SOUTHWEST TEXAS STATE UNIVERSITY ORAL HISTORY PROJECT
ORAL HISTORY TRANSCRIPT

JAMES P. BIGHAM
HORSESHOE BAY, TEXAS – 26 MAY 1999

The questions in this transcript were asked during an oral history session with James P. Bigham. Mr. Bigham amended the answers and a few questions for clarification purposes. As a result, this transcript does not exactly match the audio recording.

INTERVIEWER: Today is May 26th, 1999. This oral history with James Bigham is being conducted in Horseshoe Bay, Texas. The interview is being conducted for the NASA Johnson Space Center Oral History Project in conjunction with Southwest Texas State University History Department.

Well, thank you for joining me today. You're not a native Texan?

BIGHAM: No, from Pittsburgh, Pennsylvania, originally.

INTERVIEWER: And you went to school up there as well?

BIGHAM: No, I went to college in the Midwest to Purdue University in West Lafayette, Indiana. And then later earned my master's degree at the University of Washington in Seattle, Washington.

INTERVIEWER: How was your experience at Purdue?

BIGHAM: Great! I was from Pittsburgh of course, but I wanted to go to a good school that was big, but not too big. Also, I wanted to study aeronautical engineering and Purdue was, at that time in 1949, one of the few schools that had offered an aeronautical engineering degree. Purdue was a fine school and I thoroughly enjoyed it. Neil A. Armstrong was also a Purdue graduate and received his aeronautical degree there in 1955, which was two years after I received mine.

INTERVIEWER: Did you know him when you were there?

BIGHAM: No, I didn't. Of course, we were just students then. And he was a sophomore and I a senior.

INTERVIEWER: When did you know that you wanted to study aeronautical engineering?

BIGHAM: In grade school I always enjoyed building model airplanes and mathematics. I wasn't sure what else to do. It just seemed like a logical choice. I suppose I could have studied business, but I was advised, and I think it was right, that an engineering degree gives you a better overall background. Although it was difficult, I really enjoyed it. Later, I took a leave of absence from Boeing and earned my master's degree in aeronautics and astronautics at the University of Washington in 1965 and immediately moved to NASA in early 1966. So, aviation has been a lifelong interest. At Purdue, I was in the advanced ROTC (Reserve Officers' Training Corps) program and entered pilot training with the Air Force after graduation. There I was an instructor pilot in single engine jet aircraft after completing training.

INTERVIEWER: Right after Purdue, you were in the Air Force?

BIGHAM: Yes. I graduated in 1953, during the Korean War, and was immediately called to active duty. If you were an advanced ROTC graduate at the time, you were called to active duty right away. I went through pilot training in Arizona and received my wings at Williams Air Force Base near Phoenix, Arizona. I was then sent to instructor pilot school at Craig Air Force Base in Alabama. Then, the Air Force rushed us over to Germany in January 1955. The plan was that we would train ex-Luftwaffe (German Air Force) pilots (they had been grounded since the end of World War II) to be instructor pilots for NATO (North Atlantic Treaty Organization). This was part of rearming Germany so it could participate in NATO. But soon after we arrived there, the French said they were not ready to approve this, so we ended up training a few pilots from other NATO and U.S. ally nations during my year and a half there. But it was fine duty because we were stationed at Furstenfeldbruck Air Base. Hermann Goering had it built as somewhat of an air force academy for the Luftwaffe. It had not been bombed, and everything was first class. We had all these T-33 jet aircraft which we flew all over Europe to maintain our proficiency. So, I consider myself very lucky.

INTERVIEWER: Did you enjoy the instructing?

BIGHAM: Yes, although quite frankly I didn't end up doing much of that. But there were some challenging moments.

INTERVIEWER: What was challenging about it?

BIGHAM: Well, if you're not alert, students can get themselves and you into a lot of trouble. The trick of instructing is being able to let the students go as far as they can without excessive risk. If you take over too early, they don't learn as well. But on the other hand, if you're too liberal at letting them make mistakes, it can cause problems.

INTERVIEWER: Any close calls?

BIGHAM: Oh, we had a few. Usually on landing. It takes a lot of experience to know how far you can let a student go before you take over control, how far you can go let him go without getting you and him into trouble.

INTERVIEWER: Was this going to be a harbinger for things to come at NASA for the simulator that you worked on?

BIGHAM: Well, yes. I felt comfortable, as we'll get into I suppose, with the Lunar Landing Training Vehicle (LLTV) as the principal method for training the astronauts in the final phase of the lunar landing. We could view their control inputs on telemetry. It wasn't the same as actually being in the vehicle with them of course, but you could tell if they were making excessive control inputs and that kind of thing. From that standpoint, my instructor pilot training was useful.

INTERVIEWER: After the Air Force, where did you go?

BIGHAM: Went to work for Boeing in the Commercial Airplane Division. My first assignment was in the 707 Program. This was just about the time the first 707 was delivered to Pan American. Then Boeing formed the project team for the design of the 727, and I was assigned to work on the structural dynamics of its T-tail design, a first for Boeing. After that, I moved on to what was then called the TFX (Tactical Fighter Experimental) Program, later designated the F-111, which Boeing competed with General Dynamics for and lost. From there, went to the C-5 Program which we were competing with Lockheed for. Lockheed won that one. So, at that point, I decided to take a leave of absence from Boeing and get my master's degree from the University of Washington. This was 1964-65. Just prior to graduation, I visited my parents in Houston, Texas. I was fascinated by the manned space program, and during my visit was interviewed by the then Manned Spacecraft Center (now the Johnson Space Center). They made me an offer and I took it. I joined them in February 1966.

INTERVIEWER: When was the first time the Mercury missions caught your attention.

BIGHAM: They were still flying the Gemini missions when I came on board. I was assigned to the Flight Crew Support Division which was responsible for all the simulators for the flight crew. That was the division's main job. There were quite a few including the Lunar Module (LM) and the Command Module simulators. In fact, they were looking for someone to manage the LLTV contract. And that was my assignment until we completed flight testing of the first LLTV about April of 1969.

