SRB Recovery Ships Oral History Project
Edited Oral History Transcript

Richard P. Tubridy
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 Rick Tubridy for the SRB [solid rocket booster] Recovery Ships Oral History Project at the Cape Canaveral Air Force Station in Florida. Interviewer is Rebecca Wright, assisted by Jennifer Ross-Nazzal. We certainly thank you for taking time this morning. We know you're busy getting ready for this upcoming travel. We'd like for you to start, if you'd just give us a brief overview of your time here. I understand you've been here 30 years. Tell us how you started, and why you decided to be part of this operation.

TUBRIDY: Actually I was destined to be here before I was even born. My father was working out here on the missile program back in 1957, and they were just waiting for me to be born in order to move out here. So I grew up with the space program, with manned spaceflight. My dad was a part of it until he retired, and it's really been amazing watching it all. I never thought I'd end up out here as a career.

I got an ocean engineering degree when I finished college. I was looking for work, and I really did not even think about the [Kennedy] Space Center. A friend of mine who had worked as an intern during the summer in a similar field told me about the retrieval of the boosters, and that he had a contact. Next thing I knew, I had an interview, and I was working out here and literally became a part of the dive team from the day I walked in. I was already trained to dive.

I showed up at some diver training events where nobody even knew who I was, the guys who had been [here] a year or two.

They really hired me to start the refurbishment of the solid rocket boosters. The first couple were brought back and taken apart and evaluated, but they really hadn't started the refurbishment cycle. The third one they wanted to get going with refurbishment, then the fourth one was the launch that we lost the boosters when the parachute failure sent them to the bottom of the ocean. I hired on right after that. We just had rooms full of hardware trying to figure out how to refurbish the equipment.

WRIGHT: Share with us how that came about.

TUBRIDY: This is in 1982, and there's rooms full of corroded flight hardware that had been flown once, but they didn't really have a process in place in order to stop the corrosion, to start the refurbishment, to get them back to a flightworthy status. They were also learning real-time about splashdown loads, the corrosion that happens with dissimilar metals in salt water. It was a real learning curve at first.

I was right in the middle of it, and that was very good experience for a young engineer. I was learning from a lot of guys that had experience from the Apollo days. Of course they didn't reuse their hardware, so they were learning all this real-time. My background in ocean engineering is structures and corrosion, so I had a background in this. It just seemed to be the perfect fit.

Maybe a week out of the month we were diving, training, learning how to treat the bends [decompression sickness], [in the] recompression [hyperbaric] chamber. We had a chamber on one of the ships, and now we have it on both ships. Learning how to both mechanically run it and to help out with a victim if we ever had one. We've actually had a very good safety run. Sometimes these things happen, and you need to be prepared. We've actually helped a sport diver one time and a commercial diver. We spent time learning that.

I just started right out of college wearing a lot of hats, doing a lot of different things, staying very busy. Back then we used to work lots and lots of overtime that nowadays is frowned on ever since the accidents that have happened [STS 51-L *Challenger* and STS-107 *Columbia*]. Back then 60-hour weeks were normal, at least after a flight. That was great for a young engineer trying to get started and trying to put some money away.

I did that for about a year and a half, and they recompeted the bid for the companies that process the Space Shuttle. Everybody was sure that the incumbent companies would win, and of course they didn't. At the time we were working for United Space Boosters Incorporated, USBI. At that point we had a choice to either stay—they were going to still refurbish the non-motor parts of the solid rocket booster, but [Morton] Thiokol [Inc.] was going to take over retrieval and disassembly, as well as stacking of the boosters.

Of course my interest was with staying with the marine operations. I wanted to stay as close as I could to the marine part because of my education. So in a year and a half we transferred over, and my job became a lot more involved in the retrieval and disassembly aspects, but still working with corrosion of the booster, trying to find ways to minimize the loss of flight hardware. I got actively involved in trying to improve the way we recover the boosters.

At first it was a big scheme by the Navy, who spent millions of dollars building what they call the nozzle plug, which was an early runner of what today is known as a remote operated vehicle. They were going to have a minimal dive team just to help run the small boats and recover the parachutes and things but actually plugging the booster and dewatering the booster and transitioning it from a spar flotation to a log on its side so we could tow it back was going to be done with this nozzle plug.

Before I got here it turned out to be a disaster. They couldn't keep it running. It didn't work when they were able to get it in place. They were using very rudimentary means of the divers going down and essentially sticking a pipe in the booster. Then we would tow it back, blowing air to it the entire time. When we get it to port we would put a plug into it, and we would pump it the rest of the way in order to come up the river. That's what I came into, so we were trying to enhance the way we'd done that.

That's one of the major projects that I've worked on all over the years I've been here, the diver-operated plug. It's gone through many evolutions, always learning from the way we were doing it and the way we could improve it. For the first 20 years we did improvements just one piece at a time. We had some failures and we had some issues, all kinds of problems like flotation and things breaking, things not really built up to standard. We worked through those issues.

One of them was they clogged up a lot, because there was a lot of debris still left inside the booster that would clog it and then stop it from dewatering. On a couple of occasions we actually blew the diver-operated plug out of the back of the booster. So we made ways of letting us know if we were clogging up and ways to keep it from clogging up. We did that for 15 years or so.

