ORAL HISTORY 2 TRANSCRIPT

ALECK C. BOND
INTERVIEWED BY SUMMER CHICK BERGEN
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BERGEN: This is an interview with Aleck Bond for the Johnson Space Center Oral History Project on September 3, 1998, at the offices of the Signal Corporation in Houston, Texas. The interviewer is Summer Chick Bergen, assisted by Carol Butler and Glen Swanson.

Thank you for coming to speak with us again.

BOND: I'm delighted to be able to do this and be here with you.

BERGEN: Why don't you start by telling us about some of the things that you brought for us today.

BOND: I believe the last time that we met, we discussed just a little bit about the kind of problems that were encountered in the testing of the Apollo Command and Service Module [CSM] in the large thermal vacuum chambers at the center. The Apollo design had initially started out that it could be able to handle space thermal vacuum conditions under any kind of orientation of the spacecraft, but it happened that it was really impossible to do a design that would be completely unaffected by orientation. We did find that in many instances we had freeze-up of dump lines, the urine dump lines, some of the other fluid lines in the spacecraft had to be reoriented toward the sun in order to unstop the freezes and that sort of thing. As a result, it was necessary to go back in and put additional heaters in certain locations, also to change procedures so that spacecraft would be oriented properly toward the sun to unfreeze certain area and this sort of thing.

We found some forty-one design deficiencies. We've had windows fogging up because either the material that was used to seal the windows was not completely outgassed as a result of the lower atmosphere. The outgassing of the gases that came off of the material fogged up the windows and prevented the astronauts from being able to see clearly through them.

BERGEN: Can you explain what outgassing is?

BOND: When a material, particularly the synthetic materials—all materials outgas. Just to make it simple, when you buy a new car, that new car smell is a result of the plastic materials ... that are used in the manufacture of the interior give off certain gases, and you have that smell for a certain time, and it goes on until the materials completely outgas and you don't have that effect.

Now, in space, with the atmosphere, of course, the vacuum in space, materials will outgas into the space, but in areas, say, around the windows, you do have a certain amount of leakage to the outside, and the materials that are used for sealants and all do outgas and tend to coat up on the windows or any surface where there would be an attachment for the molecules of the material. But we did find a number of significant changes in design, in operating procedures, manufacturing procedures, that had to be made as a result of the very extensive testing.

We did two series of manned tests in which the command module was manned by three astronauts for a period of eight days. They lived and slept and ate within that chamber in thermal vacuum conditions that you encounter in space, and they went through all these rigors. We found many problems, or issues, rather, that had to be solved in order that we could proceed on the real mission to the Moon.

We also used these chambers for qualifying suits, qualifying the excursions onto the moon. The astronauts were given more or less precursor kind of training on what would be expected in a thermal vacuum condition simulating the lunar surface. So these chambers turned out to be very, very valuable in being able to assure ourselves that we had hardware that would meet all the conditions that were to be encountered.

BERGEN: We also added a question that you mentioned earlier. In your development of your training facilities, you worked with the [U.S. Army] Corps of Engineers. Do you want to explain a little bit about hat relationship?

BOND: When it was determined that we were going to have a large center that was going to be able to house and also house all the people that were going to be involved in the program as well as the many test facilities that were anticipated to be built. This was quite an expansive program, and in those days … the government would reach out to other agencies within the government to help do these kinds of things. So the Corps of Engineers was called on to provide the assistance in contracting and the building of all of the buildings.

There was a master plan for the whole center that was laid out, and the Corps was called in to assist with this initial work of doing the contracting, selecting the builders for the various office buildings and also the test facilities. Normally, the Corps of Engineers liked to more of less work by itself to get a set of specifications from the user and go off and do its thing and then do the buildings and then turn them over to the government agency.

The real interface with the Corps of Engineers was what's called the Engineering Division, which is a current operating division on the center, which is basically responsible for the maintenance and repair and the upkeep of the facilities. I was in the Engineering and Development [E&D] Directorate, and since we were going to be the ultimate users of the test facilities, in particular, we insisted that we be quite involved in overseeing whatever the

Corps did. The Corps didn't particularly like this. At least this meant that they were going to have two interfaces with the NASA group.

It provided a little bit of a controversy at first but after things settled out, they realized that here we were going to be developing facilities that were really pushing the state of the art beyond the kinds of facilities that had been built in the past and that they would need our expertise and guidance along the way. So we finally really found that we could work together as a team, and I think this was really a very vital part of the activity. We stayed on top of what the Corps was doing with the major builders.

In the case of the large thermal vacuum chambers, this was really a major step in developing a facility that was going to have the ultimate characteristics of being able to simulate the conditions in deep space in such a large facility. The large chamber had an overall dimension of 120 feet in height and 65 feet in diameter, and so this was quite a large step from the small bell jar kind of vacuum chambers that had been built up to that time, which were only two to three feet in diameter. So here we were expecting to build this very, very monstrous facility to be able to give us the conditions that you see in deep space, the coldness of space, which is somewhere on the order of three to four degrees Kelvin, which is just four degrees above absolute zero, and also the thermal heating that you see from the sun.

At that time, solar simulation was more of less in its infancy. There were a couple of approaches to getting the spectral conditions that you see from the sun. One was using a xenon bulb, which came close, but not quite as close as the carbon arc that was being experimented with at that time. After looking at both approaches, we decided to use the carbon arc, which was being experimentally developed by RCA [Radio Corporation of America] at that time. It provided almost an exact duplication of the sun's spectrum of the various light species in the sunlight.

We worked closely with the Corps of Engineers. One of the controversies that we did have, we initially started out wanting to build scale models and do the scale testing of the models before we decided how the large vessel would be constructed. The Corps was against this. They thought it was an unnecessary taking of extra time ..., so they outvoted us on that. But when we had the first pump-down of the large chamber, which I believe was in the early part of 1965, the chambers were completed and we were going through the final check-out and acceptance test, and when they got down to the vacuum conditions, the large forty-foot door, the sealing around that door suddenly began to leak, and we were not able to hold vacuum. They found out that the structure around the door was not strong enough and had deflected so that we could not maintain a seal.

We went through about a year of redesign. The Bechtel Corporation, which is the group that had done the designing, had made an error. They had not provided the adequate strength around the door to maintain the vacuum conditions, so we had to go through about a year of redesign. We did then go into building the scale models and proving the redesign before we finally undertook to do that structural beef-up. That was one of the areas where the Corps realized they needed our help, and we had relatively good relationships throughout.

BERGEN: When did you finally get all your test facilities completed?

BOND: I think the large vacuum chamber [Chamber A] [was] put into operation the following year, early 1966, when we went into the testing of the command and service module for the Apollo. The smaller chamber we called Chamber B. It had been put into operation some time before that, and we did some of the suit testing. In fact, we did some testing of the Gemini astronauts in that chamber and provided them with some training under the vacuum conditions that they would see on EVA [Extravehicular Activity].

The other facilities were put on line at various times in the 1965-66 time period. The large anechoic chambers, which were to provide a noise-free communication atmosphere so that we can test out the electronic communications of the spacecraft, they were finished in about that time period. The Vibration and Acoustics Test Facility were also put into operation about 1965, and we began the testing on the Apollo command and service module and the lunar module all in combination there under vibration and acoustic conditions that they would see at the rocket ignition and liftoff period.

The Thermochemical Test Area [TTA] was also completed about that time. We had about a half a dozen different individual test facilities within the Thermochemical Test Area. They were separated from each other because of hazardous conditions that could exist in [any] one facility. If you had a problem, you did not want to propagate that problem to anything close by, so they were separated from each other by buffer zones.

