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INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is April 1, 2014. This oral history session is being conducted with William C. Woods at NASA's Langley Research Center in Hampton, Virginia as part of the NACA [National Advisory Committee for Aeronautics] Oral History Project, sponsored by the NASA Headquarters History Office. The interviewer is Sandra Johnson, assisted by Rebecca Wright. I want to thank you for taking the time to meet with us today and to talk about your history. I want to start out by talking about how you first became involved with the NACA.

WOODS: Well, that's going to be a long answer to that question. My father was a college professor at Middle Tennessee State College in Murfreesboro, Tennessee. He was head of the Industrial Arts Department. With my brother as a junior in high school and my sister in college, the unique thing was, and the diabolical thing was he wasn't paid enough as a full professor to educate his children, so he interrupted his career as a teacher and took a job at Langley Air Force Base Ops [Operations] Analysis. There was a group of scientists and engineers to address problems for the commander of the Tactical Air Command. We moved to Hampton, Virginia. I had never heard of NACA, and I don't think most of the people in the country knew what NACA was. When we first came here, we came down the highway, and I saw all of those big wind tunnels out in the woods. Basically, though my father was an electrical [engineer]—a double E [EE]—I decided I wanted to be an aeronautical engineer. The church I grew up in—First Methodist Church—a lot of the co-ops went to that church. Back then, the peninsula was just populated around several blocks deep from the water. It's not like it is now, everything else was wood. But, anyway, we had co-ops from Virginia Tech [Virginia Polytechnic Institute of Technology, Blacksburg], and Georgia Tech [Georgia Institute of Technology, Atlanta] that, on their co-op period, attended the church and, of course, I guess, went to the Youth Fellowship to pick up girls. I became aware of the cooperative engineering program before I was a junior in high school. Playing basketball at Hampton High School, Bob [Robert H.] Tolson, Howard [H.] Robinson, and George [R.] Young of Hampton—they were all co-ops at Virginia Tech. When they were on the co-op period, they'd come down and watch our practice. Bob Tolson, who was the chief scientist out here—I got to know him when I was a junior in high school. So, I was aware of the co-op program. I was in that church. Bill [Wilmer H.] Reid—if you've interviewed Bill, Bill's in that church. I have known Bill since I was a little boy.

[M.] Lee Sisson, who was an engineer out here, heard that they wanted to build a co-op program, so if there were local high school students who were interested in a co-op program, they would come out and take the civil service exam if they were planning on being co-ops. Some of them did this then and did not really become co-ops. They just wanted a job that summer. But, they would hire us as engineering aides, and then we would get in the co-op program at Virginia Tech. I was hired the summer I got out of high school as an engineering aide. Of course, for the next five years, I was a co-operative engineering student at Virginia Tech.

It was a circumstance of the family moving to Virginia, seeing those big wind tunnels, and then having the opportunity through people I knew at the church to avail myself of the situation where I could help pay for my college education, being a cooperative engineering student. Most of what I learned as a co-op was looking at how people interacted with each other and with their bosses; who were good bosses, who were dictators, and who was this, that, and the other. It was interesting, because mainly we were an aide to engineers. We would plot data for them. We would run errands for them. Nowadays, they like co-ops to have a project. I never had a project as a co-op, but I got exposed to a lot. I got exposed to terminology. The summer I got out of high school, I was in Max [Maxime A.] Faget's branch, PARD, Pilotless Aircraft Research Division. This was the summer of '56. John [B.] Lee, who you have in the history, and Dotty [Dorothy B.] Lee, and I can't think of who else, but certainly those two. Dotty was right down the hall. John was a section head in Max's branch. Most of the other people in that branch that I worked for, plotted data for, or did things for actually stayed at Langley. They didn't join the Space Task Group. Of course, John Lee and Dot Lee and Max Faget did.

I guess, because of being able to start right out of high school, and because I never had more than a year's leave without pay, my government time started when I was 17 years old. I got credit for government service the whole five years I was in college. I think it's three years after you go from career-conditional to career. I got a call up that said that, over the five-year period, I got in eight full work quarters, which was lucky for me but not usual. Generally, they started after you were a freshman and not before you were a freshman. So, I had three years' leave without pay and tenure. They said, "We're going to have to move your EOD [Entrance on Duty] date back three months. Is that okay with you?" That was the procedure then. For every year of leave without pay, you lost a month. So, my official EOD is like September or October of 1956, and I was at Virginia Tech, going to school in the Corps of Engineering. But, you see, I started in June and did that summer.

The co-op program tried to put you in different divisions. Like I said, I was in Pilotless Aircraft the first summer. After my freshman year, I was in what was Internal Aero

[Aerodynamics], who are the people now working on the Scramjet [Supersonic Combustion Ramjet]; like Hyper-X and the Scramjet propulsion systems. That branch head was Kennedy Rupert [phonetic], who I didn't care for at all. That's neither here nor there. I was just a boy. It was Internal Aero. I worked with another engineering aide, a grown man who had come out of the service and was trying to get his foot in the door and go to college. They gave us some things—example problems—they wanted us to solve just to educate us. We started using something called Ames tables. Every co-op in aeronautics at Virginia Tech had his own copy of Ames tables. It's a big, brown report. It's the ideal gas table, where you can go in and look up a Mach number, and you'd find pressure and temperature. The reason I call them Ames tables is [NASA] Ames Research Center [Moffett Field, California] generated these tables. It's Technical Report 1135. Everybody remembered that. Anyway, after my first year in college, they gave us example problems doing this.

That winter quarter, I went to the Free Flight Tunnel, which is still on the other side of the field. It's a round ball. Charlie [Charles H.] Zimmerman invented it. Dr. Zimmerman was the father of the boy, Charles Zimmerman, who I ran track in high school with. He was an OB/GYN [Obstetrics/Gynecology physician] here. He died a couple of years ago sadly. Anyway, I worked in that Free Flight Tunnel. We tested the [Francis M.] Rogallo Flexible Wing. I don't know if you're familiar with that. It was the father of the paragliders all of these people use now, jumping off the sand dunes at Jockey's Ridge [State Park, Nags Head, North Carolina]. Francis Rogallo invented that as a kite for his children. It was also proposed as a possible deployable assist for airplanes. You could deploy this thing. We were actually testing that in the little Free Flight Tunnel. I worked with engineers and technicians and would go down the tunnel and change the controls and do things like that.