Then about in 2000 I was asked to do a redesign of the diver-operated plug, and that was a real adventure. I worked with all the divers, and the last thing I wanted to give them was a product that was more trouble than it was worth. At first I didn't have a lot of buy-in from these guys. We had to do a lot of testing and prototype testing, and I worked probably more than ever with the design engineers from other departments. It was done differently. It was done more combined within all the different resources we have at the company.

Our final product, what we ended up with, worked very well. It's worked every time we've used it. It's made to work repeatedly if something goes wrong on the first try, but it's worked on the first try every time. Basically it changed the manual operation of locking this 1,500-pound plug—that is neutral in the water—locking it in place using compressed air and the turn of a valve instead of manually ratcheting it down. So we took the workload off the divers, reducing their chances of getting the bends. We speeded things up so we could get in and out of there quicker. We had a product that was stronger and dealt with the problems that we had learned about over the years. That was one of the major projects I've worked on.

WRIGHT: You mentioned you were asked to look at a redesign. Was that from NASA management, or is that something that you all decided to do with them yourself?

TUBRIDY: It was originally very much in house. The manager of the marine operations actually ran both the marine operations and disassembly at the time, the predecessor to the current one. He asked us to do it, thinking we would do it all in house, but things aren't quite done that way anymore. In the early days you had a much freer hand. We had a weld shop, we had a machine shop, we could do these things, but the rules had tightened up. There was a lot more configuration control of ground support equipment.

We were always considered to be—we call ourselves post-flight, and we call the hardware flown hardware. Well, after about 15 years people in upper management in NASA and

United Space Alliance didn't like that word. They thought flight hardware was flight hardware and GSE, ground support equipment, is ground support equipment. It all should be treated the same. So we fell under that, and it's a lot more paperwork, a lot more meetings.

This diver-operated plug enhancement was a perfect example of that. We would have just done that on our own and sent the drawings over to Lockheed [Corporation] when we were done, and they would release the drawings. Now I had to go before the overall NASA Configuration Control Board, the Astronaut Office—people that had never been to sea in their lives asking questions [with] no idea [of what we were doing]. It just became part of it. It was a change in philosophy. That all really happened during the enhancement to the diver-operated plug.

At the same time, that same manager had this wild idea of using a one-man, one-atmosphere submersible to put the diver-operated plug into the booster. That was a big part of the reason we were automating the way the diver-operated plug locked in place, so it could be done remotely from a submarine. I was the lead engineer on that project, and I got to fly the submarine several times. On one real booster recovery I flew the submarine and put the diver-operated plug prototype into the solid rocket booster, and we recovered it that way.

That was just fantastic. The submarine was designed by a private company out of Canada. It was very well designed; it was like driving a sports car underwater. We trained and worked out the details, and we did this mission. As well as being the lead engineer I was the chief pitchman trying to sell this to NASA to go spend millions of dollars on two of these submarines, and we came very close. Then there was a change of management, and they didn't want to go that way. It disappeared as quickly as it came, but we proved we could do it. It had issues, like anything. The biggest issue is rough seas. The other issue is you always need divers to back you up, because things go wrong. If you don't have a dive team and things go wrong, you're stuck.

WRIGHT: Do you know what year that was?

TUBRIDY: That was around 2002.

WRIGHT: How did you launch the submarine?

TUBRIDY: With the ship's crane. We do other jobs for NOAA [National Oceanic and Atmospheric Administration] and the Navy. We were just down on a NASA-NOAA joint mission [NEEMO (NASA Extreme Environment Mission Operations)] down at the underwater habitat Aquarius in Key Largo [Florida]. They had two of these same submarines, and both scientists with NOAA and astronauts were flying them. Unfortunately I didn't get a chance to fly one that time, but we helped. We did the recovery and launching.

The NOAA people were studying corals, and the NASA people were simulating an asteroid mission where they would use the submarine as if it was a small space vehicle in order to put an astronaut onto the asteroid and take samples. We knew how to operate them. We knew it was within our capabilities. Of course every time you do all this, you have to sell it to safety and make sure everybody's happy with your safety factors. That went very well. Some of the interesting things I've done over the years.

WRIGHT: Yes, it really was. When you were talking about some of the earlier days you said one of the challenges for your team was to help minimize the loss of the hardware. Could you tell us a little bit more about the duties of the crew, and maybe walk us through bringing the hardware in and the process that helped minimize the loss of that.

TUBRIDY: Originally the boosters had smaller parachutes. They hit the water faster and harder, so immediately the people in charge of the parachutes were working on larger parachutes. They were also having a lot of damage to the aft skirt structures. There's a thing called a flame curtain that is between the nozzle and the outer part of the aft skirt. When the boosters would hit the water at over 60 miles an hour, all this stuff would get thrown up into the interior of the aft skirt, as well as this big geyser of water.

As well as structural failures of some of the stiffener rings that build up the structure of the aft skirt, all the paint was getting damaged. The aft skirts and forward skirts are built out of an aluminum alloy that is high in copper. It's an aerospace alloy that's made to be very strong, but it's the worst aluminum alloy you could use in salt water. It corrodes very rapidly if its paint system is damaged.

Originally they came up with this foam in order to make ramps to deflect a lot of this water that was going up there. Early in the program, because I was involved in corrosion and I was a member of the National Association of Corrosion Engineers, I went to a seminar trade show kind of thing. I saw where they had anode material, material made to electrically minimize the driving force behind corrosion.

