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ORAL HISTORY TRANSCRIPT

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INTERVIEWED BY REBECCA WRIGHT
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WRIGHT: Today is February 11th, 2016. This oral history session with Jeff Hanley is being conducted in Houston, Texas, for the NASA Johnson Space Center Oral History Project. Interviewer is Rebecca Wright. This is the second in a series of oral history interviews with Mr. Hanley, who is currently the principal director of human exploration and spaceflight programs with the Aerospace Corporation. Today we continue our previous conversation with him talking about the years he worked at NASA in the Mission Operations Directorate as a Space Shuttle flight controller and then later as a flight director.

We're going to start today by talking about STS-51D, which was the fourth flight of *Discovery*, and many people talk about it as being the "Flyswatter" mission. Share with us those experiences and how all that worked out as well as it did.

HANLEY: It's actually a tale of two missions because the story began on 51D and then it culminated in what was ultimately referred to as the Leasat [Leased Satellite] salvage mission on STS-51I. That was the mission where we did the Leasat salvage.

On [STS-51D] I was supporting in what was called in those years the Customer Support Room. Basically the payload customers would have their management representatives in a special room in Mission Control where they could interact with Shuttle Program management about what's happening with the mission. On that mission we had among other things the Syncom [IV-3, synchronous communication satellite, also known as Leasat F3] satellite. This was a big communication satellite for the military, a UHF [ultra high frequency] satellite. It was the diameter of the cargo bay, so it was very very big. We had launched at least two prior to this on the Shuttle.

The way the satellite works is when it's in the cargo bay it's switched off. It's totally dormant. Then at the moment of deployment the satellite would slowly rotate. A couple of connections, we'd command them open pyrotechnically, and the satellite would roll out of the cargo bay, and so it would end up with this slow spin. As it comes out of the cargo bay there's a switch. By the fact that it's down in the cargo bay latched down, the switch is open, so the spacecraft is turned off. As soon as it comes out of the cargo bay, the switch closes, and the spacecraft switches on, and a timer starts, basically a little computer that would sequence the different things the satellite had to do in order for it to deploy its appendages and to light the kick motor that would send it on to geosynchronous orbit.

That's the way it's supposed to work. On this particular mission, the flight crew went through the [procedure]. Now remember, we'd done this two other times before, worked just great, so this was really a seemingly high confidence thing. We ran the procedure at the appointed time of deployment. Out it comes, out of the cargo bay, but very clearly after deployment the things aren't happening on the satellite that should be happening. We should be seeing deployment of appendages and it start to spin up and its thrusters become active and it spins up. Some of that happens while the Shuttle is still backing away from it. None of that was happening.

Then the ground team tried to get a signal from it and it wasn't communicating like it should because one of the timer events was turn on the transmitters and turn on all the electronics and let's get this thing going. Clearly the spacecraft did not switch on when it came out of the cargo bay. Very unexpected. That set off a flurry of activity in Mission Control where the leaders of the safety organization came in. Many many meetings were held over the span of a few days. The classic Mission Control ingenuity kicked in to come up with different ways. What's happening here? What could be the cause of this? What can we do about it? Is there anything that Shuttle can do?

One of the theories was that the switch that was supposed to close when the spacecraft rolled out of the cargo bay didn't close and switch on the spacecraft. We didn't get a good visual on the switch. It's had a little finger that stuck outside the spacecraft, and we didn't get a really good visual of it when the deployment occurred. The safety guys and the Shuttle engineering guys and Shuttle Program management and the payload managers all agreed upon a plan that the mission ops [operations] team went and created to reapproach the spacecraft, the theory being that the switch didn't close.

Then we got to thinking, "So if we see that it's not where it should be, can we drive the Shuttle up to the side of the spacecraft, what could we do?" We came up with a way of fabricating a little device that we could strap to the end of the Shuttle robotic arm that would snag the little lever for the switch and try to force it to finally close the switch and power on the spacecraft.

The management approves the plan. We go design the rendezvous. Now we're going to rendezvous with this satellite that was never meant to be rendezvoused with. We do an unscheduled EVA [extravehicular activity], the first unscheduled EVA I think of the Shuttle Program, for two suited crew members to go out and strap on this device that we created. It was created out of the plastic covers that were on the flight data file, which were the procedure books that the crew uses to do everything, the whole mission. If you stacked all these books one on top of the other they'd probably be 18 inches high or more. We took these plastic covers and duct tape and fabricated this device which we called the Flyswatter because it looked like a flyswatter.

