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INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is July 16, 2014. This oral history session is being conducted with Henry Cole at NASA's Ames Research Center in Moffett Field, California, as part of the NACA [National Advisory Committee for Aeronautics] Oral History Project, sponsored by the NASA Headquarters History Office. Interviewer is Sandra Johnson, assisted by Rebecca Wright. I want to thank you again for coming up here and meeting with us, especially after all the confusion we had this morning. You were going to tell us about the beginning, and a little bit about your education and when you first heard of the NACA, and how you first were associated with the NACA.

COLE: I was going to high school in Tacoma, Washington. When I was a senior, in 1938—a long time ago—I had a hobby of building model airplanes. These are airplanes you design and then you fly them. At that time, aviation was just getting started, and for recreation, we would drive out to the airport and watch airplanes take off and land. Airplanes were really something, then. I built these model airplanes and started designing airfoils for them. I went to the Tacoma Library there, and here were all these NACA reports. In these reports were all these measurements on airfoils. I was just in heaven, and I was able to get airfoils for my model airplanes and so forth. You'll find that a lot of engineers, even I have had some association with Neil [A.] Armstrong, and he built model airplanes and he was my age. I knew that when I graduated, I wanted to study aeronautical engineering. I went to UW [University of Washington,

Seattle], and this is back before World War II, and I got a bachelor's degree in aeronautical engineering.

I was in a Naval ROTC [Reserve Officers' Training Corp]. When I graduated, I was immediately sent to the South Pacific. I don't want to talk about the war stuff, but I was an aircraft maintenance officer on a carrier, and I had a lot of associations with pilots. I was attached to a squadron, VC-11, and flying airplanes through actually eight battles. Of course, I don't like to talk about this too much because I get too emotional.

When I came out of the Navy, the war was over. There were no jobs for aeronautical engineers, so I joined a friend of mine and we opened a model airplane shop, and we sold model airplane supplies and built airplanes and taught classes. We also wrote for magazines. I wrote for *Air Trails*, and I published a lot of articles.

One of the things I like to mention is that whenever I gave a talk with NACA, much later, we rehearsed everything, and this is non-rehearsed.

JOHNSON: That's what oral history is—it's just a conversation.

COLE: We'll get into that later. I'm going to have a little problem putting this together. After the war, we ran this model shop for a couple of years, and then I got a notice from the University of Washington, a Professor [Fred] Eastman. They were starting a graduate school there, and they were looking for graduates who would want to attend for their advanced degree. I went out and talked to Professor Eastman, and he looked over my record, and he was concerned that I didn't have enough mathematical background. I had skipped partial differential equations. Instead, I took astronomy, and astronomy was not recognized by the university toward a degree.

I talked to him, and he was concerned about my degree, so I went and I talked to Professor Ganzer, Vic [Victor] Ganzer, who was there. He suggested that I take a lot of mathematics courses, which was extremely good advice because I took my partial differential equations and I took matrix algebra and theory.

The other thing about it was I was in with mathematics majors instead of the engineering. I got the best professors in mathematics. Vic Ganzer, when I got there, I wrote to. I had to get four professors to back me up on this, and so I actually have letters. I found the letters that I wrote to the professors. One of the most interesting ones was Professor [Frederick K.] Kirsten. I don't know if you've ever heard of the Kirsten pipe? The wind tunnel at the University of Washington is a Kirsten Wind Tunnel, and it was bankrolled by Boeing [Company]. Kirsten was mostly known for his pipe. He designed a pipe that had a radiator on it, which took out the tars. The Kirsten pipe, back in those days, was very popular.

Professor Kirsten had retired, and in order to get his recommendation, I had to go and visit his farm. He had gradually gone into farming, and I wondered, how is an engineer going to run a farm? It was amazing: he had a milk farm and he was the only place which was qualified to supply milk to hospitals because he had the lowest bacteria count west of the Mississippi. He also was building a library that had a parabolic ceiling so that if you put a light at the focus, the whole ceiling would light up. He was an inspiration to me. I got accepted to start. I was given a fellowship at the University of Washington for my master's degree, and Professor Ganzer, it turned out that Professor Ganzer had worked at Ames, and he was going to be my advisor. From Ames, he went to work for Boeing, and that was one thing about NACA. NACA was a good ground for developing people for industry.

At Boeing, he was the one that designed the swept wing, first swept wing for aircraft, and he found that the optimum sweep angle was 35 degrees. This was used in the 707 and all the Boeing airplanes for many years. Then, from Boeing, he went to the University of Washington. He didn't have a Ph.D., but the program there had all Ph.D.s except for Vic Ganzer. He said, "I just like to show up all these guys. I don't care." They tried to give him an honorary degree and he said, "I don't want that." He was doing that all the time. He'd ask us, a course we were in, "Have you got to this problem yet? Have you finished that?"