INTERVIEWER: Why don't you explain that.

BIGHAM: A little background. I'll give you some reasons for it. Basically, the LLTV was used to train the astronauts in the control characteristics (flying qualities) of the Lunar Module in the final portion to touchdown of its descent to the lunar surface, the last 500 feet. In the initial flight testing of a new airplane, the most challenging maneuver is generally the landing. It requires the most precise control. And the dangers are if you don't do it right, you can damage it by landing too hard, too long, or too short. The landing is critical. So, you really do need a simulator that gives the pilot in a very realistic way the same feel and visual cues that he would have in the actual landing.

The Lunar Module was designed to fly only in the gravity field and airless environment of the Moon. So there was no way that the astronauts could rehearse in it the lunar landing. The actual landing on the Moon was the first opportunity they had to fly the Lunar Module to a landing, and it had to be successful. So NASA recognized early on that the Apollo Program needed a really good simulation to rehearse it. Landing on the Moon, you have a strange environment, strange lighting, possible obstructions that you have to fly around which Armstrong did. As a result, funding was provided in early 1962 to NASA's Flight Research Center (FRC) at Edwards Air Force Base, California, for what was called the Lunar Landing Research Vehicle (LLRV) Program. Subsequently, FRC awarded a contract to the Bell Aerosystems Company of Buffalo, New York, to design the LLRV which was the father of the LLTV.

It was a fixed-price contract, I believe, for two LLRVs. Bell was able to deliver the first vehicle for flight testing at FRC, but provided only the parts for the second because of the

program's funding constraints. Joseph A. Walker, the famous test pilot later killed in a plane crash, was the first LLRV pilot. And he and others did a lot of testing of it without a serious accident. The plan was to fully flight test it, and then deliver it to the Manned Spacecraft Center for early familiarization and training of the Apollo 11 flight crew at Ellington Field in Houston, Texas.

In the LLRV Program, it was recognized that this was a research vehicle and that its purpose was to find out what the flaws were so that you could improve the design to make a training vehicle out of it. Make, perhaps, its flying qualities and cockpit more realistic. Work out the bugs of the avionics and that kind of thing.

When I came on board in 1966, discussions were already underway with Bell to produce three LLTVs. They were instructed to try to make the cockpit layout as similar for the landing maneuver as the Lunar Module which involved primarily using the actual LM hand controller that the pilot used to control vehicle pitch, roll, and yaw. It also required a reproduction of the LM radar altitude and altitude rate indicator which tells the pilot he is above the surface and how fast he is descending to it. Teledyne Ryan in San Diego, California, was responsible for producing the landing radar and indicator for the LM. We let a separate contract to them to produce a radar with similar levels of performance for the LLTV which they did and it was pretty good. Neil went with me to test it in a helicopter at Ryan where we had our picture taken with T. Claude Ryan, Ryan's founder and a real aviation pioneer [Photo 1]. Ryan built the *Spirit of St. Louis* for Charles A. Lindbergh.

One of the major differences was that in the LM the pilots were standing whereas they were seated in the LLTV. We had to put them in a high-performance ejection seat because, for one reason, they operated only at very low altitudes, 500 feet and below. If anything serious

went wrong, they had little choice but to eject. I mean there wasn't time to figure out what was happening if the control system went haywire or the engine didn't respond or something like that. The pilot had to bail out. And that happened a couple of times and I'll tell you about that.

Anyway, I don't remember the exact date but we awarded the contract to Bell after very difficult negotiations. We were under tight cost constraints. We let the contract for the three LLTVs to Bell Aerosystems, and the LLRV was delivered by FRC to Ellington. Neil Armstrong had been named the commander for the first Moon landing mission. He of course was very interested in all this and we worked together on it. He would come with me to Bell and Ryan to see how things were progressing and how realistic it was and suggest improvements. It was very interesting.

INTERVIEWER: He worked in fact as an engineer as well? Not only you but Neil Armstrong?

BIGHAM: Oh yes. Well the astronauts did that. I mean of course they were vitally interested in all the engineering aspects and brought practical experience to the table. If you listened to some of the crew, like Walter M. Schirra, engineers don't really know what they're doing. The pilots have to watch them. But Neil wasn't like that. He was an engineer as well as a test pilot and appreciated both sides of it.

I might add I thought the FRC people who worked with the LLRV Program never received enough credit for what they did. They had previously been assigned to the X-15 Program that you may not know about. This was an experimental high-altitude, high-speed research program that FRC undertook to explore high-Mach number flight, like six times the speed of sound. It was quite successful. Armstrong had been one of its principle test pilots. But

that program ended just before FRC received the LLRV Program, and they moved the people, project managers, project engineers from the X-15 Program to the LLRV Program. And they did, really did a bang up job—great job.

INTERVIEWER: Armstrong was one of the most experienced test pilots.

BIGHAM: Yes, oh yes. Anyway, FRC helped us to get set up at Ellington. I might say the management at (now) the Johnson Space Center had great concerns about the whole LLTV Program. They saw the dangers of it. As I mentioned earlier, it operated only at a low altitude and was a very complex vehicle. The LLTV was the first purely fly-by-wire aircraft to be used for relatively routine operations. And when I say fly-by-wire I mean there were no control cables. The pilot's commands were only by electrical signal from the throttle and hand controller. There had been fly-by-wire research vehicles, but we were trying to make this an operational vehicle. And it was not a digital system; it was analog. And in many ways it was still experimental and very complex for an operational outfit like our Aircraft Operations people to run. There was a level of expertise that was required. So JSC management just was not all that enthusiastic about the program. But the astronauts said they had to have it. We've got to do it. So management had to bow to that requirement.