It was basically a large mesh configuration that would give us a couple of tries at snagging this lever arm and hopefully closing the switch and letting the satellite go do its thing. The EVA is totally successful. We get it attached to the end of the Shuttle RMS [Remote Manipulator System] end effector. We execute the rendezvous and we go up to the side of the spacecraft, the spacecraft still slowly rotating just the same rotation that it came out of the Shuttle cargo bay with, totally dormant. The appendages are still stowed, it's still the way that we left it.

We see this lever arm sticking out like we would expect it to be, and yet the spacecraft didn't switch on. Maybe there's something hung up on it. We go ahead and try the Flyswatter. We as I recall made a couple swipes at it with the Flyswatter. Nothing worked. Didn't work.

Basically for that mission that's all we could do, but that wasn't the end of the story. Very quickly the managers at Hughes at the time—the company that built the satellite was Hughes Aircraft [Company]—they immediately started discussions with NASA management about salvaging the satellite. You may recall in those years we had done SolarMax [Solar Maximum Mission]. We had done the Westar [6 satellite] and Palapa [B2 satellite] retrievals where we retrieved two satellites that were stranded in unusable orbits. We retrieved those and brought them home. Here we were looking at could we use the Shuttle to do something to either salvage the satellite or bring it home.

In the weeks that ensued after the Shuttle 51D mission ended, a plan was quickly formulated. There was a subsequent planned Syncom [IV-4] deploy mission in the fall, mission 51I. I think as I recall the commander was Joe [H.] Engle. We go to work. This happens in the spring. This 51D mission is in the spring [April 12-19, 1985], and 51I is planned for late August, just a matter of weeks really, four months.

In that time the engineers at Hughes have to create a capability to basically jump-start the satellite using electrical connections that were only used on the ground for ground processing and for keeping the satellite safe until it was time to launch, and then they could configure it for launch and then go. They're basically what was called ground support equipment, GSE, electrical connections.

They ended up creating as I recall two what we call black boxes, they were actually white, but they were two boxes that we would use. We first have to grab the satellite. This is a big satellite. This is like a 16,000-pound satellite. It's slowly rotating. We've got to come up with a way of grabbing it. Our spacewalk folks go off and design some devices. Basically on opposite sides of the satellite there's two big trunnion pins that were used to attach it in the Shuttle. We devise a way of using those same trunnion pins with a bar between them to grab the satellite manually. Once we grab the satellite and slow it down, stop it from spinning, then we put what we call the grapple bar on it, which would have a Shuttle end effector grapple fixture. Then we could use the robot arm to grab the satellite and work on it.

That was how we were going to grab the satellite and hold on to it so that the spacewalkers could then work on it. Two boxes were created. One was used to jump-start the satellite. We would go in and connect to some of these connectors with this remote control box and basically the astronaut would then throw some switches to actually turn on the transmitters, very carefully turn on the electronics on the satellite, and command the deployment of the appendages. Then there was another box that we actually strapped to the side of the satellite that had a timer in it that we'd throw the switch and then chuck the satellite, give it a good toss.

There's some great video of all this. Ox [James D. A.] van Hoften was the astronaut that grabbed the satellite when we retrieved it and then gave it the final push when we redeployed it.

You'd throw a switch on this timer box. This timer box was mounted to the side of the satellite. It had to be very carefully connected to the plugs on the side of the spacecraft that were chosen to interface with because the plugs were wired directly to the batteries. Imagine dealing with the plugs on your car battery. When you mess with your car battery, you be pretty careful with what you're doing, whether you're jumping the car or whatever.

In fact when we were testing these boxes in the weeks leading up to the flight there was an opportunity to actually practice how we were going to do this and check out these two boxes that were created. Just in a matter of weeks they were designed, built, tested, and ready to fly. We tested them on one of the Syncom satellites that was still in manufacturing at the plant. In fact in our haste the technicians and crew members that were involved with the testing of it, there was one misstep. Actually a technician plugged in the wrong connector to the wrong socket and shorted something, and there was a great flash, and this was in a clean room at Hughes Aircraft in LA [Los Angeles, California], a great flash in the room as it vaporized the wires in this connector. The error of course was quickly determined of why that happened and they proceeded with the test and everything was fine.

