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GARY W. MATTHEWS
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is June 26, 2018. This telephone interview with Gary Matthews is being conducted for the JSC Oral History Project in Houston, Texas and Los Angeles, California. The interviewer is Jennifer Ross-Nazzal. Thank you again for spending some time with me this morning, I really appreciate it. I know you're very busy. I wanted to begin by asking how you became involved with the James Webb [Space] Telescope test at JSC.

MATTHEWS: That's a long history. It started back in the 1990s. At the time I was working for Eastman Kodak [Remote Sensing Systems]. We had been tasked by TRW at the time—who now are Northrop Grumman, and Kodak has now become Harris through several acquisitions.

Northrop Grumman had brought us onto their proposal team to help them build the telescope and to help them develop the ground support equipment to test that telescope. As part of that team, we worked for several years prior to the proposal that was written in 2001 to develop the ideas and concepts that we would put into the proposal. Then subsequently, when that team won in 2002, I believe, we were fully engaged in the program and ready to go execute.

Now the test concept has changed dramatically. What we proposed isn't what we ended up doing, but along the way we became smarter: what was really going to be possible and cost-effective versus what we had thought we could do originally. So there was a major replan of the test program in 2007. Up till that time we had been working with Northrop Grumman developing the concept. It came to a point where it became obvious that it was just not feasible.

At that time we brought a whole lot of very smart people together—from NASA, from Northrop Grumman, from Ball Aerospace, from Kodak—and really took a long step back and said, "Okay, what are we trying to do here at Johnson, and how can we most cost-effectively get there?"

We very much replanned the program. Originally there was going to be a telescope cryo [cryogenic] test and then an OTIS [Optical Telescope/Integrated Science] cryo test with the instruments. It became clear that the cost of that would just be prohibitive. We replanned that whole thing to come up with just one flight test of subsequently what we called the OTIS, the OTE [Optical Telescope Element] telescope and the ISIM [Integrated Science Instrument Module] instruments. We came up with what we felt was a very cost-effective yet very comprehensive plan to test that flight hardware. That's how I became involved almost 20 years ago now, and it's been a very good effort by the entire NASA, contracting team, our international partners. It's just been a really great effort by everybody.

ROSS-NAZZAL: What's your background? Are you an astronomer, optical engineer?

MATTHEWS: I'm a mechanical engineer by trade. Although when I graduated in 1979—seems like a long time ago now—I became involved in optical systems. I became a mechanical integration and test person through most of my career. I started out as an analyst and a structural dynamicist and really morphed into an integration and test-type of leadership role in creating these large optical systems, from Chandra [X-ray Observatory] now to JWST [James Webb Space Telescope].

ROSS-NAZZAL: That will bring up another question later as we get toward the end, I think. Did you have any role in modifying or preparing the SESL [Space Environment Simulation Laboratory] for OTIS?

MATTHEWS: Yes. I led the team at what eventually became known as Harris. Harris was responsible for bringing all the optical test equipment down to the SES [space environment simulator]. My team did not modify the chamber *per se* with all the cryogenics and the new pumping system, but they did add all of the optical test equipment.

Once JSC was done modifying the chamber, my team came in for a period of about four years and integrated all of the optical test equipment that was required to support the telescope or the OTIS, run those tests, and provide that data to the teams.

ROSS-NAZZAL: What sort of optical test equipment? Can you give some examples of what you put into [JSC Building 32] Chamber A?

MATTHEWS: Sure, there were several subsystems. In no particular order, we developed with the help of Johns Hopkins University [Baltimore, Maryland] a photogrammetry system. Photogrammetry is very old, it's 100 years old maybe. It used to be done with photographs but now it's done electronically with digital cameras. We installed a photogrammetry system which included four cameras on these extremely large what we called windmills. If you think about putting a camera on the end of a large windmill and spinning it around, we had four of those in the chamber. They looked all around. That photogrammetry system basically allowed us to know where everything was inside that test chamber to about 100 microns. If you think about something that's 40 feet in diameter, say 60 feet tall, at cryogenic temperatures, at minus 400 degrees Fahrenheit, knowing where everything is in there absolutely to about 100 microns is just amazing. It still just totally amazes me.