But anyway, we got the LLRV to Ellington and started flying it. And by then, I was working the LLTV contract, and the JSC Aircraft Operations people had responsibility for operating it. So I was out of that. They had a large trailer where the ground flight controllers communicated with the pilot, viewed the telemetry, and in general kept an eye on what was

happening during the flight. There was an outside loudspeaker so others outside the trailer could hear the communications between the pilot and the ground.

And, I don't know, it was on Neil's second or third LLRV flight. I don't recall exactly. They flew in what was a pretty windy day. It was somewhat turbulent. The attitude, as on the LM, was controlled by attitude control rockets. And in an effort to hold the vehicle's attitude steady in the turbulent conditions, it used a lot of propellant. Basically, he ran out of fuel for these rockets. He was up about 200 feet when ground realized there were problems and tried to get him down and he was trying. But as the review board later found, there was a faulty fuel sensor. So the ground found out too late how bad off he was, and he lost control of the vehicle. The attitude control rockets just stopped working. I was there watching it from outside the trailer, and I remember thinking, they need to get him down. But he lost control and said over the loudspeaker, "Got to leave the vehicle." And it had a wonderful ejection seat.

Weber Aircraft had designed this rocket-propelled seat for high-speed aircraft, but they adapted it for both the LLRV and LLTV. It delivered about fifteen times the force of gravity for about half a second which would accelerate it and its occupant from zero to roughly two hundred miles an hour in half a second. [Laughs] Once the rocket burned out, it had a mechanism which automatically separated the seat and the seat's occupant, and another mechanism that automatically deployed the parachute. So it was just [finger snap] like that. And that's what happened. He went up, separated from the seat, the parachute opened, and he floated gently to the ground. The LLRV then flipped over backwards and crashed on the runway.

They went out and brought him back to the trailer. Edwin E. "Buzz" Aldrin was there. So I went in to hear the debriefing. First thing we did was to ask him if was he okay. And he took off his flight suit and the only injury he suffered was a large bruise at the base of his

buttocks, where the edge of the seat had caught him during the 15g acceleration. But other than that, he was fine. And he appeared to be very calm about the whole thing. Buzz commented, "Pretty exciting." As far as I know, that was the first aircraft ejection he ever experienced, but I could be wrong about that.

The JSC Director, Dr. Robert R. Gilruth, appointed an Accident Investigation Board under Wally Schirra. They blamed it on the fuel level sensor, but they also placed tighter weather restrictions on the flights in terms of wind velocity and so forth to avoid that kind of thing. We only had the one LLRV. They never got around to assembling the second because, in the meantime, the first LLTV was delivered to Ellington for ground checkout and flight testing. And when it was thoroughly ground tested, we proceeded into the flight-testing program.

The feeling had been during the engineering portion of the LLTV Program that because of the LLRV experience and since it flew at such a low velocity, we didn't need to do wind tunnel testing to determine its aerodynamic characteristics. One of the major differences of the LLTV from the LLRV design was a large covered cockpit had been placed on the front of the LLTV to simulate the pilot's field of view as it would be in the LM. In other words, not to give them the full field of vision. Here's a picture of it. You can see the cockpit. And, as it turned out, it made a real difference in the aerodynamic characteristics of the vehicle.

The principle LLTV test pilot was Joseph S. Algranti, who was Chief of Aircraft Operations at what is now the Johnson Space Center. He made a number of flights in the first LLTV. They decided to see how fast the thing would go before telemetry, which was monitored in the ground control trailer, indicated an unsafe attitude control rocket duty cycle was approaching. He got going pretty fast and lost control of it. I wasn't there but did see a film of it. The vehicle rolled over on its side and began to plunge toward the ground. The ground

control people were yelling at him over the radio, "Get out, Joe! Get out! Eject!" And he did just before the vehicle hit the ground. But again that seat was so powerful, it saved him. And again, he wasn't hurt. But the vehicle crashed.

This time, Dr. Gilruth, who was an expert in aircraft stability and control, didn't fool around. He formed an Accident Investigation Board, which I had to go before and brief because I was asked to handle the wind tunnel and flight test engineering evaluations. The board was chaired by Dr. Gilruth and had as members the Chief of the Mission Operations Directorate, Christopher C. Kraft (also a control dynamics expert); George M. Low, head of the Apollo Program at JSC; Donald K. "Deke" Slayton, my supervisor's boss and head of the Flight Crew Operations Directorate; Maxime A. Faget, Director of Engineering at JSC; George S. Trimble, Gilruth's deputy; Major General John D. Stevenson from NASA Headquarters in Washington, D.C.; and representatives from the FRC. That was the Board. Those were the people we had to convince we knew what we were doing. [Laughs]

INTERVIEWER: Pretty intimidating.

BIGHAM: Yes. But what I recommended and they took me up on it, was to transport the second LLTV to NASA's Langley Research Center in Hampton, Virginia, in what was called the Super Guppy. It was a modified Boeing Stratocruiser that was used to transport the large upper stages of the Saturn rocket to Cape Canaveral, Florida. It had a modified body that was of a diameter large enough to hold not only the Saturn upper stages, but also the LLTV. So it was arranged that we would put the LLTV in that thing and fly it up to Langley to be placed in their full-scale tunnel. Which we did. [Photo 2]

The Langley people were really pleased to help us out and gave us first-class support. We mounted it in their full-scale tunnel and made provisions for operating it not only with the engine unpowered but also with it powered up because there was a feeling that the airflow from the engine might materially affect the aerodynamic characteristics of the vehicle. [Photo 3] We found out in a hurry that the villain in all this was the large canopy on the front. It was just like a big air scoop. And what happened, if the pilot was flying, even at a low velocity, at a certain sideslip angle, in other words, a certain angle to the wind horizontally, there was a large aerodynamic torque on the vehicle that tended to make it unstable. Looking at the flight data, that's where Joe Algranti had been flying. He somehow had just gotten, without realizing it, right on that sideslip angle. So as he built up speed, it forced the vehicle to yaw, and he lost control of it. So the fix, as it turned out, was simple. We just took the roof off the canopy to vent it. There were suggestions that we should put wings on it or do this or that, but that was unnecessary and too complicated. So all we did was just remove the roof from the canopy. And it was fine after that. Just fine.