But it shows that we were moving pretty fast and the danger was real with respect to messing with these particular connectors. We get there, we grab the satellite, we use the one box to switch on its systems, we use another box to strap to the side of the satellite to have its own timer in it to sequence the events that happen after we get rid of it. It all worked. This was all cooked up in a matter of weeks and it all worked. That satellite, it was referred to as the F3 satellite in the series, everything I ever heard about it since then was it was one of the bestperforming satellites they ever had. Maybe it was that four, five months of shakedown in low-Earth orbit, I don't know. But I was still pretty young, in my early to mid-twenties, in those years, '84, '85, '86, I was 23, 24 years old.

I worked in the back room supporting the payload officer. The lead payload officer for that was Ben [Benjamin L.] Sellari. The lead flight director for that flight was Al [Granvil A.] Pennington. It was one of the most exciting fast-moving things I think I was ever involved with just as a support person. I think last time I talked about the cargo systems manuals. That was my job on that flight, was to create all the wiring diagrams and explain how all the stuff worked for the benefit of the crew, the benefit of the management, the benefit of the other flight controllers, and be the basis upon which we would troubleshoot things if things didn't work right. Again very cool for a 23-, 24-year-old kid to be doing.

WRIGHT: Actually proved that theory, this was a vehicle that could provide service to space, and the philosophy of being able to figure out the problems on the ground, get them up there in a short amount of time. Lots of what the Shuttle or the STS [Space Transportation System] had been advertised to do, this mission really was a great advertisement to do that.

HANLEY: It was either work with NASA to retrieve these satellites or salvage them or pay the insurance money. From a Hughes Aircraft perspective, it was basically a business case thing. Given that NASA didn't charge them full cost for a Shuttle mission, they only had to pay basically the integration cost. There was a benefit to NASA of course, showing the utility of the Shuttle and the capabilities of humans in low-Earth orbit.

It was an impressive pre-*Challenger* [accident, STS-51L] accomplishment.

WRIGHT: No one mission is ever done just as a single mission. But were you working on other missions in preparation as well as this one?

HANLEY: Yes. In those years I had already begun working on the Hubble deploy mission at that timeframe. Hubble was probably the thing I was working on most directly in those years.

WRIGHT: That's a nice baptism by fire for you to run in all the directions that you could and still come out so successful.

HANLEY: It was hugely impressive to a 23-year-old kid, being allowed to do the stuff I was doing.

WRIGHT: Really got you started.

HANLEY: Yes.

WRIGHT: You had also mentioned a couple other missions that you felt showed the full realm of being able to encompass all of the can-do spirit and the ingenuity of flight control.

HANLEY: I think we touched last time on STS-49. I talked about the event where we went to deploy the spacecraft [Intelsat satellite] after it had been mounted in the Shuttle on top of the solid rocket motor. We went to deploy, threw the switches, and it didn't go anywhere. We tried the A side, we tried the B side. We mixed them up, and by golly, it worked, and it turned out to have been just a miscommunication prior to launch about how the switches in the flight deck of the Shuttle were wired out to the payload. Some wires had been switched or reversed or some drawing had been wrong somewhere and it had resulted in confusion about which switches were wired to what. They were not labeled properly on switch panels.

That was a little bit of an "Oh my!" moment. In terms of being on console and having things not go right that was certainly one instance. There were a couple times during that flight actually that things didn't go right. The other moment was when the Shuttle came up to the satellite and we were going to grab it with a device that was mounted to the manned maneuvering unit and it didn't work. Second time that had happened, because different device but same thing had happened on the SolarMax repair mission on STS-41C where Pinky [George D.] Nelson went up to the SolarMax satellite to use this device to grab a trunnion on the satellite and it didn't work. The satellite ended up tumbling in fact. But we were able to recover from that and SolarMax's repair was ultimately very successful.