The other major system we put in was called the CoCOA, it's called the Center of Curvature Optical Assembly. The heart of it was a multiwavelength interferometer looking down on top of the primary mirror. That multiwavelength interferometer allowed us to effectively take the 18 mirror segments and phase them into one optical element so that those 18 segments worked as one giant 6.5-meter mirror. There were all kinds of features within that that would allow us to identify an individual mirror, for example. It would allow us to change the figure of that mirror, change the position of that mirror, and understand where it was in three-dimensional space. That was really one of the major pieces of equipment that we put in.

In addition, there were three autocollimating flats. An autocollimating flat is just a very flat mirror. We put three 1.5-meter mirrors over top of the telescope and that allowed us to do an end-to-end test of the telescope.

The CoCOA just allowed us to look at the primary mirror. The autocollimating flats actually allowed us to put light through the entire system so that we could check the throughput into the instruments. We could go through some demonstrations on wavefront sensing and control, just like we would do on orbit, again to demonstrate that we understood the algorithms that would allow us to actually align the system on orbit.

Another key feature is the SES chamber was never designed to do optical testing. It was designed for human spaceflight. It was not designed to be ultimately quiet from the sense of vibration, being able to do these very sensitive optical alignments. Historically, it requires a very specialized chamber that was built specifically for optical testing. Those are scattered around the country, but there were none really big enough to test JWST.

So we took a chamber that was not optimized for optical testing, and we installed an isolation system on the ceiling, on the top of the SES chamber. There's six isolators that sit on that very noisy dome, and there's some downrods that go through the chamber, through some bellows, and basically support all of that test equipment. Isolate it from the very noisy chamber, where there's pumps going on and outside traffic going by, and truly allow us to get these very sensitive optical alignments and optical tests done in a chamber that was not designed to do that.

Those are the major subsystems. There were also some other pieces to help support the telescope. We actually supported all of the test equipment and the telescope from the ceiling of that chamber, about 60,000 pounds of equipment we literally hung from the top of that chamber. Suspended it, isolated it, in order to do this optical testing.

ROSS-NAZZAL: I can see why it took four years. It's quite an effort. I wanted to ask if you could explain in layman's terms—you mentioned the 100 microns that allowed you to know where everything was up to 100 microns. Can you explain that? If a reader were to encounter that, what does that mean exactly?

MATTHEWS: Photogrammetry, you've probably been around it and really didn't know it. What it does, it takes pictures from many different angles. It's basically a giant geometry problem of similar triangles.

If you go back to your high school geometry class, if you know some absolute distances—we had these things called scale bars that at any temperature we knew exactly how long they were. Those were the references. From those references, then you can, using similar triangles and all these different angles of pictures—which is why they were on giant windmills—know where every point was within a cloud. I would call it a little cloud, 100 microns in diameter.

If I do a quick little calculation here, I want to convert microns into something a little more—it's about four-thousandths of an inch, about the thickness of a piece of paper. Think about your desk and where it is with respect to the door. We would know within 100 microns where that desk is with respect to the door to about a thickness of a sheet of paper.

As you start to do these sensitive optical alignments that are measured in nanometers, having some gross idea of where you are in space of all the pieces really helps you understand how to do the optical alignments. Being able to track "Where's the telescope with respect to the CoCOA," "Where's the secondary with respect to the primary?"—having some secondary check on where all those locations are really helps you understand the system.

The other thing that we were able to do that the system was never designed to do is we did a thing called frame stacking. Even though those photogrammetry cameras weren't meant to be able to take a photograph, we tricked them into taking real photographs. We have photographs inside the chamber of the telescope at minus 400 degrees Fahrenheit. That allowed us to do some other investigations on some questions that we had as we went through the testing that didn't quite make sense. Having a real photograph of what things looked like, for example, turned out to be a huge help. Did that answer your question? Not sure I did.

