NASA HEADQUARTERS ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

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INTERVIEWED BY SANDRA JOHNSON
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The following is a narrative based on an oral history interview with James L. Splawn. Mr. Splawn annotated, edited, and rearranged the content, and as a result this narrative is not a complete oral history transcript and does not match the audio recording. The interview was conducted on March 27th, 2019 in Huntsville, Alabama, for the NASA Headquarters Oral History Project. The interviewer was Sandra Johnson, assisted by Jennifer Ross-Nazzal. Also in attendance were Mr. Splawn's wife, Jo Ann Splawn, and a friend, Heidi Collier.

I was born in Kentucky, raised in Tennessee, and formally educated at Georgia Tech [Georgia Institute of Technology] in Atlanta, graduating in 1957 with a degree in Industrial Engineering. My first employment brought me to Decatur, Alabama, working in private industry. So I brought with me into NASA four years of experience in private industry.

While in Decatur, I kept hearing via the news and the local newspaper about a team of Germans that were only 25 miles away in Huntsville saying they were going to the Moon! As a young engineer, I thought what in the world is that going to be like? I finally told my wife, "I don't know what's going on, but I'm going over there to find out."

I called NASA to schedule an interview. The response was "of course, we go to work at six o'clock in the mornings."

I said, "That's fine with me. I'll be there Monday morning at six o'clock." I thought well, now that's a change, that's interesting. At six o'clock I reported in and said, "Hey, I'm Jim Splawn and I've got an appointment."

"Yes, sir, come right in." At eight o'clock I was on my way back to Decatur to turn in my two-week resignation notice because I had just been hired and I was going to be assigned to the Manufacturing Engineering Laboratory, which is as the name implies. It has engineers, yes, but it also has manufacturing, which is where my previous four years had just been in private industry. On June 1, 1961, I came into NASA as a fresh young energetic engineer ready to team up with a group of Germans, that I had no idea about, to chase the stars and maybe catch the Moon in the process.

Let me talk about the NASA environment I came into. Obviously, Dr. [Wernher] von Braun had brought with him to the United States a team of about 120 of his German compatriots after they had voluntarily surrendered to the U.S. troops toward the closure of World War II. They were initially located at El Paso, [Texas] in the early '50s and came to Huntsville in the mid-1950s and were assigned to the U.S. Army Redstone Arsenal working on rockets for offensive and defensive purposes. That's also the location where in 1960 the NASA Marshall Space Flight Center was established. In fact, NASA received several hundred acres from the Army in order to establish the complex now known as the Marshall Space Flight Center [MSFC], which was named after George C. Marshall, a renowned Army General. That was the basic environment.

The von Braun team obviously had spent several years developing rockets as aggressive weapons under a totally different regime. But Dr. von Braun and his team wanted to develop rockets for the peaceful exploration of space, not military usage. That was very interesting and challenging. The organization that existed at Marshall Space Flight Center stated its mission was strictly for the peaceful exploration of space. All the engineering laboratories, Materials, Manufacturing, Quality, Test, Guidance & Control, Computational, Aeronautics, Astronautics, etc., were a collection of engineers committed to their areas of expertise. In the Manufacturing Engineering Laboratory we had about 450 employees, which included a full complement of shop personnel (machinists, welders, electrical harness, heat & chemical treatment of metals, etc.) as well as engineers. That's what I came into when I came to NASA.

Along with the assignments given to the specific laboratories, each organization was expected, fully expected, to perform their given assignment, and perform with diligence and professionalism. That was the yardstick that we followed. Also, management gave us freedom to pursue things that were "outside the box" that might have a future somewhere down the road. It was an environment where micromanagement did not exist, the expectations of the individual was high, and people performed accordingly.

We came to work at six o'clock in the morning, and if you left before six o'clock at night, you felt you were not treating your fellow worker fairly. People just wanted to do what they were hired to do, because they loved the environment, the mission, the comradery, and the teamwork. But they also loved the ability to think on their own, because if you stop and think about not only the von Braun team but all the rest of us that were coming on board, we had no mold that formed us to think like you're going to go into space. We were all learning!

That's why my ideas were just as good as the ideas of the guy sitting on my right and on my left. Nobody had *the* answer. It was that freedom of being able to pursue ideas that was very attractive.

In our Manufacturing Engineering Laboratory, there was about five of us that eventually would meet most every day at lunch time. Since just about everybody brought their lunch with them in a little brown sack, we would sit around the table and just talk. We'd dream. We'd eat our sandwiches and peanut butter cookies, talk about the kids, and all of that chit-chat. Those five guys were Charlie [Charles R.] Cooper, Charlie [Charles A.] Torstenson, Charlie [Charles D.] Stocks, (yep, three Charlies) Don [C.] Neville, and myself. The five of us met religiously, because we had a good skill mix between us. Charlie Cooper was a mechanical engineering graduate out of Purdue [University, West Lafayette, Indiana]. Again, I came out of Georgia Tech as an industrial engineer. We had an electrical technician, who was Charlie Torstenson; Charlie Stocks, a mechanical technician; Don Neville, a jack-of-all-trades. He could just do most anything. Us five, we could cover the waterfront whenever it came to having an idea that had multiple requirements as far as individual participants to develop an idea.

All of us arrived in ’61 or maybe early ’62. As we watched the evolvement of the von Braun team and the progress being made through testing of the hardware we were fabricating in our shops, we could see that real progress was being made. We were convinced, yes, by golly, we’re going to the Moon!

So then we started asking ourselves, “Okay, what’s next?” What’s next? Once we get back from the Moon is everybody just going to sit down and say, “Hooray, yes, that’s what we did”? Oh, no. We’re going to do something else. Man is going to pursue this space environment!

Will it be some long duration manned flight? Will it be a new habitat? What kind of unknown limitations might exist at that point in time? Certainly, the psychological impact of man being in space for an extended period of time was something that would have to be evolved over time. The impact of social limitations while you’re on orbit were unknown. How do you get comfortable with that? What about the health issues? All these things had to be defined. In the meantime, what are the impacts not only on them as individuals but on their families which are enjoying the good life in 1-G [force of gravity]?

Also, the scientific and the technological aspects of this space environment was quite challenging. As we sat and ate our sandwiches and talked, suddenly it was 1963, 1964, 1965, that kind of timeframe. We still had not come up with an item we thought was really something we could grab onto and develop. But we were convinced NASA was headed toward manned spaceflight!

Suddenly in ’65, we zeroed in on weightless simulation and started trying to develop what we knew, and that was mechanical devices where you can use counterbalancing situations (i.e., seesaw), where you have a technician working on one side of a balance beam, and on the other side you have a mass of weight that you counterbalance his 1-G tendency. We poured an epoxy floor, a self-leveling floor, and fabricated an air bearing device that had some articulating capabilities. No, that didn’t do very well. We talked about offsetting springs for simulating the zero-G and that didn’t work very well either.

It was summertime. Monday morning at lunchtime the conversation usually was, “What’d you do over the weekend? Did you have a picnic? Did you go boating? Did you take the kids swimming?”

One guy spoke up and said, “Let me ask you something. Did you ever watch your wife swim underwater?”

Hey, we’re all mid-20s, young, virile, and all that. We pumped our fist in the air and said, “Absolutely, you betcha.”

He said, “No, no, no, come on, be serious. Did you ever watch what her hair did?”

We said, “What in the world are you talking about?”

He said, “If you watch your wife swim underwater, her hair is floating like in zero-G.”

We said, “Oh my gosh. Oh my gosh. That’s an interesting thought.” We grabbed that thought, started brainstorming, and the end result was neutral buoyancy simulation! (Interpreted as when a body or mass neither floats nor sinks when it is submerged in water, and accomplished by a low-profile harness of distributed weights strategically placed on the body or mass, the item becomes weightless or neutrally buoyant.)

It was a long pull. Following, we’ll talk about some of that long pull, but that was how the dream and the vision was established. The wife is going to play a part in all of this stuff that ended up at neutral buoyancy!