I came back and told my boss about it, and he asked me to come up with a design. We came up with a diver-applied anode. It was a [called] zinc ribbon [by the manufacturer]. It's these pieces of zinc that we would string across the aft skirt so it would drag in the water close to the thrust vector control system, a very expensive piece of hardware. We would electrically ground it to the aft skirt, the idea being the corrosion would happen to the anode instead of this very expensive flight hardware.

It was supposed to be just a stopgap measure as they added more and more zinc anode to the aft skirt to fly, but we ended up [using the diver applied anode] for about 20 years. It actually added another dive, probably increased the number of divers slightly that we took out to sea, but that was a big success. It wasn't necessarily that it worked all that great. It was something that they realized needed to be done, and they're so slow to change the flight hardware that it was something we could do rapidly. Then they never let us stop until finally they had zinc all over the inside of that aft skirt in order to minimize this corrosion. It was a real issue with flight hardware loss in the beginning. I think it was right about the time that we were doing the enhanced diver-operated plug that we finally quit using the diver-applied anode.

The other big thing—they had plans of washing the booster and getting the salt off of it as quickly as possible, but there was a lot more we learned while we were disassembling. The quicker you can get things apart and get them into the refurbishment cycle is one of them. Another one is when we take the motor segments apart and ship them back to Utah [Morton-Thiokol, Inc./Alliant Techsystems, Inc. (ATK)]—we had thought we had cleaned and greased the joint where they mate, and we put these covers on them to put them back on railcars, but the insulation inside the boosters was still full of salt water. That salt water would leach back out onto the lowest point of the joint, and they'd have corrosion. These things might sit for months before they were processed just because it would take so long to ship them by rail.

We made a lot of enhancements on how we do that. We cut away part of the insulation they call the inhibitor, and we go to great extents. We actually water-blast inside and get a lot of the salt water out. It's things like this that improve the reusability. The number of times a motor segment can be flown, a bracket or a piece of the forward skirt can be used—they have acceptance criteria. Once it goes beyond that, they have to look at it closely. Maybe it'll fly again under special review, or maybe it's no good at all and has to be replaced with a new part. They're very expensive.

WRIGHT: These ideas and concepts that you just discussed—were they ones that your team came up with as you were working and suggested these recommendations up the line? Or were you trying to balance how much came from the people who had hands-on of that hardware when it came out of the water?

TUBRIDY: I think it was really both. It was everybody from the technician seeing a better way to do it, to the Thiokol/ATK people that came down for post-flight assessment, to the [NASA] Marshall [Space Flight Center, Huntsville, Alabama] people that ran the whole thing. We would have lessons learned meetings after every flight, and these issues would come up. I really think it was a joint effort. People offered up solutions.

There wasn't always funding to go do things. A lot of times we could do things relatively inexpensively with our process compared to changing flight hardware, which is a very expensive proposition. The anodes took so many years to start putting them on the skirt that it didn't really get completed until around 2000, but they were working on it since 1982. It's just a matter of funding.

WRIGHT: Let's talk about your role through the last 30 years. You mentioned you were a diver, and you mentioned that you were working as a corrosive engineer. Can you tell us how that balanced out over the years?

TUBRIDY: Like I said, it surprised me, but I was part of the dive team from the moment I stepped out here. I was told, "You can be a fill-in and maybe you'll get to go out every once in a while," and I never missed a mission.

WRIGHT: What was your first mission?

TUBRIDY: I believe it was STS-6. I was on the ship for 124 of the missions, for everything since STS-6, plus the Ares [rocket] launch. We spent a lot of time at sea. There was a lot of scrubbed missions; there was a lot of training. When I first got here we didn't launch very often, but we trained a lot because we were developing the diver-operated plug, which wasn't even here when I got here. We were bringing on new people and training them and getting time at sea.

Back then we had a full-scale mockup of the solid rocket booster [Ocean Test Fixture]. We would tow it out to sea, and we would make it go vertical. We had basically an air valve, and we let out the trapped air in it, let it go vertical. We would practice either recovery, disconnecting the parachutes—recovering it the way we were doing originally—developing the diver-operated plug and practicing putting it in, taking it out. In the first years when launch rates were rather low we were spending a lot of time doing that. I would say it was about a week out of the month.

WRIGHT: Were you out at sea the whole week?

TUBRIDY: Maybe Monday through Friday or Monday through Thursday or something like that. Then when there was a disassembly, the disassemblies used to take place around the clock 24 hours. Being a young bachelor engineer, I was usually on the night shift and working 12 hours a day. The disassemblies took longer back then. There was much more scrutiny of how everything was done, the processes of that being ironed out and streamlined like they were over the years.

WRIGHT: Did your role change mission by mission?

TUBRIDY: Well, when I very first started out here I worked with some very sharp engineers—they'd been here a few years longer than me—and my manager. Most all the engineers that have been in my group were divers. I think I just loved doing it so much that I stayed. A lot of people moved on. A lot of people completely changed careers. I just never had interest in going anywhere else. Unfortunately there wasn't room for advancement. I became the lead engineer of the group, but that didn't really mean much or pay much different. I made enough to make a good living, and I was doing what I enjoyed. It was always interesting.