On STS-49 Intelsat was a big satellite, as big as Syncom if not bigger. We went up and tried to use this grapple mechanism on the MMU [Manned Maneuvering Unit] and it didn't work. What we were going to do is we were going to grab the satellite, not too dissimilar to what we had done on STS-[51A] with Westar/Palapa where basically we had gone up to the back end of the satellite and we matched rates with it and then we grabbed it with the MMU.

We were going to do the same thing here [on STS-49], but it didn't work. We had to really scramble to come up with "Okay, what the heck are we going to do?" We've gone to all the trouble of planning and executing this mission. We got the solid rocket motor in the cargo bay to recover the satellite and actually rescue it and reuse it, salvage it essentially. The team ended up proposing the first and only three-person EVA. We came up with a way of positioning three crew members on the sill of the cargo bay to basically act as our grapple mechanism. The pilot and commander flew right up to the satellite, positioned it right there, and then one, two, three, they all grabbed the satellite at the same time.

This is a big heavy satellite, so they had to grab and hold on to it and stop it from rotating, and then stabilize it well enough so that one of them could put a grapple fixture on it, which they did. It worked. Getting three people out the door in an air lock that was designed for two was a bit of a contortionist's nightmare but we got it done. What it meant was we had to suit up one of the crewmen in advance and basically use a little bit of the suit time for them to just wait around till the other two could get suited up and then we found a way for all three to be able to be in there, depress the air lock, and then go outside.

Was the comm going to work with three guys out there? We worked all that out. It was again a tremendously—in real time—innovative activity to come up with a way of getting this job done. Again we were confronted with something that didn't quite work the way that we had hoped it would. We had to come up with some other approach.

So that was in the summer of 1992.

WRIGHT: Before we go, a couple things you mentioned that I'd like to ask about. One was before when you had mentioned missions, you were in the back room. Of course you had before this mission been moved up, but can you share the differences? Whereas maybe in the back room you'd been the one that would be off running in four directions trying to find all the answers, now you're up front waiting for a lot of the information. Can you talk about that interaction? Do you give instructions to the folks in the back to go look up this? Give us the insight of what it was like to be now in that position, knowing the information you had, and how you helped the folks back there help you up front.

HANLEY: There's a progression in flight control where you start out in what we refer to as the back room. There's the main control room where the front room operators sit. The payload officer in my case is the position that reports to the flight director about everything having to do with the payloads. There's a dozen other positions. There's a guy that worries about the comm system. There's a guy that worries about the guidance system. Life support, electrical, flight dynamics, crew planning. Even a management rep [representative]. A guy that does nothing but make sure that the Mission Control Center itself is working and keeps working. So there's a dozen folks that the flight director is coordinating with to execute the mission.

It is the flight director that is the ultimately responsible one. The crew in fact works for the flight director. You go read the flight rules, that's understood. One of the positions under the flight director is the payload officer, and that was the position that I worked when I was a front room operator. I started out in the payload officer back room, or what we called the multipurpose support room, MPSR. Under the payload officer would be two positions supporting the payload officer, minimum, for a given mission. There's a payload systems engineer and a payload data engineer.

The payload systems engineer typically is responsible for all of the procedural aspects of operating the payload for that flight or payloads. The payload data engineer basically works with both the communications specialist for the Shuttle Orbiter and all the ground system guys to make sure the data that comes from the payload gets to where it needs to go, whether it's distributed internal to Mission Control or it's sent out. Quite often we had what we called remote POCCs. POCCs were short for Payload Operations Control Center. We had remote POCCs. They basically were the entities that sponsored the payload. They were basically the payload owners. We would make sure that we had a good interface and sent all the data and commanding to the payload, and all that was all coordinated.

That's a minimum of two positions underneath the payload officer. On many missions we had more positions than that. If we had specialists for a given aspect or maybe a given payload on the flight we might have a specialist or a series of specialists for that payload. I began as a payload data engineer on Spacelab-1, STS-9. That was the mission that I was OJT [on the job training] on. I worked with an Apollo veteran, I think I mentioned him last time, that it was his last mission. He literally unplugged the last day of the mission and went fishing and I never heard from him again. He had been one of the principal folks that commanded the experiments on the lunar surface during Apollo after the astronauts would deploy the experiments on the surface.