A quick explanation on Neutral Buoyancy. Neutral Buoyancy, or weightlessness, is a condition achieved by placing a person in a pressure suit and pressurizing the suit. When placed in a body of water, the suit/person will float (like a balloon), and a counterbalance of weights is externally placed in the suit such that it will neither float nor sink at a chosen depth (thus, is suspended like an Astronaut in space or zero-gravity).

Where do you start? The first thing you do is you start with pointed discussion. What do we need in order to do this? Let’s make a list of “must have.” Obviously, you’ve got to have a pool of water. Then you’re probably going to need some form of a control room if you’re going to measure how hard a man is working to accomplish certain tasks. We must have a safety awareness because we are working in a fundamentally unsafe environment underwater, so we’ve got to get the Medical Center on board with us. We must have scuba gear. Only one guy out of the five of us had ever put on a set of scuba tanks, and he wasn’t formally trained, so we must get training.

Then we must begin thinking about the kind of tools that are going to be used on orbit. How do you define a universal toolkit before the tasks are identified? But then we’ve got to make those tools neutrally buoyant as well. Similarly, the test subject must be anchored at the worksite in order to perform work. Further, how does the test subject transport from point A to point B? These are all the things that we thought about immediately.

Each one of us took an assignment. You do this, you do that. We all got an assignment, and away we went. Again, I'll mention the freedom that we had at that point of no micromanagement, but still required to perform our basic assignment. We thought we might have a successful idea. Away we went.

It's a bit tricky to get some of those procurements through the purchasing department because they thought, "What in the world are you going to do with scuba tanks, fins and masks; this is not the local swimming pool or dive shop." We made all of that happen somehow, someway. Then in a field behind the manufacturing shops we found a pit that was 10-feet deep, and 8-feet in diameter, and abandoned. In the earlier days it had been used to explosively form bulkhead curved sections for tank end caps holding propellants.

Now we needed a filtration system. If I'm not mistaken, we went to Sears and Roebuck. It was a start. We began working on how to neutralize tools, very simple hand tools that might be appropriate.

Once we got into this, we made some progress, but we saw pretty quickly that we didn't have enough space in this tank to do what we needed to do. We began watching the salvage area (boneyard in MSFC lingo) for some piece of development hardware that had been used for nondestructive test purposes that we could beneficially recycle. We found a 23-foot diameter, 14-foot deep segment that had been used as a test article. This segment is used as a spacer between rocket stages when assembling vertically for hot fire testing or launch. It was perfect, and available, and it held water! Now we have our second tank!

We eventually managed to get a polyethylene cover that protected our poolside electronic equipment and permitted heaters during cold weather. Life was getting good! With the increased volume in which to work, our ideas also expanded. Our reasoning advanced from the internal confinements of a habitat to the exterior environment of space for repairs of antennas, external habitat sub-systems, external science experiments, etc. These external tasks are called extravehicular activity [EVA] or simply a spacewalk. These tasks require pressure suits, and pressure suits were a scarce commodity.

We did contact Houston [Texas, NASA Manned Spacecraft Center; now Johnson Space Center (JSC)]. "Do you have any excess pressure suits?" Of course, they thought that was pretty humorous, because they were struggling to get enough pressure suits of their own to equip the ever-increasing astronaut team. But we at least checked. "Okay, then we've got to go elsewhere." Thinking about underwater applications, we obviously thought of the Navy. We contacted [Marine Corp Air Station] Miramar Base in San Diego, California, and told them that we were seeking some high-altitude flying suits if they existed.

"We have some surplus, and they are called Arrowhead suits." So our first pressure suits were from the U.S. Navy. Now we were making progress. The tasks that we could now perform got more difficult and more difficult—we were defining them ourselves—of moving things, repairing things, and all of it had to be neutrally buoyant including the test subjects. We were starting to push our own boundaries. But along with pushing our own boundaries, we got increased confidence as well.

It's already been mentioned how the pressurized test subject is neutralized for simulating weightlessness. So, let's take a closer look at the weight harness. To counterbalance that flotation or buoyancy, an unencumbering low-profile weight harness is used. The harness has small pockets (about the size of two or three fingers). The pockets are then loaded with strips of lead approximately 2-inches wide, 3-inches long, and 1/8-inch thick (contained circular weights used by fishermen can also be used). This harness, which covers the main body torso, both chest and back, and is connected by quick-disconnect latches on the shoulders (quick-release capability should an emergency occur), holds the majority of the necessary weights. Much smaller packets of weights are placed on the ankles, thighs, and wrists.

When suited, the test subject will move to an underwater platform where scuba safety divers will place the weights on the suit. The divers will then move the activity from the platform, turn the test subject in all positions (left side up, right side up, upside-down, horizontal, vertical), and simply adjust weights in the harness until the test subject maintains stability in whatever position he is placed. For a first-time test subject, the loading of the harness will take a few minutes, but the weight distribution will be recorded for each person so that on his next visit the harness will be preloaded for efficiency. Once neutralized (basically helpless as in space), the divers will move the test subject to the test hardware for the test to begin. Per our safety regulations, there are two scuba divers assigned to each pressure-suited test subject during the full test sequence.

Meanwhile, the instrumentation and electronic guys were working on all the underwater communications links (sound, lights, TV, etc.), and on safety awareness and health monitoring equipment as well. The MSFC Medical Center doctors agreed to help us define the instrumentation needed for determining the test subject workload by monitoring heart rate, body temperature, heavy breathing, etc. Integration of these multiple ingredients to meet safety and performance requirements was becoming a real challenge. And as you'd suspect, we were starting to have priority issues between our assigned job functions and our "dream project."

All of a sudden, it was fall of '66. Individual workload was overpowering, so we started asking around the Marshall Center, "Are there other people that might have some free time late in the afternoons that you'd be willing to help us?" Several positive responses were received because the word was beginning to "leak" about what we were doing. We did get some increased staff, but along with that goes some increased publicity. While publicity is good, sometimes it is rather difficult to handle. Nevertheless, again in fall of '66, we were making progress.

Now we roll into the early part of '67. We said, "With the publicity that we're getting, how do we make this known within MSFC? We can get additional help with new and fresh ideas." We talked it through. If we go to our laboratory chief, the laboratory chief goes to the next chief, who goes to the next chief, who goes to the next chief. It's going to eventually end up in Dr. von Braun's office.

I said, "Hey, I'll take the assignment and I'll call Bonnie [Holmes]," who was Dr. von Braun's secretary, "and I'll tell her what we're basically doing and see if we can get Dr. von Braun to witness a test." I told her I thought we had a "cat in the bag" but I wasn't real sure. However, we'd like to have somebody at a high level to come and just check us out. I told her basically that we were working underwater in order to simulate weightlessness.

She replied, "I'll get back to you within a couple of days." Within a couple of hours Bonnie called back saying, "Dr. von Braun wants to come and witness what you're doing." That he did! We were quite nervous about that, but we did just exactly what we had taught ourselves to do with the meager facilities and the tools that we had to work with. The test went very, very well! It was early '67.

Let me just insert this tidbit. Little did we know that von Braun was a scuba diver! We had no idea he was an accomplished diver and had even taught his kids the skill of scuba. We had no indication if he had heard rumors on what we were doing prior to this exposure. While he could connect the dots really quick on the potential of our project, he indicated nothing to us. That said, one of the management tools Dr. von Braun used was called “Weekly Notes.” Every Friday each laboratory director had to submit a one-page note about what’s important in their laboratory, good or bad. Over the weekend von Braun would read those, and respond with notations in the margin. I did not see those notes or have any other clues that he might know of our pursuits.

In mid ’67 the first mention of a “big tank” was made. That, interesting enough, came “down” to us, not “up” from us. Obviously, Dr. von Braun had talked with his compatriots, his laboratory directors. “I think there is something powerful here, something we need to capitalize on.” Dr. von Braun turned on the MSFC facilities group saying, “We need a big tank. This will be an in-house design and build. We’ll do all of this in-house. We’ll not go to [NASA] Headquarters [Washington, DC] and ask for money to build this facility. The big tank was a nickname that lasted a while, but eventually was replaced with Neutral Buoyancy Simulator [NBS].