ROSS-NAZZAL: Yes, I think so. I'm always trying to think about the reader, the person who's going to look at this and say, "What does that mean?" It must have taken quite a while to get this hardware ready for it to be able to work at such a low temperature, minus 400 degrees. That's pretty amazing.

MATTHEWS: Yes, it was. I've been doing optical testing for 40 years now. This had some very unique challenges. As you go through your career, you have many tricks that you learn just through experience. Some of the design features that you would normally use at, I'll say, normal temperatures, even down to liquid nitrogen, which is about 100 [degrees] K [Kelvin]—going down to 20 K really provided some unique challenges. Things don't want to work. Regular lubricants become just giant ice balls and don't lubricate anymore, so you're using ceramic bearings with a hard lube. Very small heat leaks are just incredibly detrimental. A few-milliwatt leak normally you don't care about, but in this test that would blind the detectors.

One of my favorite stories earlier in the program, I would say circa maybe 2009 or maybe 2010, we actually tested the autocollimating flats I mentioned earlier up in Rochester [New York] at Harris. We had a small chamber that would go down to 20 Kelvin or so. We tested our first mirror, and we could only get it down to about 40 Kelvin. We got totally stuck at 40 Kelvin, couldn't get it any colder. We needed to go to about 30 Kelvin.

We finally gave up, and I went over to my thermal engineer. He was over there cutting these little blankets. They were probably maybe an inch, and he was putting them up in the chamber. I'm like, "Brandon [Olson], what are you doing?"

He says, "Well, I think these little blankets will really help."

I'm like, "Okay." The next time we took it down we went to 18 Kelvin. It was like "Whoa."

Again, these little things that you can ignore at higher temperatures really made huge differences at these very, very cold temperatures. That really set in my mind on how careful we as a team will have to be if we want to test down here. These very small heat leaks can really destroy a test, not only thermally but also optically. A small heat leak to the mid-IR [mid-infrared] camera system will look like a blowtorch and totally destroy its ability to image and test.

Those are some of the things that we had to be really careful about. These photogrammetry cameras I mentioned, they run at room temperature. Inside this giant chamber we had these warm cameras, so we had special windows. We had a double window where we had to really control the amount of heat leaking through that window out into the chamber, or again we would destroy this test. A lot of thought had to go into every aspect of this optical test. In fact, I kid the thermal engineers a bit that this was really a thermal test with some optics involved, versus an optical test done at Johnson.

ROSS-NAZZAL: It sounds like it, dealing with all the temperatures that you've mentioned. I wanted to ask, obviously you had been preparing for many years. You don't just want to stick in the OTIS, you want to make sure everything you've done is actually going to work. How did you guys do qualification tests and ensure before you put in OTIS that things were going to operate smoothly? Were there any changes that had to be made that you had to resolve before you could put the hardware in?

MATTHEWS: There was a series of tests. That's a really good question. Initially in the program we had proposed this pathfinder. The pathfinder was two or three segments that evolved over time just down to two segments, but a couple segments on a thing that kind of looked like the telescope. We were going to take that down and put that through some testing to make sure that we had wrung out the system.

As it turns out, the testing was greatly expanded in 2010 with, as you know, a major replan in I believe it was 2010 or 2011, something like that, where really the whole program was rethought. It became obvious that we needed more pathfinder testing. There was a series—when I was looking at the questions, I think it was five or six tests leading up to OTIS. Each one added more and more complexity.

The first one was just, "Let's see if we can get it cold. Let's see if everything survives." A cryo test, just a qualification test. Make sure nothing broke. We then added just the primary mirror. Then we added an ACF [autocollimating flat mirror] and a thing that looked like a science instrument. Each one of those we learned more and more.

We fought a lot with dynamics. The whole stack, [it's] about 80 feet from the top of the chamber down to the telescope. When you think about things changing temperature, normally you can kind of ignore it. In our everyday life, how much steel contracts or how much titanium contracts CTE-wise (the coefficient of thermal expansion), it's fairly modest. But here the telescope actually moved up, I believe about three inches, due to just the temperature change. We thought we had everything cleared, and there were some surprises where we had some interferences, as we got cold, that we didn't quite get right the first time.

