn [Jr.] and Charlie [Charles B.] Parker were running the consoles and they were going to be the main controllers. I was a trainee, you know, and so then they said, "Ed, get over on the console." I'd watched them for a few simulations, but I had never sat at the console. "Ed, get over to the console and you take the next run." Well, this terrified me, because Kraft was the flight director, and of course, in those days I really felt like he walked on water. In fact, I still kind of feel that way about him. One of my favorite people.

But we had the simulation, and it was a fairly gentle one, if you can imagine that. They didn't really throw the book at us. But in those days our data was all controlled from Goddard Space Flight Center, so like tracking data would come in from Bermuda, but it would go to Greenbelt, Maryland, and then it would ship down to the Cape. So we had all these delays, but you needed to know how to talk to these people and tell them, "Let's switch over to this data source if this one is getting noisy."

There was that, plus there was monitoring the trajectory. We had the big plot boards where we had the nominal line, and, of course, the vehicle was supposed to follow the nominal line. If it didn't, you needed to know what to do. So the seat I sat in was one of very few in the control center that had an abort switch. If you flipped that abort switch, it lit a little light in the spacecraft and it told the astronauts to abort the mission, to fire the rockets, whatever they had to do in that particular stage of the mission. So there was a lot of responsibility and it was a lot of pressure for me, but they didn't tell me that they were going to do this, so I had sweaty palms.

BUTLER: I can certainly understand why you would. I take it the simulation went okay then.

PAVELKA: It was okay. It wasn't perfect, but I guess it was their way of just throwing me in the water. After it was over, I felt a lot of better and I felt a little more confident. So I guess that's probably as good a way. It was a little fun for them, I'm sure, to see me squirm, as I didn't know what was going to go on.

BUTLER: As you mentioned, it was a lot of on-the-job training, and that's one example of that. How many simulations would you go through approximately before the mission came up?

PAVELKA: Typically, I think we would have maybe two to three months of sims where you had them pretty much every other day at least. A day of sims, if it were an on-orbit sim, there might only be two or three runs. If they were launch sims, you might have fifteen runs in one day. So it was pretty tiring.

We did have a backup person in those days, so we would have the prime person and we'd trade off. Maybe not every other run, but some of the runs the backup person would get, because it didn't happen very often, but periodically you would have a person that would be ill, or the classic problem on the freeway where they would be in an accident or whatever, and you would need to have a backup. So we, the flight crews had that in those days, and we had backups in the control center. Not 100 percent, but it's the best we could do it.

BUTLER: What then was the first mission that you worked completely on console instead of watching?

PAVELKA: It would have been the Gemini IV mission. That was where we had the blue team, and we actually trained here in parallel with the prime team that trained at the Mercury Control Center at Cape Canaveral. We, under John Hodge, we had just one ship and we trained with as many simulations as they did and, of course, we had a unique control center. We were getting the benefit of learning how all the new digital TV displays worked, how all the controls worked. We had new positions down in the—we called it the RTCC. It was the real-time computing complex.

Today, the controllers do things with a keyboard. In those days we had a position that we would call like computer supervisor or computer dynamic, and we would ask them to input certain parameters to computer maneuver, or configure the computers for launch or whatever. So we were learning all that protocol here.

Then for Gemini III, we paralleled what they were doing, but it was not really a full-up backup of the control center here. For Gemini IV, it was really our first time when we were on line. If they had asked, we could have switched over and controlled the flight from here. It turns out that the control center at the Cape had a power problem during that flight. I didn't know, and I think most of the people in our control center here did not know that they were experiencing that problem.

Of course, Kraft had his prime team at the Cape, and I think it would have been a pretty cold day before he was going to turn his control over to this other control center. I don't know what was going through his mind, but our data and our information on telemetry for the systems was all perfectly good here. From my position, we didn't really know there was a problem at the Cape until after they debriefed the flight. They were fairly miffed that we had good data and they didn't. Of course, they were in real hot seat, but just like this, they could have said, "Houston, you're in control." That didn't happen. But we would have had a good mission had they done it. The mission turned out just fine as it was, but they were very fortunate. There were no anomalies during the period when they had their power problem.

BUTLER: That certainly shows the value of having that backup there when needed.

PAVELKA: It was. Of course, NASA, from the very beginning, have always been very conscious of having backup systems and plans to control every anomaly that might happen, every failure that they could think up. You have to take your hat off to the simulation people for really doing a good job on keeping our feet to the flames on training for failures.

BUTLER: When it did come time for the missions, as you're participating in the actual ones now, you've gone through the simulations and the training, what then would your duties be as a FIDO? What were you watching for? What would you, obviously working on trajectory, if you could tell us a little bit about how that would go during a mission.

PAVELKA: Let me start before the mission and say that we had a big part in the maneuver planning. We worked with a group called Mission Planning and Analysis, whose charter was to formally document all the plans for the flight. But in the process of doing that, we had to have a very strong operational input into the plans for launch, the plans for the on-orbit maneuvers, the plans for the de-orbit and entry. We called it retrofire in those days. And the placement of the ships, and there was a lot of strategy that was operational that was our job in mission control.

So we worked to put together the plans that we would follow and then those were what we rehearsed in the simulations. So then when it came time for the flight, my main responsibility was that whole envelope of trajectory-related items that have to do with from the launch of the vehicle through the powered flight into orbit. That's one very large segment there. I'm going to put that aside for just a minute, though. Then the on-orbit would be when you would separate from the boosters and the spacecraft would be in free flight for on-orbit.

There your job was to determine with the tracking data how accurately did the booster place the vehicle in orbit, the spacecraft. What is your tracking data telling you? What is the next planned maneuver that is going to occur? Our area, the trench, let me introduce that part of it. The trench was the front row of consoles in the control center and the FIDO was sort of the team lead for the trench. The FIDO was responsible for computing maneuvers, establishing a tracking data, and he was sort of in control of the real-time computing complex, but with him were the guidance officer and the retrofire officer. In those days they called him the retrofire controller, but John Llewellyn decided that he should really be called an officer, and it became the retrofire officer. But in the beginning it was the guidance officer, the flight dynamics officer, and the retrofire controller. John, if you ever see this.

Anyway, so the guidance officer would be in charge of the inertial guidance system on board the spacecraft. There was also a radio guidance system on the ground that controlled the booster from a place called GE Burroughs [Corporation], and they had a radio guidance system that basically gave all the controls from the ground to the Titan booster. So the guidance officer had that control and then also he was responsible for updating all the parameters in the on-board computer.

My job was then to compute the maneuvers that would, for example, if you had an off-nominal orbital parameter where the booster didn't put you—maybe you had an underspeed, where it should be in—in those days we wanted an 87 nautical-mile perigee by 161 apogee. That was the orbit that we inserted into. If you had an underspeed, your high point might be 140 miles instead of 160 miles. So if you didn't correct that, when it came time to land, you were going to be in the wrong place in the orbit to retrofire. So we tried to optimize the shape of the orbit for when you would go ahead to the point where you needed to retrofire, because in those days we didn't have very much propellant on board.

So if you had your maneuver at the wrong point in the orbit, it could be that you would have not quite enough propellant to do what you needed to do, or you'd have to revise the attitudes to the point where it was an optimum reentry. So that was our job. It all wrapped up.

Then the retrofire officer, who was also under FIDOs task force in the trench, he was responsible for mass properties. That's the weight, the CG [center of gravity], the consumables, and, of course, he worked with the systems operators to find out how much water you had, how much propellant you had, how much oxygen you had. We knew where all those were located, so he computed where the center of gravity was, because when it came time to fire the engines, you need to know where the center of gravity is or you get in an incorrect response from the engine. The autopilot doesn't know where to point the engine.

So our job together were to keep the vehicle, know where it is, know where it's supposed to go, compute the maneuvers that take it where it's supposed to go, and then track it after you did the maneuver to see if the maneuver was correct. So it was an iterative process that never ended, and you always had a bad batch of radar data coming in that you had to determine that was a bad batch of data and there wasn't something different happening to the spacecraft. Because when you first see it, you believe this is real data, but in some cases those radar stations would have biases or a different problem.

