SRB RECOVERY SHIPS ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

MANNY DE LEON
INTERVIEWED BY REBECCA WRIGHT
CAPE CANAVERAL AIR FORCE STATION, FLORIDA – 10 APRIL 2012

WRIGHT: Today is April 10th, 2012. This oral history is being conducted with Manny de Leon for the SRB [solid rocket booster] Recovery Ships Oral History Project. Interviewer is Rebecca Wright, assisted by Jennifer Ross-Nazzal. We are here at the Cape Canaveral Air Force Station [CCAFS] in Hangar AF in Florida. If you would, just give us a brief overview of how you became involved with the space operations and then how you became part of the SRB recovery ship operation.

DE LEON: I went back to school at Embry-Riddle University in Daytona Beach [Florida]. When I was graduating, Thiokol Corporation [Morton Thiokol, Inc.] came up, did interviews, and hired me. I actually had been in Florida for all of the first ten Shuttle launches. I either drove down, or we would rent a plane, fly down and be over the river, over the land, and watch the launches that way. Then I hired on after STS-10 and was working here doing external tank engineering for STS-11. STS-11 through 51-L [the *Challenger* accident] I was working in the VAB [Vehicle Assembly Building] and at Vandenberg [Air Force Base, California]. Doing external tank engineering in the VAB, and then for Vandenberg we were activating the launch site for West Coast Shuttle launches, which of course never happened because when *Challenger* happened they abandoned West Coast operations. Retrieval operations needed engineering to continue so they borrowed some engineers, including me. I came to marine operations at that time and have been here ever since.

WRIGHT: What were some of the first things that you started working on when you walked into this operation?

DE LEON: In this operation most of the [Kennedy] Space Center [Florida] was concentrating on redesigning flight hardware, and nobody was working on the GSE [ground support equipment] processes for it. [NASA] Marshall Space Flight [Center, Huntsville, Alabama] was doing a lot of it, but there was a lot that was falling through the cracks. My boss saw a need, and we started working on, specifically, assembly GSE for the solid rocket boosters. We designed and built some new equipment to do just that, because in the past when they stacked SRBs it was hit-and-miss. I don't know how familiar you are with SRB assembly, but there's an instrumented aft skirt. On top of that there are four segments that join together. They are hermetically sealed; they actually make one huge 1,000 psi [pounds per square inch] pressure vessel. Then there's an instrumented section on top and parachutes on top of that.

Well, the four segments that go together weigh in excess of 250,000 pounds, and they fit together in tolerances of tens of thousandths of an inch. So the fit is difficult and critical. It used to be it wasn't really a well thought out process. Before *Challenger* it was a lot of work to get them together. That's what my particular set of projects concentrated on, figuring out, characterizing how to make them fit better. We spent a lot of time and effort making new hardware to do that. After return to flight [STS-26, first launch after *Challenger*], we went back to our duty of SRB retrieval and handed over the GSE stuff to the folks that do GSE, but they continued to use our equipment till the end of the program.

WRIGHT: Can you give some examples of some of the new equipment?

DE LEON: My particular project was called a sine bar. It was actually with some consultants, specifically Walt Whippo in Cocoa Beach here. He did the conceptual part of it and then we implemented it with him. It's a very accurate—you determine the shape of this twelve-foot diameter booster to within a few thousandths of an inch by measuring an arc that's thirty inches across. You know in a perfect 12-foot diameter circle—144-point-something actually according to the drawing—in this 30-inch arc what the three points that define an arc would be. So you measure very accurately and then you measure the next thirty inches. You go all the way around the booster, and you mathematically tie those together and then generate a shape.

You do that for the top of the segment that you're going to stack on and you do it for the bottom of the other segment. You figure out where the match is and most of the time where it isn't. When they fill SRB rocket segments they do it vertically. It's a huge 250,000 pounds of propellant pour. And the cure is not completed in the vertical, they actually cure it on its side. They call it a bread loaf effect. It takes a shape because the propellant finishes curing on its side. It takes a shape that isn't round, and it's sufficiently so that we tried different tools. We ended up with what is basically a funnel, a huge strong funnel that we attached to the bottom segment, and dropped the top segment on top of it.

They used to lift the booster at two points, and although it's a very slight deflection, it would cause the booster to change shape. So we started picking it up at four points and then varying the load to try and match the shapes as close as possible. Then you could shoehorn them together. Rick [Richard P.] Tubridy was part of the group of people that designed the set of shaping tools, things to try and force it to be to the right shape just before you join it together, and what they call the FJAF, the flight joint assembly fixture, to shoehorn them together. That was the biggest project I worked on during that time.

I also did a bunch of computer work for different assembly aids. One of the things we didn't know—nobody had ever characterized what the events were during a field joint mate. There's an interference fit, and there's three O-rings in there. When the joint comes together, nobody had ever actually taken a really close look at that process. The reason they made it a priority was because as some of those O-rings went in you would damage them. So we created some measuring equipment that very accurately measured the vertical displacement of the relative position of the joints as it was being mated, measured forces on the crane as it was coming down, and figured out what all the processes were as they were being mated. It was good work; it was interesting.