I graduated on the next mission I worked to payload systems engineer, and I wasn't OJT. I was certified payload systems engineer for the Large Format Camera on STS-41G. I was one of three people. We worked round-the-clock eight-hour shifts. I was one of the three shifts that looked after the operation of that payload. I was payload systems engineer for this Leasat salvage mission. I started out as payload systems engineer for Hubble deployment supporting an assigned payload officer for that, but I ended up being hired by NASA and graduating to becoming a payload officer front room guy for the deploy mission. The Hubble deploy mission was my first mission as a payload officer front room. Hubble had been my primary focus for several years by that point. That was 1990.

I think the other mission that I'd mention where things didn't go quite right was actually again a tale of two missions, STS-46 and STS-75, the Tethered Satellite [System] payload. Tethered Satellite was a collaboration between the Italian Space Agency and NASA. The Project was managed out of Marshall Space Flight Center [Huntsville, Alabama]. Martin Marietta [Corporation] in those years was the prime contractor essentially in the U.S. They had the task.

There's basically two pieces to it. The Italians built a satellite on which several science experiments would be mounted. The satellite, I want to say it was about maybe six feet in diameter but fairly sophisticated. Full communications system. It had a little propulsion system based on cold gas, basically a nitrogen bottle and little thrusters that would help us steer the satellite.

The Italians built the satellite. The U.S. was building what was called the deployer, which is the spool. This is a satellite that deploys on the end of a 12-mile-long cord, actually an electrical wire 12 miles long, 20 kilometers.

The spool for all that tether was down in the cargo bay mounted on a Spacelab pallet. It had a control computer and other support systems, and a long deployable boom that would extend above the level of the cargo bay so that the satellite was held away from the Shuttle structure before we actually unspooled the tether and let the satellite fly away. There's a couple of umbilicals that plugged into the satellite so that we could control and communicate with it.

We spent many months—actually many years—of preparation. I got involved with Tethered Satellite like 1988, and the first flight of it on STS-46 was 1992, so I spent four years. This was a somewhat unique situation for my team because we actually had the responsibility of operating the satellite ourselves. We weren't just coordinating with some remote POCC somewhere and letting them send all the commands. We were doing it all from JSC, my team was responsible, so a little more responsibility. The team in the back room was a little bit bigger. There were five console positions in the back room, one for the satellite, one for the deployer, one for the pallet subsystems, position for the science experiments, and the payload data engineer to make sure all the data keep flowing. It was a pretty big team.

We spent months preparing trying to think of every possible thing that could go wrong. Long story short, we got down to the end. We were creating new capabilities in the Control Center for command and control. This was one of the first missions where we heavily used what were called engineering workstations, which were basically stand-alone high-powered personal computers, but they were all networked together. But each one stood alone. Prior to that Mission Control was basically one big mainframe computer with several displays that were driven from one computer complex. It was right in these years where we were migrating toward a very different architecture for Mission Control, and this was one of the steps along the way.

We used these engineering workstations, a network of them all over the building, to run the unique software that would be needed to understand what's going on with this 12-mile-long tether and the satellite on the end of it.

We finally get to launch day. That was a very difficult summer for me because my father passed away just a month before the launch. I was stretched thin. But I had such tremendous people working with me, it was one of those times when you really realize how lucky you are to work at the Johnson Space Center, to work in Mission Control and among all these people. It had just been weeks prior that my dad had passed. We set to work after launch. Launch went great. Set to work on STS-46 attempting to deploy this Tethered Satellite for the first time.

We go power everything up. We extend this boom that's supposed to deploy the satellite up above the cargo bay so that it's well away before we actually start unspooling the tether. That all happens just fine. We go to unplug. There's a plug at the top of the boom that has a little puller on it that you operate a motor and it pulls on the back of the connector and the plugs come loose, so the only thing connecting the satellite to the Shuttle at that point then is the tether itself.

We command that thing to disconnect and it doesn't disconnect. We try again and it doesn't disconnect. We try the alternate way of doing it and it doesn't disconnect. Shoot. Our appointed time to deploy comes and goes and we're still sitting there with the satellite on the top of the boom.