The real difference between here and over where they build up the flight hardware is you don't have the oversight; you don't have five people looking over one technician who's putting together something that's going to fly in space—and that's completely understandable that that kind of scrutiny needs to happen. Here we had oversight, but it was not nearly as much. At sea, essentially our oversight was one NASA person and a representative from ATK and a representative from United Space Boosters. The engineers acted as the quality [control]. We kept a record of everything we did real-time, the requirements that we met, and anything that was out of the ordinary.

We had the leeway to make real-time decisions. When I say that, of course we were talking back to the Space Center. We had a mission operation manager who is in charge of the retrieval, and the ship's captain, but we would as a group propose [a solution] when something went wrong. One time a nozzle was broken off the booster from water impact. Other times they had failures or very high winds that caused the boosters to be severely bent. We'd have to real-time come up with solutions on how are we going to get this back and recover it. You probably had more leeway real-time doing things than you did on the buildup flight hardware side, and I enjoyed that.

How it's changed was essentially I went from one of the more junior guys to one of the more senior guys until we did the first Ares test launch, when I was the subject matter expert for retrieval and disassembly of the solid rocket booster. That was very interesting, because we were working as a team with ATK and Marshall. We were coming up with all the ways—we were going to lift something that weighed 125% more and was longer and had more pyrotechnics on it, more separation motors. I worked my way up to that, but it was still always doing something interesting.

We were down after the *Columbia* accident for a couple years. They asked me to be part of a team that went out to Houston to audit the way the guys processed the spacesuits, the EMUs [extravehicular mobility units]. That was fascinating. It was just wonderful to be on a team like that. I had been the prime engineer working on the recompression chambers and keeping them up to code and understanding life support systems, so this was another step beyond that to keep people alive in a suit out in space.

When they get in that suit and go outside, they're working at about half the atmosphere we're in here. When you're diving 100 feet you're in four times as much pressure as you are here, so it's the opposite but the same. The problem is the same, the bends is an issue. It was just fascinating to see how that was all done, meet the engineers that did it.

I believe a lot of the space program—what makes it function is young, ambitious, hardworking engineers. I really saw this where they process the spacesuits. Typically when a guy gets to be later in his career, he moves into management then you're managing people and processes. The guys that are really going to get the job done are the hands-on guys. That's how it's been here; it's always been hands on. I was asked to apply for some other positions, but I turned them down because I knew as soon as I did that was the last time I was going to dive. I was making enough money, and I was happy. I was enjoying what I did. I was hoping I'd finish my career, but now it looks like I'll have to find something else to fill a few years in. It's been fantastic, work with just a great group of people.

My dad worked from the very first rockets that ever flew. In fact he worked out in New Mexico trying to learn how to guide the V-2 rockets they captured from the Germans. He was in guidance and communications. He used to always tell me, even when I was a kid, that the technicians out there are some of the smartest people and know more about the hardware than engineers, because they're so hands on. I really learned that to be true, just a great group of people that I work with.

WRIGHT: Do you have a mission that you feel was your favorite or most challenging? What has been the most memorable part of what you were involved with?

TUBRIDY: I would have to say that it was the Ares I-X mission, because for months beforehand I was working as the subject matter expert, just having lots of meetings hashing out how we were going to do things. The booster is deeper, and there was a lot of speculation of how deep it would be. Nobody was really sure, but people were crunching numbers and coming up with things. Myself and the lead diver started calling around and asking and thinking about how we've learned to do things over the years.

We were talking to the Association of Diving Contractors [International], and they were actually the first to ask us if we had looked into using rebreathers. A rebreather is a scuba system, a self-contained underwater breathing apparatus where you scrub the CO_2 out of what you are breathing and you recycle it up. You can use the nitrogen over and over again, and you add oxygen to your mix to keep you at the right level of oxygen. You have a computer monitoring all this, and you real-time are monitoring it.

We looked into using rebreathers, but at the same time we realized that the issue with rebreathers is if you task-load the diver, like putting in the diver-operated plug, and he's not paying attention to all the monitoring of the oxygen and himself and his equipment, he could get into trouble. Our solution was to have a small team, couple of guys, go down in rebreathers and [install a device to blow air into the nozzle].

It was a device that we would attach to one of the hold-down posts of the aft skirt. Hook the hose from the ship up to it, and it would blow air into the nozzle of the booster. We would raise the booster to the depths that we were used to working at. Normally the aft skirt would be somewhere between 105, 110 feet, and the divers were doing dives from between 115 and 120 feet. Now we were looking at doing dives between 130 and 140 feet.

There's two issues. One is your time is really cut down. The other issue is nitrogen narcosis. Nitrogen becomes narcotic under pressure. It really starts happening where people feel it at about 100 feet, then it goes up quite a bit as you start going down deeper than that. Some people are more susceptible, and some people are more susceptible on one day and not another. That's another big issue that you have to take into consideration.

With the rebreathers we had infinite amount of time. We had three hours we could stay underwater, and you can stay at depth regardless of depth. When you're breathing on a scuba tank, if you're at a shallower depth you can stay down for a long long long time on that amount of air, but as you go down deeper, your time is really reduced. Every breath you take is [compressed] however many atmospheres you are deeper and you're using up that [air], you're just blowing it out. You're taking a breath, let's say of air at 21%—we use nitrox, oxygen-enriched air in our diving that maybe we're breathing 27%. Then when you breathe it out still you've only used a few percent of that oxygen. It just goes as bubbles to the surface. With a rebreather, it's recycled through so you can actually stay. At the depths we were working with you could stay for three hours. You could control your mixture, the oxygen enrichment of the nitrogen-oxygen mix, to be an optimum mix for the depth you were at and still be safe, still stay well within the bounds.