WRIGHT: Very interesting. How did your role change after those issues were addressed and into return to flight?

DE LEON: Once we did return to flight, we tried to keep doing different work with the sine bar, since it measured a large circle. We actually went and did a job for the [U.S.] Navy at the Kittery Shipyard [Portsmouth Naval Shipyard, Maine]. They have issues with submarines that are very large cylinders, and they had us measure one that they were having some issues with.

Outside of that, we stopped doing non-Shuttle engineering. After we came back to return to flight and we started having a reasonable flight rate, we didn't have a lot of time for anything else. Booster retrieval, disassembly, and refurb [refurbishment] was our reason for being here, and we just did that. In this facility we have the ships, we have all the people that man the ships.

We'd go out before the launch, wait for the launch, bring the boosters back, disassemble them here in house.

On the other side of the hangar we have a facility where we would refurb parts of it. Parts of the pressure vessel, once we disassemble them and inspect them, would go back to Utah where Thiokol Corporation—nowadays it's ATK [Alliant Techsystems, Inc.]—refurbished them. Everything else—the aft skirt, the instrumentation, the thrust vector control system, the parachutes—was refurbed here on the Space Center. Since we never developed a good fair use specification we always took everything back to bare metal as if it had just been built. Inspected it, and if it passed, then started priming, painting, reassembling, working towards a new launch. Most of that was done here on the Space Center, a lot of it here on the Hangar AF complex.

WRIGHT: You mentioned that prior to *Challenger* you were working at the VAB, and now you were here. What was your role, and how was your role defined after the return to flight? What exactly were you starting to do? You mentioned you were a diver, so they were glad to have had you.

DE LEON: Yes, that's the reason they kept me here at the hangar. As an External Tank engineer I was a process engineer. I prepared the External Tanks for flight and dealt with problems in that process. We started doing validation for the tank facilities at Vandenberg. Then *Challenger* happened, and I came down here to the hangar. My title is engineer primarily, diver is a sideline. All of our divers, all of our retrieval personnel that aren't ship's crew—and ship's crew is a very well-defined group, because you have to have a Coast Guard certification to do this—the rest of us who went to sea to do booster retrieval were considered retrieval crew, not ship's crew. There were only three that were full-time divers. When we weren't doing Shuttle launches, they were doing maintenance of the dive equipment, the recompression chambers, the small boats that we use offshore. The rest of us would go back to our primary job, in my case engineer. We had welders, we had technicians, we have safety engineers from across the [Banana] River. We say 'across the river' to distinguish between workers on KSC proper and we Shuttle workers who are on CCAFS, where hangar AF is.

My primary engineering duty was dealing with disassembly of the boosters. When we received boosters back from a launch we started the process of taking them apart and setting them up for Thiokol and NASA personnel from here, from Marshall primarily, but also from Houston [NASA Johnson Space Center, Texas] to do some postflight performance assessment. I would deal with all the ground support equipment, was involved in setting them up for that. Then once they got done with the assessment, start the refurb process.

WRIGHT: Can you share with us some of the changes or the evolution in the processes of when you first started in that role to, as we closed out the Shuttle program how that might have changed or improved? Or some of the things that you tried that didn't work as well as you had hoped?

DE LEON: Well, the process has been very similar from the start because the hardware hasn't changed a lot. Before my time here they made a big change due to SRB redesign driven by the *Challenger* incident. When we recover the boosters there's 200,000 pounds of booster in the water, and they float vertically. We can't really bring them back, something that big, towing it vertically. So we have to cause it to float and lay down in what we call log mode. The way you do that is you shove a plug up in the bottom end, push air in that forces the water out, and then it'll rise up and lay down in log mode.

Originally, just before I came to the hangar, they were trying very hard to do this with an ROV, a remotely operated vehicle. It was a plug that had motors and cameras built into it. They were going to basically, from the ship, drive this plug down up underneath the booster and shove it up in the booster. That never really worked well. We ended up having to come up with an alternate means, until they basically gave up on it and started doing a manual-type plug. The same function, just a lot smaller, because it was powered by divers.

We've made small changes to that ever since, but again the basic function is still the same. You have to plug the booster, you have to dewater the booster, you have to tow it back, you have to recover the parachutes. Parachute recovery has changed. Before *Challenger*, we used to separate parachutes by hand. When the booster splashes down you have the booster floating in the water, and these 115-foot diameter parachutes, three of them, hanging off of it. It used to be a manual operation where you would physically separate the parachutes from the booster. I think there's 36 connections, and they're just below the water level. So when the weather was bad, when there were seas, it was a very difficult, time-consuming operation for divers. You have to hang on with one hand, uncover this connector, and with one hand do a two-handed operation where you push a thumb set, slide a cap, and then pull the connector apart.

In fact I think *Challenger* was when they were going to try and fly the first automatic disconnect. On the forward deck of the forward skirt they had a system where, as the booster hit the water, the parachutes would be separated. They had a pyrotechnic nut on each of the six connections on the top deck of the forward skirt that they would pyrotechnically sever. There was still some load on the parachutes, so the parachutes would just pop off and separate and float so we could get them separately. That was a big change.