Okay, let’s shift to the big tank to understand its size and capability. The big tank is 75-feet in diameter, 40-feet deep, with 1.3 million gallons of water. Three exterior platform rings with 48 total portholes encircle the structure. Each platform has 16 portholes, 24-inch diameter, for natural light penetration into the tank and for test observers, engineers, and potentially general public viewing. There are two structural domes mounted on the ground level that interconnect through the tank wall. These are safety structures for the capability of letting a doctor enter the corresponding structure inside the tank should there be an emergency with a test subject or scuba diver. The building roof panels were replaced with fiberglass panels to increase the underwater light levels.

In mid-67, Cooper, Torstenson, and Stocks initiated an in-house elaborate and functional control room (i.e., TV broadcast quality equipment). It was fully operational in March of ’68, coinciding nicely with the completion date for the big tank.

Since Skylab was a major program and designated as NASA’s first Space Station, in late ’67 we seriously started talking about Skylab capability and its far-reaching impact. That’s when the initial talks surfaced on the potential of including astronaut training. We knew that was a steep mountain to climb. Those decisions would be made at a much higher level than what we were. But nevertheless, we could help support and influence those decisions with the capability that we were evolving with the Neutral Buoyancy Simulator.

In the fall of ’67, November 14th to be exact, Dr. von Braun came to our 23-foot tank, suited-up in an Arrowhead pressure suit, and became the test subject and, unknown to us, he brought a guest with him—none other than [L.] Gordon Cooper, one of our early astronauts. You can sense the politics going through Dr. von Braun’s head whenever he invited Cooper to witness the senior executive at MSFC becoming a test subject. That test went very well.

Five days later, on November 19th, Dr. von Braun was hosting a significant gathering of the NASA Headquarters staff from Washington, DC. There must have been some 20 of them. Von Braun sent word to us at NBS, “I want a show, and I want a good show. I want you to put your best foot forward because we’re bringing some decision makers that can influence our future.”

Von Braun came; he brought his guests. They walked to poolside first to get a visual of what was about to happen, then into the control room (located in a portable trailer) to watch and hear, via underwater TV, an exercise of simulating weightless tasks. Following that, Dr. von Braun briefed the facilities staff, "This is what I want to do with a big tank. I want it to be hi-fi [high fidelity]. I do not want any junk in there. I want it first-class." That was the direction he gave to the facilities people. That was November of '67.

Along this timeframe the Skylab Program was starting to surface. This gave neutral buoyancy a significant identity to be able to participate in a real and future program, because Skylab was going to be the United States' first manned space station! That's a big load for heavy-lifters, but von Braun challenged, "We're up to it. That's what we're going to do."

Let me explain what the total launch vehicle for Skylab looks like. The first stage of the Saturn V rocket is the S-IC stage, affectionately known as the booster. Second stage is called the S-IV or S-IVB stage, which becomes the Orbital Workshop [OWS] or Skylab's "habitat on orbit". Next is an Air Lock (AL) which is a transition module permitting the flight crew to move from the internal controlled environment of the OWS to the exterior EVA environment. Next is the Multiple Docking Adapter [MDA] for the docking of the Command Modules [CM]. Lastly is the Apollo Telescope Mount [ATM]. All of this is in line vertically whenever launched, all contained within aerodynamic shrouding. Once on orbit, explosive bolts will shed the shrouding around the AL, MDA and the ATM. Upon signal, the ATM will then index 90 degrees such that the end of the ATM is pointing directly at the Sun and will stay in that configuration for the duration of Skylab. If you wonder how tall the launch vehicle is, it's approximately 120 feet.

Our NBS game was changing and quickly. We began acquiring from the Skylab engineering design team the dimensions of this vehicle, the interior configuration, etc. Next step was to brief our requirements for NBS hardware to our shops, "This is what we've got to have. We must use materials that are different from what you normally use, because we must be able to see the astronauts or our test subjects inside these workstations, or if they're in the living quarters or performing experiments in the laboratory area." Even if you're going to exterior space for a spacewalk, you must perform all your pre-exit duties inside the vehicle. "For observation purposes, we must have an open wire mesh configuration that permits natural lighting and floodlighting to penetrate the interior for underwater TV and photography purposes and, particularly, for safety. Oh, and one critical item is there must be NO sharp edges or rough surfaces that could damage pressure suits. So shops, you guys have got to help us." And they did! That's how all of our NBS hardware was configured.

To give some idea of the size of the first U.S. manned space station habitat, Skylab, the OWS was 48-feet in length, 22-feet in diameter with a work volume of 12,800 cubic feet.

Contact was made with Houston in the Fall of '67, and we found they now had some excess Gemini pressure suits, so we were able to acquire several. Don Neville spent time at JSC in Houston to understand pressure suit design and maintenance practices. Neville and his suit technicians performed extremely well. They received high comments from the astronauts on their professional performance.

The big tank construction actually began in November of '67; completed March 28, 1968. That's a real demonstration of a fast-track construction project. All of the manual labor was done by the staff at the Test Lab. They had everything needed for an "in-house build" of this tank (welders, riggers, mechanics, electricians, etc.). Test Lab gets a gold star!

All of the NBS hardware was completed and installed in the NBS in the summer of '68, so by late summer of '68 we were fully functional with the facility complete. That included the

S-IVB second stage of the Saturn V missile, the air lock, an MDA, and the ATM. This cluster of hardware was formally renamed the Orbital Workshop. Sam [Samuel P.] McLendon coordinated all NBS hardware requirements, fabrication scheduling, and delivery to the NBS for divers to install. With this type of operation, its many systems and subsystems, its procedures being developed, safety being a strong requirement, fine-tuning of interfaces very demanding, etc., many days and weeks were required to coordinate all the moving parts into an efficient and functional operation. It was hard work, but it was exciting.

The doctors at the MSFC Medical Center were completely onboard with our operational policies, practices and procedures both for shirt sleeve (scuba) and pressure suit environments. They had invested many hours throughout our development progress. Their support was critical. A word about their detailed involvement – to assure physical fitness the Medical Center gave physical exams every 6 months to all NBS staff involved in the operational aspects of NBS, our secretary (Gail Moss) being the only exception.

Since the NBS was to be a man-rated facility, an Operational Readiness Inspection [ORI] was required. This is a team of MSFC specialists from design, quality, medical, structural, electrical, and operational organizations. They ran their investigation of all NBS systems, looking particularly for critical omissions or weaknesses and safety concerns. The first vote by the ORI team approved the NBS for manned operations, an indication of a high-fidelity facility (complying with Dr. von Braun's comment of "no junk!"). We were off and running.

The NBS capabilities for training the Skylab astronauts are strongly oriented toward the EVA or spacewalk tasks, as opposed to the internal habitat operations. The operating environment/risks between the two is starkly different, as are the outfitting of the crew (casual versus pressure suits). Consequently, the complexity of the NBS training facility had to drive accuracy, thoroughness, efficiency, and safety to the maximum.

Let's look at the operational staff requirements:

Typically, the underwater crew consists of:
- One diver – TV camera
- One diver – utility - safety
- One diver – hardware oriented
- One diver – underwater camera
- Two divers – assigned to each test subject

Typically, the surface crew consists of:
- Two pressure suit technicians
- One hyperbaric chamber operator

Control Room staffing:
- Test conductor with one backup
- One procedures technician
- One hardware technician
- Two electronic technicians (controlling pan/tilt/zoom cameras, recording equipment, etc.)
- One safety technician
- One utility
- Supervisor
- Two test observers (notes, action items for debrief following test)

By the fall of '68 we were fully operational in the big tank, and as you might expect, on September 4th we got a phone call from Bonnie saying that Dr. von Braun wants to do a swim-through and then make a pressure suit run in the Gemini suit. He did a swim across all the Skylab configuration for familiarization and then a repeat in the Gemini pressure suit. "Okay, this is what I can do shirtsleeve as a scuba diver. This is what I can only do in a pressure suit." Very interesting for von Braun to have that data point.