So the team, including the controllers, we had a person that was called Track, who would work with us for the tracking data down in the computer complex, and he would analyze this tracking data and make recommendations to the FIDO of what he thought, how it fit the other data, because our job was to know is there anything that's happened on board? Are we venting? Have we had an unusual attitude control maneuver that may have had a propulsive component? Because that would change the orbit. The tracking data would pick that up. If the tracking data said something happened, but we knew nothing had happened, then we had to edit that data out. So that was another part of our job.

Then when you did the maneuver, the retrofire maneuver to land, all you had after that point—see, this vehicle had an off-center center of gravity, the Gemini did, so depending on the attitude that you roll to the lift vector, didn't have much lift because it was just, you know how the vehicle—wish I'd have brought my model. I have a model. But we could roll the lift vector around to control whether the vehicle would go to the left of the ground track or the right of the ground track.

That was mainly the retro controller's job to do that, but the FIDO and the retro worked together, because he's wanting to know how good is our tracking data and he's wanting to know from the systems people, are we venting or is our attitude control system working properly. He's wanting to know from the guidance officer, is the on-board computer working properly, does your data look correct. We had comparisons that we were making about how the onboard computer worked.

So it all sort of fit together in the trench there, and that's why we called it a trench, because we really stuck together and we depended on each other as a unit to stick together.

BUTLER: Certainly teamwork is a huge part of all of this.

PAVELKA: Yes, ma'am.

BUTLER: That's a great overview of how all of that works together. Thank you.

You had mentioned the launch portion that you were going to come back to that. Was there anything further you wanted to say on that?

PAVELKA: In the launch, it's a set of trajectory mechanics all its own, but the part that I dwell on mostly is the on-orbit part, and that's the orbital mechanics, Kepler's laws of motion, and we had little rules of thumb about how maneuvers would affect the trajectory and how much propellant it would take. We knew all this in our head, and we had little notes on the console. But the launch, the launch was the place where people could get killed, where you had to call aborts, where things were happening so quickly that you had to have enough simulations that you knew exactly what you had to do if you had a certain problem.

So every FIDO, when he was prime for a mission, he would have the launch phase and then certain other on-orbit shifts, because we had three teams in those days, eight-hour shifts plus the overlap. But the prime FIDO for that mission was responsible for the overall pre-mission planning. He also did the launch, the powered flight part.

Remind me a little later on, I think that this will come up when I talk about memorable things, but there was a first apogee rendezvous that we did on Pete [Charles] Conrad's [Jr.] flight that was very much involved with how the launch phase monitoring and that we pretty much had to have an absolutely perfect flight with the booster to be able to accomplish.

But for the launch, it was an animal all unto itself. The data was high-speed data. Your displays would update every half second. You had telemetry data coming in, in addition to the radar data. So the FIDO was looking at two or three sources of radar data and telemetry data all at the same time, trying to decide which ones are the most accurate, best represent what's going on, because the FIDO has the potential of making this abort call that I mentioned.

So at all times what you're protecting is, I have to keep the very best trajectory here in the control center for everyone to use, but most especially for the FIDO and the flight director, who either one of them could send the abort light if there were a trajectory deviation. Now, other people in the control center could ask for an abort if, for example, their system were beginning to have a severe problem, they would call that directly to the flight director.

The FIDO, because of the time-critical environment that he was in, looking at data every half second changing, watching trends on the big plot boards and the telemetry, sometimes what we would do is if the trajectory would begin to deviate, and you know it's going to be a problem, but we had limit lines on our plot boards that we helped develop, those limit lines would protect things like the G forces that the astronauts would have to go through if they performed an abort. In those days we used like sixteen Gs. That's a lot of pull. That's about as much as they could handle without having a severe physical problem.

For example, if the trajectory were deviating and went into this sixteen and a half G line, then the FIDO would send the abort light, which was sort of a bat handle-looking thing that you had to pull up. I mean, it had all kinds of safety precautions. But ours were really the main time-critical ones in the control center.

We had mission rules that we went by. Let me just touch on that. That was a big part of our pre-flight planning. Basically we thought through, if this happens, this is what we will do. So in this case, if the trajectory deviated and went to the sixteen and a half G abort line, the FIDO will send the abort light. That's the condition and the ruling. So the FIDO and all the team, the flight directors, go through many, many hours of reviews of these mission rules. Then we exercised them in a simulation.

So then on flight day, here you're sitting in the hot seat, you know your mission rules up here. You've got your abort light, you've got your data coming in. So if on a real launch day the trajectory deviated there, we would call the abort.

In the Gemini Program, they would have done an abort where they fired the retro rocket. The retro rockets were on the bottom of the heat shield, which was up against the booster. For this abort mode they would fire the retro rockets, they called in salvo, meaning all together. That would lift and then the explosive bolts would fire, the whole spacecraft would come off the booster…. So we would have these different abort modes depending on what flight regime you were in.

Let's see. I'm not sure I want to get ahead of myself here, but there were a lot of new things that we were coming up with. For example, for certain types of launch deviations, if you cut off with a low velocity, the right answer could be, "Don't make a maneuver right now. Coast around a half an orbit up to apogee, and apply some energy there." That was a brand-new technique that, I guess, Lunney, Charlesworth, and I came up with, and I plotted out using a lot of parametric data, plotted out where we would have this line on our plot board. So that if your trajectory deviated around and hit this line for cutoff, it meant "We do not have a correct orbit, but don't try to fix it right now. Wait for it."

Now, this was tough for people to think about. Your orbit is not going to make it around, but hold tight and just wait until you coast up to apogee, which is the high point. At that point if you apply your maneuver, that's the most efficient place to raise this low perigee. So if we were looking for 87-mile perigee by 161-mile apogee, and if we had an underspeed, and our vehicle perhaps would intersect with a flight path angle, if it were a positive flight path angle, we could coast, because we were headed toward the high point. If it were a negative flight path angle, it means we're going down, we need to do something now. We need to change our attitude and fire the thrusters. But if you're coasting up, you just rest easy, coast around to your apogee point and apply some maneuver.

We had to come up with the processors and the computers that would compute what would that maneuver be, and we had to know it real quick, because most of the time we had to voice that up to the astronauts before they left voice contact at the last down-range station.

We couldn't wait until just before they—we don't have satellites like we have today for complete coverage. We had ground stations. So you were tied to this little tracking area, this little tracking area, where we also had voice.

So you hurried and you got your maneuver computer and you voiced it up to the crew, and then the crew wrote that down on what we called a pad message. Then at the right time they fired the thrusters. We gave them the attitude to go to, how long to fire the thrusters, and we even gave them backup things like, if your computer has failed, because this was a very serious, if you didn't perform this maneuver you were going to die. So we gave them even backup ways that you could look through the sextant on board, look at a certain star, that will put you in the right attitude and burn the thrusters.

So we had all kinds of what you might call back-of-the-envelope ways to give them backups, because in those days we had the computer and then we had the out-the-window, where they could look either for stars, or we had a line scribed on the window for the backup for reentry. It was a 31.7-degree angle where they would turn. If they didn't have any computer at all, they could look at the horizon and roll the vehicle until that line was on the horizon and they were in the right attitude to reenter, so that they wouldn't burn up.

So that's some of the stuff that we kind of did in the planning stages before the flight occurred. Probably more than you want to hear about.

BUTLER: Oh, no, not at all. It shows the complexities of all of it, everything that has to be taken into account, and it all did work so well.

PAVELKA: It worked.