It took this entire series of tests before we really felt confident enough that we could really test an OTIS. These five or six tests with various levels of added complexity really gave us the confidence going into OTIS that we had the subsystems understood, they were reliable, and they were going to give us the data we really needed. In the end, they worked extremely well. In planning for a test this complex you always feel that, "Boy, there's going to be some level of handwaving to really convince yourself that you got this thing right." The test data was extremely clean. I think that was just due to the very regimented process we used to get ready to test the OTIS. It provided the ability to fix things along the way. When we got to OTIS we had very good confidence that our test data was going to be good, and it really did turn out that way. We learned some things about the telescope that we had never planned to learn, because of the quality of the test equipment and the test system.

ROSS-NAZZAL: What did you learn about the telescope because of the tests?

MATTHEWS: The first hint was actually during the Hurricane [Harvey]. We kind of let the system just kind of sit for a couple of weeks. When we came back and actually started testing again, we saw something that we didn't quite understand, so we noodled through that.

We found a couple sensitivities. We were concerned because we saw, as the temperature changed, periodically on some of the electronics we could see that in the wavefront. How we found that is that we saw this frequency that was I believe on the order of 26 minutes. As we took more and more data, we couldn't quite understand why we saw this 26-minute frequency, so one of the thermal engineers from Harris started to do fast Fourier transforms [FFT] on temperature data. We had about 1,000 sensors, and so he just started taking FFTs of the temperature data and saw, "Hey, this one here—which is one of the ISIM instrument thermal panels—has the same frequency that we see on the wavefront."

We all said, "Well, that's just silly. There's no way that would happen." Then we did further testing and verified that "Hmm," when we changed that frequency on that panel we actually saw that same frequency change in the wavefront. So it allowed us to do some testing and some verification that said, "Ah, okay. That's a ground problem."

How we had this panel supported during testing was different than how it would be supported in flight. This will not be a problem during flight, but it did provide us some very important information for example on the sensitivity of the hardware and, "Was this going to be a problem in flight or not?" That's one of the examples of, again, the quality of the test equipment I think being far above what we expected. It allowed us to really interrogate the hardware, make sure that on orbit things were going to be fine.

ROSS-NAZZAL: What are your memories of the day that OTIS arrived at NASA here in Houston? Do you have any specific memories of that event?

MATTHEWS: Yes, I was down there. It was very interesting. It's something that we'd looked forward to for 4 years while my team had been at Johnson, but really 14, 15 years in the planning stage. It was like, "Wow, it's here!" Extremely fulfilling to be there that day and to be able to be part of, in my professional experience, something that monumental, and being able to be there and to help unpack it.

Literally pushing it into the clean room. Getting that lid off and getting it onto the roll and turnover fixture. It's like, "Wow, it's showtime!" Being responsible for the optical test equipment, it's like, "Our time has come, and we've got to perform here. A lot of people are counting on the team standing here right now to get this thing on the test equipment, get it hung, and get this thing cold so we can do some optical testing."

ROSS-NAZZAL: How long did it take to unpack everything and actually physically move it into Chamber A?

MATTHEWS: We got there in early May, and we started testing in mid-July. So about two and a half months to get it out of the container, into the chamber, and ready for testing. A lot of people worked two shifts, six days a week—so about 20 hours a day, six days a week—for that two and a half months, just to get everything ready to go.

ROSS-NAZZAL: I wonder if you can talk about working in the SESL itself. Once you had her in the chamber I understand you had a control center in Building 32. Talk about monitoring the telescope as you started to decrease that temperature, and some of the testing that you guys were working on.