That's what I really wanted to do—be a wind tunnel engineer. Becoming NASA in '58 didn't really change that. It didn't change Langley that much then. There was emphasis on structures and loads, but just about everybody up the line in senior management had gotten their wings in wind tunnel testing. Wind tunnel testing was the emphasis at Langley Research Center, as far as I'm concerned. That's my warped opinion. Anyway, after being in the Free Flight Tunnel, that summer I went to the Full-Scale Tunnel, which has now been torn down, even though it was a national monument. They were actually in different divisions then. The Free Flight was in Stability [Research Division]. The Full-Scale Tunnel was in the Full Scale Research Division.

My co-op period in the Structures Division was done in a 9x6 Thermal Structure Tunnel, so it was still done in a blowdown wind tunnel, and it was one of these big ones that growls and roars and just tremendous energy. Actually, I wasn't working with that group. There was another group that was officed there that was building the pilot model. That's a subscale model of a big tunnel you're going to build. You build a pilot model first to check out how it would work. That was a pilot model for the 8-Foot High Temperature Structures Tunnel that is still here at Langley.

Then, I went to Unitary Tunnel. Back then, it was called the Unitary Plan Research Division. The reason that tunnel is called Unitary is it was built by an Act of Congress called the Unitary Plan. They built a tunnel at Langley. They built a Tunnel at Lewis [Research Center, Cleveland, Ohio], which is Glenn [Research Center]. Is it still named Glenn?

JOHNSON: Yes, it's still Glenn.

WOODS: They built a Unitary Tunnel at Ames, and it was built under the Unitary Plan that had a special way, hours for building it. It was actually built to help contractors. It had labs for the contractors to come in and set up their models. It was built for the contractors developing aviation systems. That winter, I worked in Loads Division. We still had a Loads Division then. The following summer, I went back to Full Scale. That's the type of thing I did but generally all in wind tunnels.

I finished up in '61 with a baccalaureate in Aeronautical Engineering. I've gone way past NACA, but, of course, relative to the war, I was a child, but NACA had tested a Japanese Zero in the full scale tunnel that they got their hands on. They tested other war planes in the full scale tunnel. The wartime reports were generally a white report that was classified secret. We didn't do a lot of secret work. That's the other thing. NACA—the National Advisory Committee for Aeronautics. When I was a Tech, and they'd ask, "Who are you co-oping with?"

I would say, "NACA."

They would look at me and say, "Isn't that something for colored people?" NAACP [National Association for the Advancement of Colored People].

Nobody knew what NACA was. That was fine, because we were a research agency. We were generally under the radar of the politicians. We didn't have the type of budget we had as a space agency. Anything we tested was generic. We had a generic version that looked like the B70. It wasn't a B70. We really didn't test private industry's configurations. What NACA was supposed to do was provide the research and technology for them to use to develop their products. That is generally, as far as I'm concerned, what NASA was supposed to keep doing. Generally, the government doesn't build hardware.

With the building of the National Transonic Facility, the contractors were letting that go. Ed [Edgar M.] Cortright brought a lot of that stuff in-house. I think some Viking [Program] stuff was brought in-house. We have people out here that talk about their individual accomplishments and what they built and what the government builds. The government doesn't build hardware. Rockwell built the Space Shuttle. They built the Apollo capsule. Other people—the contractors—build it to the government's specifications.

I'm sort of digressing here, but, like I said, during the war, I think the focus here was on testing to support the war. The wartime projects were classified secret. We had people—expatriates—Tony [Antonio] Ferri came here to get away from Fascism. Adolf [J.] Busemann came to get away from the Nazis. We had German and Italian experts come to this country to get away from what was going on in Europe. Both of those gentlemen came to work at the NACA Langley Research Center. I don't think they've torn the building down yet. There is a low turbulence pressure tunnel in the East Area that has got a plaque on the wall of the engineers who worked there. It's a who's who in the history of aeronautics. They all went through Langley.

I wanted to go back in subsonics and work in full scale. I put in three co-op programs over there. Between my junior and senior year, when I was over there, they would give me the model and let me take it over to the Free Flight Tunnel. By then, they had it so one person could sit up and run the fan and control and model and everything. They just let me go over there and run the test myself, which was a lot of fun. Co-ops generally get to pick where they want to go. Joe [Joseph L.] Johnson, who just recently died, was one of my bosses over there. He said, "Don't come here." He said, "They're going to shut this place down. They're going to throw it away." Where I went, they have shut down and thrown away, but the Free Flight Tunnel is still over there testing. He said, "High speed is where it's at."

But anyway, I wanted to go there, so when school was over and I came out here, the guy that ran the office—he was off on vacation or something. There was a younger guy there, and he said, "We know you wanted to go over to Full Scale, but we've got a need someplace else, and we think we're going to put you here." Gene [Eugene S.] Love—he was assistant division chief. I guess Gene was a branch head then. He was building a group of facilities to address hypersonics—very high speed. One was a 22-Inch Helium Tunnel. That's where they put me. I saw the little models. They used balances to measure loads just like I did the other stuff. Joe had said, "Don't come over here. They're phasing this out." This was hypersonics. It was something new. When the guy came back to work, he called me on the phone and said, "I want to apologize. You were supposed to go where you wanted to go. So, you can go there, or you can stay where you are."

I decided to stay where I was, and so that's the reason I spent all of those years in hypersonics. To me, until probably the last 15 or 20 years or the last 8 or 10 years when they were tearing down all of the wind tunnels, it was business as usual. I got to work in hypersonics. Like somebody said, it was the golden age of hypersonics. The first thing I tested when I got out of college was the X-20 Dyna-Soar. I don't know if that means anything to you—the dynamic, soaring vehicle that, I guess, [John F.] Kennedy cancelled. I tested that in a helium tunnel and then, basically, worked on basic research in hypersonic flows; understanding the pressures, the heating, and trying to understand how this stuff worked.