The third thing about diving is oxygen toxicity. If you go too deep, the oxygen goes up and up and up until finally—it's called your partial pressure of oxygen, the amount your body sees—you can actually go into convulsions. You can do this with air at about somewhere 250 feet or 300 feet deep, or with oxygen-enriched air you can do that shallower. With the rebreathers you have to really maintain control, because you are deciding how much oxygen goes in there, you and the computer. If you go too high it could be tragic.

So we came up with this scheme of what we'd do. We would blow air into the booster, raise the Ares booster, and then put the diver-operated plug in with the normal team at the normal depths we were used to working. That all worked great, but what didn't work great was we had a parachute failure, so the Ares I rocket was severely bent and had a big divot, a big ding in the side. It wasn't broken through, but it was like a car wreck with a big divot in the side. When we were getting ready in our rebreathers, one of the newer guys on the team came up and said, "There's a big dent in the booster."

I was like, "Ah, he just doesn't know what he's looking at; he's kind of new." Well boy, was there a big dent in the booster. We still had to recover it, so we went down and everything worked out as far as putting the plug in. One of the things that worked out really nice was this idea of blowing the booster up to a shallower depth. As soon as we did that and the fifth segment simulator came out of the water, all this water started pouring out of it, telling us that its seal had failed and it was taking on water.

So we had to assess that and come up with a way of basically making a big Band-Aid to put around that joint. We let the water leak out, and we put this big Band-Aid with ratchet straps and foam and everything we could find on the ship, then we towed it home. And then there was a whole other set of challenges once we towed it home. How do you lift this? Where do you put it? It won't sit on the railcars right to be disassembled. We had to build special chocking—and we did this as a joint effort, like we do everything here, with Marshall and ATK and the experienced people here. We chocked it all up, and then we had to figure out how to remove some weight from it and how to get it apart.

Finally, when it was all said and done, we could not pull the joints apart. We had to hire a company that uses a diamond wire to cut through large things like these pipes. They literally strung this diamond-impregnated wire—I'm sure commercial diamonds, manmade diamonds—on a wire. It ran through a pulley system that would keep it tight. We literally sawed that booster into pieces, and it went to the scrapyard. That was, I would say, by far the most challenging.

We actually did this while we were flying Shuttles. We'd get so far on that disassembly, and we'd stop and have to put everything aside and go do a Shuttle recovery and Shuttle disassembly. That was very interesting, towards the end of the [missions].

WRIGHT: Were you involved with the *Challenger* recovery, the salvage operation?

TUBRIDY: Yes, I was. We were out to sea. We were still under the front that had gone through here the night before, in the biggest seas I had ever seen in my entire life. If you looked at the horizon, the entire horizon was picketed with water spouts, water tornadoes. It was the most eerie-looking thing I had seen in my entire life. Nobody got much sleep that night, and we were 50 miles from where we were supposed to be. We were essentially pointing into the sea and riding this out. This is from a west wind. It's not like the seas travel across the whole ocean. They're just coming from here out 150 miles off shore, so it was really something. We were extremely surprised that they launched. We were just flabbergasted that they launched.

Of course this is in the days before satellite TV [television]. We really didn't know—it was a bright sunny day here [on land]. It was still very cold, but it was bright and sunny here. I'm sure that's what led them to launch, but we would have been nowhere near where the boosters would have come down. We would have had to go find the boosters, find the nose cone, recover the parachutes.

We're riding it out, and I'm up on the bridge. We have no television coverage or anything, all I hear is there's been a major malfunction. They grab me—it was also very cold outside—told me to put a survival suit on, get a pair of binoculars, get out on the wings of the bridge, and we're going to head in towards what they're telling us. Nobody's giving us any direction of what to do. The manager of the marine operations is making the decisions. We are heading in to what we understand is where it impacted, so I stood out for half an hour or so on the bridge, just outside just scanning the horizon.

Of course we're far away from where anything was. Somebody comes and relieves me, and now we're getting in closer to shore. I walk down, and I see it for the first time on television—we're starting to get a weak television signal. I didn't expect anybody survived it. We came in, and we immediately started setting up to determine where the pieces were on the bottom. We used side-scan sonar, and I participated in that. We spent a period of time with the side-scan sonar finding where the boosters were, where what we could find of the orbiter.

The Navy did the salvage of the crew cabin. Which I'm glad of, I really didn't need to see that. We spent over six months out there diving. It was funny because I had just bought my first house. *Challenger* happened, and I had made arrangements to buy the house but I hadn't closed on it. I told my dad, "I can probably get out of this." I can probably say, "Hey, I don't know what my future is." He told me, "They'll need engineers more than ever," and boy, was he right. For those next two years I was never so busy in my entire life.

I did about six months of the salvage diving, of which we did six days a week. We would come in Saturday night, and we would leave Monday morning. We'd spend the rest of the time at sea doing several dives a day. We did everything from setting up grids on the bottom of the ocean—sometimes they were very fine grids, sometimes they were more coarse grids—looking for the pieces of the Shuttle. If there was a piece they were very interested in and we'd come up with a piece of it, then all of a sudden it would get down to literally a sterilization search where you would go over every square inch and make sure you didn't miss anything. Other times we were doing these big sweeping searches looking for the bigger parts.