So we got our data and flew it back to Ellington in the Super Guppy and resumed flight testing under very tight restrictions, and I was involved in that. Finally, I think about a month before Neil was to depart for the Cape for Apollo 11, we got a number of flights in with him. And he got the training that he felt that he needed for the actual Moon landing.

INTERVIEWER: How many flights was that?

BIGHAM: You know, I don't remember exactly. I believe four or five. Of course he had some previous experience in the LLRV. And we were very curious, of course, when he came back

from Apollo 11, what he thought of the fidelity of the trainer. We knew that JSC management would have liked to end the program if it could for reasons previously cited. But, Neil was very generous. He said "The Lunar Module flew very much like the simulators and like the Lunar Landing Training Vehicle, which I had flown more than 30 times at Ellington Air Force Base near the Space Center. I had made from 50 to 60 landings in the trainer, and the final trajectory which I flew to the landing was very much like those flown in practice. That, of course, gave me a good deal of confidence and a comfortable familiarity." So, and with that, every astronaut after that was trained in the LLTV and there were no more crashes involving astronauts. But they were doing a test flight on the third LLTV, and it had a complete electrical failure. So again the pilot had to bail out. So there was one LLTV left, and I don't know where it is now.

INTERVIEWER: In spite of the fact that they were dangerous, it was very necessary because they weren't going to get a second chance and you wouldn't want to lose an astronaut on the Moon.

BIGHAM: Oh, no. If Neil had come back and reported that the actual Moon landing was so much different than the LLTV simulation, that the risk of flying the LLTV wasn't worth it, the program would have been canceled. But it was just the other way around. The astronauts needed that training.

INTERVIEWER: During the mission, I mean after all this, the landing is crucial. You must have had a great sense of satisfaction.

BIGHAM: I did. I did. You know as an aeronautical engineer and former pilot, there was never any doubt in my mind that the training in the LLTV was essential. Again, if you think about it, they had not only the uncertain Moon terrain to deal with, they only had a limited amount of fuel. They had only a few seconds to make the touchdown or they're out of fuel. So it required very precise control. You know, there was never any doubt in my mind about the need for the LLTV training, which made me an enthusiastic supporter of the program.

But by Apollo 11, the LLTV engineering work was done, and I moved on to the next program, which was the Space Shuttle. Max Faget, who was the Director of Engineering at the Johnson Space Center, conceived of the Space Shuttle Program. And he formed what was called a Shuttle Skunk Works. About twenty-seven of us were located in a windowless high-bay area where we were developed concepts for the Shuttle. I was assigned as a Shuttle Manager for the Flight Crew Support Division after coming off the LLTV Program which was about a month before the Apollo 11 launch.

INTERVIEWER: So you were on the Shuttle before?

BIGHAM: Before Apollo 11. I remember watching the Apollo 11 launch in the Skunk Works high-bay area. We had a TV set tuned into mission control. So we watched the launch there and then got back to work designing the Space Shuttle.

INTERVIEWER: So there was no celebration for you.

BIGHAM: No, no. But by then, the LLTV Program had been turned over to the Aircraft Operations people. They had their hands full. As soon as Apollo 11's crew training was completed, they started training the next pilot, which I think was Charles "Pete" Conrad.

INTERVIEWER: Conrad and Alan L. Bean and Richard F. Gordon?

BIGHAM: Could be. It all runs together.

But my mind was active again in working the Shuttle. As it turned out, there were two concepts that Faget had: one was for a straight wing vehicle, the other a delta wing concept. He felt there might be some benefits to having short, stubby wings and designing it that way. But as it worked out that wasn't in the cards. We went with the delta wing design. And not only that, with a design which had a lot of drag. The reason for this was because of those big engines on the base of it—three engines on the base of the Shuttle. This causes a lot of what's called base drag. Plus the fact, for weight reasons, you didn't want a whole lot of wing area and tried to minimize that. So we called it a bomb with wings. And again, FRC got into this. They had a lot of experience with unpowered landings. There was a debate whether we should have deployable jet engines so the astronauts could have some available power to help them land. But FRC had great experience in landing unpowered landings, like the X-15 and the Bell X-3 which Charles E. "Chuck" Yeager flew. They were all unpowered landings in high drag vehicles just like the Shuttle. And the technique FRC had developed was for the pilot to pick a spot about a mile short of the runway and then dive the vehicle at it at a very high airspeed. Then, at that point a couple of thousand feet above the ground, start to level off and bleed off airspeed as you fly to the

landing point and touch down at the desired landing speed. That's the technique FRC developed, and that's the technique that is used for landing the Space Shuttle.

But again, you can't train the astronauts in the Space Shuttle. You need something that simulates its landing characteristics. And I was assigned to work the problem for the Flight Crew Division.

The first people I got with were the Boeing people. It seemed to me and later agreed to that while you can think of using an exotic vehicle like the F-102, which was a delta wing fighter developed by General Dynamics, but was obsolete and out of production, we needed an aircraft which could be supported and for which spare parts would be easily available over the life of the Shuttle program.

My focus then was on commercial aircraft, and there were three two-engine aircraft to consider. There was the Boeing 737. There was the Lockheed JetStar, which is an executive jet, and FRC had one that it used for in-flight simulation. Finally, there was the Grumman Gulfstream, which is a deluxe executive aircraft. So these three were the candidates, and we asked them to submit proposals as to what modifications they would make to their vehicles to simulate the landing characteristics of the Space Shuttle Orbiter Which they did. It turned out that the key item was trying to create enough drag. Commercial vehicles are designed to minimize drag because if you don't, they use a lot of fuel and that's money.