MATTHEWS: Sure. When we first pumped down, one of the things we fought with were chamber leaks. We had done a lot of work to make the chamber as tight as possible, because small chamber leaks—again, air and water coming in are detrimental. They actually freeze. Certainly everybody can understand water freezing, but when you're at 20 degrees Kelvin everything becomes ice. Nitrogen and oxygen become giant ice cubes on your test system.

When you start to warm up there's a thing called a burp. When that ice melts it actually sublimes from an ice into a gas again. If you've got too much ice in there and it melts all of a sudden, you can lose vacuum. I think it flashes off at about 26 Kelvin, 30 Kelvin, something like that. If you have too much ice in there you could completely lose vacuum, and that'd be extremely detrimental. You'd have all this air coming in all of a sudden, you wouldn't be able to keep up with the vacuum rates, and you could do some serious damage.

We needed a tight chamber. You have all these holes in the chamber to get wires and cables and everything through, so we'd fought with that quite a bit. In mid-July when we first pumped down, seeing that we had the tightest chamber we'd ever had before was the first sign of relief for me personally, that we had a tight chamber. So we'd gotten over a major hurdle.

Then it takes about 30 days to cool down. We spent half of July and the first two-thirds of August just getting cold. When we're getting cold there's some testing we can do, but nothing truly serious. We can get the primary mirrors kind of aligned, even though they're changing a lot. There's some stability things that we can look at as we cool down. …

No serious testing during that first month, but just making sure we have a controlled cooldown. You can break things. If you get a gradient across a couple pieces that are too big, you can actually break hardware at these kind of temperatures. Making sure we kept the gradients under control, the temperature differences between various pieces controlled, so that we don't damage any hardware—that was really the real key during that first month and a little bit to make sure that we didn't hurt any hardware.

Then, just before Harvey, we got stable and actually started doing some optical testing.

ROSS-NAZZAL: What was your role during the various testing that was going on in the SESL?

MATTHEWS: It was on and off. I was test director for some of the time. It's a 24 [hours a day]/7 [days a week] operation, so three shifts a day. I would come down and be test director for maybe a week at a time, maybe a little more, actually helping choreograph the test. The test director makes sure what's going to happen, what's coming up. He doesn't actually do any testing himself. He just directs the various areas to make sure that they're ready for this test. We had a test conductor and a test operator who actually sent commands.

There were optical test folks doing optical testing. There was flight thermal; there was GSE [ground support equipment] thermal folks. There was contamination control. Northrop Grumman was monitoring the interfaces through the spacecraft simulator, Ball Aerospace was monitoring the telescope mirrors, etc.

So the test director choreographed all of those different organizations, including the JSC thermal and vacuum system, and keeping the test on track. We had a large two-screen flow in the back of the control room that showed where we were, what tests were coming up, etc. My job when I was test director was just, again, choreographing all the things that had to happen during that shift.

ROSS-NAZZAL: Were there any major challenges that happened when you were a test director during one of those weeks?

MATTHEWS: Not really. Overall the tests went extremely smoothly. I think that is very much due to the upfront testing we did. We had a couple people that did nothing but planning. We certainly had a lot of changes through the tests, but when we came down to actually performing test A for example, that test went extremely well. But there was a lot of work coming up to that point that really allowed that to happen.

ROSS-NAZZAL: Are there any changes that need to be made to the instruments as a result of the test that was done here in Houston?

MATTHEWS: Some very minor changes. There were some mirror closeouts, for example, that we need to do some minor modifications to, but in general the telescope is very healthy. It worked as designed. There's always some little things, but nothing that is terribly concerning that, "Oh my goodness, we're going to have to tear this thing apart and do some major redesign." The data in the telescope really points to a system that was ready to go. So that's a pretty good place to be.

ROSS-NAZZAL: You had mentioned Hurricane Harvey, so I wanted to ask what impact did that have on the tests? Were you here during that time?

MATTHEWS: No, I was biting my fingernails up in Greenbelt [Maryland, NASA Goddard Space Flight Center]. It's an amazing story. Houston had not been hit with a [major] hurricane, you probably know better than I do, like in 30 years. When we first started to think about going down there in the early 2000s, "Well, there's hurricanes, but hasn't been one in"—at that point 20 years.