STS-63 they figured out that was a real problem in high crosswind splashdowns. The booster would be coming in with good horizontal speed, and if you had a high wave, the booster would hit the top of the wave. It would trip the booster, so it would start to fall, but at the same time the sensors would think that it had already splashed down so it would let go of the parachutes. You'd have this tremendous weight impacting on the water, and we lost that set of booster hardware. Those two boosters, most of them were ruined, not reusable.

So they came up with a new method of doing it whereby the parachutes don't completely separate, they just go on longer tethers. The divers then still have to separate it, but we don't have to actually do a connector. We could tie to the parachutes and cut them. We've improved lots of small things about the process, but those are the major things, that and being able to do underwater photo and video. That was never a priority for some of our local management; they didn't like that.

WRIGHT: Let's talk about that, because that hadn't had a record before you came. How were you involved, and how has that technology changed to allow you to do more documentation?

DE LEON: Before I came down we had some limited—but because the technology wasn't there, the cameras were huge and bulky, and that interfered with the dive operation itself. Our local management didn't put a priority on it. A fellow named Wulf Eckroth used to do that, and then he left the company, and I started. I picked up where he left off and had the good fortune that we changed management, and they were very willing to allow us to take photos, take videos, make a visual record of it. Since then, as technology has gotten better the cameras get better. You can do photo, you can do video, and you can do it with a minimal interference with the job.

WRIGHT: Can you walk us through either a mission that you remember or just the process of how you train someone as part of the dive team to record this documentation? I understand sometimes you immediately use it when you're back on the ship. Just to give us an idea of how that whole process works and how valuable it is to training and for safety.

DE LEON: The dive team has been very stable. We have folks that have been here almost since the start of the program. There was actually very little turnover for the retrieval team, because it's good work. We enjoy going offshore and doing this. Everybody who's here does it because they want to. It's not just a job; it's something we want to do. So training actually, the first group learned by doing it. There wasn't anybody around to learn from. For those of us who have come since, we joined the group in small numbers so there were a lot of people around to help out the new guys. You go out, and you talk about what you're going to do. They give you a job. You go work it. You have enough people around that are doing their job and keeping an eye on you, making sure that you're getting yours done. As you do this a few times, you go offshore, you do your work, you are part of the group. It's an OJT [on-the-job training] program really, because there really aren't a lot of ways you can train to recover a 200,000-pound object offshore. There aren't any.

WRIGHT: Is there a minimal amount of time that you have to put in certain training procedures before you're actually used in a mission?

DE LEON: Yes, absolutely. To join the group of divers you have to be at least a certified scuba diver, advanced scuba diver. That's the most basic requirement, and you have to have logged thirty dives, a fair number of dives. You can't just have gotten your cert [certification] and expect to come do this work, because scuba is really just an operational aspect that gets you to the job. So if you're not really familiar with what you're doing underwater, your concentration is going to be there rather than on your job. There's a minimum experience level.

After that, of course you start training. We have a physical fitness test that you have to do every quarter. You have to pass that. You have to dive with the group. We used to do more training dives, but unfortunately we're not doing enough of that. You would have to go out on a certain number of training missions. We do go inland to blue holes, to freshwater dives to practice. You have to do a certain number of those, and three deep dives with the group before you would actually be able to go offshore and do the booster retrieval. Then when you're at booster retrieval you get the least complicated work, which is pushing the DOP [diver-operated plug]. Physically it's a lot of work, you just hold on and swim. The installation of the DOP is not difficult, but you have to be aware of what's going on inside the booster. You have to watch that the plug seats before you latch it. Then there's a process to seal the connection and attach the air hose.

So for somebody who's just getting started, there's a job that requires you to be there and then gives you the opportunity to watch and see what's going on. And it's also an evaluation. We've had divers that came out and ended up not being able to do the work because just it was an overload for them once they were underwater.

WRIGHT: It certainly is a different type of activity than a scuba diver would do, because you're actually doing work.

DE LEON: Yes, the scuba is just a means to get to your work, yes.

WRIGHT: How many divers are on a retrieval team?

DE LEON: Typically we take out eight divers. We're all retrieval crew and divers. We try and break that up. The underwater work takes anything from twenty to thirty minutes of work underwater. The first part is the hardest, installation of the plug. Depending on the weather we will send typically four people to do that and hold the rest of the work for the last four. If there's bad weather, if the booster is surging, if you have issues with the nozzle—every splashdown is different—the nozzles get torn up. If there's problems installing the DOP on the first dive, you have a second team that can do that. We're limited by Coast Guard regulation to no decompression dives, so we have a limited amount of time underwater. We have basically the two dive teams to do the work, and if we don't get it done then we have to wait a day till all the divers are fresh again.

WRIGHT: Has that happened on occasion?

DE LEON: Yes.

WRIGHT: Can you give us any examples?