Finally, we said, "Yes, we finished that."

He said, "Well, let me show you," and he'd go to the blackboard, and in three lines, he says, "If you use calculus variations, you can prove that in three lines." We had spent weeks on it. Vic Ganzer, and then it happened that the students there in graduate degree, there were four students from China. They went to the University of Washington, and they went there because they wanted to be close to the capital of the country, and they thought the University of Washington was close. The Chinese students were a good association. They would stay up all night, and then when they got sleepy, they would sleep on their oak desk, flat-out. You'd come in there in the morning [and find them].

Where I was very fortunate was that it happened that [A.] Scott Crossfield, you may not have heard of him as much as Neil Armstrong, but Scott Crossfield, in World War II, was a Corsair pilot. Ganzer [gave us] a desk together in the attic of Guggenheim Hall, and here's a pilot from World War II and an aircraft maintenance [officer], and we really got along fine. The main point at Washington was that their program, they weren't qualified for a doctorate, but just a master's. They ran it like it was a Ph.D. program, and we had to have orals [exams]. Before I went into my oral, I was talking to Crossfield. In the orals, they had our advisor, Professor

Ganzer, then we had the mathematics professor from math department, and then we had two other professors that taught [aeronautics]. Scott said to me—I'm going into the orals and he said, "I think he's going to ask you to derive the equations of motion of an airplane."

That's a very difficult derivation, so I said, "No, he couldn't ask something like that—that's too difficult. Well, maybe I'll go through it and see." In that derivation, there are several little tricks you have to go through, so I went through, "Oh, yes, I got to remember that."

I went in there and that's what Ganzer asked me to do, derive the equations of motion. I go to the blackboard, and I'd just gone over it. The thing I've always wondered is if Professor Ganzer tipped Scott off—"Tell Hank what I'm going to ask him."

The other unusual thing was the math professor, he was very upset by all this because he said, "I do not like to think of my mathematics being done for anything practical," because my thesis was on a major problem of aileron reversal. These are my letters [showing letters to professors]. I've gone through them. Yes, here's my thesis. It turned out that the course in matrix algebra [was very useful in solving the] aileron reversal [problem].

The story at the time, the B-47 was just being built by Boeing, and it was being reviewed by the Air Force, down at Edwards [Air Force Base, California]. They set up a review stand and they had the pilot, they had the review stand of all the generals and everybody, and the plan was the B-47 was to come down and fly at low speed in front of the stand and make a climbing turn to the right. It turned out, the pilot came down and instead of turning to the right, he went to the left, and he didn't mean to. It turns out that at the speed, he got a little too much speed in, and there was aileron reversal.

That was a major problem that Boeing had at the time, was aileron reversal. What it is, when the pilot goes to roll right, it goes left because the wing twists in such a way that the wing

twist is more powerful than the ailerons themselves, and that rolls the wrong way. Vic told me about this problem, wanting to know if I would take it for my thesis. I have a picture here I'll show you [photo of Professor Ganzer and Cole in wind tunnel with model]. This was during the project. I just found it this morning—I was looking for it. I thought about this.

Here's Vic Ganzer and me. This was the swept wing in UW, UWAL [University of Washington Aeronautical Laboratory], they call it, the aeronautical lab there, their wind tunnel. As we went through this project, my thesis was written to design this wing. I was a model-builder, so I built the test models. Here are some pictures. What we did, we had a straight wing and a swept wing. These were the configurations, here. One thing I ought to mention, you see this electric motor, here? This is on a sting which rotates these, and you measure, you deflect the ailerons and you measure all the moments and everything. There was a surplus store that I went down to—I needed an electric motor and I had to design a drive—and they sold stuff by the pound. I saw this radar.

You know, in the front of the airplane they have a radar with a disc that rotates like that? It was driven by this electric motor. I paid $10, they just weighed it, and it was quite light, so I only had to pay $10 for this thing. I took the electric motor out of there and I built a gear train. This turned too fast for that, and we mounted that on a sting. This is a gearbox, here. We mounted that on here to drive the thing. One reason I'm going into all this detail is that when this project was about half-done, I was on the GI Bill of Rights to fund me going through for college.

JOHNSON: You weren't working for NACA during this time?

COLE: No. Professor Ganzer told NACA about this. They said, "We like that, we'll fund it," so I went off the GI Bill and I went to work for University of Washington Aeronautical Lab. I did all this work, the model work and everything, under money from NACA. NACA, they were working with universities a lot. We had a wind tunnel.

JOHNSON: This was done in the university wind tunnel, not NACA?