It wasn't a huge concern, but as we started to really plan for OTIS being there we did do a lot of hurricane planning. A lot of us took FEMA [Federal Emergency Management Agency] training. "What if we're on the clean room floor and a hurricane is coming? How do we safe that hardware?" We built some special emergency tents, for example, that could be deployed. We had contingency plans on how we were going to handle that, if we were, like I said, on the clean room floor. Once we were in test, we had several "slices in time" I'll call them where, "If it happens at this time this is what we'll do. If it happens during when we're very cold this is what we'll do."

A lot of planning for personnel safety. "Where will people go? How will we evacuate people? What kind of training do people need to be on the ride-out team, what training do people need if they're going to be in the facility during a hurricane?" A lot of planning went into actually getting through a hurricane that most of us thought, "Well, it hasn't happened in 30 years, what's the chances it'll happen in 2017?"

That's history now. It did happen at probably the worst time, when we were stable cold. It happened much differently. The planning was pretty much around I'll say a normal hurricane that would roll through and be gone in a day or so. This thing kind of just hung out for a week and rained like heck. The scenario really morphed over time.

Certainly the main concern was personnel safety. You can fix hardware, but we wanted to protect the folks that were there. We were stable cold, and we got people into safe locations. We did keep one shift of people in place at Johnson to ride out through the storm. The rest of the people were either moved away or they were in what we hoped were safe places.

We just kind of let the system sit there cold, and as long as we had electricity we could keep it stable cold. We did have contingencies. If we lost electricity, it would warm up rather quickly to nitrogen temperatures, and that was planned if that happened. But somehow the electricity stayed on. We just let the system sit there for I think it was a couple weeks. It was a couple weeks of nail biting to get through that.

ROSS-NAZZAL: I can imagine, especially being in Greenbelt and not being able to see, other than what was on the media, which was impressive, the amount of water that was coming in.

MATTHEWS: Yes. The roof—everything leaks, there was water pouring down into the control room. They had to make kind of a little hut to cover the computers in the control room. The chamber obviously stayed dry, but you do worry about all this water coming in. "Could it start to short out equipment and really be detrimental?"

Having to live through that from afar was stressful. The people certainly in the middle of it were obviously more highly stressed. You couldn't move. So between monitoring the hardware, and trying to sleep, and trying to eat was much more stressful than what I was going through. People really did a heck of a job in not losing the test during that period of time.

ROSS-NAZZAL: We haven't talked much about all the various testing that happened once it was in the chamber. Can you give some of the major highlights of those tests that were done?

MATTHEWS: Sure, there were obviously telescope tests and then system tests. There were certainly tests to verify the telescope itself. For example, we phased the primary mirror, we aligned the secondary mirror. We looked at the overall wavefront of the telescope and made sure that was adequate.

There were some thermal sensitivities of the telescope that we did. When we were transitioning temperatures, for example, we would look at, "How did the telescope change alignment during that change in temperature?" On orbit you may be looking in one location with respect to the Sun, and then when you slew over and look at another location, that angle to the

Sun changes slightly. It will change the gradients, the temperature of the telescope a little bit. The telescope is designed to be able to do that, so some of the testing was designed to understand, "Will it do what it's designed to do on orbit?" Those kind of tests were done.

There was a lot of testing of the science instruments, again, looking through a real telescope for the first time: the NIRCam [Near-Infrared Camera], the NIRSpec [Near-Infrared Spectrograph], the MIRI [Mid-Infrared Instrument], the NIRISS [Near-Infrared Imager and Slitless Spectrograph], the fine guidance system. Those were all tested to make sure, again, looking from a real telescope perspective, "Did they respond the way we would expect them to respond?" There were, again, telescope tests, instrument tests, OTIS tests where the whole system was tested end-to-end. That was done during that cryogenic time period.

ROSS-NAZZAL: Were you down here as the test came to an end and was rolled out of Chamber A?