The arc jet facility where we did the testing of the thermal protective materials, again, I think that was in the 1966 time period that that was finally completed. It was used for some of the just proof-testing of the Apollo heat shield material, but it really came into the fore for testing and developing the TPS [Thermal Protection System] that is used on the Shuttle.

I think we talked about the kind of dollars that were spent in those days. I don't have a sum total. I think it was somewhere in excess of over 100 million dollars at that time, and translated in today's dollars, that would be several times that figure.

BERGEN: In early 1967, the Apollo 1 [Apollo 204] fire occurred. Can you talk about your involvement in the investigation of that fire and how your testing facilities were utilized?

BOND: When the fire occurred, NASA almost immediately established an investigating committee. Dr. Floyd [L.] Thompson, who was the Director of the Langley Research Center, was selected to head up that committee. Dr. Max [Maxime A.] Faget, my boss at that time, was appointed to be a member. People around the other various centers of NASA were also appointed, and specialists from the outside were called in, as well as North American-Rockwell personnel and some other experts on fire problems.

The committee did most of its investigating down at Cape Canaveral, and, as I recall, Max was away from the office quite a long period of time—it was a period of weeks—while they were investigating what the cause of the fire was. So I more or less had to continue to run the shop and keep things going on our end to really support to a large extent the investigations that were being carried out. We were asked to do materials fire propagation studies and various laboratory kinds of testing, whatever the investigating committee needed.

Additionally, we wanted to understand the mechanism of how the fire started and where it did start, and it was conceived to come up with what we called a boilerplate type of test device that simulated the command module in size and volume. In our initial simulation, we almost exactly duplicated the materials, not only the fabric materials that we use in suits and the hangings on the wall ..., but also the wire runs and all their insulation. The instrument panels were simulated in very high fidelity, and we had ignition sources that were planted in the test article in order to start the ignition process… We were able to duplicate to the fullest extent that we knew, of the conditions that did occur in the command module.

Of course, it was a horrendous sight, really, to see how those materials in that atmosphere could just almost instantly start to burn. It was like a blast furnace inside that command module. No one, certainly, would have survived for very, very long, just a few seconds.

Anyway, we continued that work because we had to go in to be able to proof-test the redesign, and so we did numerous, numerous boilerplate tests using that kind of hardware for both the command module and, subsequently, the LM [Lunar Module]. We tested under the revised atmospheric conditions. We went to a combination oxygen-nitrogen atmosphere, and we completed many, many tests that simulated the conditions that were going to be looked at with various new substitute materials.

Now, in the interim, [we] also started a series of development tests on materials for practically every material that was in the command module: the soft goods, the Velcro, there were nettings on the wall to contain documents and that sort of thing, the materials that were used to insulate the wiring… We just started a whole process of trying to develop materials that would be—there's no such thing as "nonflammable," but you can make them almost nonflammable, and certainly [so] in reduced oxygen atmospheres.

So we started that process, and as I recall, we had something like maybe a million to two million dollars we spent in a period of twelve to eighteen months in developing that array of [new] materials. I think most people have heard of Beta cloth, which [is] used on the suits. That was developed and proven in that time period. A material that substituted for Velcro that was less flammable was also developed, as were a number of insulations for the wiring.

So that went on in that time period in order to be able to retrofit the interior of the vehicles and then prove them out to be much more safe than had originally been the case. So that went on during that period from January of '67 until sometime in 1968, when we were able to give the revised and redesigned interiors a clean bill of health to be able to fly men safely.

We still had some very rigorous fire safety kinds of procedures and observations that we instituted in order to be able to make sure that should there ever be any inkling of an ignition source, the astronauts could handle it.

BERGEN: Also as a result of the fire, NASA started to use safety, human liability, and quality assurance positions, I guess, and you were involved in establishing these offices.

BOND: I was asked by Dr. [Robert R.] Gilruth and George [M.] Low and George [S.] Trimble [Jr.]—my arms were both twisted off, practically—to take the position of heading up the Flight Safety Office and also the Reliability and Quality Control Offices [SR&QA]. At that time, those organizations were fairly small and were staffed by, as I recall, something like maybe fifteen to twenty or so people that had been selected to do that from the beginnings of Mercury.

With the fire problem, it was realized that SR&QA was going to have to be a much more stronger organization and also one that would cover many, many aspects of the business of manufacturing, producing, ..., the hardware as well as the analytical work that was going to be required in order to be able to oversee what was being designed by the program offices and the manufacturers. To cover that, I was asked to go in and head up the organization, to strengthen it both technically and managerially, and make sure that we also had procedures where we could maintain a good control, not only of the hardware, but also of all the processes that could possibly result in some kind of a mishap and also in the testing.

At that time, shortly after the Apollo fire, there was a fire in one of the chambers at the School of Aviation Medicine, where I think there was at least one death and some other people were injured as a result of testing in a closed chamber in an enriched oxygen atmosphere. So there was a great deal of emphasis on how do you test with occupants in heavy oxygen environments and make sure that you have procedures that will allow the people involved to be safely—at least improve the safety of those kinds of procedures.

So we instituted procedures for the ground-testing in oxygen-rich atmospheres that were very, very severe. Before tests could occur, we specified that the process, the testing procedures, ... had to be reviewed by my new organization and also had to get the final approval of Dr. Gilruth… So that created a lot of extra work for the management at JSC [Johnson Space Center]. These procedures were developed and put into effect, and because of the then rigorous requirements, we made absolutely sure that nothing went on like that without our full knowledge of how it was going to be carried out and that it was going to be safely done. We also imposed those same procedures on ourselves and our test facilities.

Then getting back to the safety and reliability activity that was done with the programs, we had representatives not only at the manufacturer's plant but also at all the subcontractors, the supply and hardware. They had to oversee and maintain the quality control in all of that hardware that was going to be going into the assembly of the spacecraft, and also had representatives at the Cape to see the handling and sign-off of procedures that assembled the spacecraft and for testing, whatever testing the Cape did.

This took a period of about eighteen months. I built up the staff from this relatively small group up to about something, as I recall, over 200 people. Once I had that done, had the procedures in place, then I went back to Dr. Gilruth and asked him if he would allow me to go back, as he had promised, to go back to my working position in E&D, and he did. After that eighteen-month period, I did return back to the Engineering and Development Directorate.

BERGEN: While you were developing or expanding the safety and reliability quality assurance areas, where did you pull the people from? Did you get them from within NASA, or did you go outside of NASA?

BOND: Some of both. There were some specialists within NASA. There were people in engineering organizations that tended toward the safety kind of activity that came, and we pulled them into the organization, plus we did a lot of outside hiring. We had a lot of good people.

One of the fellows that I want to talk about a little bit was Jack Jones, who headed up our quality control organization. He was the old nuts and bolts kind of inspector type, and he didn't hesitate to call a spade a spade. It didn't make any difference to him who the managers were, whether they were higher-up or low-level managers. He always spoke up and said his piece, and if he saw something wrong, he called the shots. He was a big help in maintaining and making sure that the hardware quality control was maintained and met the requirements.

I had a lot of other good managers, like Bill Bland, who was my deputy, and Mack Fields. These people were really dedicated to the program. They did a tremendous job.

BERGEN: How receptive were NASA personnel and NASA contractors to all these changes you were making, which were so much more rigorous now?

BOND: I don't think there was any opposition to it at all. In view of what had happened and the fact that it was so necessary and vital that we do have a strong maintenance of control over the kinds of things that were going to go into putting the vehicle together, I think there was a very cooperative acceptance of all of that. There was a little reluctance on some of the people that were doing tests away from the center, the imposition of pretty hard requirements on them, but, as I recall, I don't think there was any serious opposition to it.