As you would suspect, many, many hours were now spent over several, several months fine-tuning every aspect of the operation. We had to create written procedures for safety, operations and individual tests. Fortunately, we now have on staff a technical writer, Pete

Nevins. All of the steps the flight crew would eventually follow on orbit were developed and documented by the NBS staff, the test conductor, Elmer [F. "Buzz"] Bizarth, and his control room staff, would be leading those step-by-step procedures for our own test subject as well as the flight crew.

As the Skylab hardware became more and more mature, upgrades to our NBS configuration were mandatory. To have a good simulation, you must have up-to-date hardware. It's a time-consuming and iterative process.

As a reminder, Skylab was the first space station for NASA's space program. NASA had pushed a lot of frontiers, certainly including the lunar landing. But one frontier was still open—determining how flight crews will respond to long-duration exposure in the zero-G space environment. Skylab was designed to pursue this frontier by utilizing three separate flight crews, for three separate missions, each extending space exposure of 30 days, 60 days, and 90 days yielding a data base of 540 man days on orbit.

As we go into early '70s, the Skylab program is moving swiftly, and so is the demand for NBS support. After taking a hard look at our forecast manpower requirements and test schedule density, the decision was made to contact the Navy to determine if divers could be assigned to NASA Huntsville. We contacted the Navy. "We need 10 divers; can you help us?" After an explanation of what we were doing, and why, and for roughly how long we would need them, the eventual answer was, "Yes, we'll help." Ten Navy SEALs [Sea, Air, and Land], an elite group of individuals with multiple skills, reported for duty three weeks later. They are trained as a working unit and proved to be an exceptional teammate for our type operation. They were excellent.

As the Skylab program matured, several requirements for EVA or spacewalks were being defined. Here is just one example, but somewhat typical of a compulsory procedure and task assigned to the flight crew. Accordingly, it's necessary to develop and mature the process and procedures of the elements that assures success, such as transporting from point A to point B, materials handling, securing the crewman at the workstation for safety and freedom of body movement while engaged to perform task assignments.

Let's look at the exchange of the film cassettes for the ATM telescopes. This is a two-man task (and I should mention that it is customary that all EVAs are two-manned events). The film cassettes are about the size of a thick cushion (8-10 inches) on a big sofa. One crewman must transverse out of the air lock, across a path leading to the sun end of the ATM, while the second crewman remains in the airlock area. A powered telescoping device will send out the new cassettes and return the exposed film cassettes. Sounds simple, but here's what had to be developed. The translation path was equipped with a handrail, sized for a pressure suit gloved hand, and routed appropriately for noninterference with experiments and subsystem components mounted along the pathway. At the sun end, a foot-restraint device must be available for anchoring the crewman so that he has freedom of body positioning with arms/hands free to perform the assigned task. (This description of mobility-assist devices and anchorage at a workstation is typical for Skylab EVA activities – and they were developed in the NBS to interface appropriately with the pressure suit boots.) Many similar EVAs would be required to collect data samples from various experiments, make maintenance repairs on subsystems, install new experiments during subsequent missions, etc. Materials handling must be fine-tuned and second guessed; fine-tuned to give the first crew a good shot at handling all the materials defined for the activation of the OWS, and second guessed for the second and third crews for additional experiments that would be subsequently defined.

Maybe it would be helpful to explained the rotation system used on test subjects. After the procedures are documented and you're ready to start evaluating performance capabilities between man and machine, then you need a rotation of test subjects. At the NBS, we had multiple guys that served as test subjects. Though following the same established procedures, their individual feedback could vary, "What if we do it this way, what if we do it that way?" That's all good while you're still in the formative stages. You adjust or redesign as appropriate. Then you retest the process again. We would do that homework with our own MSFC teammates. Their differences of dexterity, strength, body build, aptitude, skill mix, etc., offered a good cross section representation of the nine crewmen that would be active on orbit. When sufficiently developed for flight crew evaluation, the astronaut(s) would fly in, receive our briefing of the task, suit up, and run their own evaluations. It was this iterative rotation process that builds strength, and confidence, and acceptance by the entire flight crew.

As an aside, let me address three peripheral items in which the NBS was involved.

(1) While NASA was wanting to define the medical and numerous other impacts on the human body in a hazardous environment, a program called Tektite was defined, deployed and staffed in June 1970. A habitat was located at the [Great Lameshur Bay, Saint John, US] Virgin Islands and placed in open water at a depth of about 25 or 30 feet. Men would live in that environment for 30 days, never surfacing. Tektite was a steppingstone to get some early information about the impact of such isolation and environment.

We volunteered a diver to participate. Our engineer, Charlie Cooper, volunteered and was selected to be the systems engineer. If you recall, he's the mechanical engineer, so he was very comfortable being the systems engineer for Tektite. The project utilized some mental games as a part of the study, wanting to determine what the confinement and conditions might produce. For example, tasks were given containing surveying points along the ocean floor with requirements to figure out how to get from point A to point B, etc., following the provided surveying data. Similarly, other tasks were provided day by day to track their mental capabilities to assure clear and rational performance. Those tasks worked really well and produced good insight. But the isolation impact was a bit frustrating because of too much idle time. This is another example of acquiring data for isolation impact and physical data on functioning in a hazardous environment.

(2) MSFC desired to build a friendly team comradery within the community and the tourists that visited Huntsville and the Space & Rocket Center. An agreement followed that the NBS would be one of the items on the bus tours which occurred every 2-3 hours. The ground-level portholes became a very popular viewing area for literally thousands of people every year. Good marketing!

(3) The Huntsville school system contacted the MSFC Public Affairs Office requesting the NBS visit each fifth grade classroom and demonstrate the pressure suit function. The school system stated the fifth grade kids were at a very key age for shaping their future. The NBS staff accepted the challenge to visit every fifth grade class in Huntsville. After explaining how the pressure suit works, a suit technician would put it on, let the kids feel a pressurized suit, and watch their eyes dance! Then they had the opportunity to put their heads inside the helmet, hands inside a glove, and smile for the camera! The Q&A that follow was excellent. This activity contributed twofold, hopefully: educational to the community (through kids), and

exciting to the youngsters on the value of a good education. NASA and MSFC strongly encouraged this type activity in the 60s and 70s. It was an exciting process!

In the '72 and '73 timeframe, 15 different astronauts were trained. Nine would become the prime crew, six would be backups. The crews would be on orbit for 30, 60, or 90 days. They had a common goal, but different backgrounds and personalities. So, the database for extended stay on orbit would be vastly expanded.

My memory says there were 51 planned experiments preflight for the first crew. And those 51 experiments did not include the volume of student experiments being prepared locally for on orbit evaluation.

We come now to the launch of Skylab 1. The date was May 14, 1973. It was a great launch. Everything looked great, very successful. We now had our first space station for the United States en route to an orbit of about 250 miles. But the jubilance soon turned to concern, because the onboard sensors monitoring health and wellbeing of the structure was starting to give some disturbing readings.

The air-to-ground data showed the temperature inside the Orbital Workshop was on the rise. Then, the sensors from the two solar panels that provide power for the entire OWS, indicated we only had one solar panel that is deployed about 5 degrees and then stuck or trapped, and no report at all from the other solar panel.

Do we have a stranded ship? Or do we have bad sensor readings? Eventually it was determined that the sensors were correct and we did have problems on orbit. Two major problems! The internal rising temperature was above 120 degrees. Obviously, this was a non-habitable workshop.

The other problem was power. Power is required to run the experiments, preserve the on-board 30-day food supply, provide climate control, communications, data transfer, doctor/client interface, etc. So, it's serious. Two key systems were now very much in question.

At neutral buoyancy, as quick as we heard there was a problem, we immediately called a meeting to alert the staff and, since our NBS capability would most likely be a key player in corrective actions, lay out a loose plan of preparation. Each manager was tasked to review their area of responsibility and give a response at our next meeting in two hours. We agreed to start at the top and work our way to the bottom with an all-hands review of every system to assure that everything was in top-notch working condition. We were confident our NBS could simulate the not-yet-defined solutions for those major failures. We wanted to make sure we were ready, and we were.