The timing of the deploying the satellite had to do with lighting. Basically the orbital lighting. We wanted a good long daylight view of the satellite while it was close to the Shuttle as it was flying away. We missed our deploy window on the first orbit because the plug didn't come unplugged. We worked the problem. We come up with a way; we tell the crew to command the spool to let the tether be slack a little bit and tell them fire the main jets on the Shuttle and see if we can use momentum to get this plug to unplug. It worked. Oh, great. We tighten up the tether again. We got the satellite unplugged.

Of course now it's on batteries and the timer is running. This thing will last maybe a couple days on battery power. Every hour, every minute is precious. We get all spooled up, literally, ready to attempt another flyaway, as we termed it. We run up to the next deploy window.

I mentioned these ground workstations. First flight we're really using these in any significant way. Just moments before we're supposed to have the crew command flyaway, nearly all the workstations on that network failed. Some kind of software glitch that basically took down all of the important ones anyway, if not all of them. Unfortunately that was one of the criteria for being go for flyaway is to have the ground system functioning at least minimally. We miss the second deploy opportunity while we recover our ground system capabilities. We get all that recovered.

We come around to our third deploy window. Finally it looks like the stars are aligning, and sure enough everything is good. We give the go flyaway. The crew hits the button and we start to deploy, and it's working. Everything's working, and it's beautiful. The tether is probably deployed a couple hundred meters by the time we hit what was called the zone of exclusion, which is a little cutout in the satellite network coverage. The geosynchronous satellites looking back at the Earth, there's a little zone out in the Pacific that neither satellite could see. When the Shuttle passed over that part of the Earth we lost signal. We were happy. We'd been working. Three revs [revolutions] it took us to get the flyaway done. It's doing its thing. It's going out. We hit LOS, loss of signal. We're all relieved, because we all got to take a break.

That's the way it is. In Mission Control you drink a lot of coffee and in the era of continuous TDRSS [Tracking and Data Relay Satellite System] coverage, breaks were premium, let's just put it that way, nature's call. We're all patting each other on the back. All right, we got it done, we're going now.

We take our break. We come back. At AOS [acquisition of signal], Jeff [Jeffrey A.] Hoffman, one of the crew members—I think I told you about my four occasions of getting bad news from Jeff Hoffman. Well, this was one of them. This may have been the first one actually. Jeff Hoffman on the downlink, "The deployer has stopped." The tether is slack and we are in the contingency procedure for making sure things stay under control, 256 meters. This thing is supposed to go out 20 kilometers. It's stuck 256 meters away from the Shuttle.

What the heck is going on? Of course the cargo system's manual. All the foldout drawings come out. All the malfunction procedures come out. We're doing it. Of course there was no canned procedure for this particular scenario. Probably for two or three revs we're working on different aspects of troubleshooting what it is about the deployer that caused it to stop.

After many hours of contingency procedures, test procedures, checkout procedures, power cycling things, doing everything we could think to do, we started thinking about more and more different scenarios as time went on. One of them was we would never get it spooled back in, so what are we going to do. We started talking about a spacewalk and started the crew actually preparing to do a spacewalk. We told them, "Go do all these preparatory things in case we have to do this to manually grab the satellite and latch it back down in the cargo bay."

The satellite was not made for that. Like with so many of the things the Shuttle has done actually, spacewalks and EVA was not part of the design. But we had prepared for that in those four years and all those meetings that we'd had. One of the things we had done a lot of work on was different things we could do by EVA manual override to either enable the mission to continue or to retrieve the hardware if the mission didn't go right.

We were prepared for that. We had that in our hip pocket. We worked up a manual control procedure for the crew to manually discretely command the spool to slowly reel this tether back in. We ended up retrieving the satellite on the top of that boom, getting the boom retracted, getting the satellite latched down in the cargo bay, without needing a spacewalk.

The management went, "Whew, I'm glad that's over." But the mission was essentially a bust after so many years of work. Not only a disappointment for us locally here but for the project folks at Marshall, the Italian team who had worked right alongside with us, the Martin Marietta team was totally befuddled about how this happened.

After the flight, a formal investigation was initiated by NASA into the mishap of why did this thing not work? In the end it was determined that a matter of weeks before launch when the spool down on the Spacelab pallet had been mounted to the pallet, in order to get it to sit quite right on the pallet they had to put in what are called shims to get the clocking of it and get it wedged in there just right. The shims had a bolt that went through them.