BERGEN: Then after you decided to go back to the work you did before, basically, you took the position of Assistant Director of Chemical Mechanical Systems?

BOND: Yes, that's correct. It more or less was the same kind of a job that I was doing before I left. I had a slightly different title, went from manager to assistant director, but it was more or less over several divisions, the five divisions that I had overseen before for Max, more or less making sure that, from a management perspective, they met their requirements of supporting the programs and manpower and particularly on specific critical issues that we provided the necessary manpower to look into specific problems and help the program office in solving or helping with the contractors and their development and helping with design problems that they may have encountered.

The other part of the job was to make sure that we had the necessary staffing. We had to support requirements for providing staffing to all the organizations, the budgetary requirements for the monies that were going to be needed for doing in-house testing. As I guess I've indicated earlier, we did, in these very large test facilities that we had established, one-of-a-kind facilities, we had established those to do the certification and qualification of the hardware to be able to undertake the manned missions. So we had a large responsibility for conducting those tests on articles, test articles that were manufactured by the contractors and brought to JSC to undergo the testing in those test facilities. We provided people to staff and oversee those tests, along with the contractors. We worked in concert with the contractors. Their people came, and together we worked out the test procedures ... that would be required for certifying that hardware, to finally give the stamp of approval, yea verily, that this hardware is acceptable and ready to go into flight.

BERGEN: Were there any issues that stand out in your mind from this latter period of the Apollo Program, that you worked in this area, any issues that you dealt with in the testing and qualification parts?

BOND: There were many issues. There were no issues that were really controversial, that said that the contractor had a different position or opinion like that. These were worked out with the program office.

I guess I had a bit of an issue with the program manager of Apollo at one point in time, Joe Shea. He wanted to do a full-up test of the Command and Service Module in the thermal vacuum chambers using all of the propellants and cryogenics that were used in the fuel cell, full loads. This is one of the things I opposed. It wasn't necessary to test the tanks that were going to be carrying these cryogenics in the thermal vacuum. They were done separately, and we could do the operation, say, of the fuel cells, by piping in the oxygen, fuel, and hydrogen, rather than having a large tank of hydrogen and oxygen together in that chamber, which could, if it had ever had a problem like we did experience on Apollo 13 subsequently, if we'd had that inside the chamber, we could have had a very catastrophic situation.

So I opposed allowing the test to have those kinds of conditions, and I prevailed, and we fed in the products from the outside. So there was that kind of a controversy every now and then, but we usually worked those kinds of things out.

BERGEN: Did your facilities ever do any work during missions like Apollo 13?

BOND: Very much so. Very much so. The usual. For any missions, of course, we had all of our E&D people manned an activity in which each of—we had what we call subsystem managers for each of the major subsystems of the spacecraft, and those people with their helpers ..., manned, during the operations in space, manned the stations in order to keep up with the status of what their particular system was undergoing. These people would just maintain a minute-by-minute around-the-clock kind of activity, keeping up with the status of their particular system. When something happened, then they would go into a major energized mode, if you will, and make sure that they could explain what their anomaly or problem was at that time, and feed that information over to the people in the operations center.

The operations people were staffed, to a certain extent, to also understand those problems, but the back-up and the real expertise in depth came from E&D that supported the operations people. I guess this is an area that maybe hasn't been given the proper recognition and all. In most of the things that you've seen on television, you always saw the operations people and how they got together and solved all the problems. This wasn't really the case. Their back-up and the in-depth analysis and understanding of those problems came from the E&D specialists that were manning all those stations and studying just what was going on and coming up with a lot of the solutions that were fed then to the operations people, who subsequently fed them to the crew.

BERGEN: As the Apollo Program was ending, you were going to be gearing up to work on the Skylab. What did your division do in preparing for Skylab?

BOND: We continued the methodology that we had adopted in Apollo. We had subsystem managers for the spacecraft components, and we supported the program office for Skylab. Since it was more or less a use of Apollo hardware, it was just a natural evolutionary kind of process to continue doing the same thing. I do not remember any particularly unusual situations with that process in getting Skylab ready to fly. It was more or less a step-by-step follow-on process of doing whatever necessary support there was for the Skylab activity and getting it ready for flight.

However, once the Skylab flew and a very short period after the launch, we found out that some of the insulation was wiped out off of the Skylab. It became very apparent if we didn't have that insulation, that all of the cargo that was being carried up, which included food and medicines and supplies ... to last for months, was going to be seriously damaged unless we could control the heating. So it became very necessary to try to figure out, well, what can we do to come up with some kind of a fix that we can protect those materials and get it up there in time.

So it became a very, very hectic period of some ten days from the time that the launch occurred to the time that we came up with a fix that could be flown to handle the Skylab thermal problem. It happened in the month of May, and you may remember that there was a novel written, *Seven Days in May*, which had something to do with some heavy activity. I think it involved espionage… Anyway, we dubbed this "Ten Days in May" as the period that we were involved in on trying to come up with the Skylab fix.

I think the idea of a parasol was brought up by several engineers. I don't know that there was any particular person that can be attributed with that idea. It seemed to be a natural. You needed a cover to come over and cover over the damaged area, so that was really the concept that we were beginning to hone in on.

In the meantime, I recall getting very little sleep or rest during that ten-day time period. In fact, I remember at least one twenty-four-hour period of no sleep at all. We had flown over to the Marshall Space Flight Center for a meeting on trying to develop strategy and approach to how to handle the problem, and then flew back, got our people in motion to do all the kinds of testing and support of the parasol, and I think we had another couple, one or two, trips back over there, back and forth. I remember George Low [Apollo Program Manager], of course, was very heavily involved in directing the activity.

One of the things we had to do after we accepted the idea of trying to develop a parasol and the mechanism to deploy it, was what material was going to be used to make the parasol from, what kind of fabric material. Several materials were proposed, but you couldn't be sure whether the material would last very long in exposure to the very heavy radiative conditions of the sun. Most materials will rapidly deteriorate when exposed to unfiltered sunlight, and even in filtered sunlight, you see a lot of the plastic materials that we use here on Earth eventually become decomposed, discolored… Well, in space, where the intensity is so much greater, the materials really change character very quickly, so we had to be sure that we had a material that was going to be able to hold up, at least for some significant portion of the time that the Skylab was anticipated to be in mission.

So we got our various vacuum chambers, and we had a large number of smaller chambers that could conduct materials tests at very high sun intensities to simulate those conditions. So we went through a round-the-clock testing, of high-intensity testing, in order to be able to prove that the materials will last a significant amount of time. Finally, with this accelerated kind of testing, we were able to prove out that we could select a material that would have those properties that would be able to withstand the exposure in the Skylab.

Once the material was selected and it was put together with the mechanism that was going to deploy it ..., we did test in the labs to certify the deployment ..., and wrapped it up and put it into a package and sent the astronauts off with it, and they did a marvelous job of putting it all together.

BERGEN: It was successful?

BOND: It was.

BERGEN: When you were testing for Skylab, did you have to change any of your testing procedures to take into account the long-duration flight that Skylab was going to have, since they were going to be up there for months instead of days?

BOND: Other than the materials testing for the parasol, that was a change in procedure. Otherwise, for anything that the command and service module were going to see, it was an exposure in space, but longer than Apollo. We did account for that, but I think that, again, the main thing was making sure that you could stabilize thermal conditions so that you didn't have any freeze-ups and that sort of thing or unusual hot spots.

BERGEN: Why don't we take a break.