Also, we worked on what we called 'lifting entry.' The Air Force has always wanted what they call 'immediate recall.' Immediate recall has always been a military mission—never a

NASA mission. It means, no matter where you are in orbit, no matter what orbit, you can de-orbit immediately and get back to the continental United States. To do that, you have to have a lift to drag ratio, which is the way an entry vehicle glides of at least four. We spent a lot of time trying to develop L/D 4 vehicles at Mach 20 in helium. Basically, we found out that, for a vehicle that you can control and fly, L/D 3 is about the best you can do. Back then, I thought, well, I'll never see anything I worked on fly, because we don't have the metallic heat shields, we don't have the propulsion systems, and we don't have the heat protection, because, to come in at that low an angle, the thermal environment is huge.

The decision to build the Space Shuttle changed all that, because I got to work on something that flew. We were working for Gene Love. I had been in the Aerophysics Division under Johnny [John V.] Becker. Johnny Becker is one of the grand names for the X-15. Johnny is still alive at 97 years old out in Colorado.

Anyway, we were in the Aerophysics Division under Johnny Becker. Love was assistant chief. It was first called the Space Shuttle Research Division, and they made Gene Love the chief. He got the tunnels he wanted, particularly the Mach 20 Tunnel. It was dedicated to working on the Shuttle. When they were first looking at the Shuttle, it was called Integral Launch and Re-entry Vehicles. George [E.] Mueller was the one that started the studies. They had six or eight working groups looking at aerothermodynamics, aerodynamics and heating, structures, loads, and everything. If it was eight working groups, six of them were chaired at Langley. If there were six working groups, four of them were chaired at Langley. We immediately worked directly for Love. He was down at a JSC [Johnson Space Center, Houston, Texas] meeting when Max trotted out his straight wing orbiter.

Gene brought the drawings back. Because, in the Helium Tunnel, we could—I should have written notes so I'd give some order to this—but anyway, we could test wood and plastic models. The reason you have helium at high Mach numbers is that you don't have to heat the gas. In a wind tunnel, you expand the gas to get high Mach numbers and high speeds. When you expand it, the temperature drops, so you have to heat the gas so that it doesn't liquefy. When you get up to about Mach 14 or 15 or so, you have to heat the gas so high that you're melting your wind tunnel. You don't have to heat helium, because it doesn't liquefy until 1 or 2 degrees absolute, which means it's like minus 350 degrees Kelvin, minus 400 and some degrees Rankine. Of course, the reason it doesn't freeze everything is, as soon as it goes through the shockwave, the temperature comes right back to ambient. So, we had a model of Max's—not his first, but we worked on the second—straight wing orbiters in the tunnel for two weeks after Gene Love came back from JSC.

In the interim, while we were doing basic research, people proposed an electron beam for nonintrusive testing. That means you shine the beam in the gas, and you measure stuff. You don't have to put a probe in there to measure stuff. Well, the sort of unique thing about helium is that it's so cold that the electron beam just—and if I had brought a picture, I could show you. If you've ever seen a picture of a Shuttle model re-entering, and it's pink. That's the electron beam. That was taken in the helium tunnel. I took that picture. It makes a shockwave. We had this electron beam so we could see the shockwaves on that straight winged orbiter. It showed how you had shock to shock interaction.

When you have two shocks run into each other like that, you get amplification of the heating. You can have heating as high as 40 times the heating at the nose, which causes the blackout. That, among other reasons, is why we at Langley and Max were at odds over the straight winged orbiter, because, before he died, Max did an article in *The New Yorker*, and he said, if they had built that thing—the straight wing—like I wanted it, it wouldn't have crashed. Max was a mechanical engineer, and he was a fantastic manager and a fantastic thinker with the Apollo, but he didn't understand aerodynamics.

The current Shuttle—the main reason for putting straight wings on it is so it lands easy, because it's got to come back and land. At subsonic speeds, most of your drag comes from the base. That's the reason airplanes come up like this in the back. It's called boattail, because, if you've got a blunt base, you've got a lot of base drag. Of course, the straight winged orbiter would have a blunt base with the rocket engines. Actually, the final Shuttle orbiter lands better at landing speeds than Max's straight winged orbiter. I digress. This really doesn't have much to do with the history you are doing.

JOHNSON: Well, that's okay, because it's all part of your history.

WOODS: That's true.

JOHNSON: That's perfectly fine.

WOODS: Because of these pictures we took of Max's orbiter and whatnot, in 1970, we had a get-together of JSC and Langley, because Gene Love had developed the HL-10. That's one of the lifting bodies—not this HL-20 that the Dream Chaser is, but the HL-10. So, at this meeting, when Max trotted out the straight wing orbiter, one of the guys at [NASA] Headquarters [Washington, DC] asked him, "What about the HL-10? Could it do this mission?" That's when, I think, we had initially four big contracts. I forget who the contractor was. The HL-10 was the subject of one of them, the straight winged orbiter was the subject of another one, but there were other things in there. At this meeting we had in the spring of 1970, I had a talk where I showed movies of these flow fields on the various orbiters.

When the JSC guys came in, they all had on 10-gallon hats, cowboy boots—Bob [Robert R.] Gilruth, Chris [Christopher C.] Kraft, and a Phoebus [Virginia] boy comes in wearing a cowboy hat and boots. I think Ed Cortright and Oran [W.] Nicks were there by the end. I don't know if Oran came with a cowboy hat or not. Anyway, of course, Mr. Love was there. During the meeting, Love shocked everybody, because he withdrew the HL-10 from consideration. He said, "This won't really do this mission." Everybody thought it was my configuration versus your configuration.

The only reason I'm telling you this story is I up giving my talk, and I'm showing movies of how the shocks are interacting on Max's straight wing. He says, "All of this means nothing. It means a hill of beans." He said, "This stuff is garbage. It has caused a lot of problems in Washington, because they don't know what they're looking at."

I thought, "Well, what will I do now?"

Gene Love said, "You had your say. Shut up and let the boy finish his talk." Of course, I was 30 years old at the time. Of course, Max had no idea I was the co-op that had been in his branch all of those years before.