COLE: Yes, this was done in a University of Washington wind tunnel, a Kirsten Wind Tunnel. This will give you an idea of how this thing was very complicated [referring to NACA Technical Note 2563, *Experimental Investigation of Rolling Performance of Straight and Sweptback Flexible Wings with Various Ailerons*], and I had to cut all these airfoils and build this all up. Being a model-builder, I loved doing it.

JOHNSON: You did it all yourself, that's great.

COLE: Yes, I built this all myself. This shows in the wind tunnel, you can see how the wing is deflecting, here. We finished this project about the time that I was going to graduate, and in fact, we did finish it when I graduated. We sent the report to NACA, our write-up. [NACA] Langley [Research Center, Hampton, Virginia] was reviewing this. At the same time, I had graduated and I had received a telegram from Ames, offering me $4,600 a year as a GS-5 [General Schedule pay scale]. I had some other offers from North American [Aviation, Incorporated] that were much better, but since I had been in the military for five years, it meant I could get 30 days'

vacation if I went to Ames, and also, I liked this area. I had a softness in my heart for NACA. I came down here and I reported on January 1, 1951.

JOHNSON: That must have been pretty amazing for you, reading those NACA reports when you were younger, in the library, and then having that published by the NACA.

COLE: That's an amazing thing. When I think back on this, when I started going over, reviewing this, I think, "My gosh, how lucky was I to have the professor that designed the swept wing, and Scott Crossfield?" Scott Crossfield also went to NACA, and he was the first man to set the two times the speed of sound record. Chuck Yeager was the first [to break the speed of] sound—Scott Crossfield was two times the speed of sound, and that was in the X-5.

JOHNSON: You said they asked you to come to work and you started in January of '51?

COLE: Yes. I arrived here and I was assigned to flight research. Harry [J.] Goett was the division chief, and Steve [Steven] Belsley was the branch chief. At the same time I arrived here, we were getting reports back from Langley, questions about the report, and so I was working nights to answer these questions. Here I am, working at Ames, and I'm also working for Langley in the same time.

Belsley, he was the most fantastic guy. He was very loved. He was known around the Center here as the guy, if they had a meeting, he's on top of everything and very vocal about it. I used to have people ask me, "How can you work for that guy?" Steve, within the branch, he was on top of everything and he was on your side. If somebody else questioned you, he was there on

your side. The assistant division was Larry [Lawrence A.] Clousing. Larry Clousing was a test pilot at Ames that did a lot of ice research, but he walked me down to the hangar down there to see Steve, and on the way, we ran into R.T. [Robert Thomas] Jones. I don't know if you've heard of R.T. Jones?

JOHNSON: I've heard the name.

COLE: He was the advocate for swept wings at Langley. R.T. started much earlier at Langley and he was trying to get people to go into swept wing. Here, I've met the one who designed the 35-degree—of course, the Germans developed in the war—and here's R.T. Jones. He and I, we did a lot of things together during the years, and he was a good friend.

I got down and they introduced me to Belsley and I start talking. The first thing he said, "Did you take a course in servo mechanisms?"

I said, "No. It was on the list but I turned it down because I took matrix algebra instead."

He said, "Well, I have a project for you. Here's this book [holding book], this *Theory of Servomechanisms*, [Hubert M.] James, [Nathanial B.] Nichols, [Ralph S.] Phillips, and this is a Dover book, it cost $2.25." Can you imagine? All this information. He said, "Read this and then come back in a month and we'll talk about the project."

I really worked on this thing. One of the things you learn in graduate school is to teach yourself, and that's the main thing between undergraduate and graduate school. This was a fantastic book. In fact, it has some things in the back here that I really have been using up to now. This was a radiation lab at MIT [Massachusetts Institute of Technology, Cambridge], and it's famous. They were designing radars and things like that in those days. I read that, and it

came back and gave Steve a brief course in servomechanisms. It was fascinating reading, and it's all about transfer functions and when you put an autopilot on an airplane, you write all these mathematics for equations of motion, then you put an autopilot in there, and the equations all connect. That's what servomechanism theory is. [Then Steve] started telling me about designing for negative static margins.

Are you familiar with airplane modes at all? Longitudinally, an airplane has two modes. It has a short period oscillation and then it has a long period, where it goes along like this, and so forth. The autopilot is designed to even that out. For a pilot, an airplane has to be stable, but it turns out that for performance reasons, if you move the center of gravity back, you can get better performance. This report was an *Investigation of Stability at Negative Static Margins of a Supersonic Missile with an Autopilot sent to the Pitch and High Angle and Pitching Velocity* [NACA Research Memorandum A52A14]. The important thing about that is that this idea, this was confidential, of course, and I have no idea whether they actually put it on, but I think it was a Sparrow missile that it was used on, but I don't know that because the NACA's policy is not to report on specific vehicles, but get the concept. The concept's what's important.