BOND: I was with Eagle Engineering. I was asked to do this. We went back and reviewed from the very beginning how man-rating activities started with us. Man-rating was something that really, I believe, was a phrase that was coined by the Air Force, and I believe

… NACA, when we were doing the high-speed airplane flight program, back in those days. It had the same connotation, basically, how do you design a really high-performance vehicle here, because we were using rockets and all of that, which was kind of new to the idea of manned flight, and so they had special procedures for looking at that for the safety of the pilot…

BERGEN: In 1975, you were promoted to the position of assistant director for program support. How did your job change when you moved to that position?

BOND: I don't think there was a great deal of change. It was more or less doing about the same kinds of things, except I had responsibility of assuring support to the programs with all the divisions of E&D, rather than just the five that I mentioned before. The climate was that, again, we were in an intensive program to assure the support of the Shuttle activity and continued to participate in design reviews. We had all of our specialists, subsystem managers, that, again, had a portion of their particular subsystem of the vehicle that they had to tend to and oversee the engineering and development of, and also the subsequent testing.

It just was spread over the whole E&D organization from a standpoint of assuring the necessary engineering support to the program. Again, the same kind of management responsibilities of staffing and budgeting were also part of the problem, promotions, contractor evaluations boards, this sort of thing, which was really just an extension of the same kind of activities that I had been doing before. It just happened to be somewhat more broader.

BERGEN: Because you had some different systems underneath?

BOND: Yes, navigation and guidance and—what were some of the other divisions? Still the same organizations: structures and mechanics, propulsion and power, crew systems. It extended into the electronics area. We had a new part of the organization that was called the SAIL, Shuttle Avionics Integration Laboratory, and that was a major activity to prove out and certify that the combination of all the avionics put together would work right and properly. One of the buildings was devoted to it, where we brought in all the electronics, put it all together, and ran various kinds of tests to assure the compatibility of the avionics systems to work together and do their job. It was a broader kind of requirement.

BERGEN: What were some different things that you had to do in Shuttle development than what you did during your Apollo and Skylab work? What were some different testing or different issues that you had to deal with, with Shuttle?

BOND: Shuttle, of course, being a different kind of vehicle than Apollo, since it was going to be a reusable type of vehicle, it still had the same kinds of technical requirements, being able to, of course, exist in space, be able to have a large part of the vehicle opened and exposed, the cargo bay, to the environment of space, we had to be able to take a very hard look at how it was going to be operating under those kinds of condition. One of the major proof tests, of course, was to test and certify the thermal viability of the vehicle under various operating conditions.

Of course, the reentry was a different kind of a reentry than we had on Apollo. We don't land the Shuttle with parachutes or anything like that. There is a drogue chute that slows it down after it does land, but the kind of testing on the Apollo materials was, again, a challenge to go a different kind of a route. We thought about ablation materials to begin with, but it was ruled out, as it was going to be a messy problem, because each time that you flew an ablative shield, then you would have to replace it. So we didn't even consider that for very long.

The concept that we looked into were more durable materials, particularly for the wing leading edges and for the nose of the Shuttle. We had to have a very, very durable material that could take repeated heating under numerous number of flights, that wouldn't deteriorate and wouldn't have problems. We came up with a material that we called "carbon carbon." What it was, we start off with a rayon material, and it was laid up in layers and it was carborized and then recarborized, and it became a very hard, structurally sound kind of material when it was made into the shape of the wing leading edges.

It had one particular problem, that it had to be coated with a material that was going to be durable and did not allow penetration of hot oxygen into the core materials, and that was one of the concerns in developing that. It worked out fine. The leading edges and the nose cone on the Shuttle have really never given us any kind of problem.

For the other part of the vehicle, the underneath side is covered with what they call the TPS, the Thermal Protective System, made up in blocks, and it could be manufactured in different densities. Depending on where it was to be located on the underside of the vehicle, we could distribute the density according to the—the higher density was going into the higher heating areas, but it still is a very light kind of a ceramic brick. It could be anywhere from nine pounds to twenty or twenty-five pounds per cubic foot. That's very light, really, in comparison to the ablative materials.

Again, the TPS had to have some kind of a protective coating over the top of it. The basic TPS was really a pure silicon dioxide sand material that was made into very fine fibers and then compressed to the right density in brick form to form the little bricks that go together to make up the underside. But that had to be coated with a thermal protective layer. As you see it today, it's a black material. It's intentionally made black. A black body will do most of the radiation of the heat away from it, that it absorbs on the surface will be radiated out. Only a small fraction of the heat will penetrate into the inner layers, and that was why we were able to glue this onto an aluminum structure without affecting the aluminum with the high heating.

The material on the outside is what we call a borosilicate, which is a glass, boron and silicon. It then is made black in order to have this property of radiation, and as a result, you have a light ceramic brick that is protecting the underside. On the top side [of the orbiter], where the heating is not so intense, we use more or less a fabric material that is a fiberglass material impregnated with certain plastic materials.

That all had to be developed and proved. We went through a very rigorous process of proving. The one, I guess, main concern we had as we were beginning to approach the initial flight test of the Shuttle, of the orbiter, was whether or not the bricks, once they were glued on, whether they were going to stay on. In the initial transportation of the orbiter [piggy-back on the 747 carrier] from California to the Cape, the tiles were not all completely installed. There were some portions that were left uncovered, and as a result, during the transport down to the Cape, several tiles were dislodged and were lost or flew off. So that became a major concern of whether or not in the more rigorous requirements of supersonic flight, were these tiles going to spall off and break and that kind of thing.

So we had to go into a real major testing program that consumed quite a bit of time in the installation of these tiles onto the surface. We had developed a pull test that would actually test each tile. There are several thousands of those tiles on [the orbiter], so you can imagine the very extensive time-intensive, time-consuming time period that is required in order to test out the strength of the adhesive binding the material to the structure.

Again, we did certification testing of the cargo bay doors, which become the radiators that radiate the heat that is collected from the avionics and interior of the vehicle into space. That had to be proved and checked out. We had several modifications that were required as a result of those certification tests, some design changes.

Those were the major kinds of problems that I recall that had to be addressed in the orbiter development. There were others that had to do with the solid rocket motors and things of this sort. The oxygen, hydrogen-oxygen tank, those were other kinds of problems, and the thermal protective material on that large [liquid hydrogen/oxygen] tank also had to be looked at very intensively in order to make sure that we were not going to have some kind of a problem with heating up the tank materials.

BERGEN: Did your job change any because of the political changes in the space administration? You didn't have the kind of money for Shuttle development that was available during the Apollo years. Did that affect you in any way in your position?

BOND: There were some budgetary problems toward the latter part of the Shuttle development program. We were forced to have to go in and take a good hard look at the needs for still continuing to operate the major test facilities, and I was under the gun several times about whether I should close down the large space chambers and delete that from the budget… So it was a continual fight to be able to get enough resources to continue to man and do the testing.

We found some new ways of how to operate some of those facilities with less people. We became more innovative. Budget crunches are good every now and then, because it makes the people get a little bit sharper and look a little bit more introspectively into how they do things, and just because you do something a certain way doesn't mean it's always the right way, that you should continue doing it that way. You should always try to see is there a better way to do this with less resources. And we were forced to do that in some of the budget crunches, which was good. It was good. Now, in some cases, you get down between a rock and a hard place, there's just no other way to do it, so you have to bite the bullet and say, "Well, I'm just going to quit doing that, and we'll do without it." But those cases were relatively rare.

BERGEN: Were you fairly confident, when the Shuttle finally launched, of its ability to withstand reentry and operate satisfactorily?

BOND: We were. Initially, at one point in time in E&D, we had a general consensus that we ought to fly the Shuttle unmanned. We had a rule that had been established way back in Apollo that we would never fly man in space until the vehicle had been thoroughly tested in space under the same conditions, and that was why we had several unmanned entry vehicles, in not only Mercury, but Gemini and also in Apollo. Before we ever committed man to fly in those conditions, we were able to prove that the vehicle could handle those conditions. This we could not do in the Shuttle.