The spool is a great big spool, several feet long, with a motor on the end of it. There was a little device very much like an open cast fishing reel, a little level-wind mechanism thing that goes back and forth to wrap the tether on and off the spool in a controlled way, so that when you reel it in the tether doesn't bunch up all in one place.

This level-wind mechanism wants to go back and forth as the spool unspools. Whoever did the engineering for installing these little shims on the footpads of the spool mounting, they did not look at the clearance between this little shim and the bolt that goes through it and the mechanism that is the level-wind.

What happened was the bolt stuck out too far. This was an engineering change that happened just three or four months before launch. They didn't check the clearance with this level-wind mechanism. We get out 250 some meters, and the level-wind mechanism is supposed to hit the end of the stop and then start the other direction, but it hit this bolt that's sticking out too far, and the bolt would not—if you bind up the level-wind mechanism that makes the spool stop, because it's all geared together.

Really? A bolt that was probably millimeters of interference. It didn't take much to bind it up. So that was the outcome of the investigation. Negotiations with the Italian Space Agency go on and a reflight of Tethered Satellite is scheduled. We're all elated because all the work we put into the first mission, all we had learned along the way, and I was elated that we were going to get another crack at it.

Fast-forward to 1996, STS-75. Again many months of preparation. Now we have migrated over to the new Mission Control, which was then called the White FCR [Flight Control Room]. Now engineering workstations are the norm, because that's the whole Mission Control platform now, it wasn't just this experiment. Things have come a long way. We were much better prepared. I felt probably as prepared for that flight as any that I ever flew, which I couldn't say about STS-46. STS-46, it was all an experiment. STS-46 was my first lead where I was the lead payload officer.

By STS-75 a lot had matured, including me. Again we power things up. Everything's going pretty good. We had a problem with communication between laptops in the flight deck and some of the science computers. We figured that out, it ended up being a bad cable in the flight deck. We switched out the cable, started working fine.

We get on to deploying. One of the lessons learned from the first flight is they got rid of that connector at the top of the boom. They just got rid of it. They figured out a way to not need it, so that got eliminated from the design for the second flight, so we didn't have that problem.

We roll right up to the time to do the flyaway. Everything lines up. It works. Everything's working great. We get past 256 meters. We all sigh a sigh of relief. The control of the deployer is all working. It's all just by the numbers. It really was very satisfying to see the system work. The whole system including all the Shuttle's role in it, was really a beautiful thing.

About halfway out to the 20-kilometer point, we're starting to get news from the science people that they're seeing wonderful data, really impressive data. One of the attributes of this 12-mile-long wire is that when you pass it through the Earth's magnetic field it will create a voltage, and it can be a power source. We're demonstrating that on this mission. We're firing up these electron guns down on the Shuttle cargo bay to actually make the circuit with the magnetosphere. That's all working and even the science experiments are working, it's fantastic.

Versus their models, they're seeing this thing perform a whole lot better than their models ever predicted it would in terms of this power generation thing. Everybody's just amazed at just the initial data that we're getting. Deployment continues. Late in the deployment I turn and talk to my flight director, Chuck [Charles W.] Shaw. I report to him about the reports we're getting from the science team and how great the data is and everything's working great.

Then I hear Jeff Hoffman's voice at around 19,000 meters, about 19 kilometers. All of a sudden he reports the tether has broken and the satellite is flying away. Total stunned silence in the room. Did we really hear what we think we heard? We start looking at our data, start trying to look at what the satellite is doing. Everything's gone to zero on the deployer side of things, and we are stunned.

Immediately dealing with a sense of defeat. There's nothing to do. Immediately there was no recourse. The satellite is off now in another orbit, and we eventually lose contact with it. The radio's range goes out of range. We go to work on what just happened, where is the satellite, do we have any recourse, what recourse do we have?

We set to work using the C-band radars around the globe trying to get the radars to locate the satellite for us, to try to get a state vector on it as to where is it and where is it going. Eventually it comes back around to where the Shuttle will be temporarily in range of the satellite.

Every day the satellite still will pass over Houston. We do a few things. First we get busy on what would it take to go retrieve the satellite, and we start putting a plan together to do that.