MATTHEWS: Yes, I was down there. We did some testing at the end, again to understand this thermal sensitivity problem we had uncovered. Then I was down there pretty much through putting it on a plane and shipping it out to Northrop Grumman in California.

ROSS-NAZZAL: Looking back, what do you think are some of the more memorable moments or events that you recall while you were working on this test? You were working on it for many years, not just the time that it was in the chamber obviously.

MATTHEWS: I think I've been through this a few times in my career. It's always satisfying to see the hardware being tested. That's certainly one of the highlights, building hardware that is going to perform on orbit.

Almost beyond that are the people, the relationships that you develop during these times. You almost become a family. In fact, I think last year I spent more time with people at Johnson than I did with my own family. You build up this relationship with people that you really miss when it's over. As the telescope was leaving, you look at this team of people that you've spent the last between [5 to 20 years] years living with.

It's very much a mixed blessing, I have to tell you. It's mixed feelings of "Geez, this is coming to an end. All these people are going to go in different directions and do other great things, but they won't necessarily be doing that with me." There is really a sense of "Wow, I'm going to miss all this." That's almost as, and maybe in some respects, even a bigger reaction than seeing the hardware leave, is the relationships.

ROSS-NAZZAL: You had mentioned earlier you had worked on Chandra. Are there similarities, or is it a completely different experience working with James Webb and OTIS?

MATTHEWS: From the team perspective, I think very similar. We worked 10 years developing Chandra. Again, very specialized test equipment there down at [NASA] Marshall Space Flight Center [Huntsville, Alabama] to be able to test in x-rays versus really cold. So very different wavelength spectrum but very similar problems and challenges that you have to deal with.

Again, a very family feeling. In some respects it's the Thanksgiving dinner that never ends. These large programs take large teams of very dedicated people to make successful. We become very focused on that end, and this family just becomes totally focused to make this thing happen.

In each of those cases it takes a lot of dedication, a lot of personal sacrifice. A lot of people—and I can't even begin to give you a number—spent most of 2017 away from home, away from friends and family. Same thing happened on Chandra. Years spent away from home, or working two and three shifts a day, six days a week with very little [few] breaks to make these things happen. That's a similarity that I think is common in many of these large programs.

ROSS-NAZZAL: You mentioned you were working before the test for about four years on the hardware that was going to go into the SESL. Did you relocate to Houston or did you remain up in the Maryland area?

MATTHEWS: I actually relocated from Rochester. I was in Rochester for about 35 years, and I relocated to Greenbelt in 2010 to be closer to the hardware. At that time, we were going to be building the telescope for Northrop Grumman. We were going to be developing all this new hardware for SESL. I decided that I really needed to be closer to all those people to make this thing successful. My kids were grown, so my wife and I relocated to Greenbelt to be closer to NASA and be closer to the hardware. Even though I wasn't relocated to Houston, being closer to NASA so that we could, on an hourly basis, try to figure out how this thing needed to happen.

Harris did relocate about a half a dozen people to Houston, but most people traveled back and forth. They would stay for three or four weeks at a time and work.

ROSS-NAZZAL: What do you think were the most significant challenges for you during your years working on this test, getting things ready, or during the test or afterward?

MATTHEWS: Just the long-term worry of getting this complex test system to all work at one time. You get a piece to work now and a piece to work later, but could you get this whole complex animal to work for 90 days when it needed to work?

[In the] tests [leading] up to the OTIS test, something would always go wrong. We tried to put everything in place that we could to make that happen. Some of the equipment was getting old. A lot of it was designed I'll say between 2007 and 2010. It was designed, and we actually built a lot of the hardware between 2010 and say 2012, 2013. Started putting it in the chamber in '13, so some of it was getting old.

We had a couple computers still running [Windows] XP that as you know—I forget what year it was, but Microsoft said, "If you have an XP machine, you're done." For example if you got a new motherboard it wouldn't run XP, that motherboard would not support the peripherals that it needed to run. We had a lot of plug-in boards that would run various aspects of the test hardware. And a new motherboard, those interfaces were all different.