BUTLER: Throughout the whole program. Mentioning that it was a different thought process for people, as to maybe it's not time to react right away, maybe wait until you come up for the apogee, ties into the whole orbital mechanics idea with rendezvous. As you were building in, obviously, the Gemini missions, that was a key point to be able to make Apollo possible. At first some of that wasn't as well understood when they started with it. I think it was on Gemini IV, Jim McDivitt tried to do a rendezvous with the booster, but wasn't able to, because some of the processes hadn't been entirely—

PAVELKA: That was a situation where the instincts of the pilot were to drive straight at the target, we'll call it, the booster. It turns out that Kepler's laws say that if I apply energy at this part of the orbit, it's going to raise the orbit over here. If he were firing in a horizontal mode, what he would begin to do, he should stay in the same orbit with the booster, if he wants to rendezvous with it. But to move over there to it, what we didn't know in those days was, a radial maneuver rather than a horizontal maneuver thrusting at the target would be the way to go, because that would bring you back right to the target one orbit later. Again, you have to be patient.

In those days, a lot of the astronauts were test pilots, silk-scarf guys, we called them. They were excellent stick and rudder men. In this case, I think what happened was that the pilot instincts took over and he would thrust toward the vehicle. Well, initially, he would move that way, but then orbital mechanics would take over and he would begin to realize that velocity that he'd put in with his thrusters, 180 degrees around there, it's raising his orbit. So he's getting over there and he's going away from the target, rather than to it, because the

Kepler laws of orbital mechanics are taking effect. So then he would thrust some more, just made it worse.

So after a while they called it off because of the use of the propellant. Those types of rendezvous were studied, because when you're very close to something, the strategy for a rendezvous, it's almost proximity operations and it's a little different strategy than if I launch and my target vehicle is 1,200 miles in front of me and I have three days to plan maneuvers between now and then to get there, which was the classical way that we planned rendezvous.

We sort of invented the book on the rendezvous in the Gemini Program, and as you said, it was to make sure that we had that capability for the Apollo lunar program, because it was absolutely mandatory that we know how to rendezvous in a routine and predictable and comfortable way, repeatable way, because the lives depended on it. That was their way to get back.

So for Gemini we start out with very simple sets of maneuvers where we would have maybe sixteen orbits, sixteen orbits times an hour and a half would be how long you would have for this rendezvous. In the course of that, we would plan maneuvers that would adjust height, if we needed to change the phasing. What our computers would do is our computers would propagate out sixteen orbits, tell us where we were going to be, and then we would know how to make small corrections in either the height or phasing maneuver to correct phasing.

Then at some point we would have phasing maneuvers, height adjust maneuvers, and then finally we would have, for the later rendezvous, we had what we called a co-elliptic maneuver, where we would go at some constant distance, maybe ten miles below. So that would give us a very slow catch-up to the target, that would give us a good opportunity to track both the target vehicle and our maneuvering vehicle, make other small corrections, so that we would have a perfect condition when we did what we call terminal phase initiation, TPI, is what we called that maneuver. That maneuver would be the last maneuver that you do before you would intercept the target.

So we had, I guess, the first real structured rendezvous like that was supposed to be the Gemini VI, and because we had problems with the target vehicle it became the Gemini 76. That was unique. It was supposed to be our first real taste of rendezvous, and yet in our computing complex down in the first floor of the control center, it was looking for an Agena to be the target vehicle. The Agena was a big stage that had big rocket engines on it, and certain kinds of thrusters and certain kinds of mass properties. We had certain formats of the tables that we used to control that.

Now, what we have in there is a second Gemini is the target, and it has different thrusters, it has different characteristics, different weight, etc. So one of our challenges was very quickly to come up with a way that we could package the Gemini characteristics in a target vehicle slot in our computing complex to where we could treat it just as we treated the Agena target vehicle and it would be passive. But to do that, we really had to go in and modify some of the code in the computers to accommodate a different characteristic, a different set of characteristics for the target vehicle.

So that was a little bit of a surprise, but again, we had worked with the people building the code and, of course, they were the programmers. We weren't programmers, but what we knew was in English language we knew what needed to be done and we knew the capabilities in the English language, not in the ones and zero's code. So we would get with the programmers and the people that were the computer controllers and figure out how we would modify the codes. Some of us went over to the IBM [International Business Machines] Building and worked with them to talk about how the changes would be made, what kind of testing we needed to have.

In those days, it's really almost funny, but we had IBM 7094s, which would do 1 million instruction per second. Your home computers do hundreds and thousands of times faster than that today. It's incredible. But in those days, that was pretty spiffy, and of course there were no home computers in those days.

So the first rendezvous. Then we built on everything. Once we had that mission behind us, we debriefed, we talked about what was our next step. We wanted to become more and more—our operational capabilities, we wanted to be more failure-tolerant so that if we had anomalies at any point in the flight, the rendezvous technique would be forgiving and it could accommodate those things. Later I'll talk about this similar thing in Apollo.

So then we went through the series of Gemini missions, each of the rendezvous missions building on the other. I need to refer to my notes here for just a second and make sure I have this right. Let's see. It was Gemini XI. Gemini XI, we wanted to try something very aggressive and new, and so it was Pete Conrad and Dick [Richard F.] Gordon's [Jr.] flight, and we were going to try a first apogee rendezvous. What first apogee is, is here you are on the Earth, and you launch here at the Cape, right around here, forty-five minutes later is your first apogee. So normally we had been waiting sixteen orbits to rendezvous. We were going to do this in forty-five minutes.

What it meant was that you had to have an absolutely perfect launch. So we defined a little tolerance box at insertion that was equivalent to a half second of launch window. So you had to have absolutely on-time ignition, a perfect vehicle trajectory, and all the systems are working, and the radars and everything else is working.

Steve Bales and I worked with Pete Conrad and Dick Gordon a great deal on our techniques, because we had a lot of backup things that we used, little charts that we had where they could do things manually if they had certain failures on board. They had a special simulator, a hybrid simulator, in St. Louis, that we went there with this Bales and I and Conrad and Gordon went there and spent a day in the simulator going through these backup techniques.

So to get to the bottom line, when it came time to fly Gemini XI and we really had rehearsed this, but we knew it was very success-oriented, I guess you'd say. We knew everything had to be exactly right. On launch day, everything went absolutely perfectly and we had our first apogee rendezvous.

That didn't catch on as something that we decided we wanted to do. After looking at how precise everything had to be, we decided that that was not in keeping enough with things that could happen in the real world and it was a little too ambitious. We knew we had that now in our bag of tools. If we needed it, we knew how to do it. But as far as embracing that as a way that we wanted to do business, it was better to get into orbit, let your vehicle be checked out, look at all your systems in zero gravity, make sure that they're working properly, how is the crew doing, start doing the maneuvers in a methodical build-up way. We decided that would be the best way to go. So that's a little bit about how we evolved to where we got for the rendezvous techniques for Apollo.

We pretty much took the code that we had for the basic maneuver techniques out of Gemini, moved those into Apollo, changed them for what we needed to change because of the booster and the spacecraft differences. But as far as Kepler was concerned with the orbital maneuvers, we didn't really change a lot.

BUTLER: Certainly just took and built on all of those experiences.

PAVELKA: It was very much a building-block-type approach and it worked well for us.

BUTLER: You mentioned the first apogee rendezvous and then you mentioned that most of the times before that you had done the multiple orbits before you would rendezvous. Were there any other different types that you would test that fell in between those?

PAVELKA: Yes, we did. I'm not sure I can recall each of them, but we had a couple that were intermediate that would be like a fourth orbit. Then we decided that the sixteen orbit was really the best as far as being able, within the propellant that we had, to be able to take out the types of dispersions that—in other words, let me go back a little bit. When we got a booster delivered from the Martin Company, they would say there is a certain dispersion envelope that we expect for this vehicle. If you take those dispersions and the uncertainties of how well the Gemini spacecraft can hold attitude and how well those thrusters can perform exact velocity maneuvers, if you take all those uncertainties into account, it's smart planning to be able to have something that will handle that times ten, if you can, every time.

So we looked at the different rendezvous for contingencies. If we had a reason why we needed to be in a certain place, maybe battery power was running out or something like this, and you had to have an earlier rendezvous, we looked at them for those type reasons.

But for our work horse, so to speak, the ones that were like sixteen orbits seemed to be the most forgiving and handle the most dispersions.