DE LEON: I don't remember the exact mission, but there was one where the seas were such that the booster surge was tremendous. The thing weighs 200,000 pounds, but it's still just floating in the water. You have this object that's going up and down in the waves, and because of its mass, if the waves are the right period and intensity, it creates a situation where it reinforces the motion of the booster. The booster will go up and the wave will drop out from it, and then the booster will fall. Of course 200,000 pounds, the mass, it doesn't just go back to where it started, it goes beyond there. If you have the right sympathetic situation, the wave rise again gives the booster more flotation, so it goes farther.

We've seen 15 feet of the booster going up and down. It isn't real fast, but it's irresistible. Like I said, the first thing you do is push the plug down. The plug weighs 1,600 pounds. You can't get between it and the booster, or you will be hurt, so you have to swim the plug down with the booster going up and down. On top of which, the booster out of the water acts like a sail. If you have a lot of wind, in addition to the wrong conditions in the waves, the booster will travel because of the sail. And as it's high, the wind can push it so it'll actually also have a kick. It's doing up-and-down and side-to-side motion.

You're trying to push this 1,600-pound object down the side of this moving booster. When you get underneath it, you have to hit the nozzle hole. You show up down there with the plug and all of a sudden the nozzle just picks up and goes over there ten feet. You go after it over there, and now it's over here. Now it's up and now it's down. We've had occasions where you just expend the divers. You're not only swimming down, you have to swim to keep up with the booster as it's traveling. You get to the bottom, and you chase it around to the point where you run out of time. So you leave the DOP and let the next team try it, and we've done that. I recall one launch where we couldn't get the DOP in and the weather got worse, so we just called the operations and we waited for a day. The weather got worse, and we waited for another day. Then the weather cooperated, and we could get the plug in. We did the job and came home.

That was unusual thankfully, but there were several occasions where you get the DOP down in there and for whatever reason couldn't get it seated. Once you push the air in and you have the booster laid over, you have a check valve in the hole where the water comes out. We put a check valve in the hole where the air goes in just to make sure that once you disconnect it's not a path for water. Well, the check valve broke. So we got the plug in, we have the booster, we're pumping air to it, and nothing's happening.

We had to physically go back down to the bottom of the booster, extract that plug—having planned for such possibilities; we carry a spare onboard—take the spare and put it in and then do the rest of the retrieval. It's always something; very few trips went without some issue. Like I said, the first operation separating the parachutes, there was always issues with the parachutes tangling with the booster. Usually it would only take a few minutes to separate them. Sometimes the parachutes would be tangled with themselves once you got them off the booster, and it was very often that we would have two parachutes tangled up on deck come up together. Occasionally we'd have all three parachutes in one big ball. It was never one trip that was the same as any other.

WRIGHT: You just train the best you can.

DE LEON: Yes, you deal with it as it came, because that's all you could do.

WRIGHT: When issues would come up, how was the communication between the divers and the people making the decisions? Explain that process, using that scenario that you just talked about. Things changed, so you had to go back and rethink, and go back and redo.

DE LEON: Well, before every operation we generally categorize them as hazardous operations. Anything that has a hazard or risk to the people or the hardware, we'll have a pretask briefing. We do our pretask before the trip, before the mission, the specific job. But once the divers get in the water, there really isn't any communication. It's just us doing the job, and you deal with the problems that come up as best you can. If you can't, then every individual has the opportunity to call a timeout and just say, "No, I don't think this is going right. There's a risk to person or hardware," and we all have to respect that call and just stop and regroup.

We've had very few occasions where that happened. We usually would attack a problem and figure out that we weren't going to overcome it, so we would go back to the surface and we would have another pretask. If we knew what was going wrong, we could figure out how to deal with it, or at least the next thing we were going to try. Then the next team of divers—or if the problem was on the surface, if the problem was with a parachute, that group would go do it. But during the actual operations there's not a lot of coordination that you can do with the divers underwater.

We do have an underwater communications system, but it's cumbersome so we give it to the safety diver. There's one diver whose only job is to watch out for everybody else. He doesn't have a physical work job, he is just there to make sure that nobody gets in a pinch. If somebody does get caught by something, there's somebody that sees it and can start to do something about it. He is typically the one that wears the com [communications] unit, and he can talk to the ship, relay, "We're at the aft skirt, we're installing the plug, we've got the air hose connected."

Thankfully there were very few occasions when he had to call up and say we have a problem. One time he actually had to call and say we've lost a diver. One of the divers had to abort. On the way down he couldn't clear his sinuses so he had to go back to the surface. We also have what we call a standby diver, somebody that can jump in the water if we have a circumstance where a diver has to abort and can't finish the job, or if something should happen and you need an extra set of hands. On that one occasion—and that's the only time I can ever remember that it happened—the safety diver called up and said we had a diver abort, and they sent the standby diver in after the other diver came to the surface. He was all right, just sinus squeeze is something that happens.

Once you're underwater, the team has to know what they're doing and be able to communicate with each other and attack a problem, because we're on our own.

WRIGHT: In the team of four you said that one was the safety. Is one a lead?

DE LEON: Well, the lead is nominal. You have certain tasks that have to happen, and anybody can do them, but somebody has to decide who's going to. We take turns, "For this dive you're going to be the lead." That person says, "You're going to hold on to the float ball." As you push down the diver-operated plug, it's got a flexible hose on the end of it so that when the booster is in the horizontal that hose has a weight on the end. We call it a catcher's mitt; it's a metal grate. That hose is pulled down by gravity, so it seeks the same place as the water is. You draw as much water out of the booster as you can.