Of course, from '68 to '72, it was all Shuttle. Of course, when they got in the final configuration, we still did some tweaking and whatnot. A guy named Bernie [Bernard] Spencer, who is dead, did a lot of wind tunnel tests. I think we did something like 80,000 hours at Langley alone, but maybe that was 80,000 total. I'm not sure, but we did a lot of testing that wasn't even requested by either Johnson or the contractors, trying to keep our foot in the door so that we would know how to respond if problems came up. Of course, that's, again, what I think we always did at Langley, and that was our mission, as far as I was concerned, to be ready to respond if there were some problems.

During that period, over at the helium tunnel, we called ourselves Outpost Six, because the Shuttle was pretty much locked up. They were doing all of these new paper studies on what we were going to do in space now and all of the single-stage-to-orbit stuff. I forget what the studies were. They were nationwide studies with contractors and all of the [NASA] Centers in them, coming up with what Shuttle derivatives would look like, what this would look like, and what that would look like. A lot of whatever high Mach facilities were in the country had been shut down. The Air Force was working on secret projects for boost glide vehicles that would boost up and then glide a long ways. We were the only game in town as far as Mach 20, so all of the work that our little group was doing in this—I meant to ask [Phillip] Brockman when he came to work here, because he worked on that. This was the mid-seventies, I guess. The Shuttle hadn't flown yet, but we were doing a lot of work for the Air Force and for the Air Force's contracts. I didn't put the boost-glide vehicle down there. I didn't think about it.

Then, the Aerospace Plane reared its ugly head. That put light back into hypersonics. Hypersonics had gradually died. Aerospace Plane has always been a figment of somebody's imagination. Lana [M.] Couch—I don't know if you're familiar with Lana Couch. She was at Headquarters. She's dead now. They wanted the ready hanger—the F-16s. They wanted a vehicle sitting out there that the pilot runs out, jumps into, takes off and flies to orbit. Then, when he deorbits he comes back and lands like an airplane. They had a lot of these studies in the Air Force in the fifties.

So, when the Aerospace Plane came along, that's what it was all about. Tony DuPont—one of the DuPonts whose inheritance was predicated it would match whatever he earned—so Tony was a Beltway bandit. He had a contractor firm up there. He and a guy named Bob [Robert] Williams were at DARPA [Defense Advanced Research Projects Agency]. Bob Williams was a Virginia Tech graduate. They had this vehicle they called Aerospace Plane, and that's what started the contractual studies that went along for a time before, finally, they recognized, just like what I was talking about—the lifting entry vehicles—we didn't have the heat protection, and we didn't have the propulsion. The same thing is true with Aerospace Plane.

Those technologies are still not there. They're still not there today, even though we've flown Hyper-X at Mach 7 and Mach 10, you couldn't put a man in that thing. It's a flying axe head made of Tungsten. Its main purpose is to carry the scramjet engine to prove they could get thrust greater than drag, because, if you can't get thrust greater than drag, you can't accelerate.

Dan [Daniel S.] Goldin—enter Dan Goldin—single-stage-to-orbit, X-33, X-33 competition, X-34. By then, we had had some reorganization. I was still doing the same thing, but I was working more in the 20-inch Mach 6 tunnel. The vertical lander, the so-called DC-X that Pete [Charles C.] Conrad worked on at McDonnell Douglas—it would land on thrusters, like Buck Rogers, and take off on thrusters. That was one I ended up testing to get the database on, but in aerothermodynamics, we were testing the X-33 and the X-34 during that timeframe.

Hyper-X was interesting. It's not a clean separation to get away from the Pegasus. Rockets in tandem—that's clean. You shut one off, it falls away. The Shuttle is clean, because they're in parallel and drop away, but on Hyper-X, it's got this support sitting up under it. I forget how many data points we did down in AEDC [Arnold Engineering and Development Complex] at [Arnold Air Force Base] Tullahoma [Tennessee]. They'd have a captive trajectory rig where they could move. You're in a wind tunnel. You've got the gas flowing. Of course, we needed to study this at Mach 6 or 7, because that's how fast the Hyper-X was going to be going on the rocket when it separated.

I think the Hyper-X was fixed, and we had this great big Pegasus model behind it. They could move it around. It's called a captive trajectory. You move it, and you get data, so you can get the aerodynamics and see whether or not it will fall away from it, it will catch up to it or hit it, or things like that. We had people in tears, because we kept saying, "This is not going to work." I got to work with a guy named Scott [D.] Holland, who is the age of my son. He's the branch head of the secret branch out here now. He is just a great engineer and a great person, but we spent long, sleepless 24-hour shifts down in AEDC working on Hyper-X. We spent a lot of time in the tunnels up here working on Hyper-X to build that database. Of course, we had a successful flight.

I didn't mention and I didn't put down that, for a while, after X-33 to 34, I got involved with the missile people down in Huntsville [Alabama], AMRDEC [U.S. Army Aviation and Missile Research Development and Engineering Center]. It's not the missile command as such. It's the people that research missiles and they work with Dynetics Corporation. It's Redstone Arsenal people, it's the Army people. They had a Russian missile they wanted to get a database on. They had managed to get that through the British. A British engineer was involved. We built the model and tested a 20-inch Mach 6 and got the data for them for like $25,000. Nobody got to tax the money—not the lawyers.

Nobody else got to tax the money, because it was brought in through the Army Aviation connection in Langley, which means the money came in and I got all the money to do the work. That's the reason we could do it for only $25,000. There was another missile project that came as a result of that. That was an education for me, because missile aerodynamics and airplane aerodynamics are entirely different, and I knew nothing about it. That was a good experience.

I was trying to think what I was working on when I retired. I guess we did a water squirting project with a guy named Ken [Kenneth] Jones from Marshall [Space Flight Center, Huntsville, Alabama]. There was an exercise called Decadal Planning. No one could give you a reason, but I'm assuming it was to have fuel in space. They wanted to place 10,000 pounds of water in orbit on a weekly basis or something like this. Somebody wanted to use the gun launch to shoot these projectiles into space. What happens is, if you're at sea level conditions and you shoot something at enough velocity to get to orbit, it will probably melt. The dynamic loads would tear it up, or the temperature would tear it up.