So that was a dilemma at that time, and those in favor of flying man for the first time in the Shuttle came up with rationales that we had done enough to prove that the Shuttle could handle it. Well, of course, we were pleased whenever the Shuttle did its job, but it was a nip-and-tuck situation for a while.

BERGEN: When did you retired from NASA?

BOND: I retired in January of 1982.

BERGEN: But you still continued to work for NASA?

BOND: Yes. I retired on the 29th of January, which was a Friday, and went to work for the University of New Mexico on the following Monday. This was a little job that was—the

University of New Mexico maintained a technology utilization office at the Johnson Center. The position had become available, and they needed a representative to take care of that activity for them. It was a natural for me. I had been doing more or less a lot of technology utilization in my job as a deputy. Whenever entities came to the center, outside entities that might need some kind of help or advice or counseling on how to maybe do some of their development work, they would inquire whether or not there was anything in the NASA technology development area that might be able to help them with their problems. So I had gotten used to doing that kind of thing anyway, and when I went over to the University of Mexico, it was just sort of a natural transition, and I enjoyed it.

One of the things that it allowed me to do was to maintain my contacts throughout the NASA world, all the different centers in NASA. I had quite a number of friends and specialists that I knew all around the NASA circuit that I had worked with and conferred with on many other occasions, and it allowed me to continue to maintain those contacts and also to make some new contacts with other specialists that I had to call on from time to time to help get me the answers, help solve some problems for some small manufacturer on the outside that was begging for NASA help to see if there was any kind of NASA technology that might be able to help them.

I had some very interesting ones. In fact, as I recall, there was one company here in Houston that was packaging cornflakes, if you will, and they had a problem with the sealants on the bags of cornflakes as they came down the assembly line. The inner bag that seals the cornflakes—or maybe it was some other cereal—weren't getting properly sealed or was too time-consuming, and he was asking for help to help with his sealing and processing problem.

There were many other kinds of—we had a lot of electronics people that would come to us for help. One of the problems that I recall was with electronic systems for airplanes with airplane radars that could see ahead and into high-intensity storms that might cause problems of downdraft, where airplanes, when they meet a downdraft, can have very, very high excursions in altitude as a result.

The Langley Laboratory had started such a research project in that time period, and I was able to get some help from one of my friends up there who was involved in this program, a fellow by the name of Norm Craybill, who was doing some research in forward-looking radars that would sense those kinds of atmospheric disturbances… There were many kinds of problems like that that I was able to help certain people with, and it gave me a great deal of satisfaction to be able to take some of the technologies that NASA had spent so much time and effort on developing, and make them known to the industrial complement of the country.

So I continued on that job for a period of about two years, but shortly after I had started that job, my good friend Owen [G.] Morris, who had just started the Eagle Engineering organization, came to me and asked if I would help out on a couple of proposals that they were working on. I helped out on one, and then one led to another and became kind of a regular thing. I was asked to do more and more for Eagle, and because of the very high demand for that work, after about two years I did have to depart from the job with the University of Mexico and do more or less full time with Eagle.

I continued my work with Eagle Engineering up until sometime, I believe, in 1995, or maybe it was early 1996, when it became apparent that an organization or company that really was not managed or owned by minorities was going to be able to get very much space work. So I decided at that time—I was on the board of directors—I decided at the time I would kind of stop my work and my career at that time. I figured about fifty-two or three years were just about enough. So I quit and started doing "honey-do's."

BERGEN: Before we end our interview, I would like to talk to you about a couple of small committees that you were on. You talked about you'd done some technology development before NASA, bringing it to the economic community. Was that part of your Urban Systems Project Office that you participated in?

BOND: After the Apollo Program, we found that there was a lull, really, between Apollo and Shuttle. We had actually started a small group of engineers that would start studying the ideas of a reusable vehicle, and we put them on the back forty and more or less have them do their thing separately from the rest of the organization. So there was some time period in there when a lot of the engineers really didn't have a full activity on the ongoing work that was Skylab…

Also, a directive had come from President [Richard A.] Nixon at that time, was asking NASA if it might be able to help out on some of the domestic-energy problems that the country was facing and looking into. So I thought, well, gee, we might be able to use some of these energy-saving features that were naturally incorporated in spacecraft hardware systems, particularly the environmental systems.

So I got together with the assistant chief of Crew Systems Division, Ted Hayes at the time, and we discussed the possibilities of maybe using some of those kinds of features in energy-saving for the problems that we experience here on Earth. So we came up with the idea that maybe we could design some apartment complexes that would utilize those kinds of features.

I went back to Dr. [Christopher C.] Kraft [Jr.], who was then the director of the center, and I asked Chris if I could select some engineers to work on some problems like that, and that the request from President Nixon was some specialists to work with the Housing and Urban Development Agency, the HUD, since it was their, really, responsibility to do those kinds of things, but we would work with them with our expertise and see how we could use some of that technology for some of the energy savings on multi-dwelling complexes.

First of all, the name of the organization was MIUS, Modular Integrated Utility Systems. I put Ted Hayes in charge of it. Chris gave me the okay to go ahead and select some twenty-five or so engineers that I could pull in and start that support activity with the HUD. We came up with a number of very interesting studies. Some of those ideas and concepts are in practice today. The orientation of buildings, of course, have a lot to do with the kind of thermal input that they have from the sun … and also the treatment of the outside surfaces, the reflective materials you see on buildings these days. The primary purpose is to make sure that a lot of the heat is ejected rather than absorbed within the building.

Another idea we had was whenever you manufacture electricity a great deal, 35-40%, of the energy that goes into making electricity, turning the generator, is discarded as unusable always recover. There were some studies in our space programs, and for a moon colony you would want to recover all the water and reprocess it ... for drinking purposes. That was another idea, to recycle the waste water, not for drinking purposes, but for watering the lawns or washing clothes or that sort of thing…

So those ideas were fed into the HUD. We did this for about two years or so, and then the emphasis began to get back on supporting Shuttle requirements. Chris told me, "Aleck, it's time to pull the troops back in and [get] them reassigned," and that's what we did. But it was a very interesting time period, and it gave the guys an insight into how we can use those technologies to do other things.

BERGEN: Another thing that you were part of with the special advisory panels, the Viking program manager?

BOND: Yes, that was an interesting time. I looked back at some of the literature that I still have in my files on that, and I find that Dr. [Edgar M.] Cortright, who was then the [Director of Langley]—I think this was in the 1971 or '72 time period—asked for the center's help on overseeing what was being done on the Viking Program. Viking was a program that NASA Langley was responsible for. The prime contractor was the Martin Company out in Denver, but also the Jet Propulsion Laboratory (JPL) played a major role in the testing and developing of the hardware. JPL [had] an excellent group of engineers and scientists that have always done a fantastic job in doing their work.

But anyway, we were asked, since we had been to the moon, had deployed systems to go onto the moon's surface, and since the problems of landing Viking on Mars were not exactly the same, but similar in certain respects, we were asked if we could lend some of our expertise to the Viking Program. So I was assigned, along with Scott [H.] Simpkinson, to participate in their design reviews and to confer with them on certain kinds of problems and issues as they came up in their development.

I made a number of trips in the time period from '71 to 1973 or '74, to Martin-Denver, and also to Langley, and I got a number of our people in E&D involved in structural analysis and some of the pyrotechnic systems evaluations, that sort of thing. We were able to contribute, I think, to helping Viking be the success that it was. At least I like to think that we were useful in that respect.