In order to keep it out of the way, we have a float ball attached to it. Somebody has to, when you get to the aft skirt, take that float ball and force it up into the nozzle. Somebody has to, after you've done all the pushing, get up under the plug and blow air to make it go up. Somebody has to drop the legs on the DOP to seat the DOP in place; somebody has to inflate the seal bag. Tasks that have to happen.

The lead, what he does is he assigns somebody. One person could do it all once the plug is there, but it's easier and more reliable to break up the tasks. That allows one person to be doing it and a couple other people to be watching, in addition to their tasks. Everybody's workload goes down, so you can do your job and be a backup for everything else that has to happen. The lead and the two working divers—or if the weather is bad you'll have three working divers, if the weather is really nice you can have just one other working diver. The lead is a nominal position. You make the decision beforehand, but when you get there, everybody knows what they're supposed to be doing. You can be doing it and watching and making sure everybody else is okay and that they're doing what they're supposed to be doing.

WRIGHT: The teams of four, do they train together or do you mix?

DE LEON: Yes, everybody [mixes].

WRIGHT: Do the boats have specific divers that work one ship compared to the other ship?

DE LEON: No. The captain and the first mate and the cook were pretty much always with the ship, and a lot of the crew would stay with the ship, just ended up that way. Most of the ship's crew and the retrieval crew, we just went where we were told. We deliberately mixed it up so that everybody can work together. We don't have one group start doing something different and then you get somebody else [to] join them and now you don't know exactly what's going on. You make the whole process transparent to everybody else. Everybody knows what you're doing, and how you're doing it. We have the same expectation from each of the groups.

WRIGHT: Tell us how the photography mixed into this process.

DE LEON: Well, it used to be a sideline. Wulf and I would take cameras down, and when we weren't in the middle of doing something else we would take pictures. Occasionally they would actually allow us to take the video camera. As we got farther into the program the postflight assessment folks wanted some of that video and pictures, so we started doing a specific dive before the retrieval dives that were video and photo assessment. They didn't use them often, but occasionally.

You'd have the boosters here in the building and they would see a ding, a loss of paint, a bent piece of metal. They'd use our photos and videos to try and get an idea of when that happened. If it was something that we did to it during the recovery process, if it was something that was done at splashdown, or the real concern was if it was something that happened during flight.

WRIGHT: How did your group use the photo and the video documentation that you were starting to accumulate?

DE LEON: Not a lot, not for work. The nice thing is that being at sea, being with the ships, being on the water is very photogenic. So most of the use there was just because "I'm in the picture," me and the booster. We archive it, we have kept it for reference, and occasionally we use different shots when we're trying to describe something to somebody. If we have a new vendor for a new part that's going to go on a ship or for recovery, we did have to talk to new vendors because the whole Shuttle system was designed in the'70s and built in the '80s. A lot of the ship's systems, a lot of the hardware we were using, we kept using past the time that anybody else in the world was using it. We'd have a piece that would break and nobody in the world made it anymore, so we'd have to find something to substitute for it. We'd take our videos or pictures to somebody and say, "This is what we used to do. We need a product from you that does something similar."

The other use is the biggest use. We used to go do lectures—schools, dive clubs, universities, the Propeller Club in the Port [Canaveral, Florida]—pretty much anybody who wanted us would ask for a diver to come out and talk about the process. So we'd have a set of pictures of the launch, of the dive, of the different things that happened on the ship as part of a PowerPoint presentation.

WRIGHT: Were there processes and/or technology that you developed that is being applied in the commercial world or industry? Or that maybe you perfected?

DE LEON: No, not really. We have adapted a lot of industry equipment to do what we were doing. We have not actually developed a lot, because our application is unique, there's nobody else doing this. The Ariane [rocket] folks asked us for a little expertise when they were starting to launch their program. Actually it was NASA folks who were asked by Ariane to cooperate. They talked to us about what we did and how we did it, and they ended up doing their own thing using Russian divers once they got boosters back. Their first problem was they weren't getting boosters back.

WRIGHT: What are some of the other modifications or changes that were made to the ships that impacted operations? We've got a GPS [global positioning system] that works well. How did that assist in what you were doing as part of your normal operation?

DE LEON: Improved technology improved the operation. Originally the ships themselves, the hulls, keels were laid about the same time as the first launch. The first launches were recovered using the vessel called the *Bering Seal*. It was a vessel of opportunity, but the ships have been the same ever since. They were built to do this, and very little modification done to the actual vessels. We did install flume tanks. The ships are shallow-draft because they have to come up the river, but for an oceangoing vessel, for stability, what you want is a very deep-draft vessel. Our girls just aren't, so you have this ship that floats like a cork on top of the water, which made them a very bad place to be in bad weather.