It was the stuff that they were very interested in not getting into somebody else's hands. We just kept at that, and when that was finally over I came back here and they were well under way. My engineering group had doubled in size. We brought a lot of people over from the VAB [Vehicle Assembly Building] with Manny [Manuel DeLeon] who you'll interview. He was one of the guys that came over, [became] part of the crew. I believe he was working on the external tank at the time. He came over, and we worked for two years.

Our role was to put together the boosters during stacking in a much more controlled and scientific way of mating them. When you think about two boosters coming together, they're just two big round pipes, and you're joining them. Well, a 12-foot round pipe is not really round. When you fill it full of propellant and let it sit for so long, then put it on a railcar and it finishes its aging, its setting up, like concrete, it actually becomes a unique shape. We call it a bread loaf, but it would actually become a unique shape.

In the early days when these joints were a different shape, they wouldn't know until they had lowered the one onto the other and they had trouble getting it together. They had come up with their own methods of doing it, but they were very unscientific. They would use a piece of all-thread and try to tighten it together. Then real quick undo it, and before it could regain its shape you would mate it. Now of course all the emphasis was on the O-rings. The new joint was being designed up at Thiokol, who we worked for at the time. They had all their engineers working full-time on the flight hardware, so we were working on these ways of making the joints go together more scientifically, [with] more control.

One of the things developed in my group—I just had rudimentary parts to play with. Some very brilliant people came up with a way of measuring three points over about a three-foot area around the joint. Run it through an algorithm, and it would come up with the shape of the booster. You would do that for the mating side and the tang and the clevis, then you'd know what those shapes were.

We had this inert solid rocket booster they used for training over at the VAB, and we tried all these different ways of shaping it. Lucky for the program, the guys at the VAB that operated the cranes and the ground support equipment that lift the boosters were working on their own ideas. Once again NASA is involved, ATK is involved, everybody's giving it [their all]. They found by manipulating how much load [was on] each of the four legs of that lifting beam, they could actually change the shape of the bottom half. As you change the shape of the top, you change the shape of the bottom, which was a very eloquent solution.

Our solutions over here, what I was working on, were much more crude. They were these things that had to be light enough and small enough to go up the elevators, and you put together on the stack and would press the booster. Using this device we could determine the shape of the booster, then we would take efforts to massage it into a shape and not have to remove it. We could actually leave this installed while we mated the mate. This stuff worked, but it didn't work as well as what they came up with in the VAB. We actually put it in a box and kept it for about 15 years. I was finally notified they were going to scrap it at some point, but it was a really neat device, the final product. We did a lot of prototypes.

Then at the same time I was working how are you going to pull the joints apart during disassembly. The original joints took about 7,000 pounds [of force] to pull the joint apart. The new joint with the capture feature and the tighter joint was going to take—we heard numbers all the way up close to 100,000 pounds. The real numbers that we've measured since are about 60,000 pounds, so takes about 10 times the force to do it.

They used to use these inflatable air bladders on the separation rings to push it off. We actually still use that device to push the forward skirt and the aft skirt off because they're not a tight joint, but in order to separate the solid rocket motor joints you need something that could do a lot more. I was in on the beginning of that project, and actually ended up handing that off to another guy that we brought back on, a very very good engineer, Bill Nichols, who finished that project up.

I was working on a third big project, which was called the J-seal bondline inspection tool. The idea was that when you're putting the solid rocket boosters together there's a gap between the propellant out to the joint, and in that gap there's insulation, inhibitor. At the joint with this new clevis and tang and the capture feature and the interference fit, there was also a big piece of rubber that went all the way around that was called the J-seal.

The J-seal would actually make a pressure seal and collapse as you pushed it together. What was there before, during pre-*Challenger,* was the putty that was so famous for getting spit out of the failed joint when the O-ring failed. They didn't want to use that putty anymore. It was a big issue when you're mating it. How much putty you put in? How do you have it all set up? It was an issue. Did you really seal it, is there voids, is there paths?

So they got rid of the putty, and they came up with this J-seal. But they were a little worried that this J-seal might fold in a way they don't understand, so my biggest project was this inspection tool. It had a spider-like frame that sat on top of the segment that was just mated, and it had a periscope, like a mast to a sailboat, going down through the center of the booster. We had this 100-foot-long fiber-optic cable—this is back in the early days of fiber-optic cable when they were hugely expensive.

Nowadays they can do all kinds of fantastic things with this, but this was just basically one long fiber-optic cable that you could do a video through. Now the challenge was how do you make this fiber-optic cable snake out of the bottom of this mast, squeeze right between about three inches where the solid rocket motor fuel is above and below, go out, come within the focal length of the J-seal, swing it around and do a 360-degree inspection, and then pull it back out.

Actually this very brilliant engineer who was really an inventor, a guy we hired as a consultant, came up with the basic idea and I implemented it. If you remember those toys you had as a kid, it was a bunch of pieces of wood—it might be a clown or something. You pulled the string, everything comes tight, and he could dance around. Well, that was this guy's idea. All these plastic pieces were held together by cable wires running through them, and it had the fiber-optic run through the center of it, then at the end it had springs that kept the wires in tension.