Dennis [M.] Bushnell was in a meeting. If you know Dennis, he's our Chief Scientist here. He had done work on something called RAM-C [Radio Attenuation Measurements] years ago that had to do with trying to broadcast through the shock—the plasma—to broadcast through that. They squirted nitrogen. They squirted liquid. Dennis shoots from the cuff all the time. He said, "Well, you're carrying water. Just squirt some out the front." It is a very effective coolant. As a matter of fact, Gene Love had us trying to look at a project that nobody thought was doable, and it turns out McDonnell Douglas had already done it in a flight project. One thing they used was water through the nose.

Anyway, we came up with just a simple, straight hemisphere nose and hooked it up to city water—which means we couldn't really squirt at real high pressure—but we hooked it up to city water and ran the test. It just showed that water was much more effective than ablation or anything else at cooling it effectively. That was sort of fun. That's basic research, and that's what was really fun.

I can't think of anything I particularly contributed. A paper I did for one of the Shuttle conferences about real gas effects of Shuttle—I liked that paper a great deal. Another one I did on a helium simulation. Dick [Richard T.] Whitcomb, who is in those papers, he was the one that came up with the Transonic Area Rule. He had an 8-Foot Transonic Tunnel. The Transonic Area Rule was one of the first things I worked on plotting in Max Faget's branch. It's when you have an airplane where you give it a wasp waist. What happens when you get to the wing—you take the area out of the fuselage—that wing—and for some reason, the flow recognizes you've done this, and you get less drag. Dick Whitcomb, he developed that. Generally, most of the accomplishments out here are team accomplishments. They're not individual accomplishments. I know a lot of guys who will say, "I did this. I did that."

I don't think that's so, but now I'm totally digressing. I love Langley. I don't like what's happened to it. I don't like the wind tunnels being torn down. I don't buy this baloney that we need all of these brand-new "Taj Mahal" office buildings. We can afford them, but we can't afford to keep our wind tunnels. It's done. They're torn down.

JOHNSON: Well, let's go back for a few minutes.

WOODS: Okay, you ask questions.

JOHNSON: You came in at a unique time. You were very young when you came in. Was it '56 when you were first here? And then, in '57, Sputnik [Russian satellite] happened, and it changed everybody's thinking of what was going to happen and the fact that they formed NASA as a response to that. Just kind of give us an idea of what was going on. I know you were just a student and a co-op, but do you remember the atmosphere?

WOODS: I don't recall it changing that much. I need to go back and read some. There is a great work called *The Hypersonic Revolution*. It was a two-volume set that did not include the Aerospace Plane. There is a third volume now. You can still get it, probably, from the Wright-Patterson [Air Force Base] History Office. It didn't cost any money. You contact the woman in the Pentagon, and you may know who I'm talking about. It starts with a German—Max Valier in 1935. They were trying to build an Aerospace Plane. It's always been the Aerospace Plane. It really talks about the interactions and those things. To me, when I was down on the co-op program, I know I would see at night—I'm trying to think of what the Army kept trying to launch [Vanguard Rocket].

They kept having explosions. They kept blowing up. Then, the Sputnik made it. That said, well, Russia is ahead of us. To me, I don't recall a lot of fear and trepidation at Langley Memorial—it's no longer Memorial Laboratory—Langley Research Center, because there had been studies that Charlie Zimmerman was in. Of course, William [J.] O'Sullivan had come up with the big [Echo] balloon satellite. We could go out at night and see that thing going over. We had things up there. Of course, when Kennedy said, "We're going to the Moon within the decade," that put a lot of pressure on it. By the time I got out here in 1960, we were testing Apollo capsules, because they had already settled on Apollo. Of course, Mercury and Gemini and some of these other things had gone.

We always had color TVs set up in the conference rooms and watched them when they were on. The one time we didn't have a TV set up was when [Space Shuttle *Challenger*, STS-

51L]—when the first one blew up on launch. My son was home from school, watching it. He called me, "Dad," he said, "The shuttle blew up."

I said, "Oh, God!" That's what we always worried about; not what happened to *Challenger* but what happened to [Space Shuttle] *Columbia* [STS-107] on re-entry. The first flight of the Shuttle to orbit and the first return was probably one of the most emotional, with us waiting to hear if it's going to come out of blackout. A lot of people said, "Oh, those tiles are going to come off like a roofing shingles, and it's going to burn up."

No, it is sad that Congress, the politicians, and bureaucrats didn't allow funding to develop a follow-on system for Shuttle. To me, it's sad we're going back to water recovery, back to where we were before. The Shuttle is really fantastic. You didn't have to worry about the metal getting hot, because you came up with an external insulation. Really, if you held a tile in your hand, you'd wonder why this works, because it's just like Styrofoam. You may have held one; I used to have one.

Sputnik—I know it was in the news. I know everybody talked about it. There was one study called Round One. There were all sorts of studies that NACA was doing before NASA was created, looking at higher and faster—what it was all about. The Lifting Body Program—the reason that program was there, and the reason they looked so funny, is because they were trying to see if we can build something that gets enough lift off the body that it can glide to Earth. Actually, the landing techniques they developed with the [Northrop] M2-F2 and the HL-10 and the [Martin Marietta] X-24—three lifting bodies—one Air Force, one Ames, and one Langley—that's how they land the Shuttle. The original Shuttle contract wanted a vehicle with jet engines in it to fly around. You can't take jet engines to orbit.

I was giving a talk at a Kiwanis Club one night. A guy asked me, "Why didn't they keep flying the Shuttle off the 747?" He had seen with James Bond movie where they actually flew the Shuttle off a 747. The guys in the branch I was in—John [P.] Decker—John died of a heart attack at 35—they looked at the C-5. Actually, they said the C-5 was a better choice, but we couldn't get a C-5. We had plenty of 747s. They did computer simulation showing what you had to do and how to do it to get the Shuttle off the 747. The only reason they put it on the 747 was so you could practice landing.