BUTLER: You've mentioned a couple of the missions now. I believe on Gemini XII—and you had mentioned some of the backups that the astronauts had in case something went wrong with the computers, because they did have to do these things at that certain time. On Gemini XII, I believe they had a difficulty where they did have to put the sextant into play at one point, and with Buzz [Edwin E.] Aldrin [Jr.] and he had even a lot of background in rendezvous. Can you mention a little bit about that?

PAVELKA: Well, Buzz was probably the strongest person we ever had on theory. He had done many studies on it. A lot of the astronauts had learned everything they knew after they came on board here. Buzz sort of brought him a lot of background and theoretical, so it was very natural for him, in light of a computer failure and problems where he had to go to the backups, he understood just second nature, he understood the theory of how the inertial positions, shooting stars with the sextant, and how this would work as a backup method for computing maneuvers for rendezvous.

For that particular rendezvous I was not on the consoles. I'm giving you my recollections of what I learned and what I was told. But he had absolutely no problem in using the backup techniques and the sextant. We had a number of pre-thought backup techniques that had like curves that were drawn that would say if you have this reading, then this is the attitude that the vehicle should go to. We had a number of charts like that, that the crew would carry with them in addition to Earth map things that they could roll around that had the ground tracks on them that would move manually. So that they really had a lot of independent ways that they could calculate things. But they needed information from the ground as best they could get it on where was the target vehicle and where they were.

Now, if their computer was not working and we had to give them that information in more of a time and space pointing thing, or look at these stars, do this type of alignment. That's about as far as I can go on that.

BUTLER: Sure. Were there any other incidents on any other of the mission, or not even incidents, or any memorable moments on any of the other missions on Gemini that you'd like to mention?

PAVELKA: There was a high profile of public interest and media interest in all the Gemini flights, and after each shift, I mean, almost for the whole program you were on console and it didn't matter if you were on console from 6 a.m. to 2 p.m., or 10 p.m. to early in the morning, after the shift was over, the flight director, and he would select one of the controllers for an interview, and they would go over to the media building. The press were over there and they would debrief that shift. There was a very high profile of interest there.

Probably the most memorable moment I can think of in the Gemini Program was when the control center was online and we had proven that everything that we had really worked several years for was coming together. Then we saw anomalies in simulations and then anomalies in flights happened, and we were able to handle it with the control center that we had, with the people, the procedures. That just was a very fulfilling time.

I'll repeat that back in those days we didn't realize that we were doing anything very unusual at all, because our world was—we were immersed in this group of people and that's what we all did. I didn't know that the other people in other walks of life weren't doing similar things. It just didn't occur to you. You were so busy that you paid attention to trying to do the very best job that you could do, and in those days you didn't really worry much about a career path. I never heard the word "career path" until I was a supervisor fifteen years later.

What you did is, you did your very best and you trusted that your supervisor would take care of you. I was fortunate to have some of the best supervisors. We'll probably get to this later, but in 1968 I was only there four years, I became a supervisor, so I not only stayed on the console for the remainder of the Gemini flights, but we had a group of people that were beginning to break off and look at the Apollo profiles. There was a whole series in the beginning of those that were unmanned that I had from '68 to about '70. We not only had the flight dynamics officers in that section, but we added in the retrofire officers.

So it was really then called the trajectory section, and then in addition to that we had the guidance section. So those three made up the trench. So we took what had been three sections and made it to two. So I had the FIDOs and the retros, and for, I guess, a couple of years there I tried to learn as much as I could about what the retros did, but my main hands-on part was still as a FIDO. We'll talk later about the fact that I had to step in one of the later Apollo missions, because we had a medical emergency with one of the retro officers, and I had to take on that hat. But I don't want to jump quite there just yet.

What I would say is, taking on the job as a supervisor, I loved working with people. I loved the job. There was not quite so much administration in those days. It was more of a technical leadership job, and not so much a time cards and budgets and any of this type of stuff. The main strategy was, we had missions now finishing up the Gemini Program beginning the unmanned flights of the Apollo Program and they were beginning to overlap.

One of my jobs as supervisor was to figure out how to staff the lead person and the other two shifts on these two programs that were overlapping. That got to be fairly hectic, and, of course, the guys always wanted to—by this time we were beginning to get quite a few more people in the group, too, because we were beginning to staff up for Apollo. So the people always wanted to have the more important or aggressive assignments. Not very many of them were content to have the sleep shift unless there was another important shift [for them] on that mission. Although if they were the top guy on this [other] flight, they didn't mind being the sleep shift on this flight, because you didn't have to do very many simulations for that and you were really simulating a lot as a lead controller.

So there was a balancing act with that number of people, and, of course, it was highly technical because the Apollo guys were off learning a whole new set of vehicles and systems and trajectories that went with Saturn and the Apollo vehicle, and we were trying to finish out the last three flights of the Gemini Program. So we were flying a flight a month there for a while, and it was like the Dunkin' Donut man, you met yourself going out the door in the morning, almost.

I had a young family, and so we didn't get to spend as much quality time with our families when they were young as we'd like to, because we were simulating just to keep up with what was happening next on the closeout of the Gemini Program and the buildup for the Apollo.

BUTLER: Certainly the families had their own sacrifices that they did make there.

PAVELKA: They were great. Looking back on it, you kind of realize that there's some stuff you missed that you just can't quite go back and get that, but you can catch up with your grandkids. [Laughter]

BUTLER: You certainly can. You certainly can. We have found that the grandkids like to hear these stories. That's one of the benefits of the oral histories.

PAVELKA: Right.

BUTLER: Moving into Apollo then, as we've come to the end of Gemini and you're moving into this supervisory role and trying to figure out how to reach this balance between the both, how much were you still primarily focused on the Gemini missions yourself, or did you also begin that Apollo training and working on some of those unmanned missions?

PAVELKA: The very beginning of the unmanned Apollo missions I was pretty much depending on the lead people that I assigned to participate in the mission planning and the trajectory design. What I had gotten involved in heavily was how we were changing our computing complex to handle the new maneuvers. We had a lot of reviews on changes that we made in the computing complex.

But we had some very talented people in our area. They were young people, but they were highly gifted people, and we handed them lead responsibilities. Of course, we had backup people behind them. And we kept a close eye on how the simulations were going.

But I was involved in like this flight-a-month business and my primary technical focus remained on the closeout of the Gemini Program. My branch chief understood what was going on, what he had done to me, so to speak, and was very helpful in helping the oversight of the early planning for the Apollo unmanned. Now, there were only two or three of those got very far before we closed out the Gemini, because that part of it was only three months long.

I'll just mention a couple of the people. We had Phil [Philip C.] Shaffer, [H.] David Reed, Bill [William M.] Stoval, Jay [H.] Greene. These folks were all in the section and they were very talented, capable people. They picked up some of the planning for these early Apollos and did a fine job. Some of them tended to want to be so complex at what they did, that they frustrated the people in the mission planning area. Remember that, again, our role from operations was to add the operations flavor and the operations perspective to the planning, but our charter was not primarily planning.

However, I'll give credit here, I guess, to Dave Reed. He did a lot of the planning for one that we called Apollo Saturn 258, and it had a rendezvous where you went away and then they called it a double bubble, it came back like this. I'm motioning with my hands, but you're trailing and then the vehicle goes down in altitude and then begins to catch up, and then finally there's a rendezvous. Dave made this planning so complex that we actually had some letters of protest from some of the people in the mission planning community, because he was driving them to their knees.

So what we had to do was balance this energy and this talent that we had and channel it into the right direction, because we had some folks that would like to their part and the part that the mission planning people did, roll it all together. "We'll do it all." And they probably could have. But in order to keep peace in the valley, we had to keep our people within their charter.

So let me just go ahead and move into early Apollo. The first Apollo mission that I worked on was actually one of early manned Apollo missions. I was not the lead on that, because we had had several of my lead people that had been planning those while I was finishing up the Gemini Program. But it was a very steep learning curve because those people had been off line for several months learning the new systems, the new computers. The computer system was totally different. There were more computers and they operated differently, much more capabilities.