We put a plan together and actually go and implement. We actually send engineers over to the ground station there at JSC that's called ESTL, Electronic Systems Test Laboratory. It has a ground antenna. Now that whole facility was not configured to do any of this, but on the fly we are able to set up a radio link from that ground station to the satellite. Once we know where it is, so the C-band radars find the satellite, we get a hack on where it is and when it will pass over. Then we can use the ground station to try to communicate with it, and we find the satellite, and we communicate with it.

We get busy doing that, get busy looking at how would we capture it and retrieve it. We attempt to get some surveillance of it from other optical ground sites that we have access to. The management of course is meeting, meeting, meeting on all this. What are we going to do? Do we do anything? I think the management was very torn about whether to even attempt to retrieve it.

We did make contact with the satellite and when we officially got radio contact with it, what we found was the satellite had switched itself off. We surmised that it probably did that because the ground radar zapped it—they went into high power mode to find it. The satellite was more than likely susceptible to strong radio pulses, and that can cause the electronics to wink out. What happened, we think, is that it caused the computers to reset and switch a bunch of stuff off, and it ended up causing the valves for that nitrogen propellant system to open up and deplete all of the propellant. So the satellite was empty of propellant and the lights were out in terms of the power.

We went over to ESTL with all of the commands. We had to actually enter the commands into ESTL's computers by hand in order to send commands to the satellite to slowly bring it back to life. We found the state of it. It was also spinning quite rapidly, which again was an indication that these valves had opened up and the thrusters had caused the satellite to spin up. It was spinning at a pretty good clip.

Then we got the optical hack on it. We actually got some photos from an optical site of the satellite. With that data, that was pretty much what killed any idea of going back to the satellite, because what had happened is when the tether broke, the 19,000 meters of tether came coiling up toward the satellite, and the satellite spun up. It had created a snarled mess around the satellite of all this tether, so it was a hair ball of tether. It's spinning rapidly, there's no way to despin it, and it's got this mess of tether around it. That pretty much told the management we're not going to go mess with that, we're not going to compound one failure with another, because it's probably low probability we'd be successful.

They broke the news to the Italian partners that we are not going to attempt a retrieval, and it was the right decision. We were all disappointed, because we had all put this work into—we're getting all worked up about grabbing it, saving the day again. But it was not a wise move to go try to do that.

So we still have communication with it through the ESTL, and we actually turned the science experiments on, and over the next few days of operations we still got more science data from it. As the satellite and the Shuttle passed each other occasionally, we could fire the electron gun experiments down in the Shuttle cargo bay that would put electrons out into the magnetosphere and be detected by the experiments up on the satellite. There was still magnetospheric science that was achieved even after the tether broke that I'm told was pretty compelling data.

We did salvage as much as we could from the situation, but that was the end of tethers in space, at least on the Shuttle. It was working quite nicely, and the investigation afterward—this tether when the satellite is out and the tether is deployed 19,000 meters and it's cutting through the Earth's magnetic field, a potential of 3,000 volts gets created, and it took only a small imperfection in the insulation. If you see a wire it's got the rubber or plastic insulation on the outside.

On this tether down the middle of the tether there was the conductor, the copper wire, and it was wrapped in an insulator. There was enough of a tiny flaw in the insulation that as the tether spooled off of the spool and went through the different mechanisms before going out, as it went through one of the pulleys it shorted, and the short at 3,000 volts, it burned through the tether. What was left is the tether broke about halfway up the boom. After the event there was a little piece of tether just sticking outside of the boom, the end of the tether that had broken. I don't know what it was about that project that was just not destined to be successful fully.

WRIGHT: Learned a lot from it, but just didn't accomplish all the objectives.

HANLEY: Right. It was really doing both missions, 46 and 75, where I learned much of my team management skills. Not just because of the large back room that I had where I had the various specialists for different aspects of the payload, and not just the operational responsibility that my immediate team had. But it was the knitting together of the engineering team, the science team, the Italians. This was a very large team. Plus being the focus for coordinating with all of the

Shuttle disciplines that were involved, which were many because there were many aspects of the Shuttle that were integral to making it happen.

I learned a ton of what would ultimately serve me as a flight director by doing those missions.

WRIGHT: Sounds like it's a good place to stop. When we come back maybe we'll talk about some of those pieces and then how you took those forward and made them work. I appreciate it today.

[End of interview]