Of course, in the first practice landing, they put a cone. They put a boattail on the back of the Shuttle so that it wouldn't have all of that base drag. Once they got used to landing it light, then they took the cone off and said, "All right. Now do it." That technology was a result of the Lifting Body Program; how to go about landing, doing a zoom maneuver, because you didn't have a wing. They dive at the ground, build up all of this speed, and then feather like this, going real fast, and then bleed the speed off until they set down. Of course, one of them did crash.

There was a science advisor named [George A.] Keyworth [1981-1985]. He was saying the NASA does too much for the aeronautics industry. The aeronautics industry needs to do its own research. We put together a big pitch at Langley to show that the only way we were able to do Shuttle is we had a strong R&D [Research and Development] base in aeronautics. That idiot Dan Goldin—a lot of people said Dan was crazy. I hope he's not a relative of yours.

JOHNSON: No.

WOODS: Revolution—not evolution; everything we've done in aviation space has been evolution. It has evolved from what has gone before with small changes. That's the reason X-33 was doomed to go nowhere. That was totally ridiculous, and a lot of money was spent on it. Generally, it's 25 years from the technology to the demonstrator and to the use. If you looked at the Lifting Body Program in 1960, the Shuttle's first flight was in 1981.

But, of course, a lot of other things got developed in that time—autonomous landing systems and a lot of other stuff. It's never really that simple. Getting back to Sputnik—to me, and I guess to a 20-year old, worrying about trying to get out of college, the NACA and the people you get to work around, and the people you got exposed to—I know guys that have had bosses they went screaming to get away from. I always had really good bosses. Actually, the worst boss I ever had was a friend of mine, because he let everybody else manipulate him. I wasn't going to do that. He let all of the fair-haired guys manipulate him and everything. Art [Arthur] Henderson was my first section head as an engineer. Then, I guess it was Paul [F.] Holloway. Paul died in the last year. You're talking about a history of the NACA. If Gene Love was still alive, you could talk to him. You're talking about a mind. That guy was fantastic.

The whole approach was here is a problem and how do we solve it. Lay out a methodical plan. Go do it. I think Sputnik probably caused more grief for the Army in Redstone, because they were having all of those failures. It was a hardware problem. We were still, basically, a research center. Ed Cortright—all of the work he brought in-house to get Viking done, because we had the shops. We had the machine shops, and we had the technicians. That's the other thing I learned as a kid. These technicians may not have college degrees, but you worked hand in glove with them. You'd get their advice when you were building a model or whatnot. You worked hand in hand. We've always had that at Langley. Have you got another question?

JOHNSON: Yes, I was going to ask you—when they were forming the Space Task Group, and when they were going to be moving to Houston, did you ever have any desire to go with that group?

WOODS: No, I didn't. One guy I knew, [C.] Howard Robbins, went. The reason Howard went to Houston—he'd used up all of his graduate study leave at Langley. I think they had a policy that, after you got your graduate study leave and got your degree, it was a year or two before you could take off and do this again. So, after Howard used up all of his graduate study leave, I was in graduate school at the time up there. Howard was one of the co-ops with Bob Tolson. Howard co-oped there. After he used up all of his graduate study at Langley, he transferred down to JSC. As soon as he got there, he went right back to graduate school. I was up at Tech registering. "What are you doing up here?" He said, "I'm at JSC now. I've got more graduate study leave." What was your question again?

JOHNSON: I was just asking if you had any desire to move once the president made that announcement.

WOODS: I probably wasn't in a position to. Like I said, a few of Max's branch went, but a lot didn't. I think there was Joe [Joseph H.] Judd, and there was Abe [Abraham] Leiss. There was Ralph [A.] Falanga, there was Woody [Willard S.] Blanchard and Woody [Sherwood] Hoffman. This was, of course, when you were in a room with a section head there and the desks go around like this. Chris Kraft wanted to go big time. Chris developed an anti-fire system for airplane crashes. He worked at the hangar in Flight Division after he got out of Tech. He developed a fire suppression system, I believe it was. I don't know if that had anything to do with it directly, but nobody would implement it. I think he saw going to the Space Task Group, of course, as a certain—I guess he was a guidance control guy, as much as anything, in the original [Flight Director] in the guidance [Mission Operations] Control Center. Of course, Bob Gilruth was head of the whole thing. Max went, I think, as a division chief, and within two years was Director of Engineering. I think there were people that wanted to go. Bill [William I.] Scallion, I thought, looked at going. I don't know if he went down there and said, "To hell with this," and came back.

JOHNSON: A lot of people did because of the timing after a hurricane [Carla].

WOODS: That's true. I mean, we have our hurricane problems here but not like y'all. No, it never entered my mind. I wanted to work in wind tunnels.

JOHNSON: You mentioned that—that you wanted to be an aerospace engineer, but your father was an electrical engineer. Was it moving here and seeing the wind tunnels that made you want to do that?

WOODS: Yes. Hell, if we had stayed in Tennessee, I'd would probably have ended up driving a milk truck. That wouldn't have pleased my father, but, for some reason, I wasn't doing that well. Right after moving up here, I started getting A's in math. Maybe the teachers were easier up here than they were in Tennessee. If I had been a 23- or 24-year old, very ambitious engineer with maybe delusions of grandeur, I might have done something like that, but I don't like change.

JOHNSON: You mentioned that the NACA was more under the radar. I know, once NASA came into being, there was more tension to anything involved with NASA.

WOODS: You had to succeed.

JOHNSON: Did that change the work environment as far as what you remember?

WOODS: No, because, again, the areas I worked with, even though it was hypersonic blowdown tunnel and we were modifying the tunnel, of course, we had the system now. We could see the flow. It was like we had our own toy to play with. Like I said, the models are like this. They're much, much smaller. Langley pioneered in strain gauge balances no bigger than your finger that you could use. Over at the Free Flight Tunnel, the balances were these big, box-like things, but it was stuff I couldn't tear up. These little balances are easy to break and tear up. Every day was something new in a helium tunnel. It really was. It disappoints me that they don't give it the credit, but I'll tell you one thing, Gene Love gave it the credit. He wanted that tunnel going with him. That man was really special.