That's fine if you're at home or you're in a commercial environment where you've got constant turnover, but these were one-off items. A year before the test we actually went out—there's a company that had bought all these motherboards, and they'd bought a whole stack of XP licenses. We actually built an old computer as a backup, because we were concerned if one of these computers died, you couldn't go out to Fry's [Electronic's] or Newegg and buy one. We started to put in place some backups such that if we had a computer go down, a motherboard go bad, we could actually have something to plug in there. That was one of the big challenges, making sure some of this aging hardware, we could get it through the test. So we put some insurance policies in place to make sure we could do that.

ROSS-NAZZAL: That's funny. You think of NASA as being the leader in science and technology, but to hear you're using XP machines, that's kind of amusing.

MATTHEWS: Yes.

ROSS-NAZZAL: What do you think is your most significant contribution to the test?

MATTHEWS: Oh, it's pretty minor actually, I think. For most of this test I was just an orchestrator. I was just directing a lot of really smart people and very dedicated people to do what they do. My part of it I feel was pretty inconsequential compared to what I saw a lot of people doing through this test. I can't thank those people enough for the dedication they had and the commitments that they made to make this test a success.

ROSS-NAZZAL: Do you think that this will be your last project of this type? Will you be retiring soon?

MATTHEWS: I hope not. I'm working on some new programs. WFIRST [Wide Field Infrared Survey Telescope] is a very exciting program with some really fantastic science. Not only in dark energy, which is its main thrust, but also the possibility to fly a coronagraph for the first time in space is very exciting.

As we start to think about future systems, with respect to the 2020 decadal survey for example, I think planet finding could be—it's certainly in the mix—a very exciting science. I think the public is very enamored. The big question, "Are we alone?" Flying a coronagraph and getting that on-orbit experience I think is going to be very exciting.

There's programs called LISA [Laser Interferometer Space Antenna], which looks at gravity waves. They've verified gravity waves on the ground with LIGO [Laser Interferometer Gravitational-Wave Observatory], and the sensitivity we'd get in space would be phenomenal. There's some really fantastic science being thought about, being planned. There's the four decadal studies going on right now from x rays out to far IR. Yes, I'd certainly like to be involved in helping get some of these new programs started, getting WFIRST well on its way. I hope I'm not done yet.

ROSS-NAZZAL: You sound like you've had a great career. Before I let you go—I apologize, I've run over by just a couple minutes—are there any other people you think that we might want to talk to to capture some of this history?

MATTHEWS: Sure. Lee [D.] Feinberg, Charlie [Charles B.] Atkinson. Probably Allison [A.] Barto, Mark [F.] Voyton, Juli [A.] Lander, Ritva Keski-Kuha I think would be some great folks to talk to.

ROSS-NAZZAL: Great, always like to ask people. Conrad Wells had given me your name, and so I wanted to just have other people weigh in. I wanted to ask though, before we closed out today—was there anything else, or something that you wanted to talk about that we did not cover that we should know about the test, or your involvement that you wanted to put on the recording?

MATTHEWS: No, I don't think so. I think we did a pretty good job of covering everything that I can think of. Is there any other directions you wanted to go?

ROSS-NAZZAL: I don't think so. I think we've covered the highlights. As we move through we'll have different questions for different people. You're the first interview for this project. We will learn more about the test, we're interviewing Jonathan [L.] Homan on Thursday. I think we'll get a different aspect there and see what comes of that.

I really do want to thank you for your time today. Like I said, we'll be sending you a copy of the transcript so you get a chance to review and edit. If there's anything you want to add, feel free. I appreciate your time.

MATTHEWS: I appreciate the opportunity. Thank you.

ROSS-NAZZAL: Thank you. Good luck with your upcoming projects, they sound fascinating.

MATTHEWS: Thanks.

ROSS-NAZZAL: All right, have a good day.

MATTHEWS: You too, thank you. Bye.

ROSS-NAZZAL: All right, bye-bye.

[End of interview]