A fellow by the name of Carlos De Moraes was the project manager, a very good friend of mine, and he happened to have been an associate of mine when we were both working back in Pilotless Aircraft Research Division at Langley. So it was a double pleasure to be able to work on that and also to again work with my close friend Carlos.

BERGEN: Another committee you worked on was the one that dealt with some of the initial issues with the lunar receiving laboratory. Can you tell us a little bit about that?

BOND: Yes. I don't know how I really got involved in the lunar receiving laboratory. I guess it was because we had sort of built up a reputation of being able to handle facility problems in their design and construction. But somehow or other I got involved initially with the Committee on Back Contamination. There was a concern, and we didn't realize there was so much concern within the other agencies of the government, that there might be some kind of a problem. "Hey, you're going to the moon. You're going to be bringing back all this foreign material, might be bringing back bugs, microbes, diseases, who knows what."

We had studied the Moon's surface and how it had been under almost continual bombardment for these millions of years, and our general feeling was, gee, if anything could live under those kinds of conditions, it would be a miracle. Anyhow, these other agencies certainly prevailed, and they said, "You know, we can't take any chances." Of course we had to agree.

I got put on the Committee for Back Contamination. There were a number of agencies that were involved in this. There was, of course, the [U.S.] Public Health Service—that was the primary one—Department of the Interior, Department of Agriculture, the U.S. Army, and of all other agencies, the Air Force was also involved. I don't know why the Air Force was, other than one of my interfaces was with one of the Air Force people. Anyway, I worked on that for a couple years before this—let's see. I think the reason I finally ended up getting off of that was because the Apollo fire had occurred in January of '67, and because of the very heavy demand on that work for the Apollo fire investigations ..., I had to turn that work over to Bob [Robert O.] Piland, who was also a member of E&D. But I did have Jim McLane, who was my technical assistant and who had handled many of the facility kinds of problems for us. Jim continued on into the design and development of the lunar receiving facility and was very helpful in working with the committee and assuring that we did not have to change our approach to doing Apollo…

Of course, we had to make sure that we could accommodate the astronauts and the lunar rocks ... in a safe kind of manner so that they were not going to be affected by whatever environment they saw in lunar receiving. Again, that was an interesting part of activity that I was in.

BERGEN: Were there any other special committees or extraneous things that you did that we haven't discussed?

BOND: There were a lot of extraneous things and special committees. [Laughter] There were always many committees within government work. I think I've mentioned some of those kinds of things. I had to be on boards, materials review boards. We had a special ongoing committee for developing a set of—Dr. Gilruth wanted to make sure that a lot of the expertise and rules and guidelines that were developed early on in the programs were not lost, and he wanted to document those kinds of things. So we did have a special committee for developing "These are the do's and these are the don't's in designing spacecraft."

Some very hard rules came up, like redundancy requirements. If you've got a redundant system, you don't put both circuits in the same location. If this one gets whacked, both of them get whacked, so you separate them to prevent any kind of damage from any unforeseen happenstance.

But there were always many committees, contractor evaluation, performance evaluations… I think we've talked about the primary activities that I've been on.

BERGEN: You had such a long, distinguished career. What are you most proud of when you look back over your career and what you did?

BOND: Well, my wife's proud of it. I felt I was extremely privileged to be in the right place at the right time to be in on the pioneering activity that took place early on in getting into manned space flight and then being able to continue into more or less the maturity of the program. I felt that I was indeed fortunate to have had the opportunities to experience all those kinds of things and to participate and hopefully contribute to the programs.

BERGEN: There were so many high points during the program, like when Neil [A.] Armstrong and Buzz [Edwin E.] Aldrin [Jr.] landed on the moon. What were your feelings when that was finally accomplished?

BOND: Oh, just tremendous exhilaration. These guys were the real heroes, to be able to go to that unknown planet, or body in space there, and descend on it and get out of that spacecraft and do the things that they did. It was just an awesome kind of a feeling, to have had a part in being able to do that. But those were the real heroes, the ones that risked their lives to do that and undertake those very rough training periods and do all the things that they had to do in order to be able to get ready to go on those missions, particularly the early astronauts that were in Mercury.

I was re-reminded just recently with astronaut [Alan B.] Shepard's [Jr.] memorial service that was conducted over here at the center, about some of the rigors of the training that they were exposed to. They had to undergo the desert survival training, the jungle survival. They had to eat bugs. Those kinds of things these guys were willing to put up with in order to be able to—they were fantastic people, and I think the nation really owes these guys a debt of gratitude for what they did go through in order to be able to be a part of that initial program and get started.

BERGEN: We also owe you a debt of gratitude for all the work you did.

BOND: Well, like I said, I was having fun, along with that. [Laughter] It was a real tough job initially, when we first came down to Texas and had to pay our attentions to doing

Mercury, starting Gemini, build the center. Those were days when we worked ten, twelve, fourteen hours a day and sometimes seven days a week in order to be able to get the job done, and it was rather hectic at times. We neglected our families. I look back on that, and sometimes I regret, during the formative years of my two daughters, not being able to spend as much time as I would have liked to with them, but it's also been very rewarding.

BERGEN: Where would you like to see the space program head in the future?

BOND: I think I'm sort of on the conservative side. I am not sure that we need to start really, make a rash decision, to try to go to Mars at this point in time. I think the idea of a Mars mission, even though a lot of the people are saying, yes, we have all the technological capability to undertake that sort of thing, I personally feel there's a great deal more to be done, particularly [on] the transit time between Earth and Mars. You know, that's anywhere from nine months to a year to get there, and once you get there, what do you do? You set down on a very, very foreign, hostile kind of a planet. It's going to be hard to do much of anything unless you take a big contraption with you to be able to house whoever the occupants are ..., and you're not going to do that on initial missions.

So I think we had better learn to understand all the rigors and problems that are going to be involved.

BOND: I think the approach that has been suggested, of course, that we study the moon and go back to the moon, maybe with a small colony, and learn how to exist in that kind of an environment and then branch out and think about, maybe, later on, I don't know how many years away, but at least let's do the moon colony kind of thing and make sure that we can support life and do it fairly effectively before we start trying to branch out into activities on Mars and taking man to Mars.

The other side of the coin, the unmanned space exploration activity, to me, has produced some very significant and very interesting results in all the planetary studies… There have been some fantastic vehicles that have been produced and flown, and, of course, JPL has been involved in quite a number of these. To me, the Hubble Telescope was, I think, one of the most gratifying kinds of things that NASA has done, as far as being able to see into deep space, and the idea of being able to peer into almost our very origins is just a mind-boggling kind of awesome thing, and I think we ought to do more of that. Looking into the heavens and finding out really what this cosmos is all about is a very interesting thing that we need to spend more time and effort on, and money.

BERGEN: How do you feel about the international cooperation? We didn't talk about Apollo-Soyuz. Did you have any participation in that program?

BOND: We supported the Apollo-Soyuz activity. We did quite a bit of work with the Russian teams that came over, and we found those people to be very excellent engineers, very excellent, very friendly people, and we had a good rapport with them. Of course, they were interested in our test facilities and how we did things, and they were kind of amazed at some of the things that we did. We worked well with them, and of course we put the astronauts through—and the space chambers gave them the testing to support that. Yes, we had a very interesting and—I think it turned out to be a very effective way of getting to understand and learn more about the Russians and how they do things and their engineering approaches ..., and they learned from us also. Yes, that was a very effective program to bring about that cooperation. I'm just afraid that the financial problems that Russia is getting into today is just going to kind of affect how they're doing on the Space Station Program now.

BERGEN: Before we close, tell us about your book. We failed to get it on tape the first time you told the story.