In fact NASA used us for some trials for space sickness. The NASA doctors figured out that space sickness and seasickness are very similar, so they wanted to try some new drugs on us. They characterized our vessels, and it turns out that before the flume tanks, we were the number two worst vessel to be on for conditions that would cause seasickness. The one that was worse is the Coast Guard recovery boat. I think she's like in the seventy--foot range, the one that you see in the videos off Alaska where they physically tie themselves in and they can do barrel rolls on top of the water.

As part of that they decided that maybe the ships needed some improvement, so they put in some flume tanks, which is basically a tube that runs across sideways on the ship and has baffles that have a mass of water in it. So as the ship rolls one way, the water goes with it, and the baffles keep it from coming to the other side quickly. It damps the roll of the ship, and it really has helped. It doesn't eliminate the roll, but it used to be when you were on the bridge the ship almost had a snap to it. You would roll from one side, and it would just jump, just snap back and forth, and it's dampened that a lot.

Other than that, the technologies have improved communication more than anything. We go out the day before launch, and it used to be we had radio. You would communicate from the ship to shore, and you would try different frequencies. If you didn't have good communication, you just didn't have good communication. Not a lot you could do about it. When they launched, somebody here would radio a countdown. Terry [A.] Widdicombe used to sit at the desk and radio the countdown and we would know they launched. If the weather was good we would see it. If not, not even bad weather, just overcast, you wouldn't know it until you'd hear the booms of the boosters coming in.

We had our radar sets. If the weather was good you could see the boosters of course, but in bad weather you'd find them on radar once they pop up. When they first hit the water they lay down, but they're still hot. The opening on the pressure vessel is at the back, in the nozzle, so it burps air, takes on water, and the air, the volume that's inside of it, cools. Then they go back vertical. When they're horizontal, with our old radars they were very hard to spot. When they go vertical you'd be able to see them on radar and you'd be able to know where you were going.

Nominally we are seven miles from the impact point. When you launch, you throw something 140 miles away. All things being perfect, you know exactly where it's going to hit, but nothing's ever perfect. You have different densities of air. You have layers with winds going in different directions. So there's an error zone, one in ten chance it's going to be this far.

The ships, I think there was a one in six million chance of them falling that far from the projected point of impact. We're nominally seven miles from impact, but we've been as far as fourteen miles away and as close as three. When they impact, even if it's dark or totally bad weather, you always know they're almost about to hit the water because you hear the sonic booms. There's these two very loud noises, booms, that come down that are associated with the boosters about to impact.

When that happens you know they're out there in the water. You know you have to go. You know what direction you're going to go, but you need things like radar to be able to see them in bad weather because you don't know how far you're going to go. You don't want to run into them obviously. Things like GPS make the job easier, they make things run more smoothly. Nowadays with satellite TV [television] we actually watch the launch, which was something we could never do.

WRIGHT: Do you remember about what mission that was or what year?

DE LEON: STS-85 we were still using radio because it was a bad weather launch. I remember we had marginal communications, though we could hear that they launched. It was probably around STS-100 that we got SATCOM [satellite communications], and it was not long after that that we had satellite TV.

WRIGHT: Were you involved at all when the ships began to bring the ETs [external tanks] in from [NASA Michoud Assembly Facility, New Orleans] Louisiana?

DE LEON: No, not really. There was no retrieval crew, it's really just a minimal ship's crew. I did some photos and video for it, but primarily the ship is a shuttle. It drags the tank from Port Canaveral to Michoud and hands it off at either end to tugs [tug boats]. Although we have plenty of bollard capacity, we can pull; we can't really control something that big, especially when you get it in a channel or near fixed objects.

We need tugs to move the external barge more precisely, so we rented tugs to bring the barge from the VAB to the port, and then we would take the tow from there to Michoud. Tugs would line her up, so really we were just towing. I never made that trip, it was all just ship's crew and back then I was just retrieval crew. Nowadays I do have my Coast Guard cert, but too late to do that.

WRIGHT: What other areas would you like for us to know about the operations that you've been involved in, or other aspects that you think most people don't know that you take care of?

DE LEON: It seems like it's always a surprise to folks that NASA has a little navy. I wish we could do more. We have a lot of capacity; we have a lot of talent. We have a lot of people that can do a lot of stuff, but we're constrained. We can't really go out in the port and solicit work because we have a very unfair advantage. There aren't many ships that are as available as these, and with effectively a low overhead. We used to do—in fact we still do Navy jobs and marine fisheries and NOAA work. They basically pay for the vessels during that time, so they get us cheap. But you can't really do that in the real world because that's very unfair competition. We can only do it for government customers, other government agencies, so we have a lot that we can do and that we can't.

WRIGHT: Jennifer, questions you have?

ROSS-NAZZAL: Yes, I had a couple. You said that you can't really pinpoint where that solid rocket booster is going to go every time, but is there a specific region or area where you know we need to head that direction?