The main problem was creating enough drag to simulate the Shuttle landing trajectory. In-flight reverse thrust appeared to be the best candidate. But on the 737, Boeing was unable to do that, so they lost that competition. It was just that the 737 engines are located under the wing and there would be too much turbulence and buffeting from in-flight reverse thrust to allow that.

Now, on the Lockheed JetStar and the Gulfstream, their engines are located on the rear fuselage, just below the tail. They're just a little forward of the tail. The Gulfstream had a high T-tail where the horizontal stabilizer is located at the top of the vertical tail. On the JetStar, the horizontal tail is about half way up the vertical tail.

We decided to do an in-flight fly off. Grumman had one of its test pilots fly a Gulfstream to FRC. And of course the FRC already had a JetStar. So we asked them to demonstrate in-flight reverse thrust for both aircraft and see what happened. Very carefully.

It turned out on the JetStar, because the tail was closer to the engines, there was a lot of buffeting. When it went into in-flight reverse, the flow out of the engines would go up and around the horizontal tail and really shook the rear end. Whereas on the Gulfstream, the plume from the engines passed beneath the stabilizer and the buffeting was fairly minimal. So that was the key in our selecting the Gulfstream as the in-flight simulator. We had to get a name for it and initially thought about the Shuttle In-Flight Simulator or SIFS. But we decided that sounded like a venereal disease. So we renamed it the Shuttle Training Aircraft or STA, and that's what it's known as today.

So we solved the drag problem, but you still had the problem of the lift. On the Shuttle, you had a low lift delta wing, but the Gulfstream was a high lift vehicle. So you had to find a way of reducing lift on the Gulfstream. What we did was to have Grumman modify the wing to provide large wing flaps. These were then modulated by the simulation as a function of the vehicle's angle of attack (the angle between the aircraft's pitch attitude and the relative wind vector as measured in real time) to match the Shuttle's wing lift characteristics. Then, you had a very sophisticated closed loops digital computer system developed by Honeywell. It compared the actual performance of the Gulfstream as measured by rate gyroscopes and accelerometers

against a mathematical model of the Space Shuttle. It then automatically moved the Gulfstream control surfaces so that the flying characteristics of the Gulfstream as the pilot saw and felt them were the same as they would be on the Shuttle—the handling qualities if you want to call it that. It was a pretty sophisticated little system. Again, the pilots were enthusiastic about it once they had an opportunity to fly it. JSC bought two initially, and it's still in use. In fact, I believe JSC has purchased more of them, and they are being used to train all of the Shuttle pilots.

INTERVIEWER: And these were considerably safer than the LLTV?

BIGHAM: Oh yes. The reason was that you had power and fuel to buy time. If something is not right, the pilot can take it out of reverse thrust and go around (as do commercial aircraft). So to the best of my knowledge there has never been a serious accident. But I left JSC in 1989, so I really don't know what's happened since then.

INTERVIEWER: You moved on to the Space Station Office

BIGHAM: Yes. I was the Project Manager for what was called the Phase B, the preliminary design phase of the STA. JSC later formed a separate division to actually handle the STA production, and I moved on to the Space Station. This was back in early 1981 as I recall. I was requested to come over as Manager for Space Station Avionics in the newly formed Space Station Office under Robert O. "Bob" Piland, who was the JSC Manager. Which I did. I later became Manager for what was called the Space Station Information System or SSIS.

Right from the beginning, NASA Headquarters in Washington wanted to make this a very universal program. They wanted to not only have all the other NASA Centers participate, but to give them a significant piece of the action if you will. This included Lewis Research Center up in Cleveland, Ohio; Langley; Ames Research Center in Moffett Field, California; Kennedy Space Center in Florida; and Marshall Space Flight Center, in Huntsville, Alabama. They also brought in the European Space Agency, the Japanese Space Agency, and Russia.

So it was a universal affair and not only from the standpoint of the Station flight components. Each of the many contractors involved had their own computer systems for tracking the parts, their status, and so forth. And then there are the many scientific research systems. I mean that on board the Station there will be many experiments put together by different agencies. They all want data. The question was do we let everyone do their own thing or do you try to have some order to this, some level of integration? And the Jet Propulsion Laboratory in Pasadena, California, suggested that we should make an effort to see how far we could go in integrating all these things. Computer networking, at that time, was in its infancy.

So anyway, they made me the Space Station Information System Manager for the JSC Station Program Office. NASA's intent, when I joined the Station Program in 1981, was to fly the Station in 1992, the 500th anniversary of the discovery of America.

Well then Congress got into it. And every year it seemed we had to go through a major redesign mainly get the cost down. So when I retired from NASA in 1989, we really hadn't progressed that far with it. And here we are in 1999 and we're just now starting to launch its components. One of the major problems we had, and you always have in the manned spacecraft program, is keeping up the design of the computer systems with the rapid advances in the computer and software industries. Because at some point you have to baseline something so you

can get on with integrating and producing it. In the meantime, the industry's out there rapidly advancing computer systems technology, software technology, and networking. So you have to design a system which is flexible. But back in 1981, networking was something you talked about, but no one had really done anything with. And there was an international group trying to agree on standards for networking that everyone could accept. I think, eventually, Microsoft developed many of these standards. But then I'm not really sure. I haven't followed it, so I don't know what is on the Station now. But it was interesting at the time.

INTERVIEWER: Frustrating?

BIGHAM: Frustrating? Yes. I just felt we were beginning to make progress when I retired in 1989. And again, I just don't know what's happened since then.

One interesting thing that occurred was that early on we decided that we needed a major meeting to get a lot of the key people together from the various NASA Centers and Agencies to discuss how to proceed on this. As it worked out, we were having the meeting at JSC when the *Challenger* accident happened. And we were all together in a large room trying to get organized. I guess there were about one hundred people there when one of the secretaries came in and said the *Challenger* had exploded. We didn't have TV set readily available, but we had a radio which we listened to. We turned the volume up, and everyone listened to the news reports. In the meantime, we did locate a TV set and tied into the mission control loop and commercial TV. And we're paralyzed; everybody's just paralyzed. We sat watching the replays on commercial TV. That went on all that day.