BOND: This book is titled *Technologies of Manned Space Systems.* Back in 1963, I was invited to go to Athens, Greece, to participate with a group that was intending to put out a book that would address many of the disciplines, engineering and technical disciplines, of space flight. At that time I went over and met with the person that was going to be an editor of the book, a fellow by the name of Enoch Durbin from Princeton. We discussed the components of the book ..., and after that came back and started writing my portion, my chapter.

I went through quite a number of months—I think it took somewhere on the order of nine months to a year to write the chapter—sent it off to the publishers, went through several iterations on galley proofs and changes ..., and sent my finals in. I guess this must have been in 1964-'65, probably around '65, and then I heard nothing more about it.

Then in the fall of 1981, when Dr. Faget was retiring and I'd gone to his retirement party, a young fellow came up to me and handed me a copy of this book, and he says, "Would you autograph your book for me?"

I said, "What book? What are you talking about?"

He says, "This book that you have published."

Gee, I looked at it, and I was just dumbfounded. I didn't know what to say. Anyway, I got the information, and I called the publishers and had a long discussion with them, and I asked them why in the world they published the book without even letting me know. They took my chapter and made a book. The other authors failed to produce their part, but the editor went on and had my chapter published as a book, and failed to let me know anything about it. Well, I had some nice words to say to the publishers for that lack of professional courtesy, even. I was happy to know that it was published, but not to let me know for that period of time and for me to find out about it in that fashion just—anyway, the book was published, and it covers all the basic technologies that we were utilizing at that particular point in time. That's something that I was proud to have been able to do.

BERGEN: Is there anything else you'd like to add before we end?

BOND: Yes, there is. There is something that, again, I think I'm a little bit proud of. This particular publication is called NASA Reference Publication 11-13, published in August 1983, and it's titled *Design Guide of High-Pressure Oxygen Systems*. NASA has had many instances of problems with handling oxygen and designing systems for oxygen-handling, not just the Apollo fire, but in any number of instances we had problems with the spacesuit development. In fact, we had a lab fire in the crew systems laboratory with the [then new shuttle] spacesuits.

As I mentioned earlier, there was a fire in one of the chambers over at the School of Aviation Medicine that had used oxygen atmosphere, and they had a significant problem. We had a problem in one of the Shuttle systems, the oxygen system. We had the Apollo 13 problem, which was brought about by an explosion of the oxygen tank of the fuel cells. So we had many instances where problems had to be addressed and solved by our engineers and designers at that time.

The last instance, one of the problems with the Shuttle system, kind of energized me that we need to pull together all this information and at least put it into some kind of a handbook and save it for the engineers and developments that were going to be coming on after us. These were problems that were addressed and lessons learned and solved that I particularly wanted to make sure that they just didn't reside in the people's minds, that they did get put down and documented so that future engineers would have access to that information.

So I started having a group of our engineers that had been involved in these systems put together all of their basic and key kinds of things that they had done in modifying valves, different kinds of hardware, materials that we use, seals, etc., into this design guide. We started this, I guess, about eighteen months before I retired, and it was completed about a year and a half after I retired, but I continued to work it even after retirement because I felt it was very important and necessary that this information get properly documented and used by the industry and ourselves. So I thought this was a very important thing, and I felt good about being able to finally do that as a last input, some of my legacy to NASA.

SWANSON: You did considerable work in the reentry systems—maybe I'm not correct; correct me if I'm wrong—but the ablative versus heat sink material.

BOND: Yes.

SWANSON: Why did they choose to use the ejection system on the Gemini spacecraft rather than the escape tower system. Was that related at all to some of the work that you had done?

BOND: Of course, it didn't have anything to do with heat shielding. The initial approach to Gemini was to be able to return the vehicle without the use of parachutes. The idea of using a parasail at that time had come into vogue, and there were a number of people, Jim Chamberlain, particularly, who thought that a paraglider would be an approach that could be used to bring Gemini back. We worked on that for quite a while, but were never able, really, to perfect the paraglider system. [The ejection system entered into the Gemini initial design along with the paraglider.]

Your question on why we didn't use an escape rocket system, it was studied. It seemed as though maybe using an escape rocket wasn't going to be necessary. We had a lot more confidence in the Titan system that the Gemini used as a booster. I thought that the most crucial time period would be during the launch period or on an off-the-pad abort, and that ejection seats could be used and safely used to be able to eject the two astronauts and bring them down on parachutes. So that particular approach won out in all the studies, and it was a give-and-take thing, I believe, for one—I'm not absolutely sure on this, but I think one of the reasons was the ejection-seat approach allowed you to have a lighter total overall weight than the escape-rocket approach, and it also simplified the launch operation. You didn't have to go through the initial launch and eject the escape tower and all that kind of business like we did on both Apollo and Mercury.

So, as I recall, that was the reasoning, and, of course, ejection seats had been in continual use by the Air Force, so there was a great deal of confidence that the ejection-seat approach could be used effectively.

SWANSON: The ejection seats were dropped after Gemini, then they went back to the escape tower in Apollo. I was wondering why the Gemini was unique in that they didn't carry ejection seats over into Apollo.

BOND: That would have involved, I think, more critical design issues of having doors in the side of the command module that would open ..., and there was concern, certainly, in going that route you could affect the structural integrity of the command module. The command module's structure was a very rugged kind of a structure, if you will, and then the heating that it was going to be seeing on the reentry was a lot of more severe than Earth orbital reentry. We had to design the Apollo heat shielding not only for the nominal entry mission, but also for the condition where you're coming back from the moon and you have a skip-out. You first hit the Earth's atmosphere and skip out, and then you come back in at much more severe conditions than would have been experienced. We never experienced that. If you look at the

Apollo heat shields, the amount of char material is relatively small for the amount that is there, but it was actually designed to be able to accommodate the case where you skipped out and then had the more severe reentry conditions following that skip-out.

So I don't think Apollo ever studied the use of ejection seats. I may be mistaken. Maybe they were studied early on, but I think the idea that we needed to have a very integral structure that was sound and rugged and you didn't want to interrupt that with doors. Just having the nose end of it that would allow access from the LEM was all the opening that you wanted, plus the one side door that the astronauts went into, that was quite rugged, and it offered some problems, as we observed in the fire, and that had to be changed. There was a great deal of design study and attention paid to how we would redesign that door in order to be able to get the astronauts out quickly in the case of on-the-pad problem. So the idea of having other kinds of doors where you would eject, I don't believe that was really ever considered.

SWANSON: I really enjoyed your talk about the work on the Shuttle thermal tiles. There was a story that I read at one time that there was problems of moisture condensation on the Shuttle during the pad, when it was sitting on the pad, and once it got into space, that moisture would condense and freeze and cause the tiles to work out. A solution to that that I heard, and I just wonder if you were involved in this, was that they sprayed the exterior orbiter with essentially Scotchguard to repel this moisture. Were you involved with that?

BOND: The fabric material on the topside were sprayed with Scotchguard. I'm not sure that there was Scotchguard used on the tiles.

SWANSON: And that there was some reaction to the spray. Eventually it started to erode some of the material on the [unclear].

BOND: Affect the adhesive, maybe, of the—

SWANSON: [Unclear].

BOND: No, I don't recall that that was a problem. The use of the right adhesive and making sure that you had the minimal pull force on the tiles was like something that we went through quite a bit of work to be able to be assured that the aerodynamic forces were not going to exceed—and coming up with the right number to test to was something that was very closely looked at. If I recall, there was something like a fifteen-pound pressure that is applied, pull vacuum pressure, on each tile, fifteen pounds per square inch. I'm not sure whether that was something on that order.

BUTLER: I have a couple of questions. You talked about technology utilization. Is that something that could be a big selling point for getting more support for the space program and showing how it can be beneficial to different applications on Earth?