DE LEON: Yes, it varies for each launch, for each mission. The last launches we did were all International Space Station so they were all about 130 miles off Jacksonville [Florida]. There's actually a website that the postflight assessment folks put together. They have a map of all the impact points. When Shuttle was going to Mir the azimuth was lower, so we were still the same distance from the Cape because a Shuttle launch is going very close to the same orbit. The boosters have the same power so it's going to be the same distance from the Cape, it's just a different azimuth. The ISS [International Space Station] were the most northern, then we had the Mir missions. There were a few Department of Defense missions, satellites the Shuttle carried up were at a different azimuth. Then there were a few purely scientific launches where we went due east. There's a band about 140 miles away from the launch pad. It just depends on exactly where on orbit they're going.

Even for an ISS launch it's a moving target. Our charts show the window opening. They're going to land at this spot. And for every minute, that spot moves over ten miles or so—for five minutes it's ten miles. It's a ten-minute window, and we have three sites. They shoot for the center, which is the nominal launch. They let the window open, and in case they have bad weather they can back up. If they see bad weather coming they can just target the launch window opening, but they prefer to go for nominal because that uses up the least energy to get to the Space Station. Then there's up to five minutes after that where they can still launch and still make the intercept with the target on orbit.

So long story short, there's no one place. They calculate it for each launch, and they calculate it for each window opening, midwindow and window closing. We know where that is, they tell us. But there's no Xs out on the ocean that we can point at and say that's where it was.

ROSS-NAZZAL: One thing we haven't talked about is life on board the ship. What's it like? How long are you typically out there? What do you guys do to pass the time when you're not getting that SRB?

DE LEON: Satellite TV has been a great thing. We go out the day before, and it used to be we would come back as soon as we got the boosters, which means we'd be out the day before. We'd have a day of operations if everything went right, and then we'd be coming back for a day. So the minimum trip used to be three days. When you leave the dock, you have to have everything you're going to need because we're 140 miles out. You can't call Ace Hardware and have something delivered; you can't call the pharmacy and have something delivered. The captain has impounded stores for medications. We have everything onboard that you're going to need to do a recovery, so when you leave the dock you're ready.

Basically all you're doing for the first day is traveling to where you're going. Those of us who aren't ship's crew and aren't standing watches—people bring books, used to be we'd bring videotapes, watch movies. We'd read; folks would play cards. On the many occasions when we had launch delays, folks also brought fishing poles. Fishing is something that a lot of people like to do. It's always been on a noninterference basis. If you go out, everything's ready. There's nothing to do for recovery until they actually do a launch, so we're sitting on station. They delay a day, folks throw a line over the side, some of our guys, do it at every opportunity. When they're not doing something they'll throw a line over the side. They always catch, but very few occasions do they get a lot.

Then there's some of us that don't really care about that. I mean I like fish, I like catching, but the gear and the baiting and the waiting and the cleaning and everything else, I'm plenty happy to pay for my fish. Everybody would bring their collection of movies, and in the early days we didn't have that many so we would watch the same movies over and over again. If you had launch delays, you'd see the same movie four or five times. Later on, folks got their collections of DVDs. Nowadays we have satellite TV, so most of the time if the weather is good enough you have real entertainment.

After STS about 90 it was a four-day trip minimum because of budget considerations. It used to be three days. We would go out day before, do our thing, about a day's worth of work, and come back. Our arrival back here is when disassembly starts. Because of the time of day of launch and the amount of time it took to tow back, a lot of times we'd show up back here with boosters in tow on an off-shift. Used to be priority was to get them apart, so they would plan on that and they would have people here to do the disassembly whenever we arrived.

They, for budgetary reasons, decided that they had defined booster performance well enough that they didn't need to know as soon as possible. So we would tow back at a rate such that we always showed up here at the start of first shift. Instead of towing back in 24 hours or so, you would tow it back in 24 to 36 hours. You would set the rate to show up at a good time for everybody else, so the later flights we were out a minimum of four days if the launch went off on time and everything worked right.

But for weather, when you're offshore you don't have any choice. The weather is what the weather is. We were off of Jacksonville waiting for a launch one time ten days. We went out, and the launch was delayed a day. Then the launch came up, it was delayed two days. We went like that, one day, two days for eight days before they finally launched. Then we got the boosters and we actually ended up being out ten days in bad weather. It's just a bunch of people on ship. We know each other; we're just hanging out. Have you guys been on the ships at all yet, had a ship's tour?

WRIGHT: Not yet.

DE LEON: They're big, but when you got 23 other people that you know and there's no gym—there's a lounge, there's a mess deck. One of the biggest problems is that there's a walk-in fridge. If we're not out too long there's always food in it. One of the biggest problems is eating too much. And there's nowhere to exercise. We had a couple folks trying jogging around the ship, and it just doesn't work well. There's not much distance you can go. With a ship in seas it's almost hazardous to do. One fellow brought aboard a rowing machine. People have tried that. But again, with the seas it's hard to do any motion that requires you to do repetitive action lined up with a machine.

ROSS-NAZZAL: Do you guys have any traditions when you take off or when you come home?

DE LEON: No, not really. It's another day at work. Which is cool when the weather is good.

ROSS-NAZZAL: Did you tell us how long you can dive for? I was looking through my notes and I didn't see that.

DE LEON: It's variable. It depends on how deep you go. The regulations are that we can't plan a decompression dive. If somebody were to get stuck and you ended up staying so deep that you had a decompression obligation, that just happened. But you can't plan that. If you look at the Navy dive tables, it changes. If you only go down 100 feet, I think you have 20 minutes.