Then the next day, we got everybody together and said we had to make a decision. Do we go on with this or should we cancel, reschedule? But everybody agreed let's get on with it. Which we did and periodically we'd stop to get the news reports. But President Ronald Reagan came down and we stopped the meeting briefly so if people wanted to they could go and see that ceremony. I watched it on TV. We were still doing work trying to get things assembled. But it was a real shock, a real shock.

INTERVIEWER: How did that compare to the Apollo 1 fire?

BIGHAM: I would say it was probably even more shocking because of the public nature of it. So far as NASA people were concerned, it was bad. Both were bad. I mean here we were flying a civilian for the first time, the teacher S. Christa McAuliffe. And it exploded on television in full view around the world. So in terms of its impact, it was much worse, much worse.

In the Apollo fire, the Accident Investigation Board was headed by Frank Borman, the astronaut. And they did a whale of a job. I mean, they had to figure out what had happened, go through a complete redesign of the Apollo Command Module as well as looking at other aspects of the program and trying to maintain a schedule of getting Armstrong to the Moon before the end of the decade. And they did. Did a fine job.

Now because, I think because of the visibility of the *Challenger* accident, the president had no choice but to name a high-level review board, which was, I think chaired by former Secretary of State William P. Rogers. And Neil Armstrong was on that. It had other scientists with no background in manned spaceflight. I feel we would have been much better off if we'd handled the investigation just like we handled the Apollo fire investigation. We'd kept it within

the Agency. It would have moved along faster but without a lot of adverse publicity. But it wasn't possible to do that. So eventually things worked out. From that standpoint the *Challenger* accident was much worse than the fire.

INTERVIEWER: Deke Slayton had said that any mission—any crew could fly that. Were all the crews that similar? So for example if Armstrong's crew had to back out of Apollo 11, could they move a crew in?

BIGHAM: Well, there had to be a certain amount of custom training for each mission. I think probably what he meant was that they could be trained. You could take any crew and they could perform any other mission given the proper training. But each mission was different, had its own objectives in terms of experiments and so forth.

INTERVIEWER: You had said some very interesting things we didn't get on tape. So I'm going to ask a few questions and hopefully it will go just as well. We were talking about the realistic future and I guess what my question is what can we expect in the future?

BIGHAM: Like I say, I think Daniel S. Goldin is a great Administrator and he's leading us in the right direction. The problem that he has to deal with is shrinking budgets in terms, with inflation and all. Slowly getting the Space Station assembled in orbit and that's, as I say, we originally planned to fly that in 1992 and here we are in 1999. And I don't know when they expect it to be fully assembled. It's probably three, two, three years off yet and manned. And that'll be tough

to do probably with the budget constraints and Russia's failure to produce as they said they would. We have to subsidize them.

Beyond that, certainly research is being done on Mars exploration. And there's a good unmanned Mars program going. And eventually perhaps we'll do that. But the nation really has to make a commitment to that kind of thing. Right now the focus is on the Space Station. It will be interesting to see how that program develops and what if anything comes after that. And if there's another dimension, if there's another *Challenger*, another Shuttle accident, why that can throw the whole thing into—

INTERVIEWER: Right and do you think that's a possibility?

BIGHAM: Yes, it's always a possibility. Goodness knows we have enough experience in it. But it's a very complex vehicle and things do happen. It can happen. It can happen.

INTERVIEWER: What was your greatest personal accomplishment at NASA?

BIGHAM: Well, I felt the Lunar Landing Training Vehicle Program. It was a very complex program. It didn't have much management support because of the dangers of it—the adverse publicity, they thought, which might result from any accident. But we did have the two accidents. We got through those okay. Fortunately, it was not picked up by the wire service. And it went on to be a very successful training program. The astronauts all felt it was realistic and that they absolutely needed it in preparation for the trying to do the landing on the Moon. So I was very proud of that, proud of that role.

INTERVIEWER: And I had used the term earlier that you had "survived" at NASA for such a long time. You shied away from that word.

BIGHAM: Survived, yes, it really wasn't that way. I guess you never quite know at NASA what's going to happen next. I was fortunate moving from the Lunar Landing Training Vehicle Program on to the Shuttle Program in its very early stages. And stayed with that through the 1970s and moved to the Space Station in the 1980s. The assignments within those programs were somewhat fluid. But in the Shuttle Program, I guess the major accomplishment was getting the Shuttle Training Aircraft Program conceived and under way. In the Space Station Program, initiating work on the integration of the many scientific and operational computer systems that the Space Station is going to have. And again, I don't know where that stands. I left the program in 1989 and here we are 10 years later and I haven't kept up with it. So I don't know really.

INTERVIEWER: You had made a comment that I liked earlier that the Space Program was a young man's—

BIGHAM: Oh yes, yes. Chris Kraft pointed that out when he retired. He says, "You know, the pressures and the challenges of the space program are such—it's more for the younger men." And I think he meant twenties and thirties and us old guys ought to get out of the way. So that generation which did Apollo and Space Shuttle and is now retired. And the Space Station

Program, I know has been taken over by the two generations after us. They're running that. And I think that's the way it should be.

INTERVIEWER: Well I think that's everything that I wanted to go back and cover. I think that's a good way to end it. At this point, you got away from Houston and retired up here.

BIGHAM: Retired up here and determined to move on with some new things. As I mentioned I'm involved in civic activities. I'm an elected director of the property owner's association and mentor in the high school program. My wife's very active in civic activities. I've got my handicap down to nine and trying to bring that down further. I gave up golf when I worked for NASA when I joined them. I played some up at Boeing. But we were working six, seven days a week. There just wasn't time. So I gave it up for twenty years. And thinking that when I retired, you know, it would be like driving a car, would come back real fast but it hasn't. It's taken a few years to get my handicap down.