Of course, remember this was all really designed for the goal way out there was to do the lunar rendezvous. So to do an Earth orbit mission with this, you didn't quite use all the capabilities that these onboard computers had. But what we wanted to do was test those out. So we tried to influence missions that would exercise each one of the features that were in the onboard computers, the propulsive systems, all the onboard systems, as well as the crew capability to do backups in the event of failures. We wanted to exercise all that in these early manned missions, so that when we stepped off out of Earth orbit we had a lot of confidence that our kit of tools was complete and we knew how the tools worked and they worked okay.

In this time period, my focus very quickly became the translunar mid-course. In other words, when you apply the translunar injection maneuver to go out of Earth orbit, you're on a coast period for 240,000 miles, and there's a change into the Moon's gravitational field out there. There is a lot of time, but the sensitivities were that you needed to be within, in the very beginning, like 60 nautical miles of the lunar surface when you went around the closest point.

So I began to dwell on how the processors that would compute these maneuvers for mid-course correction, how would those work for the translunar coast and then back for the transearth coast. This problem included the fact that we knew precious little about all of the different harmonics of the Moon's gravitational field, that it was not a smooth basketball, but it was lumpy and there were these mascons [mass concentrations], these concentrations where the gravity would actually change an orbit. We had been fortunate enough to have some early lunar orbiter data.

We imported a young man from Jet Propulsion Lab named [W.R.] Wollenhaupt, and he was pretty much the free world's expert on lunar gravitational potential. He actually came to work for the Mission Planning and Analysis area, but we had to integrate his knowledge into this mid-course package and also the lunar orbit package that we had in our computers in the control center, because this was beginning to be fairly theoretical.

We'd never done this before. We knew what you could do in Earth orbit and how vehicles behaved. We knew a lot about the solar system, but we didn't know exactly how well our 85-foot radars that we brought online—we brought like three of the big deep space 85-foot dishes on from Gulfstone and Canberra and other places, how accurately would these work, how well could the data be brought into the control center.

So I spent probably most of my free evenings for about a three-month period over to IBM Building along with people like [James L.] Leroy Hall and Bob [Robert] Regelbrugge and others, testing these mid-course sequences that we had over and over and over again, because we had several different types of mid-course strategies that we could use between here and the Moon. Some of them were called free return. Free return was a nice warm feeling, because if you executed it properly, you did your translunar injection and during the coast you did this free return mid-course correction, and if nothing else happened, you would swing around the Moon and come right back home and be set up for entry. Of course, never quite would work exactly that way, but that was the goal of that sequence.

Then we had another one called best adaptive path, that would actually minimize the fuel used, because we only had so much fuel available to go out to the Moon and then to come back. So the whole strategy of what types of mid-courses that we would use, how well the logic worked, was all the theoretical information folded in there correctly, we simulated and simulated and we used lunar orbiter data. Our friends in Mission Planning, we got to be one big happy family there, because we had to understand that we had exactly the right package in there.

The translunar injection was important, too, but that was targeted by the Saturn booster. It had onboard logic, and we paralleled that logic in our computers here in the control center. But they had some logic called hyper surface targeting, and that was all put together by our friends at Marshall Space Flight Center and [Wernher] von Braun's team of people.

The Saturn was probably one of the most magnificent boosters that you could ever imagine. I still marvel at what they did with that. I mean, that was such a fantastic piece of hardware. Of course, I'm mainly a trajectory guy, so I will refer to the guys that dealt with the systems as "those systems weenies," you know. They just do systems.

So the Saturn targeting for the translunar injection, there were opportunities to correct whatever happened at the end of that with this mid-courses, and that's exactly what we were trying to do was be able to take a deviation from that TLI maneuver, make whatever mid-course corrections on the way to the Moon, so that you got just in there with the right, we called it pericynthian, the closest approach.

Then we had another new process called the LOI, the lunar orbit insertion. That was a brand-new processor, and what it had to know was, it had to know all about orbital mechanics around the Moon, because its job was to take this trajectory that was speeding in from the Earth, slow it down to the point where you were now just orbiting around the Moon. It had to put you in an orbit that was a safe orbit. So it had to know all these lunar harmonics over the gravitational field around the Moon. It had to know all the Keplerian things, plus all the maneuvering characteristics of the Apollo.

So more testing, wee-hours-type testing on the LOI maneuver. I guess we progressed along with our testing in parallel with these Earth orbit, low-Earth orbit maneuver missions. Then we had a high apogee, Apollo 8, where we boosted the orbit way out just to do a big test of the S-IVB engine, but not so far as to get out of the Earth's gravitational field.

Then I guess we decided that we might go around the Moon and might do that early. So a team of us, they didn't want to talk about it much until they were sure that it could happen. So Jerry [C.] Bostick, who was my branch chief at the time—and again at this point I'm still the section head in the trajectory section—Jerry and I began to plan toward what would it take to go around the Moon and into lunar orbit, rather than just do a high apogee or whatever. We worked for several months on that, and probably the other people were busy enough that I'm not sure that they thought about what was going on. Because we were planning later flights that would go to the Moon also, so you could always cloud your questions in a way that it could apply to a later mission.

But the whole thing had to be opened up to three full teams of people in time so that we could do the right training, because you don't want to just say, "Surprise!" Then the people are sitting there not knowing whether they're confident. When you're on the console, you have to have confidence that you know what your tools will do, you know what you can do. You know that you've trained every way that you possibly can. If you don't have that confidence, it's a terrible feeling sitting on the console.

So we introduced that idea. We had three great teams of people. It was a wonderful flight. We got to exercise our mid-course strategies and our processors. It all worked great. The tracking data confirmed that we—and see, that's rather independent. When you fire that mid-course correction, you think you know where you're sending the vehicle, but when the radar tracks the vehicle and comes back and says, yes, that's really where it's going, then your confidence builds. So on the way to the Moon, we began to feel better about our deep space tracking, about our mid-course calculations.

So then comes the time of going into lunar orbit. Well, the only way you can test that is to do it. I was on console, but we had practiced that and we had a fine processor to calculate the maneuvers, and we had a lot of confidence. But the truth of it is, we had never really done it. So we're all there and it's feeling a lot like a simulation and we compute the maneuver and everything looks very similar to what things have looked in the past. So the maneuvers get voiced up and the crew writes it down, they read it back, everything is just fine.

But then the vehicle ducks behind the Moon, you have loss of signal, and time passes. And it was not until that time that we all realized how well we did this maneuver. The test of that is we're calculating what time the vehicle comes back around and you get radar and telemetry back, and voice. We should know whether, if we hear them early, that means something. If we hear them late, it means something else. For example, if we hear them late, it means they have a little more energy, they're higher. If we hear them early, that's not good, it means they're going faster. It means they're lower. You go faster as your orbit gets lower.

So we all begun to get exactly the tenths of a second of when we were going to have acquisition. There were some sweaty palms and everyone was nervously going to the restroom and checking their sack lunch, whatever you would do. But deep down inside, we were all just praying that this was going to happen just like a storybook, and as it turns out, we were lucky and it did. They got some great pictures popping around the Moon.

[Frank] Borman was a great guy to work with. He was not a pushy—he was a very unassuming regular kind of a guy. We had a lot of respect, the whole team had a lot of respect for him, because he would come sit down with us in meetings where we had our control team there, and roll his sleeves up and work with us. I mean, it didn't matter whether he was going to have a space suit on later or not, it didn't matter.

So that was a great experience there and it was very memorable. It was probably some of the whitest knuckles I've ever had. When you think about all the training that we had and the confidence that we tried to build up and all these things that were new, that was the one, I guess because it was a fast happening and it was a hazardous thing. The mid-courses you had time you could do that, you could track, you could watch, see how it went, you could correct. The LOI maneuver was not forgiving. You had to do that right, and so there was a lot of tension.

BUTLER: Certainly for the first time ever doing that.