You'd have a path where this bunch of little plastic pieces would go through and turn 90 degrees and then go out between inhibitor, and you would be watching on the video camera. It had a couple of little probes, and you would see when you came up against the inhibitor, then this mast would turn 360 degrees on the spider that held it in place. Because the boosters are built to a very high degree of fidelity of measurements, everything would be exactly the same on each booster.

We did prototypes, we went out and sold the idea, we got funding. Everything was happening very fast, you didn't have these design reviews like you have now. It was, "Get it built." We finally took this up to Huntsville where they had these dummy boosters at a facility that was like a little mini launch pad. They were putting these new joints together and setting off an explosive inside and monitoring the way the joint reacted to the pressures. So it gave me a perfect model of what a real joint, two segments joined together, would be like.

We had just a little window between tests, and we brought it up there and put it in. It worked perfectly. The only problem was what you saw was very hard to interpret. What do you do now that you have this information? Let's say you see a little wrinkle or a little place where it's not quite bonded. There's a little open spot. Our resolution wasn't all that great. What they ended up doing at the VAB when they stacked the very first flight after we returned to flight, was they sent a man down on a boatswain's chair. That's a sailing term, but basically a seat hanging from the crane. They would lower this guy 26 feet down into a booster, and he would sit there with a flashlight and look.

He probably had about as good idea as we did, but that was a feel-good thing. They did for a launch of two, then they quit doing that. They really thought this device that I built was going to cause more problems—not that it was going to [damage] anything, but that it was going to open a can of worms of questions. Now you got this thing put together, the last thing you want to do is take it apart because you're going to do more damage. That J-seal had almost like a 3M [Company] pad, kind of rubber that stuck. So now you're going to undo that, you're going to have to clean this up and clean that up, put [in] new O-rings.

They were confident enough in their design that this ended up [not being used]. It's funny with *Challenger*, after my salvage work, I ended up working several projects that didn't get used but were extremely exciting to work on. I wish I would have been the hero that came up with the right one, but I think this happens a lot in the space industry. You're prototyping, and you're just not really sure where you're going to end up [using].

WRIGHT: Very reflective of what you've explained to us about how so many of you have skills and talents that you are able to use in different places.

TUBRIDY: Oh yes, you get input. Like I said, the best place to get the input is from the techs [technicians], because they won't hold back. They get afraid when top management comes around, and they might not say something. But they're not afraid to talk to me, because I'm the guy jumping in the water with them. All our guys—our welders are divers, our electricians are divers, everybody wears multiple hats. It's not just a couple engineers, everybody does multiple functions.

WRIGHT: I wanted to ask Jennifer if she had a couple questions. Did you have some thoughts?

ROSS-NAZZAL: Yes, I did have a couple questions. You were talking about some of the improvements that were made to help the crew bring back those boosters. Was the number of divers ever changed over the years? Did you take out more in the beginning and as things improved you had fewer and fewer?

TUBRIDY: It was the opposite. At first we had a relatively small dive team, there might have been five or six divers on each ship. Then there were some other guys that were experienced sea hands but were either older or just their position didn't lend to it. They were on the back deck helping, maybe even driving a small boat but they didn't dive. You'd make more dives. You'd do more things. Until after *Challenger*, the parachutes had to be manually disconnected from the booster because of STS-4 when we lost the booster because of the parachute failure. We had to manually disconnect them, until they finally changed the design. You still kind of have to manually disconnect it, but it's better, it's safer for the divers.

In the early days you were actually doing more. In the early days it always seemed rougher. I thought that was just because I was young and got more used to it over time, but I actually did a study for NASA and I found out that those launches before *Challenger*, just by pure coincidence or random odds, were much rougher than we saw for years afterwards. The seas for the first 25 launches were typically six-to-eight-foot. Nobody was really keeping track of that, then they started keeping exact track of everything after *Challenger*. They asked us to go back and look—it was fairly recent, it might have been part of the Ares program. We took all the logbooks and we found out what they were. It was surprising but not surprising. It was much rougher.

ROSS-NAZZAL: Would you tell us about some of the equipment and hardware that you use as a dive team?

TUBRIDY: Yes, there's been a big change in that. As well as the changes in the divers—like I said, there's more divers now. We actually have a guy on the back deck that his job is safety, and [the responsibility rotates]. Whenever we launch a boat or are doing some kind of lifting operation or something hazardous or recovering a parachute, there's a guy that wears a green helmet. He is the safety guy. He is not supposed to get involved in the operation. He watches everybody. And of course he's a diver. He's helping out on the dives. We've added that; we've added safety.

We've always been adding things for safety. When I first started diving here, somebody in NASA had decided that he thought the bends was the worst that could happen to a diver. Well, drowning is a lot worse than the bends. We started with 80 cubic foot of air in a scuba bottle, which is typically what a sport diver uses. They felt at the beginning that well, they can't get into trouble with that. That kind of thinking is completely turned around. Now we dive with 200 cubic feet of air. We dive with technical diving rigs where we have two separate regulators on our diving gear, first stages and second stages. Typically a diver might have what they call an octopus, another second stage to give to somebody who ran out of air. We have two completely separate rigs where if you blew an O-ring or your regulator failed you can literally reach back, turn off valves and shut that off, and still have half your air.