INTERVIEWER: Well a nine handicap is nothing to sneeze at.

BIGHAM: No. I'm playing some of the best golf of my life right now.

INTERVIEWER: Well what was interesting too, you had mentioned that you didn't keep in contact with astronauts or engineers, anyone that you had worked with. Is that because of the distance or because that was the job and you left it at that?

BIGHAM: Well, maybe I was a little different. I liked to separate my personal life from my business life. I actually lived in Houston and commuted out to the Space Center.

INTERVIEWER: You were in downtown Houston?

BIGHAM: I lived near the Galleria off Memorial Road. There was no problem commuting since you were always going against traffic. I drove into town on Memorial and then out Interstate 45 to the Center in the morning when all the traffic was coming in and vice-versa in the evening. So, I didn't have a lot of close personal relationships out there. But I very much admired the people I worked with. But when I came there, I was a bachelor and did all my dating in Houston. [Laughs] There weren't that many single gals at NASA; most lived in Houston. Eventually I got married and continued to commute from Houston. But although I really enjoyed the people I worked with, I've lost contact with them.

INTERVIEWER: Well, I think that's everything then. Again, thank you.

JAMES P. BIGHAM

November 11, 2005

Dear Neil,

I enjoyed *First Man* and am sure it will do well. It's not only your biography, but also includes other important events of the Apollo program less well known. It's good to have it for the historical record.

As you might expect, I was especially interested in that portion that reviewed the history of the LLRV and LLTV. I noted Bill Anders comment that in his view the LLTV was "a much unsung hero of the Apollo program". I've always believed that to be the case, particularly with respect to its predecessor, the LLRV project at the Edward's Flight Research Center. It's a story that, so far as I know, has not yet been told in its entirety. A while back I discussed this with Gene Matranga (in retirement). Gene said that he and Wayne Ottinger had indeed written the history of the LLRV, but had never been able to get FRC's management to approve its release. I've always felt the story of the LLRV/TV projects to be an interesting one involving many of the key people of the Apollo Program.

I was disappointed to read that Dr. Hansen confused your LLRV ejection with Joe Algranti's accident in LLTV #1. Hansen's speculation on page 330 that JSC's telegram to Headquarters reporting the altitude of your ejection was "purposely exaggerated" is grossly in error. Your ejection of course did occur at about 200 feet, and a good deal more than the two/fifths of a second before vehicle impact. I suspect Dr. Hansen was influenced by Chris Kraft's memory of your accident as related in his book *Flight.* Chris had written, confusing it with Joe's accident, that you ejected only two/fifths of a second before vehicle impact and that it was from the LLTV. The results of the investigation of the LLTV #1 crash were unfortunately missed in *First Man.* I happen to believe that investigation, headed by Dr. Gilruth, contributed greatly to the fact that there was never an accident in the LLTV involving an astronaut.

From the beginning it was agreed that my division would have responsibility for the LLTV contract, and that the Aircraft Operations Division would then have responsibility for all LLRV and LLTV operations. This was later amended during the difficult LLTV contract negotiations (Deke had set tight funding limits) to have LLTV flight test done by AOD and Bell at Ellington rather than at Bell's plant in Niagara Falls. This made some sense since it was hoped that by then AOD would have gained sufficient experience in the LLRV to conduct an effective test program.Unfortunately, this proved not to be the case. Both Dean Grimm and I (and I recall Matranga and Ottinger) realized that the complexity of the project made it essential that AOD bring people onboard early on for training at FRC in LLRV operations, but it never happened.

Both accidents, in my opinion, were caused primarily by the inexperience of AOD personnel and not by any vehicle malfunction. In your case, it was allowing a flight in unsafe wind and turbulent conditions that were double those set by FRC. In Joe's accident, it was the failure to monitor in real time the duty cycle of the yaw thrusters while attempting to expand the flight envelope. Although Wally Shirra's investigation of your accident did cite the weather conditions as a factor, it did not get into the staffing and funding problems at AOD. It was only after Joe's accident that these were seriously addressed, resulting in much needed improvements at AOD.

At the time of the delivery of LLTV #1 to EAFB, I had been reassigned from my position as technical manager of the LLTV contract, and was no longer involved in the project. I happened to hear about Joe's accident just after it happened. I immediately drove to the LLTV site and found Joe sitting alone in his office in the deserted hanger. I asked him what had happened. All he could say was that he lost control for some reason. After viewing movies of the flight, I asked him why he waited so long to eject. He said he felt he needed to get the vehicle in a level attitude before he pulled the handle. But as I wrote Chris about *Flight*, I often wonder if Joe thought he might be able to regain control.

The flight movie revealed that the vehicle initially diverged in yaw. An analysis of the telemetry data displayed real time showed that all systems appeared to be working normally. Unfortunately, however, the decision had been made not to display the operation of the yaw thrusters real time, but it was recorded. The analysis showed that aerodynamic forces had built up that commanded the yaw thrusters to operate beyond their capacity at the speed planned for the flight. After reviewing the results, I recommended that LLTV#2 be loaded into the Super Guppy and flown to Langley for testing in its full-scale tunnel. This was approved, and I was put in charge for JSC of the testing and evaluation at Langley.

The LRC staff wanted to help, and gave us outstanding support. We quickly determined that the cause of the divergence was the cockpit enclosure. As the vehicle's sideslip angle reached minus two degrees, a yawing moment rapidly built up that exceeded the ability of the yaw thrusters to counteract. The fix we decided on (the remaining days to the Apollo 11 launch were of the essence) was simply to remove the top of the enclosure thus venting it and eliminating the excessive yawing moment. We were also able from the wind tunnel results to develop a preliminary flight envelope for the LLTV defining its allowable maximum speed at various angles of angle of attack and sideslip. All this had to be verified by flight test however since, although we tried, we were never able in the tunnel to obtain good data with the engine running (too much vibration).