The next day, the Skylab SL-2 crew—[Charles] Pete Conrad, Joe [Joseph P.] Kerwin, and Paul [J.] Weitz—was scheduled for launch. But that launch was scrubbed until repair solutions, hardware, and tools could be fabricated, verified, and repair procedures developed. Whenever the SL-2 crew did launch, inside their capsule would be all the materials and tools needed to solve those problems.

By evaluating data from the onboard sensors, launch videos, and numerous other sources, the diligent MSFC engineering force prepared the following failure scenario.

- A breach occurred in the micrometeoroid shield when passing through the maximum dynamic pressure region approximately 60 seconds after launch, tearing a panel from the vehicle skin surface.
- The exposed area of the micrometeoroid shield, being exposed to full sun rays, resulted in interior OWS temperature rise.

- The destroyed panel completely tore away one of the solar panels from Skylab.
- Associated debris trapped the deployment of the second solar panel.

All of MSFC was now on full alert! (So was JSC in Houston, Kennedy Space Center in Florida, and NASA Headquarters in Washington!)

As failure data became available, we began collecting hardware for simulation evaluations. Since the dimensions of the shroud that encased the solar panel was known, we requested the shops to fabricate a to-scale stub section of the shroud for our NBS use. Then, the "best guess" configuration of the debris/strap that limited the solar panel to deploy only 5 degrees was added to the stub shroud. Divers secured this segment to the underwater OWS exterior surface at the location of the failure. Now the chase of access, tools, procedures, etc., could begin.

An immediate concern surfaced on accessibility—the entrapment area was located in an area where crewmen, it was thought, would never be required to go. Thus, no handrails, no foot restraints, and no crewman assist devices existed in the area. So, a mental picture would be like a crewman trying to ride an elephant with no saddle! We'll forego all the trials of multiple ideas and go straight to the final solution. To set the stage, let's define the problem areas in the order in which the SL-2 crew would most likely pursue.

Problem #1 – Temperature

Both JSC and MSFC were extremely active in finding a solution to reduce the internal OWS temperature. JSC determined a penetration (a scientific airlock) through the wall of the OWS to the external atmosphere, which offered the potential deployment for an umbrella type of sunshield. This idea became the temporary repair assigned to the first crew or SL-2 crew. (More later on training and on orbit performance.)

MSFC pursued the more permanent repair. The Materials Laboratory assigned Bob [Robert J.] Schwinghamer the task of finding a material that would withstand the rigors of the sun for up to a year. The temporary sail that provided coverage for the 30-day mission provided much needed additional time for the development of the permanent sail. If I understand it correctly, there's an approximate 240-degree swing every time you go from daylight to dark and, of course, the crew was circling the Earth every 90 minutes—a very harsh and demanding environment! Bob was successful in his material mission. (More later on training and on orbit performance.)

Problem #2 – Power

After numerous ideas with fabricated hardware and underwater testing, the following was chosen as the best of the rest. A 1-inch diameter aluminum pole, made in 5-foot sections with male/female fittings on opposite ends and lockable to prevent separation while in use, was designed, fabricated, and successfully tested. Only 25 feet of poles with candidate repair tools were needed to reach the solar panel strap area. Sounds simple, but remember this must be assembled on orbit by crewmen in pressure suits and all these piece parts must be controlled on an EVA in zero-G.

Note: A stringent, limiting requirement on tools and equipment for any – and – all repair schemes MUST be storable in the already crowded Command Module.

The Apollo Telescope Mount had four (4) solar panels in a windmill type configuration. These panels deployed safely after the ATM was indexed toward the sun and began producing power as scheduled. It was determined that a portion of this power could be remotely/electronically diverted to the OWS but this small amount of power did not diminish the need for primary power from the trapped solar panel. (More details to follow.)

An interim summary: The above synopsis is an interim summary providing an insight into the two major Skylab problem areas, and a quick look at the bottom-line repairs that saved Skylab.

For the 10 days following SL-1 launch, NASA in its entirety was on full alert to salvage Skylab, in particular MSFC and JSC. So, let's review some of the things that were happening.

We did not know how many days would be required to work the repairs, but the scope of the task included working all the details of the solutions, documenting the procedures, training the flight crews, preparing the repair hardware for launch, getting the hardware to the Cape [Canaveral, Florida] for insertion into the Command Module for launch. That was the task that lay in front of all of us.

Beyond that, we were preparing for any unknowns that might be late arrivals or hidden in the downloaded data packages. As the system problems were being verified, the NBS staff began brainstorming the type of tools we could either make or buy to solve the problems. A number of candidates surfaced. For the trapped solar panel, a simple pry bar to place beneath the strap to pry it free, or some type of metal cutter (scissor type), like a pruning shear that you use on heavy shrubs, or cable cutter. Those were possibilities.

We started that pursuit knowing we would need to make those tools neutrally buoyant. As a crewman's personal backup, a bone saw was contained in the OWS First Aid/Medical Kit. This bone saw is a small diameter cable, approximately 12 to 18-inches long with circular rings (similar to key rings) on each end. The cable contains woven cutting barbs, similar to a barbed wire fence, for the cutting surface. One finger on each gloved hand is all that's required to operate. The crew circled the bone saw into a small neat circle, placed it in a cloth wrap, and simply taped it to the front of the pressure suit as a final backup – pretty ingenious, huh!

JSC of course was heavily involved with the flight crews and the training that was going to occur. Two days after SL-1 launch, a couple of astronauts that had worked closely with NBS throughout the development cycle for Skylab arrived in Huntsville to assure crew operability. Astronauts for all three missions participated in all our deliberations right up to SL-2 launch date.

Launch of the SL-2 crew occurred on May 25, 1973, 10-days after the launch of SL-1. The launch went beautifully with tons of well wishes from hundreds of coworkers that had given their absolute best efforts to save Skylab for its full mission.

As the crew approached the wounded Skylab, the visuals they observed and reported back to ground matched very closely with the engineering description/mental picture/hardware duplication that had been created prelaunch. For all the troops on the ground, the ensuing communications boosted the confidence in the repairs that had been so thoroughly formulated. The crew did a "fly around" and prepared for the "standup EVA". JSC had devised this idea of performing a standup EVA for freeing the trapped solar panel.

For use in training, a Command Module was flown from JSC/Houston to the NBS at MSFC for the purpose of simulating the standup process. The Manufacturing Lab shops fabricated the supporting framework and divers installed the structure for locating the CM in the NBS at a close proximity to the mockup of the solar panel with the entrapping strap. The thought process for the standup EVA was that Pete Conrad would fly the Command Module in close to Skylab and maintain that close proximity a station-keeping mode. The CM would be depressurized and the hatch opened. Now in pressure suits, the plan was for Paul Weitz to stand in the lap of Joe Kerwin, who would simply bear hug the knees of Paul for security and stabilization.

A couple of the 5-foot poles (explained later) with a shepherd's hook attached at the end would be hooked around the confining strap. With a few sharp jerks, the strap should yield and the solar panel go free. The process was perfected in the NBS with flight crew members' participation and approval of the plan.

As an on-orbit first attempt, Conrad flew in close and maintained the position. Paul hooked onto the strap and gave a huge jerk. The Command Module moved in closer to the Skylab. Skylab didn't move, the strap did not move, the solar panel did not go free. The CM simply moved closer to the Skylab. It was a good effort, ingenious thinking, but unsuccessful.

The crewmen made the decision to dock, enter the OWS, and go to the next item of business. After the successful dock, all stowed tools and candidate repair equipment were moved into the OWS. Once inside the OWS, their first major task was to address the temperature problem, now hovering in the high 120 degrees or low 130s depending on their orbital location in the daylight or nighttime orbital cycle. Houston had developed and provided a concept of an umbrella or parasol device that could be deployed through an existing scientific airlock, which provides a passageway to the exterior of the OWS. Fortunately, the scientific airlock was conveniently located in the immediate area of the now missing meteoroid shield. The parasol was deployed, triggered to open, and the 19-foot by 21-foot device opened nicely. The temperature began to decrease to the mid-to-high 90s level. Good work! We were now habitable for the 30-day mission.