PAVELKA: Right.

BUTLER: When they came back around the Moon and radioed back and it was on that exact moment that you had calculated so precisely, the feeling must have been pretty neat.

PAVELKA: It was a feeling of relief and we were tickled and we were proud, and some of the guys had little flags and they were waving them. It was just really like you'd climbed a mountain and you were finally at the top. That was sort of a climax point for us and we were thrilled to death.

BUTLER: Many people have indicated that Apollo 8 was almost a bigger moment for them than Apollo 11, because it was achieving so much for the first time and it was actually getting to the Moon for the first time, and had so many unknowns to it. Whereas, Apollo, by the time of Apollo 11 there was only one unknown left, was the landing. Do you have any thoughts on comparing the two?

PAVELKA: I think I would agree that, at least for me, the excitement was more because it was the culmination of so many new things. Frankly, at that point in time, we weren't thinking ahead of how important landing on the Moon and bringing rocks back would be. We were enlarging the envelope where we worked. We were getting it a little larger and a little larger. So I would say, for me, the excitement was much more. The landing on the Moon, the big unknown there was, of course, the performance of the lunar module [LM] in that environment, and again, our knowledge of how the trajectory would give you the pinpoint landing and that.

Again, where I sat, the actual opening of the door and stepping down on the Moon was almost passé because what I was about was getting there. We were in the middle of every orbit of the command module around the Moon, while they were on the Moon, we were busy computing "what if" emergency launch times for every time they could lift off, because if something happened to one of the suits or the oxygen supply in the LM, or the propellant in the LM, or a dozen other things, we had to be prepared to get out of there right away.

On [Apollo] 8, we were essentially in a safe mode when we were in lunar orbit. Once you were there, it was a balanced situation and you were just moving along waiting to come back to Earth. But getting into lunar orbit was probably the very high point.

Moving—is it okay to move to [Apollo] 11 and talk about that?

BUTLER: Actually, if we can take a quick break and we'll change the tape and then we'll go right on to [Apollo] 11.

PAVELKA: Okay. [Tape change]

PAVELKA: Apollo 11.

BUTLER: Apollo 11.

PAVELKA: Let me begin with a little bit of background comment from the standpoint of the supervisory role again at this point. About this time, the assignment of people, particularly the lead operators, is beginning to be more of a challenge. We had two people that were highly qualified to be the lead operator that would be on console for the landing of Apollo 11. We had Dave Reed and we had Jay Greene for FIDOs.

Because Dave Reed had been the lead operator on the previous mission and doing a fine job, but it was totally gobbling up his time, I assigned Jay Greene to be on console for the landing. At the time it was just another shift that had to be pulled. I wasn't thinking of it as this plum.

Well, Dave Reed was incensed. He could not stand it. He was going to be on console for the first landing, and he went to my boss. We ended up sitting down, and I went through the rationale, and he just was not going to have the time to spend in the preparation because of his other assignments that he was totally involved in.

And another ground rule that we had from Chris Kraft was he wanted his very best and most experienced operators on console for Apollo 11, because we had folks, some of the folks that we were using them in other capacities, they were a little more experienced, but we were using that experience in some of the planning. Brought those people back in. So we ended up putting our most experienced team of FIDOs, retros, guidance officers, other people in the control center, on console.

As it turns out, this one that I just mentioned in particular was Jay Greene and he would be on console. I assigned myself to come on console the shift right after landing. So it would be Jay Greene. At the time, I was not making anything more of it than the technical balancing of the work, but I heard a lot of complaints over the years from Dave on that, and I think it ended up frustrating him to the point where a few years after that he quit NASA and went to work in Boston for the Department of Transportation. A very gifted person.

Bill Stoval was another one of the gifted young men that was on console with us. We had a fine team of people.

To get on to the mission now, 11 was pretty much played out just the way the rest of them did as far as the planning and the performance of the vehicles and the ability of the people and the tools that they had. What was new again was the lunar module, and, of course, all of us in our training, we had to do a landing with a lunar module as part of our training. So we knew some about the controls, the handling, the systems, because even though our area was trajectory and guidance, we needed to know what the other capabilities were, what the systems limitations were so that when things started happening, we could understand when the systems people would say, "This system is degrading."

So when it was time for the landing, we had pretty much like a simulation, and my team came in early for the landing, because we were going to be on the shift that was—for the landing had been on a long, very long shift, and the landing was sort of at the end of their shift. So we were kind of doing our handover in the console there and they said, "Hey, the crew is opening up the vehicle early and they're going to start the EVA early."

Of course, again, for me, I was so immersed in what I was doing, it went right over my head. We'd just keep working and, of course, the big screens are showing the TV that's showing him stepping off, and his famous words and that. Again, at the time what I was remembering is, that my family was at home and they had all the neighbors over watching it on TV, and I was kind of wishing I'd be there with them watching it on TV. That was a thought for the moment, because, again, most of what we were doing, we had trained so much, that it became routine feeling as far as this happened, now this happens, that went the way it was supposed to.

So if I were a systems person, I would be very excited about how my lunar module had just done this first landing. But my part of it was, it's a machine that was supposed to do this type of trajectory and we fed it this information and that worked out fine and it landed where it was supposed to. So I guess I felt like that the important thing of getting on the Moon was that we gather the rocks and set the flag and those kind of things. That was a very proud moment when they set the flag and that. So 11 was very memorable. There was a lot of excitement.

Then one of the really, really rewarding times was when the lunar module lifted off the Moon and we then gave them the maneuvers to do the rendezvous, which we had been working so many years for. Of course, the lunar rendezvous was successful.

The crew—you never know how tired the crew is, how well they're feeling, or how badly they're feeling, or if they're an upset stomach. You don't know these things when you're in the heat of the battle, because the aeromed flight surgeons made it a practice of not sharing that information. Occasionally, if they needed to for some particular reason, they would share with members of the control center. Most of the time it was the flight surgeon and the Capcom and the flight director who would know if there were problems.

So we're going by how is the vehicle performing. If the vehicle is performing, the crew must be doing okay. We're hearing what they're saying on air-to-ground, but if they're sick, unless they key the mike the way John Young did one time, we don't know how they're doing.

So it was an excellent feeling in the trench there when we had the rendezvous after the first lunar liftoff. Then we began to prepare for "Let's do our transearth injection," TEI. That was the retro job. He did the bring-them-home maneuvers. So he was busily making sure—you see, when they bring anything back, we not only have to know how many consumables they used, but we also have to know if they brought 147 pounds of rocks or whatever, where they're stowed, because we're going to do a maneuver that accounts for those things and where the center of gravity is for the vehicle, because this transearth maneuver is a very important maneuver. If you have enough dispersion in that maneuver, you can end up calling for more fuel to correct it than what you have on board, and that's a bad day. So you want the very best trajectory that you can have, the very best knowledge of the mass properties, the very best knowledge of the orbital conditions.

On top of that, we have to know back on Earth is there a storm in the Pacific Ocean where our ship is going to land, because we have to target for a landing point here that we corrected all the way back and we can change. But if, for example, you're going to land in the Indian Ocean, and there's a big storm there and you really need to change to the Pacific Ocean, much better if you target that and fold that into the transearth injection maneuver and then all your corrections are just very small corrections to remove any dispersions, rather than "Let's change the ocean that we're going to."

So those are the things that you're thinking about, and we had thought about those earlier coming back from the Moon, too. But again, this time we had other uncertainties and new things that were involved, because we were bringing additional cargo back and we needed to know where that was and we needed to know any anomalies on the systems for the command module.

BUTLER: Earlier you had mentioned that you were highly involved with the mission planning beforehand for a lot of these reasons, figuring out everything along the way. Moving into Apollo 12, they wanted to get that pinpoint landing down. Apollo 11 hadn't landed quite, it was in the area planned, but not the exact spot, and that was important for the later missions. Did you have much involvement in helping with that planning for that pinpoint landing?