In the meantime, Dr. Gilruth had appointed an accident investigation board consisting of himself as chairman with his deputy George Trimble, Chris Kraft, George Low, Max Faget, Deke Slayton, General Stephenson from Headquarters, and Gene Matranga as members. I briefed the Board on the wind tunnel results, and was put in charge of the flight test planning and data analysis. The Board required that I brief them after each test flight (all flown by Bud Ream). To make a long story short, it was a highly successful flight test program, and we were able to get it completed and approved in time for you to complete your training.

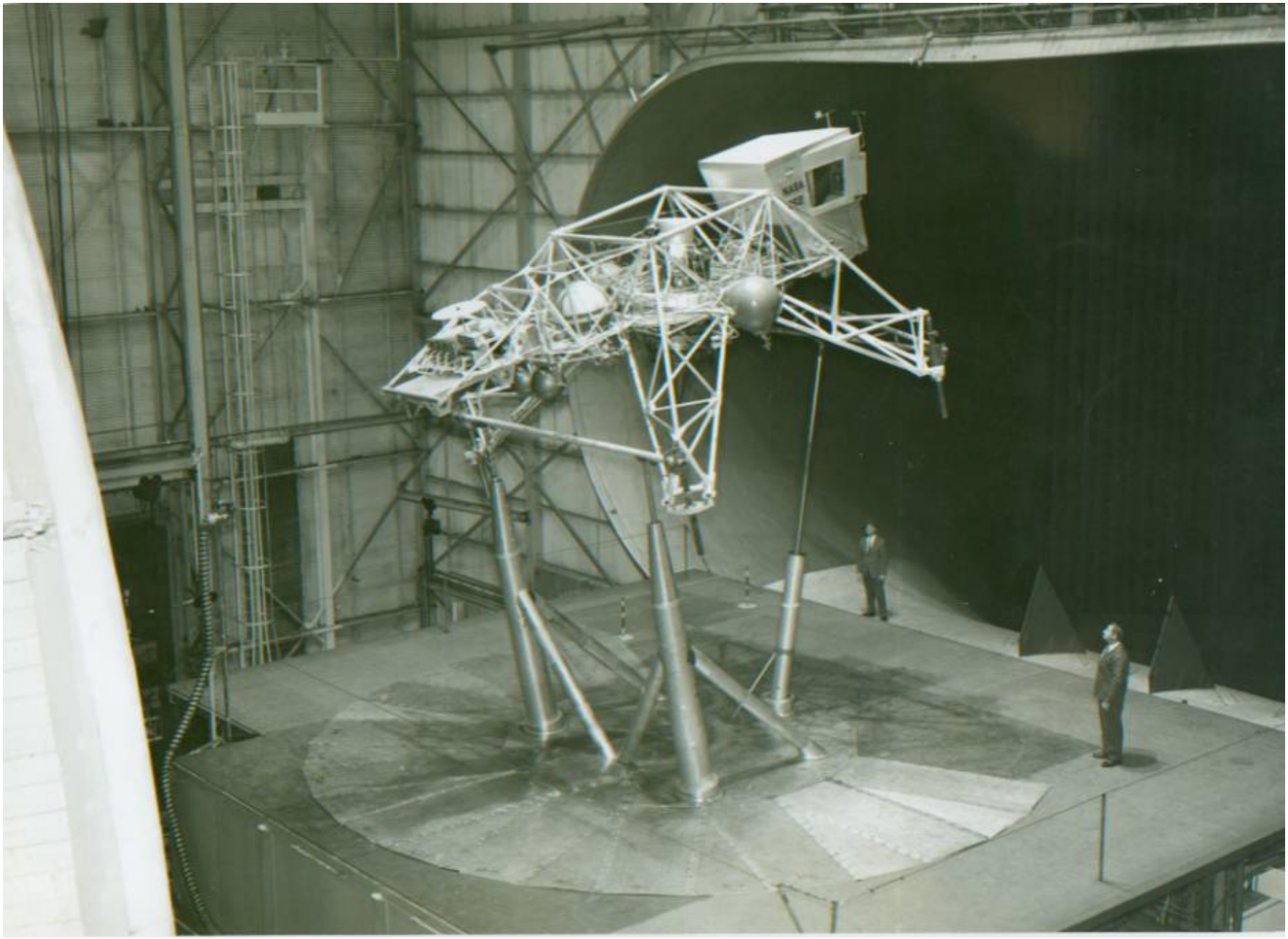
Dean Grimm was tasked to brief the Board on other concerns. In our initial meeting with the Board, it was clear Chris hadn't changed his view about the project, and it didn't appear he was going to be of much help. And we felt the Board needed to focus on the administrative as well as the technical problems. After talking it over, Grimm and I decided we should meet with Pete Armitage who we knew had Chris's ear, someone we knew fairly well, and someone generally aware of our problems. We briefed Pete on those additional matters we believed the Board should consider in detail, and asked that he pass that information on to Chris. Pete did just that, and my guess is Chris in turn talked to Dr. Gilruth because soon afterwards his deputy, George Trimble, a former Martin Company VP, asked Grimm (outside of the board) what he could do to help. As a result, the LLTV staffing, funding, and facilities were improved markedly, and this in my view had everything to do with the subsequent safe and successful training of the Apollo flight crews.

After completing the flight test program, I was assigned as the Flight Operations Directorate representative to Max Faget's Space Shuttle "Skunk Works" team under Jim Chamberlin. It became apparent after approval of the unpowered Orbiter landing that an inflight simulator for training the crews was essential. I was put in charge of the design definition effort which resulted in the selection of the Gulfstream II as the Shuttle Training Aircraft. But I still regard the LLTV project as the more challenging of the two.

Best Regards,

Neil Armstrong and T. Claude Ryan at Teledyne Ryan, June 1968

LLTV unlading from the Super Guppy at Langley Research Center, December 1968



LLTV in the Full-Scale Tunnel at Langley, December 1968