The temporary sunscreen provided excellent sun screening for the SL-2 mission at Skylab. For clarification, this device was proof tested only in the 1-G environment. So we now have an OWS that has minimum power (temporarily redirected from the ATM) and a temperature environment that is not desirable, but acceptable. After some rest, the SL-2 crew shifted their focus and initiated the repair of the trapped solar panel.

After several candidate solutions had been evaluated in the NBS, the following description of hardware and procedures describes the plan for the repair. Given the confining storage dimensions of the CM, and the distance the crew had to travel over unplanned external territory of the OWS, an extendable length mechanism had to be developed. A scheme of aluminum piping, 1 inch in diameter, divided into 5-foot segments (to fit inside the CM), with a male/female fitting on opposing ends of each segment, and with a locking device to assure no separation during operation, was ultimately provided. Let me say the Manufacturing Lab shops were key in fine-tuning this design. This basic design became our primary and master tool to repair both major problems. A continuous clothesline rope (110 feet in total length) traveling through a pulley at the end-segment of the 55-foot pole would allow the crewmen to attach the interchangeable tools and activate that tool with the rope. Each candidate tool would lock into the pole end for freeing the encumbering strap. A pole length of only 25-feet was required for the solar panel repair.

One crewman (#1) left the airlock and located in the permanent foot restraints at the ATM film cassette exchange position. From this position, #1 could see the area of the entrapment. Crewman #2 would remain stationed at the airlock. Crewman #2 would begin assembling the 5-foot pole sections and passing the assembly to crewman #1 with the chosen tool installed in the last segment. Carefully and slowly, crewman #1 began inching the pole toward the entrapment. Crewman #2 relocated his position by holding onto structure members, and by using a chest tether to attach to a radio antenna base, can now help guide the pole assemble toward the strap. Ever so slowly, the jaws of the cutter were slipped around the strap.

Crewman #1 eased tension via the rope hooked to the cutting tool modified arm length (to gain mechanical advantage), and with a countdown between both #1 and #2, the two applied significant force. The jaws closed; the strap was cut; the solar panel was free!

The panel moved slightly, but did not deploy. The solar panel design incorporated a hinged control damper, which, as suspected, was frozen due to the long cold soak period of time on orbit. Nominal force, however, would open the hinge. As planned, and with a provided strap retrieved from the airlock, crewman #2 hooked a strap (Beam Erection Tether [BET]) to the end of the solar panel beam and secured the running end of the strap to the superstructure. Both crewmen, now having a transportation device (the BET strap), squatted beneath the strap and from a deep knee bend position, thrust upward, freeing the frozen hinge. The solar panel was now free and began its movement toward full deployment. A major problem solved! And a strong lesson learned for the future of space exploration on what crewmen can do in space.

Meanwhile, back at the NBS, a follow-the-leader step-by-step simulation was active throughout this solar panel repair process in case they were needed for suggestions on how to solve an unexpected problem – thanks to on orbit communication link directly from the crew on orbit and into the NBS facility and headsets of the test subjects and underwater speakers for the operational crew. A joyous celebration erupted! Skylab was functional for the complete mission as far as power was concerned. The SL-2 crew was fantastic in working with us at the NBS – nothing beats good teamwork!

The SL-2 crew activated the workshop, they made it habitable, and after solving two major problems, they conducted experiments, conducted their assigned science tasks and made the OWS tidy for the follow-on SL-3 crew. The two major problems, deploying the temporary sail and acquiring power, set the stage for the total Skylab mission. They really did an outstanding job.

Significant data could be transmitted both up and down because of the now available power level. The exposed film from the Apollo Telescope Mount would be brought back for analysis. The tasks performed the SL-2 crew demonstrated a tremendous knowledge expansion of what can be accomplished on orbit.

SL-2 crew returned home after a stay time on orbit of 28 days. For the postflight debriefing, it was my privilege to attend. Here are some of the personal points the crew made. One bar of soap for three guys for 28 days – we can do better! The shower was a blessing, but the pull-string to prevent water escaping from around the neck of the encapsulating device was uncomfortable and worrisome. The shaving cream and deodorant both dried out while on orbit. The pressure suit dry time after an EVA is about 10 hours. The thigh restraints at the food table worked well. There was no problem with visual perception. The lighting was excellent both day and night, but most of the lights were mounted on the 1-G ceiling orientation – need to break that habit. The reminder cues or flags at the workstations were very helpful.

The crew did comment the procedures developed in neutral buoyancy were very good; and the foot restraints and handrails were excellent. Joe Kerwin made the observation, "You can replace anything that malfunctions if you have good foot restraints and good handrails to get there." Pete Conrad made the observation that even with a 55-foot pole, he could maneuver Kerwin on the end of that pole if he (Pete) just took it easy and careful. That observation with the associated physics made the point very interesting and beneficial (lesson learned).

Many other comments relative to experiments, medical, food, etc., were made but will not be addressed herein. Suffice it to say, there were many lessons learned in 28 days that would be of significant importance to the planning and operation of the International Space Station [ISS].

Next up is the SL-3 crew, Owen [K.] Garriott, Jack [R.] Lousma, and Alan [L.] Bean. They launched on July 28 of 1973. Good launch and everything was normal for docking and moving into Skylab. The crew excitement was high about spending 60 days in Skylab. The OWS was inviting now, comfortable, tidy, and ready for new occupants. Their OWS activation chores were smooth with no unplanned interruptions. However, one problem remained to be solved, to install the permanent sail to assure continuous internal temperature control.

After settling in and establishing their routine, the crew was ready to install the twin pole sail. It's appropriate to understand and appreciate the many skills and procedures that were involved in defining the final solution that the crew is about to install. So, let's do a flash-back.

MSFC has a strong Materials Lab and it was their task to find a material that will last up to one year in this cruel direct sun environment. If I understand it correctly, there is roughly a 240-degree shift every 90 minutes as you circle the Earth and continuously cycle between daylight and nighttime, a harsh and ugly environment for any fabric material. Bob Schwinghamer was named as project lead, an engineer proven to ingenuity and resourcefulness, and also a player in the early NBS scheme. Given the criticality of this item, the International Latex Corporation [ILC], located in Dover, New Jersey, and fabricator of the Apollo Pressure Suits, was requested to send two seamstresses to Huntsville to assist in the fabrication of the to-be-defined sail. Two seamstresses arrived with their personal sewing machines and special thread used in pressure suit production. Many days were spent in fabricating multiple configurations of varied materials for testing. Finally, after evaluating numerous candidate materials, coupled with hours and hours of testing, a treated Mylar material proved successful.

One of the NBS Navy SEALs was skilled in parachute folding and rigging. With this background, he was given the task of designing a fabric packaging scheme with individual elastic constraints for control and dispersing of both the sail and the rope. The seamstresses produced the end item, using their magic with a sewing machine.

Simultaneous with the pursuit of a sail material came the task of deployment, a task requiring two crewmen. It was mentioned in the description of the hardware developed for the solar panel repair that the pole became our “primary and master tool” for the repair of the temperature problem as well.

After positioning all the materials inside the airlock for the installation of the permanent sail, crewman #1 would exit the airlock and appropriately locate and secure the v-base plate and the vacuum packed fabric container holding the sail and rope onto the handrail leading to the ATM, providing a vantage point for visual observation of the temporary parasol. A portable foot restraint, designed specifically for such a need and incorporated in the OWS as standard equipment, would be adjacently secured on the superstructure.