BOND: Well, NASA has done a lot of that. Back when I was involved with it, there was a stronger technology utilization office in Washington headquarters, and they would put out periodicals giving a lot of the details of a lot of these technology developments and their possible application. There are many instances where the applications were related to real-life products that were produced, you know, like the Teflon frying pan and the Velcro, many kinds of things. A lot of the materials that were developed were applicable to many other uses.

In fact, one thing I didn't mention, I held a materials conference at the center in 1972 or so, and we had invited many of the companies to participate. What we wanted to talk about were the array of materials that had been developed by this resurgence of effort here to get more nonflammable materials. We had our people give papers on the various materials that had been developed. I think it was a full day or day-and-a-half conference.

One of the comments that I had made in my introduction ... was the fact that the only way that you could get real, true results of whether or not you had solved a problem on flammability of interiors, particularly in aircraft interiors. At that time there had been three or four different airplanes that had problems with fires in the interior, and the materials that were used in the interiors had essentially just burned very, very vigorously just in ordinary atmospheres. I made the comment at that time that the only way to really understand and be able to do anything about those kinds of things was to replace a lot of the materials and do *in situ* kinds of tests in the actual environment and the actual full-size article.

Just a few weeks after that, I got a call from a vice president of United Airlines. He says, "Aleck, you made some comments about being able to do something about upgrading the capability of the aircraft interior to withstand fires. I've got a fuselage up here for you from a 737 if you want to come get it, and you can do your testing."

So I went to Dr. Kraft. I said, "I'm going to need about twenty or twenty-five thousand dollars. I need to transport this fuselage down here from someplace in Philadelphia," I think. I said, "It's given to us gratis by United Airlines, and we can use it to do these *in situ* tests on airplane flammability."

He said, "You've got it."

We got the fuselage down, and we did any number of tests of that fuselage with all kinds of materials that we had developed. Our sister center out at Ames was also involved. I think we made a contribution to the airplane safety activity with those tests.

But while I'm at it, I got the Houston Fire Department interested in fireproofing some of their suits, and some of those things you see on them—I shouldn't say I did. I had a guy by the name of Matt [Matthew I.] Radnofsky. He was a real eager guy, since passed on, but he was instrumental in wanting to really spread the word on fireproofing materials. We did this business with the firemen's suits, children's night clothes and all. We had several instances of children burned because of the very high flammability of the thin nightgowns and pajamas that were being used at that time, and we suggested some other kinds of materials.

We investigated interiors of just normal apartment homes ..., where you have sofas and mattresses and all that, that would burn up. Not only do they burn, but the materials that they're made out of these days are made of these very toxic synthetic materials, and when they burn, they give off some just horrible gases that are almost immediately deadly. So we tried our hand at even some of that. So the fireproofing business, we tried to spread the word as much as possible.

Do you have some other questions about technology utilization? The Tech U. office, as I said, was a very strong component back in those days that I was involved with it, but gradually, I guess because of budgetary problems, it was sort of cut back and I'm not sure to what level. They still do have a Tech U. office, but I'm not sure how strong and effective it is at this time.

BUTLER: I know they still put out a spin-off book that kind of talks about some of the different utilization, but I don't think there's a lot of widespread getting the word out there. So that's what I was curious about.

Looking back over every one that you worked with when you were at NASA and even afterwards, are there any particular people the have stood out for you over the years that maybe you'd want to say a few words about?

BOND: Oh, golly. I'm afraid I'm going to leave out a bunch of them. My memory won't bring all the names back, but there were certainly a number of people that I was proud to be associated with and to have work with me and for me that I do recall. I think I've mentioned

Jim McLane's name a couple of times. Jim was one of my special assistants, and he did work on the facilities for me ..., and then he subsequently became the head of the Space Environment Simulation Laboratory Division, and he ran that for me up until his retirement.

Another one of my technical assistants was Jesse Jones, Jesse came out of the Propulsion and Power Division, and he worked with me as a special assistant. He headed up the Thermochemical Test Area for me, did a wonderful job. I think when he finally retired, he went to one of the universities, went to Texas Tech [University], as one of their professors up there.

Dick [Richard E.] Mayo was another special assistant to me for a while, and we had him go back over to the Crew Systems Division, where he was chief of the division for a while.

Joe Kotanchik, who was my assistant chief in structures and mechanics, was a very close friend and a wonderful structures man. He became the chief of the division when I went up to the directorate office. Joe passed on a number of years later. He actually was workaholic type of guy that died on the job. They had to carry him out of the office. He just seemed to want to work all the time.

[H.] Kurt Strass, another close friend, who worked with us for a while down here in Texas. He finally missed Virginia so much he wanted to go back up, and he left to go back to headquarters. He was a compatriot and close worker at PARD.

A couple of guys that were also in the Space Environment Simulation Lab. I think I may have mentioned him the other day, the last time we talked, Richard Piotrowski. He was the one vacuum specialist expert that I was able to hire on back in those times when we were just beginning to find out what creating a vacuum was all about. He did a real yeoman's job in being able to help us with the design of that facility.

Rudy Williams came to us from a company on the West Coast, and he was a specialist in solar simulators and an optics man and physicist. He did a yeoman's job.

Golly, there are many others. Some people in the Structures and Mechanics Division: Bob Johnson and also there was another Johnson, R. E. Johnson and R. L. Johnson. They were both Bobs. Both of them were graduates of Rice University. They were specialists in materials sciences, and throughout the Apollo Program we had many, many kind of problems with materials. In fact, I always have told my young engineers that one of the most important areas of understanding and study is the materials capabilities, that if materials are wrongly used, you can always get into problems. If you've fully characterized the material and know how to use it and do not try to extend it beyond its capabilities, you're in good shape. But once you try to go beyond what it can really do, then you're going to have problems. We had a few of those where we didn't know the full capability of the materials. But R. E. and R. L. were both experts in materials. They helped us out on many of the kinds of problems.

Phil Glenn, who is still with the center, he is one of the young guys that I believe I hired him back in those days, that has made, I think, a pretty good name for himself.

I guess I could go on and on. A fellow by the name of [David] Greenshields that was involved. He was deputy director of the Structures and Mechanics Division. He was more or less responsible for getting our arc jet facility up and running, and running right.

Ralph Sawyer, who headed up our Communications and Tracking, he was another one of the guys that did a yeoman's job. And many, many others. I know I've left out many other guys that I could mention, but those are the ones that come to mind immediately.

BERGEN: It sounds like you worked with a great bunch of people.

BOND: Yes, we did. We were fortunate in being able to attract the kind of talent and expertise that came on to the Apollo Program back in those days, in the early sixties. We put together a very wonderful team that was able to do the job, and it was a real pleasure and a privilege to be able to work with all these guys.

BERGEN: Looking back, when you first got involved with the space program, back in Virginia, would you have imagined where it would lead, where it would go, and where you would end up?

BOND: No. If you asked me what my thoughts were at that particular point in time and I was asked to work on Mercury, that's about as far as it went. I could not project immediately. Now, after we got into it, yes. When President [John F.] Kennedy says, "You're going to the moon," yes, we were. You're able to expand your thoughts and all much, much further. But at that time, my immediate problems was, hey, how do I get this thing done? How do I do what I've got to do here? I couldn't sit and have the luxury of thinking about how far we were going to go…

Of course, there had been a number of different depictions of going into space, but even back then, I think I mentioned the last time we talked, about the early studies for Space Station. So, yes, I envisioned that eventually we would go into a Space Station.

BERGEN: Thank you so much for coming and sharing with us again. We really enjoyed it.

BOND: Thank you. It's been a real pleasure to be able to sit and think about and reminisce over some of those times. Those were really glorious days for me. Thank you.

[End of interview]