Nowadays we don't use the Navy dive tables, you use dive computers. They go with you, and based on where you are right now and where you've been on this dive it figures out how long you can stay right where you are. Typically we're at about 120 feet, which is about 15 minutes.

ROSS-NAZZAL: That's a short amount of time.

DE LEON: Yes. And if you have problems, you call it and the next team tries to get it done. They have the same amount of time, and hopefully based on what you got accomplished they can finish. If not, you wait till the computer says that you're able to dive again.

ROSS-NAZZAL: What do you do after you put in the plug? Do you come back up?

DE LEON: Yes.

ROSS-NAZZAL: Do you need to do other work?

DE LEON: Well, we have other work to do, but as far as the recovery goes, the last thing you do when you install the plug is put a hose to it, an air hose. The booster sits in the water and you're pumping air into it. Water is coming out, and in about twenty minutes it starts to get vertically unstable and it ends up laying down. During that time, the divers are back on the ship. There's one boat, a small crew, that stays out to hook up the booster to the ship for the towback. But everybody else, we're back on deck and we're covering the parachutes that we already recovered. We're putting away our dive gear, we're cleaning up the small boat, we're cleaning up the deck. We're separating the parachute from the frustum that we had pulled on deck earlier, just basically finishing the day out.

ROSS-NAZZAL: Has there ever been a time when you've been on one ship, and the other ship needs some assistance and you've gone over to help?

DE LEON: Yes. There's always a little bit of a rivalry there too. It's not that there's a lot of push to it, but it's always fun to abuse the other ship for taking longer than you did. And there have been occasions when things break. Early on we were towing and one ship's air compressor failed, so we actually had to use the compressor from the other ship during the towback, hooking onto the other ship's booster.

We have had occasions—thankfully it was a false alarm, but we had a diver that we thought had a decompression hit. Pretty much everything stops. We have enough people on each ship to work the recompression chamber for a diver, but the more people you have on hand, the better off you are. We sent our ship's EMTs [emergency medical technicians] over there and a couple people to help operate the [hyperbaric] chamber. Again, thankfully it ended up not being a real problem. Got him on deck and started to get him out of his wet suit, and it turned out he had just put on too much weight. It was too hard to breathe in the wet suit. As soon as he opened up the wet suit it was like oh, I guess that wasn't a heart attack.

ROSS-NAZZAL: I just have one other question. Walking around here I've really only seen men. Is this primarily an all-male crew?

DE LEON: Yes. It was not intended, that's not a deliberate thing. In fact when we were working on validating Vandenberg we had a girl diver out there. When that operation shut down, we had the two ships that we were using here, and they had one large vessel that they were going to use out at Vandenberg, *Independence*. Brought her here and her crew came with it. They had not ever done a dive out there, but she was on their dive team and the whole team was becoming booster divers. They were going to come up here and dive with us, but it ended up never happening because of *Challenger*.

At different times we have had a lady cook, not assigned to the ship, not a regular, but a fill-in. On the *Freedom* we had a lady engineer, and on *Liberty* we've had a lady engineer, but all of those ended up being short-term. The one who was assistant engineer on the *Freedom* just got tired of it. She went over to safety engineering.

The other lady engineer we had actually on the *Liberty* was here for a while, but she ended up going over to the oil patch in the Gulf of Mexico. Different work, better pay. We only ever had the one girl diver. Actually the girl engineer on the Liberty passed the PT [physical fitness] test. She was becoming a diver, and then just ran out of time, ran out of missions. So yes, it has been predominantly all-male, but never on purpose. We have taken female observers and had different lady ship crew, but just worked out that way.

WRIGHT: Well, thank you for your time and for all the help.

[End of interview]

The following comment was added by Mr. de Leon after the interview.

One last comment – I would like to express my feeling of what we, as a people, should be doing in space.

Using the European discovery of the New World as an analog; Columbus (or Vespucci or Eriksson) "discovered" the New World, and following vessels could still set foot where Europeans had never been. They looked around, claimed the land for their country, and went *home. They didn't stay long enough to get an understanding of what they didn't know about these new places they had visited.*

Even the thousandth ship to the New World carried individuals aboard that would travel to places and see things no European knew existed. Even establishing outposts were just steps in becoming intimate with a small part of the New World around their doorstep. History shows that they missed a lot. It would take many years of living in this new place to understand it in its own context instead of just as an extension of the Old World.

That time in history is analogous to where we are now. We've had many important "Firsts" but those were explorations. We have just established an outpost but that's only a step toward living away from Earth. Our robot eyes give us a picture of what is beyond our reach, but it cannot replace the experience of living there.

Someday, we will have descendants living full time away from Earth. It falls to us to make the advances and learn the things they will have to know to get them there. That is worthy and exciting and we should be dedicating effort to exploration, but we need to be mindful that settlement is important too. Our outpost in space needs to be a bridge, not end point of our effort. Exploration is exciting and important. And extending humanity's presence in space is how we make it possible for our descendants to be able to reach even farther.