JOHNSON: Through your years here, the technology changed quite a bit from using human computers to actual computers.

WOODS: It did, but in some cases, if you've got something that's working out for you, why change it? A lot of times, in trying to prove the technology in some of the wind tunnels, we ruined the wind tunnels. We spent hundreds to almost millions of dollars and ruined the tunnel. Doug [Douglas] Dwoyer—I don't think he ever worked in a wind tunnel in his life. Years ago, who was the guy at Ames that said the computer is going to replace the wind tunnel? Doug Dwoyer, before he became director of research, said, by the year 2000, airplanes are going to be designed by low-paid technicians sitting at a computer terminal. Well, that still hasn't happened. Doug Dwoyer was the driving force behind getting rid of these tunnels at Langley. I think there have always been people at Headquarters—they have shut down the Unitary Tunnel, yet Ames still has its Unitary, and so does Glenn. Now, Lesa [B.] Roe is on—I guess, because of the modernization job that's going on at Langley, they've got her at Headquarters, I think, maybe to address the whole thing across the agency. I don't know.

I know I didn't talk about the Shuttle Phase B extended evaluation that actually was only one spring and summer out of my life. We were on Phase B in the Shuttle. We still had two-stage, fully reusable and hadn't gone on to the External Tank yet. Gene Love and Paul Holloway put John Decker, the boy that died, and me on this Shuttle evaluation team. We had about 5 or 6 guys from Langley, maybe 10, 15, maybe 20 from JSC, and about 35 or 40 from Marshall. The Marshall people were taking that McCullough chainsaw plane. Do you know what I'm talking about? The plane—the golden circuit—the Cape [Canaveral, Florida] to Marshall, to JSC. I think they rented the plane from the McCullough chain saw company, didn't they? That was a lot of fun, but when I look back, to think we went through that evaluation, and we finished up in July in New Orleans [Louisiana]. We started up in March and got to meet a lot of JSC people.

Of course, when I co-oped in the Loads Division, Milt [Milton A.] Silveira—I don't know if that name means anything to you.

JOHNSON: We interviewed him.

WOODS: Milt was in the Loads branch here. Bob [Robert C.] Goetz—I got to know him over at the Loads group, too. I got to meet a lot of people at JSC and a lot of people at Marshall; a good group of people. It was something I'd never even been exposed to before. I think several times Paul, I guess, tried to further my career. We've got the programmatic people now and the management people. I was never meant to manage or be a boss. I was never meant to be programmatic. I was meant to work in wind tunnels.

JOHNSON: You brought some of these papers, and you were mentioning some of the social activities and that sort of thing, being very young when you first started out here.

WOODS: People's social life revolved around the Center. Like I said, they had these dance bands come out. There was a bigger name. It wasn't Tommy Dorsey. I think they had Glen Miller out here one time. The carnival was always a lot of fun. Well, it's like we don't have a paper anymore. They want everybody to go to @LaRC—an internet version. Just about everything that contributed to the morale over the years they've shut down. Part of that is security, and part of it is legal. Legal has always said, "These old people are going to sue us or something."

They're always worried about people coming to the carnival—some teenager drinking or something. We made $40,000 off the carnival one year. That was the profit. That's when we finally got them to let us build that gym over there—the gym that's behind the Activities Building. That's not a government building. That was built with non-appropriated funds. That's the people's building. When they were starting to build all of these new headquarters buildings, the first thing they were going to do was tear that building down. I said, "Don't those people know that's not their building to tear down? It was built with non-appropriated funds."

We had Bingo. About the only place you could have Bingo was airbases and places like that. We had Bingo. They made money off of the carnival. We made money off of Coke Machines. They shut down the carnival. We used to have a turkey shoot. "No, you can't bring shotguns on this field." We did it for years.

I saw that X-24B around there—the picture. I forgot about when the Air Force was trying to do X-24C. I was working on that as well. I guess I got exposed to how politics is a lot more than just politics. The instrument people wanted to use the electron beam as a probe. It didn't work out, but it made all of these great visual effects that we could see them in the tunnel. They didn't want anything to do with it—no, no. So, Art got them to build a beam that our technicians could handle, and then we started getting all of this publicity for the pictures. They were saying, "You all stole that from us," and they wanted no part of it.

The same thing is true. When I first came out here, and even when it became NASA, there was no space and aeronautics delineation. When we were testing Max's straight winged orbiter, our directors were Director Group One, Group Two, Group Three, and Group Four. When Gene Love's division was created, which became Space Systems Division but it was Space Shuttle Research Division, they put us—and I don't know if it was because of some internal politics—they put us over with the Structures Directorate. There is still no delineation between space and aeronautics.

As a matter of fact, Love put me in for a raise, and the structures guy didn't want me to get it. He took that as a cause célèbre. That was when I got my [GS-]13 [General Schedule pay scale], but he made sure I got it. The reason I talk about the politics when I mention the electron beam, the Headquarters said, "Look, we've got to have a clear divide line between space and aeronautics." So, that's what we became. There was an aeronautics side of the house and a space side of the house. The Aerophysics Division stayed in the aeronautic side of the house. Even the Mach 6 Tunnel stayed in there.

I guess Love knew he didn't want to depend on anybody else for the wind tunnel data. Like I said, he got Bernie Spencer and George Ware. He already had us in hypersonics. He got some subsonics guys from the aeronautic side of the house, over in Space Division, because, really, the aeronautics people, once the contract was let, once the authority to proceed, if the aeronautics people are involved, they wash their hands. We don't need to be involved. A lot of people thought that the Space Shuttle Research Division would disappear because a contract had been let. Of course, our work was just starting.

The point I'm making is that the aeronautics wanted nothing to do with it, and the Shuttle work began to take over everything. We had our aeronautics people. All we needed was to get time in their wind tunnels. All the Space Systems Division engineers did just about all that wind tunnel testing that was done on Shuttle in-house at Langley.

The thermodynamics people were working on the Jovian Probe going to Jupiter. The re-entry of Jupiter is way worse than anything else because of how big it was. A lot of the entry physics people were working on the other planets and other stuff. The Space System Division was working on the Shuttle. Again, there was that split between aeronautics in space and aeronautics getting upset because they weren't getting any work. That's my view of it. I digress a lot.