PAVELKA: Only from the standpoint of that that fell in my overall area of responsibility from the section standpoint. The detailed planning of that would have been with a retrofire officer. The thing that was unique there was we carried that as, they called it a DTO, or detailed test objective, for that mission, meaning you could have done exactly what you wanted to do or what you did on Apollo 11 for 12, but they wanted to see, if it were possible, how well could we do this within the tracking accuracies and the dispersions of the maneuvers and so on. Believe or not, sunspot activity even affects the atmosphere which can affect that, so were had our folks working on was there any unusual solar activity.

I might also mention that for all the translunar activity, the solar activity was really monitored carefully. That was not monitored exactly in our area, but it was peripheral to our area because it affected the Earth's atmosphere, which could affect the landing. But as far as the pinpoint landing, the main thing I would say about that is, the program decided they wanted to use that as an objective to determine how accurately we could land this particular hardware. There wasn't anything unique about [Apollo] 12 that demanded pinpoint, as far as the content of the mission. It happened to be a program objective that was set. So, luckily our folks were able to carry out and we ended up not having any systems failures or anything unusual, so it worked out.

It was success-oriented. Sort of like our first apogee rendezvous was success-oriented. It sort of helps you bound the envelope of where you can operate, how well can you do these things.

BUTLER: As you were working through the Apollo missions, working with the team, and you've mentioned several of the different individuals that you've worked with along the way, and at some point Captain REFSMMAT came along. This might be an interesting time to work him in. How did that all come about?

PAVELKA: Captain REFSMMAT. Actually, we were coming up in late Apollo and—wait. I take that back. No. It was in early Apollo. Gene Kranz thought in the military way about the morale of his troops, so to speak, and he wanted a way that he could kind of raise the morale. So he talked to me about something that we might be able to do that would be a way to get the esprit de corps, get the people really up and help the team spirit.

So I came up with a number of sketches and we ended up with Captain REFSMMAT. REFSMMAT stands for Reference Stable Member Matrix. It's a technical term that had to do with the computers on board, and it is the way that the computer knows if the body axis of the vehicle is pointed this way and the gyros, and this way the reference mat gives you the conversion so that you know where are you pointing in space. It gives you to the inertial attitude. So REFSMMAT just happened to be a term. We said, "Well, we'll come him Captain REFSMMAT."

This is out of Gene's book, *Failure Is Not An Option*. We actually had six of them in all, and this photo here is not a very good photo, but it shows beginning where my finger is over here, the very first one and there's a progression of them, the last one is actually not Captain REFSMMAT. On your far right, the last one is actually Captain REFSMMAT's arch enemy, Victor Vector.

The whole idea behind all of these was that it gave the controllers a way to blow off a little steam, or when something was happening. Back then, and a lot of people remember this, but the *Fugitive*, the original *Fugitive* movie with the one-armed man and all that, well, the very first Captain REFSMMAT has quotes, like, "He knew the one-armed man did it." It had all kinds of little things that were in at the time. Twiggy, the skinny model, was in. There was comments about Twiggy on there.

So it was a way, in a humorous way, for people to put stuff down. Other people would come by and visit at lunch and they would look and write their little thing down. So it was a way to have a little bit of fun, let people blow off a little steam. Sometimes if someone would get upset about something, there would be a little comment on there about that. But that was a fun part of the thing.

Gene captured that in his book here, along with a lot other neat things that he captured. Kranz was one of my supervisors for probably all but about four years of my thirty-three-year career, and he's a fine guy to work for. He was not the easiest guy to work for, but he was a great guy to work for, one of the greatest leaders that I ever knew. I think people like Kraft and Lunney, Kranz are the ones that I really knew that inspired you to say, you know, "I would follow this man anywhere, whatever he said."

So that was kind of where Captain REFSMMAT—and that spanned a period of maybe over five or six years, maybe longer. We just left them up until people wrote so much on there that they wouldn't last any longer, and I would sketch up a new one just on a desk pad and put it up out in the hallway on a side of like a supply locker, and people would go by and write their stuff on it.

BUTLER: That shows the camaraderie in the control center.

PAVELKA: It would help the team spirit, because there was always a little competition between the trench and the systems guys, and the flight director. Everyone has their own little group that they're closest to. The flight rules and the simulations sort of brought people together.

One of the guys that was a bachelor, they complained because of the travel budget. So he wrote on the Captain REFSMMAT that he offered to—people would write things as if Captain REFSMMAT said them. Like, say, "He offered to walk to the Cape, so as to not strain the travel budget." They were sarcastic things, but the more sarcastic, the better the guys liked it.

BUTLER: It certainly was a unique environment.

PAVELKA: It was different. And there weren't any ladies in our environment back then. I think it was early—well, let's see. I'm not sure of the exact year, but I remember the first lady that was in our control center was named Poppy Northcut [phonetic]. She was back in one of our staff support rooms. Probably, I mean, everyone had a pretty important job that worked in the control center, but in the grand scheme of things, you know, it was an average support room job. But since it was so unique that it was the first lady flight controller, there was a lot of notoriety and pictures in the paper and pictures with the mayor of Houston. You know John. You've met John Llewellyn.

BUTLER: Yes.

PAVELKA: John was a little miffed when he saw the pictures of Poppy in the paper. He didn't see anything real special that she did. But, of course, she was breaking new ground in the control center.

Now, when I retired, we had, I don't know if it was 50 percent, but I mean, there were lady engineers and other tasks in the whole organization. It was not unique at all. But there was a high period of evolution in the work force there. I don't know if that was just in our environment or whether that was everywhere, but it was extremely unusual to have anyone other than a secretary as a female worker for probably the first ten or twelve years that I worked for NASA.

BUTLER: You certainly saw many changes like that from the composition of the work force to the computers, as you had mentioned earlier. Those changed immensely from when you first came in with Gemini until by the time you retired in the nineties.

PAVELKA: Right.

BUTLER: If you could reflect a little bit on those changes and the differences.

PAVELKA: Probably in the early nineties our directorate decided that they would begin to use computers with engineers at their desk. We had a number of people that were sort of trekkies, you know, that had their own computers or knew about them, or people that their business was computer programming. Well, I was none of that, so what they did was they made us do our daily time charges on the computer. So they forced us, kicking and screaming, to begin to use computers. So they brought them in and set them on the desk. So it began with, well, you begrudgingly put your time sheet in, and then little by little you find out that, well, you could type a memo here on this, and you could make a graph with this.

Of course, in our area we loved graphs. The trajectory area we thrived. If we didn't understand something, we would plot it to see if it would tell us something. So little by little, we began to get more and more involved with computers, and within a couple of years, most of the engineers were doing their own composing of their activity reports, as well as the routine stuff on the computers, and they were beginning to want more and more capability.

Well, NASA was not exactly on the leading edge of what was out there. We were always one or two generations behind private industry in terms of how powerful the computers were or what spiffy computer programs you had to do things with. That got better past the sensitivity of how that could be useful was better appreciated by management. But in the beginning I think a lot of the management sort of felt the way I did, they put up with it, but they didn't really embrace it.

About the time Windows '95 came out, I was really beginning to embrace the computers and, of course, by that time—I'm stepping ahead a little bit here—but I was then a division chief. Let me just mention an intermediate step there, because from the trajectory section that I had, I was selected as a branch chief in the Flight Planning Branch. The Flight Planning Branch had been led by Tommy W. Holloway. Tommy was going away to become a flight director for the first time, so I took his branch over, the Flight Planning Branch, and this was before the first Shuttle. We were about a year away, year or year and a half away from the first Shuttle launch when I took over that branch. So we had all of the launch and landing. Maybe I shouldn't jump to Shuttle yet. Is there something else you want to talk about before that?

BUTLER: Actually, we're getting close to eleven o'clock. I think before we do move on, I'll ask Kevin and Tim if they have any questions on what we've covered so far, if that's all right. Kevin?

RUSNAK: Yes, I had a couple. One of the things you've been talking about is the use of computers and how they've changed and the importance of that to the job you had to do. Do you think the trajectory planning and all this, and even the operations, would have been possible through the Apollo period or Gemini without the use of computers?