We're diving with nitrox, oxygen-enriched air. When we do a booster recovery, nowadays we're diving with computers that keep track of everything. You can download them, and you can see exactly what the person did afterwards. But at first it was all dive tables and keeping track of your time, it was all real-time like that. Really we were doing more difficult dives, because we were just learning how to do this stuff. Now we're diving with computers.

When we go out on a booster recovery we dive the oxygen-enriched air as if it's air, so we give ourselves an extra safety factor. Your body is getting less nitrogen-induced [air] that could cause the bends. You got the extra safety factor and the extra air, so that stuff has improved tremendously. When I was first here it was hard to get a wet suit. You got hand-me-downs. That's all improved, now we get the best equipment. Well, we did until the program ended. Different managers thought different ways. Our management today is the most safety-conscious and is willing to do whatever it takes to keep the divers safe, because that's one thing out here you can't survive, a casualty, somebody hurt, somebody killed.

ROSS-NAZZAL: You mentioned you had chambers on the boats. Have you ever had to use those?

TUBRIDY: Yes, we have. I want to say it was three times with our divers. I was there for two of them. One of them was in the very early days. We were on a very rough mission and the lead diver was doing some very strenuous dives, and he had just made a dive before me. He'd gotten out of the water, and I went in and went down to the bottom of the booster with some other guys. When we got to the surface they said, "Jerry lost feeling in half his body," literally went limp. They put him in the chamber on the other ship, and the guy was in a panic. I'm like, "Calm down, there's nothing much we can do here. Let's just get our gear off and get back to the ship."

Sure enough, he had either an embolism or the bends. He had a bubble lodge in his brain or his spine and literally was hemiplegic. Put him in the recompression chamber, put him on oxygen, came right around, never had a problem again. The doctors, these experts at the facilities we send them to for follow-up treatments and evaluation, told him he should never dive again because they don't know what caused it, and you take a risk. That was his job, maintaining the dive gear. He was around a couple years after that, but it changed his life. At least he wasn't hemiplegic. He completely recovered as far as day-to-day.

One of them I really wasn't around for, so I wasn't really sure what happened. The weirdest one was [to] a guy [who] got out of the water. One of the things we do we that didn't do in the beginning was have a standby diver. There's always a guy suited up ready to go in case anything happens regardless of where we're diving, even if we're out back inspecting the hull. This guy got out of the water after making a dive. He had a computer that was keeping track of everything he did, and he dove a completely normal profile, very easy dive. This was not during a mission, this was training. No deep depths, didn't stay long, nothing. He was sitting in the front of the boat and Larry [F. Collins] was driving the boat. Me and another guy were underwater. We come up, and there's no boat. We're looking around, then my partner says, "The boat is on the ship." "What?" "The light's on in the recompression chamber." Well, I knew that was a bad sign.

Essentially he was sitting there in a pair of double tanks, and he just did a face-plant right where he was sitting. We got him in the chamber, and it was a little rougher this time because he was completely unconscious. They got him in that chamber in less than ten minutes. They blew him down, and they put him on oxygen. It took a little longer, but he came around completely. He's fine. They sent him up to the university, and they worked him up. He doesn't have any issues day-to-day. But once again, because of the seriousness of the hit, they told him never to dive again. He didn't. He still works out here. He's an assistant engineer on one of the ships, but he quit diving. Usually the bends is a pain in the elbow or shoulder or something. You treat it, you get better, and you should be able to dive again. But these cases you weren't.

The other two cases—one time there was a commercial diver. Although he was a fantastic diver, he didn't believe in going by the rules. He couldn't make enough money spending that little amount of time underwater, so he thought by living right, eating right, being in great physical shape that he could beat the odds. And he couldn't. He had a major—they call it the chokes, which is like everything, the bends and embolism— [his] whole body [was saturated] from the gas that's absorbed in your body. He ended up dying in our chamber with a doctor sitting beside him. We get him alive for hours, but he died.

There was another sport diver that ran out of air on the bottom. He came up too fast and had issues. We happened to be going out and ran across [him], and the Coast Guard asked us if we could assist. We put him in the chamber and he got complete relief. That all turned out good. We got a lot of good publicity. They're great to have. They're really mandatory if you're 150 miles away from the closest chamber. There are codes about maintaining them, and that's what we do. We've improved the way we make sure everything's ready to go, training everybody over the years, improved over and over.

ROSS-NAZZAL: The only other question I have is did you help out with the ET [external tank] barge ops [operations]?

TUBRIDY: No, not really. It's like the Navy jobs right now. I'm too expensive to send on a cruise, being an engineer. Sometimes things come up. Like the towing bridle that we use to tow the barge, I'll get involved in an engineering sense about the loads. We've actually got monitoring devices because people are concerned enough about the loads. I worked on that end, on the ship's equipment end, but I've never taken a cruise up there.

The funny part is my wife is the fill-in cook for the retrieval ships. She's done several trips to Michoud [Assembly Facility, New Orleans, Louisiana] with the barge, and she's done other great fun trips that I didn't get to go on. We have done several recoveries together and several NOAA missions together. I encouraged her to take the job full-time. We had one cook retire, and then we hired another guy that had medical problems. The other guy didn't work out, so she ended up doing it for about a year solid, and then filling in when people go on vacation. That was great to be able to share this with my wife, that was fantastic. She loved every minute of it.

WRIGHT: Well, thank you. We appreciate everything you shared.

TUBRIDY: You bet.

[End of interview]