JOHNSON: I was going to ask Rebecca and see if she had a question or two.

WRIGHT: I do have a couple. If you go back to those first years that you were here, can you recall or share with us some basic principles or some basic tenets that you might have learned during that time period working with all of those NACA people that you carried through your career?

WOODS: Well, of course, the use of the ideal gas tables—that's something you use that to get through college. As a matter of fact, just a few years ago, a guy named A. B. Blair—and I didn't realize this was very true, and a lot of people don't use it—I ended up talking to John [D.] Anderson over the telephone. John Anderson is from the Smithsonian [National Air and Space Museum] and the University of Maryland. John Anderson wrote the textbooks—Dr. John Anderson. He's Professor Emeritus at the university. He was [Curator of Aerodynamics] at the Smithsonian after he retired from teaching at the University of Maryland—anyway, a guy that works in transonics. I worked in hypersonics, but when we started doing X-33, each engineer did it across a free range. There was a subsonic tunnel when we went to do this. Again—the basic use of the gas tables that I learned early on—I would have learned it as a senior if I hadn't learned it early on as a co-op, but that I continued to use throughout my career.

A.B. told me one time about max loads on launch. He said, "They always occur right around Mach number 1.4." He may have said Mach number 1.414, which is the square root of 2. Well, I thought about that, and I got the equation out. In calculus, you take your first derivative and set it equal to zero—yes—you take your first derivative and set it equal to zero to determine, I guess, your maximum, and the second derivative—I've forgotten how to do this stuff. Anyway, I got out that table, put that equation out, I differentiated it, and I set it equal to zero. It comes out that your dynamic pressure—the Q to total pressure in that gas table—you take that equation, you differentiate it and set it equal zero, and it comes out the Mach number is the square root of 2. Now, that's an ideal gas mathematical equation. The high temperature of hypersonics that you have changes a lot of stuff. The gas comes apart and all sorts of things. The terminology—I learned terminology working with engineers way before I got to it in the classroom. Being a co-op, as far as I'm concerned, made getting a college education a lot easier.

What I carried generally or tried to carry with me was, again, watching the way people interact with each other and their supervisors. People have retired out here, and the way things have gone the last few years, and it's been going that way for some time, and they said, "We can't get them out here to go to alumni—" We have a Langley Alumni Association. We meet the second Tuesday of every month for lunch at the cafeteria. A lot of people, when they retired, said, "I don't ever want to go back out there." To me, that's sad, because this place is great or was great. What was accomplished here was really something.

WRIGHT: Another alumni mentioned that expression about when he 'got his wings.' I noticed you used that terminology when you were talking earlier about getting your wings.

WOODS: Was he talking about his retirement wings?

WRIGHT: I think it was NACA. Even though it was during the transition that some people who might have been short [time]—that they went and gave them their wings.

WOODS: That's another story. I've got worse than that. I've got a plaque that's got the [NACA] wings up here and the [NASA] meatball down here. That was courtesy of this guy, Bernie Spencer. He was a Grade A conman. They made some plaques. I had a choice. That's right. As a matter of fact, a friend of mine who I was talking to the other day—he got out of Lynchburg College [Virginia] with a math and physics degree, and he came to work here, I think—wasn't NASA created in about September?

JOHNSON: October 1st of '58.

WOODS: I think he came to work in June of '58. He had the option. He got the wings. Bernie Spencer was doing something for somebody. It would have been a hard decision for me to make. I probably would have gone with the wings. Bernie knew all of these guys in the shops. As a matter of fact, he swiped some of my models that I was having built and gave them to somebody as a display model. Anyway, he made a plaque for somebody that had the wings and the meatball on it. When Larry [Lawrence] Edwards retired, Bill [William H.] Phillips, my college roommate and my office mate who I lost to cancer about four or five years ago, got a plaque made like that for Larry.

Wayne [D.] Erickson—I don't know if you know Wayne Erickson. He was a fantastic engineer out here. He was on the Air Force Science Board for years. They were working with Larry over in the Aerospace Plane Office. Maybe it was hyper—no, it was still Aerospace Plane. He asked Bill, "Can you get me one of those?" So, Bill got him a plaque. When Wayne retired, they had already gone through the process of giving him a plaque. So, he comes over to our office one day, and he says, "Bill, they've already got me a meatball. Here—you take this back." So, it was under a table in my office, wrapped up in brown paper.

When I retired, they said, "We've got to work on your plaque."

I said, "No, you don't have to. You just give me the little piece of metal. I'll put it on the plaque." The wings—they do a really nice plaque now. It's etched in gold. It's a little thing like this with the meatball on it and a little plaque down here. This thing is about this size. It's got NACA wings up here and a meatball down here, and a "presented to" plaque over there. So, I didn't see any reason to get anything else, since I had that under the table in the office.

JOHNSON: It was easy to get it.

WRIGHT: Not many people have a plaque ready to retire, so that was pretty good. Thank you.

WOODS: I wouldn't have had that. I may have gone for the wings or I may not have, because I was just a kid, and it was two or three—I guess it was three years—the summer of '56 and fall of '58; two and a half or whatever.

Several years ago—and they may have given them to everybody—it was on one of the anniversaries of the NACA something—you know the little meatball pins we've got—the 5, 10, 15, 20, et cetera, et cetera? They came up with a little set of wings. I think everybody at NASA Langley got them, but it's a nice, little collar pin that's got the wings on it. It always tickled me that I never really thought about it or talked about it. Nobody really knew what NACA was. People around here, of course—famous around here—they've got NACA-nuts—all of those weird guys! They're tight. They're cheap.

JOHNSON: They take things apart.

WRIGHT: And they put them back together! Well, thanks for coming in today.

WOODS: Well, I'm afraid I should have gotten my thoughts more organized. I've been doing a little babbling. I couldn't have worked in hypersonics at any better time.

JOHNSON: You were there at the right time, weren't you? That's excellent. Well, thank you very much.

[End of interview]