PAVELKA: Absolutely not. There's no way. The thing that we were doing, the processing, for example, of the trajectory data, it would use hundreds of thousands of individual data points and it had smoothing routines and you'd finally come out with a vector, and the maneuver calculations that we did, even for Gemini, for the rendezvous, there's no way that you could have done all that manually. We were able to do a little work manually on rendezvous, but we could have never determined the orbits manually. So computers were an absolute necessary tool.

The evolution of computers in the control center, we were pushing the state of the art on that, because we needed bigger, faster, just whatever they had. In those days, IBM sort of had a monopoly on what was in the control center and so we were always just, you know, what are they going to have next? They came out with the 360s, we thought that was the greatest thing in the world. But, yes, that was a crucial element.

RUSNAK: On a lighter note, you've been alluding to some of the other people in the trench. You've mentioned a couple of descriptions here and there of some people like John Llewellyn or whoever. The trench is certainly known for its colorful characters. We've heard about you guys from many different flight controllers and flight directors we've talked to. So I wondered if maybe there were any more personal stories you'd care to share about yourself or some of your colleagues, from kind of the heyday of Apollo or whatever, that you think might shed on light on their character, some ones that, I guess, are clean enough to tell on camera.

PAVELKA: Well, this is a little difficult, because we were surrounded by characters in the trench. Let me just mention a couple. Of course, John Llewellyn, Marine-type guy, you know. I'll just make one short story about him. John was a retro. John was several years my senior. He had come from the Langley, Virginia group, and he had that little West Virginia twang in his talk, so people loved to hear him talk. He was a fairly foul-mouthed guy, and I'll just leave that part at that. But he was very colorful. John had a little farm, he had cattle and he liked little horses and stuff like that. He had a little sports car, a little Triumph sports car, that he drove from Alvin up, and we'd have simulations of the flight.

One evening he was running very late for his shift. Someone may have already told you this story. But he came zooming into the site on JSC, and he went into the parking lot. He was coming on console. Didn't see any parking places, so he just pulled up on the grass. It was a TR sports car. He went in, got on the console, and pulled his shift. And partway through the shift the flight director got word and asked if there anybody that had this car. John said yes. John felt like, "What I'm doing is important, and if that's what I got to do to get here on time, it's no big deal."

Well, apparently it got the attention of the center director, and they pulled John's parking sticker. John was not one to kind of roll over. So, John was this horse person. So John would come in and park his pickup with his horse trailer on it, and pull his horse out of the horse trailer and ride his horse on site. That got some attention and eventually that all passed. But he was not one to give up easily.

I'll tell one other quick one about John. After one of the Gemini splashdown parties—that was sort of a tradition and we'd go over to a place in Webster called the Singing Wheel. I think it may be a German restaurant or something now, but in those days the

Singing Wheel was the place to go. They had an upstairs and a downstairs, and we usually would take over both. I'm not sure whether the regular customers would leave. I think we kind of drove them off, because we were pretty rowdy.

But one evening, John left a splashdown party, and he was sort of well lubricated, and he got in his little sports car, and there had been some fairly heavy rains, and on the way back to Alvin, one of the big ditches, like in the area where the rice canals were, John kind of skidded off and ended up in this rice canal with his little sports car, and he was like up to his chest sitting in his car, and he was just feeling good enough that it didn't really bother him that much. He got out and waved somebody down and they pulled him out of the little rice canal. He told them to continue pulling him until the car started. He got the car started and took it home. That probably ruined it. He complained to me that the thing that really chapped him about this was that he had a new pair of shoes on. So that was John. He was probably the most colorful.

Steve Bales, another guy, he was one of our guidance officers, a very, very intelligent guy, but sort of an absent-minded professor-type guy. Steve probably didn't get married until he was in his late forties. He did get married. He married a doctor, a lady doctor. But Steve was sort of the absent-minded professor type, and being a bachelor through most of those years in the control center, sometimes he wouldn't make it on console exactly on time. Like sometimes we would call him up, if he was supposed to be on console at 3 a.m., and it was 3 a.m. and he wasn't there, you'd call. We woke him up a couple of times. We had recorded some of this. We had all the voice-recording stuff and we could get playbacks of it. So we played back one of his wake-ups one time and it was very, very humorous. We had to wake Steve up and get him going.

Let's see. Stoval. Bill Stoval was one of our FIDOs. He and Steve Bales were both Mensa. They were extremely intelligent guys. Stoval was a young man from Casper, Wyoming, who came straight out of school, very intelligent, quick study, a natural at learning. But he also, for several of his early years, he was a bachelor. One other one, Phil [Philip C.] Shaffer, who was a large red-haired guy, we called him "Jolly Red Giant," because he was so big. He probably was 300 pounds and about 6'6", I'm guessing.

But anyway, my wife and I, Joyce, we would invite [Phil and] Bill Stoval for a home-cooked meal occasionally. On one occasion we invited them over, and Stoval had a little sports car, one of the very early Datsun sports car. It was called a Fair Lady 2000. Anyway, he wanted me to help him change his sparkplugs. I said, "Oh, we can just do that very quickly before we eat dinner."

So we get out there, and three of the sparkplugs come out okay, and the fourth one will not come out. Now, I'm going to cut to the chase on this one, because it's a long story. But Stoval ends up standing in the engine compartment. One of the plugs is frozen. It's an aluminum head, somebody's overtightened it, and crimped or set the threads. It's like welded in there. So Stoval, and he's a young, athletic—I mean, he's standing inside his engine compartment with this tool with a long cheater bar on it and he's pulling. Well, the sparkplug twists off, even with the head, so you get this part here with the white on it, and the threaded part still in the head.

So here I've got this friend of mine at my house, we're wanting to eat, so I'm wanting to get him out of my face. So I said, "Bill, I don't know what in the world to do except we might be able, if we got the right-size drill, we might be able to drill just the threads, then we can come in and clean the other part out and put a sparkplug in."

So we go buy a special drill and we drill this out, and we get a magnet down in there, and we get it all cleaned out and we put the new sparkplug in and it's a little bit loose. Our drill had not been exactly on center. So I said, "Bill, I don't know what to do. I'm not a machine shop."

So finally I said, "The only thing I can think of is, since there's a little bit of tolerance there, we might be able to take some epoxy and put it around the sparkplug threads, thread it in there and then let that harden and that might be good enough to hold the plug in there where it wouldn't wiggle around."

So we did that, and while the epoxy was drying, we went in and had our meal. Well, Bill starts the car up afterward, and it starts up just fine. So he's headed home. He gets about two or three blocks from the house and—poof! The sparkplug blows out of the head. He lived in La Port, we lived in Friendswood, so it's about a twenty-mile drive. So he drives his car all the way to La Port on the three cylinders with it going, "poof, poof, poof."

I've always worked on cars. I love to restore old cars. So my reputation as a mechanic was tarnished by this story of wanting to epoxy the sparkplug in, but I knew of no other way to get him on his way. It's unfortunate it didn't work. I think something we have now called JB Weld would have worked, but the epoxy probably just got hot and cracked and that was that. No one ever let us forget that.

BUTLER: I take it he eventually was able to get it fixed?

PAVELKA: He took it to a machine shop, they had to take the head off and machine it out and what they called a heli-coil in there, new threads and it worked. That was probably needed from the very beginning, we just didn't know if what we were going to do would get us by or not. It was one of those make-do, you know, where you die trying. We died trying.

BUTLER: That's right. You were controllers—

PAVELKA: Yes, we can do it.

BUTLER: That's right. That's what got you through the whole Apollo Program and everything. That's great.

RUSNAK: That's all the questions I had.

BUTLER: Tim?

FARRELL: He's pretty much talked about the one I was going to ask.

BUTLER: We're about at eleven o'clock now, so I don't want to keep you any longer today. Would it be possible to give you a call? There's certainly a lot we haven't covered with Shuttle.

PAVELKA: Sure.

[End of Interview]