In the airlock area, crewman #2 would begin pole assemble, careful to place a pulley adapter to the end of the first segment, and begin passing the continuous assembly to crewman #1. A closed-loop rope (flagpole type) would be threaded onto the pulley. The assembly would continue until the 55-foot length had been obtained. Crewman #1 would place and secure the pole into the v-base plate. This cycle would be repeated for the second pole. Crewman #2 would then relocate to a position where he had a side angle view of the progress of the sail deployment. Crewman #1 would place a sail eyelet onto a hook on the closed-loop rope on both poles. Crewman #1 would, very slowly, pull the rope (some 6-8 inches) for a short deployment on one pole, then on the other pole. Crewman #2 was watching and coaching. A pull on each rope would pull the permanent sail from its storage container and into its deployed position. This slow, continuous cycling worked beautifully. The controlled payout of the sail and the rope from its elastic-looped packaging design was perfect. After full deployment of the sail over the top of the parasol (now a 2-layer configuration), all loose ends were secured at the v-base plate. Task complete!

Skylab now had control of its temperature, thanks to a lot of ingenuity and smart engineering by all concerned! Skylab was fully functional for its entire mission!

A few words on NBS activities. For the neutral buoyancy sail, we could not use a plastic/solid sheeting material because of the water drag. An alternate open weave material like a fishing net, or tennis net, worked nicely. Again, the seamstresses worked diligently with us to obtain the correct dimensional configuration.

Also, remembering that our operating environment is 0-G. The packaging of the clothesline rope, and the sail, was critical. Each item MUST be kept under control within the package and retrieved pull-by-pull with NO mistakes (we definitely did not need globs of spaghetti entangling the crewmen, i.e., rope material). It worked underwater for training, and it worked in space!

The NBS worked the procedures and perfected the tasks for the crew. The Navy SEAL completed his stowing and dispensing task, placed the flight package in a fabric container, processed it through a vacuum chamber to withdraw air/moisture to compact its volume and the 30-foot by 40-foot sail with associated rope was placed in a 14x14x8-inch package for placement in the CM. Quite impressive!

All of that was accomplished. Now flightworthy and ready for placement into the CM were 22 poles with candidate tools and v-shaped base plate, the sail package, a universal foot restraint, and implementing procedures for a combined weight of 128 pounds. The package was flown to the Cape and launched to orbit with the SL-2 crew on May 25, 1973.

For the SL-3 crew debrief after 59 days on orbit, as you would suspect, their big task was to deploy the twin pole sail over the parasol. The crew was very complimentary of the hardware that was provided, the procedures that were developed, and the NBS training they received. The interfaces between man and machine, coupled with materials handling, really paid dividends. And the crew so stated. It all worked really well.

The preplanned objectives for retrieval of ATM film cassettes, conductance of experiments, including the student experiments, all progressed without major difficulty. But the overload of work being crammed into the schedule given daily to the crew was becoming a point of conflict. The scheduling of tasks between the ground and the crew ultimately resulted in a positive and efficient scheduling pace for all subsequent manned missions (i.e., a lesson learned). After scheduling modifications, it was a more relaxed onboard environment for productivity for the crew.

Then came the Skylab SL-4 mission scheduled for 90 days with crewmen Jerry [Gerald P.] Carr, Ed [Edward G.] Gibson, Bill [William R.] Pogue. They launched on November 16, 1973. Once on orbit, and as you'd expect, they benefitted from nine man-months of learning from SL-2 and SL-3 activities and functioning in the weightless environment.

The SL-4 crew had no carryover malfunctions to correct, nor an anomaly that required anything out of the ordinary for them. Ed Gibson had been one of the crewmen that had spent lots and lots of time as observer, swim-through, and suited test subject in the NBS and was both knowledgeable and proficient of the planned total Skylab missions. The crew completed their broad agenda including the gathering and packaging of experiment samples, collecting samples while on EVA of both metal and fabric materials that had been exposed to the harshness of the space environment, and gathering documents of importance in preparation of closing Skylab in a safe mode for eventual reentry. The samples, particularly the ones on the exterior of the OWS, would be analyzed and tested for composition shifts for future space applications. Their return collection of data and samples were key to many, many lessons learned for man and machine. This crew of Carr, Gibson, and Pogue were very proficient, very competent – they really did a nice job on orbit. Before undocking, a final float around assured the crew all was secured and safe. Now, it was homeward bound!

The three missions on Skylab set an endurance record of 171 days of manned occupancy, basically 6 months of exposure, or approaching 37,000 man hours of experience that Skylab provided for follow-on habitats and flight crewmen wherever and however they may be used. Significant data from the onboard experiments and EVAs established an impressive baseline of medical knowledge and weightless exposure. These data would be of great benefit to designers, engineers, program managers, and follow-on crewmen for the next Space Station (i.e., ISS) and related space explorations.

Now, with the Skylab mission successfully completed, how was the NBS to be used? The Orbital Workshop, the Apollo Telescope Mount, and the majority of the hardware used for Skylab was removed from the tank. Next, a full-scale structure of the cargo bay for the Space Shuttle was installed. The NBS usage to support multiple and varied cargo carried aloft in the Shuttle cargo bay contributed significantly over the ensuing years. As an example, telescopes in space had been used as a prime justification for going into space. The Hubble Space Telescope, a MSFC program, representing a dream of many astronomers for many years, was launched to its planned orbit from the Shuttle cargo bay. However, after an extensive on orbit soak, a manufacturing defect was ultimately discovered in the mirror that hampered its performance (documentary film fuzzing was progressing to an unacceptable level).

The flight crew practiced extensively in the NBS in the 1993 timeframe for their servicing mission to repair the mirror, a very major task in and of itself. The training, tools, and procedures worked again. Another superb accomplishment was registered. Problem corrected. Hubble continues to function today!

Another major contribution for future operations was the handling of large structures. When you focus on how the International Space Station was assembled on orbit, you begin to appreciate the functions of man, machine, and weightlessness. An early mission of the Space Shuttle was to deliver to space the first element of the ISS. A permanent tool incorporated in the Shuttle cargo bay was a crane. The crew operated the crane, lifted this base element from the bay, and placed it overboard as an initial task. Crewmen then maneuvered the structure from the area of the Shuttle and parked it, awaiting the next structure delivery. Mating occurred. This maneuver, repeated literally over and over for dozens and dozens of missions, as the "18-wheeler" delivered to space, populating the ISS. And the flight crews were the construction crews that assembled these structures – again, zero-G can be our friend! The flight crews used the NBS to develop construction techniques and procedures as a training resource for handling these large structures.

Significantly, there were both mental and physical lessons learned for habitat design, medical and health considerations, and operational planning, during Skylab missions. The endurance of the flight crews, how long can you stay out on an EVA, how much work can be accomplished, how you team with each other on orbit, along with the social mixtures, is a strength and output of Skylab that will be key for space adventures in our future.

You look back at Skylab and it's almost like we were writing a textbook, because there were so many things we were doing for the first time. It was going to be used to help teach, guide, instruct, and challenge follow-on crews. Skylab was a huge success. We at NBS have been given some accolades, "Hey, we certainly helped salvage and contribute to not only Skylab, but our space future," and I will accept those accolades on behalf of the NBS team, because I deeply think we did just that. But it's not a dead-end street by any stretch. Just because Skylab is a part of our history, it's also a part of the textbook learning we have successfully accomplished. So, we share both history and future.

The total investment in the Skylab mission is reported as 2.6 billion [this estimate is documented in SP-4012, NASA Historical Data Book: Volume III, Programs and Projects 1969-1978, https://history.nasa.gov/SP-4012/vol3/ch2.htm.] It is humbling, yet with pride, that NBS played a significant role in its salvage and completion of such an important NASA investment.

Let me give an acknowledgment on what a fantastic facility the Neutral Buoyancy Simulator turned out to be. Obviously, we received significant help from top management, Dr. von Braun and his laboratory directors who helped us accomplish the many things that Marshall Space Flight Center and NASA has accomplished. But again, the environment that existed with Dr. von Braun and his associates was one of not micromanaging. Let's give everybody, everybody, enough freedom that if they have an idea, work on it, see if it's credible, see if it's something that is in the realm of possibility, and then go push it, go hunt it, go accomplish. That's exactly, if you look back at NBS, what happened for us. We were given the opportunity and the freedom to go chase a dream and a vision. It was fantastic!

Then as we observed Skylab winding down, much thought was given to how to reward our team. The idea evolved of all attending the launch of SL-4. That request was placed into the system. My understanding is it went all the way to von Braun. The answer came back, “I want everyone at the NBS, every diver, technician, engineer, secretary that participated in the training and problem solving for Skylab, I want them at the Cape whenever Skylab 4 crew launches.” And so it was – we were there! What a great reward, what a great launch! The reward could not have been better nor more appropriate!

If you look at the NBS operational period, we did significant work both inside and outside the normal NASA boundaries that existed, but we were given that freedom. The Space & Rocket Center with the far-reaching number of people that were exposed to NASA because of not only the Space & Rocket Center itself, but the bus tours that visited daily through MSFC, including the NBS; you’re talking thousands of people a year back in the early ’70s that received insight into a national goal set by President John F. Kennedy. That’s a great contribution to the general public community, and a tribute to NASA manned flight programs.

As another example of the impact outside the normal NASA boundaries, a major safety feature, a Recompression Chamber, is located on the top deck of the Neutral Buoyancy Simulator. This equipment provides medical treatment for divers who have suffered "the bends," an internal body issue that occurs when a diver surfaces too rapidly from depths and in violation of established diver safety procedures, a staging process.

In the early ‘70s, the Tennessee Valley Authority, TVA, which controls all the dams on the Tennessee River and some of its feeding tributaries, had a hard-hat diver that was welding on a floodgate chain at depths of 150-180 feet on a dam in the Smoky Mountains. A storm moved in requiring the support team to surface the diver as soon as possible. After surfacing, the diver began showing symptoms of the bends, pain and paralysis.

The TVA staff phoned the NBS and stated, "You guys have the closest recompression chamber, and we have a diver that showing the bends, can you treat him immediately?" We responded, "Yes, by the time you get here, we'll have all the arrangements ready." They responded, "We'll drive from these mountains to the closest airport and we'll land on the Redstone Arsenal's airfield with the patient."

While the chamber was being double checked for operation, notices were given to MSFC security, medical center, and management; the Redstone Army Fox Hospital provided an ambulance for transportation to the NBS. A Huntsville Neurologist, Dr. Frank Haws, was contacted and agreed to assist in the treatment.

Time is critical in treating the bends. Blood clots can form when the staging process for ascent is violated, and these blood clots can result in paralysis. Diver Claude Flippo arrived late in the night; treatment occurred throughout the night and the next day under the doctor's care.

The Flippo family arrived from Florence, Alabama (about 65 miles away) and spent the night and next day in the NBS facility. We acquired Army cots for their semi-comfort. In conversation with the family, it was determined that Claude's brother was Ronnie Flippo, a Senator for North Alabama. Senator Flippo visited his brother during the treatment process. So, a little neighborly treatment for one of our own!

The treatment of the bends was successful, blood clots were cleared, and mental functions were normal. However, Claude did suffer some paralysis in the left leg.

On the one-year anniversary of Claude's treatment, Claude and his wife returned to our NBS facility to say, "Thank you for what you did for me a year ago. The comradery among divers was very evident and much appreciated. Your hospitality to my family was exceptional and much appreciated. So, thank you." It was a total surprise, but what a great day!

The recompression chamber was a safety item for protection of our own divers, never dreaming we'd have the opportunity to treat someone in the close community. But that was the way the Marshall Center functioned. We were a community-oriented facility then and remain community-oriented today, ready to help in any way we can.

Dr. von Braun was a very committed and challenging visionary and a fantastic leader. His heart was big, his passion contagious, his challenges were beyond the sky, and he was always selling! He would go to the Cape for a launch, and sometimes return with a guest, like Walt Disney. He would call Bonnie from the Cape and say, "Hey, Bonnie, I'm coming back home, I'm on the NASA plane, but I've got a guest with me, Walt Disney. I want him to visit the neutral buoyancy, because I want him to understand how we test and train flight crews for operations in space." Bonnie would call us and say, "He's in the air, he'll be here in a bit with a guest." We'd make it happen!

Then there's other guys much more oriented to underwater, like Jacques Piccard, who is a famous Swiss oceanographer. He and his team have been pushing the depths of 30,000 feet underwater for science and unknowns. Another phone call from Bonnie saying Dr. von Braun says, "I don't have Jacques Cousteau but I have a key technical staff member and he wants to go in the tank." There were swim trunks and scuba gear waiting for them.

Again, it was von Braun with his salesmanship, explaining not only to the VIPs, the general public, and the decision makers from Washington, DC, who provided funding, "This is what we do, this is how we do things for future programs and future space, this is why we need consistent and additional funds for our future." As a young engineer, it was amazing to witness these exposures.

Permit me to close with what I consider the most significant VIP event of the history of Neutral Buoyancy. It occurred on October 21, 1970. As you know, we landed on the Moon in 1969. In '70 the three Apollo Astronauts, Neil Armstrong, Buzz Aldrin, and Michel Collins, went on a worldwide tour as a goodwill tour, and to bring credit to the United States for what had been accomplished for all mankind.

When they were in Russia, and as a part of their verbal exchange with the cosmonauts, they posed the question and made the invitation, saying: "Why don't you come to the United States as our guests, and let us show you around our country, including NASA? We'd love to have you visit us." They accepted the invitation. Cosmonauts [Vitali] Sevastyanov and [Andriyan] Nikolayev, crewmen on the Soyuz 9 flight for 18 days, came to the United States, bringing along an interpreter named Barsky with them.

While in Huntsville, in October of 1970, NBS again floated to a top position of interest. Von Braun said, "I want you to visit and witness what we're doing." The three Russians came to the facility with Buzz Aldrin as their escort. Astronaut Rusty [Russell L.] Schweickart, the guy who had done a tremendous amount of work as a backup crewman on Skylab, was our astronaut that took the lead for the underwater tour.

To see Rusty Schweickart explaining an Apollo pressure suit to Russian cosmonauts was something special. The cosmonauts were so intent on understanding through an interpreter how the helmet mated to the neck ring, how the gloves interconnected at the wrist, how the umbilical and medical monitoring connections mated to the suit, etc. To observe their curiosity was educational and satisfying. Then for a cosmonaut to suit up in a NASA pressure suit for an underwater follow-the-leader experience with Rusty in the lead was very special.

Our medical doctors gave a quick double check of the cosmonaut's heart rate and breathing, much to the surprise of the interpreter (as reflected by his body language). The cosmonaut observed how Rusty got into the Apollo pressure suit, and then, he himself, donned the pressure suit. On the NBS top deck, Rusty took the lead with donning of his helmet and gloves. The cosmonaut followed Rusty's lead with his fellow cosmonaut standing close by and with the interpreter on a headset in the control room. Into the water they both went onto the platform where the ballasting weights were added.

Once trimmed out, the safety divers moved both to the Skylab hardware. When the test director received a thumbs up from the doctors and the safety team, the test began. For the next 50 minutes or so the astronaut and the cosmonaut played follow-the-leader through the Skylab hardware, performing tasks as they traveled from station to station. Following the test, the cosmonaut seemed most pleased with his experience. They shook hands, nodded their heads, and smiled at all operational staff they could encounter, including suit technicians, divers, control technicians, doctors, etc. As they were traveling to their next event, they were asked, "Do you train your cosmonaut teammates similarly in Russia?" The interpreter responded, "No, but we're thinking about it!"

It was a very exciting time. It was pressure packed. Oh, my goodness. I told our crew, "It'd be one thing to have a significant problem with an astronaut. Think what it would be if we had a real difficulty with a cosmonaut." We, obviously, were on our Ps and Qs—it was a fantastic day, just an absolute fantastic day!

Let's put this in perspective. It was very interesting that we had a Russian cosmonaut in a NASA pressure suit following an American astronaut while participating in an underwater test on NASA Skylab hardware in 1970. And further, it all started with a lady's hair free-floating underwater! That's how far it's come – that's how far it went!

A final word I think is worth mentioning is national recognition. The Neutral Buoyancy Simulation facility was officially designated a National Historic Landmark in 1986.

End of story.

[End of interview]