JOHNSON: Right, it was the research.

COLE: Yes. My other reports, like the B-47, I don't say "B-47," I say, "A swept-wing airplane." Are you familiar with the B-2 bomber, this flying wing, the Northrop [Corporation] flying wing?

JOHNSON: Yes; I've seen pictures.

COLE: What makes that possible to fly as well it does is it has a negative static margin. What they do instead of having the aerodynamic stabilizer, the autopilot stabilizes it. They get better performance that way. The other thing that came up later on, when we were in flight research, and George [E.] Cooper—was George Cooper interviewed at all, do you know?

JOHNSON: I don't think so.

WRIGHT: He decided not to.

COLE: I think his hearing is a little bit difficult now. They were doing the F-86, I don't know if anybody mentioned, in flight research, we had an F-86 airplane. He was doing the piloting and the studying. What you do, if you start cutting down the static margin of an airplane, then the controls become very sensitive. The question was, could a pilot fly an airplane with negative static margin? Because it's not stable, and the controls become very sensitive. A lot of research was done on that here, later on. A negative static margin is something that is carried through even today, a lot of airplanes.

Anyway, we got this report done in a year and published it, and so, I got a real head start with NACA because I had the aileron reversal model report came out, and this came out. I had two reports in the first two years. The thing about it was that they worked you hard, but it was fascinating work. In flight research, we had a mathematician [Marvin Shinbrot] who was real sharp [and ready to solve equations]. The thing about a mathematician is he solves things and he gets an answer, but he doesn't see what the answer means.

In flight research, we had a mathematician, and then, I was, fortunately, again, as I was with Scott Crossfield, Belsley put me on a desk with Bill [William C.] Triplett, and Bill Triplett was one of their senior people there. I learned so much from him, being across the desk. He taught me on the F-86 that they were doing, there's a thing that they use in flight research. When you want to measure what an airplane does, you have to put an input to it in some way. They have a thing called stick-banging, which what they do on the stick, they put a chain—it's got a stop here, on the stick—and the pilot pulls it very rapidly back and then pushes forward against the stop again. It makes the control surface a triangular motion, like that. That makes everything go. The wings, flaps, and the airplane goes through all these contortions. Then, you mathematically extract the characteristics of all these modes from the response you get.

I learned that technique from Bill Triplett. They weren't much into air elasticity at Ames, then, and I brought that experience with me. About that time, the Air Force provided NACA with a B-47. There's a B-47 [showing photo]. This was the first swept-wing airplane, and it was a bomber. It was the forerunner for the 707 commercial aircraft. This airplane, they built 2,000 of them, and it was the SAC, Strategic Air Command, bomber for nuclear, into the 1970s, I think, was the last time.

[In reading over the oral history transcript I noticed that I had failed to mention the branch reviews that Harry Goett held every other Tuesday morning. These were very important events in which Harry asked every project engineer what they had been doing. Some of the answers were very humorous like, "I have been thinking," followed by a long pause. Others were very complex. Elwood Stewart was deep into Weiner's prediction theory which left us all a little bit glassy eyed. Marvin Shinbrot often described his "method function transformation," which he was developing, etc. Harry would ask pertinent questions and Steve would intervene if

he thought Harry was out of line. The important part of this was that many of us would go out to a one-martini lunch afterwards and discuss all that went on. This not only brought us together, but also led to solving many of the problems.]

That was the nice thing about the NACA: the NACA was an advisory committee on aeronautics and we got our money from the [U.S.] Presidents and we didn't have to argue any politics or anything. Aircraft companies and the Air Force and everything, they gave us airplanes to use in research. The Air Force gave us this—this was one of the first 10 that were built. Harry Goett called me up, and I remember he started telling me about there were two projects with the B-47 that are going to run. One is the loads problem, which Langley had, and stability and control was the other region. They were asking for somebody to make a proposal on stability and control, so Harry called me up and he said, "Do you think you can do this?" [Showing photo of B-47.]

JOHNSON: Yes, this is a full-sized plane.

COLE: It's 80,000 pounds, empty, and 116 feet in wingspan. I thought, "Well, sure, I can do it." NACA's policy was I think they had a ratio of 3:1, if you had a scientist, the project engineer would get three people to help him. I got a couple other real good people and then, of course, you also have the support of the machine shop and the model shops and the instrumentation. NACA gave part of the project, the B-47, to Ames. The airplane was flown to Langley, and they instrumented the airplane. When the airplane was being instrumented, I went back down to Edwards.

Joe [Joseph A.] Walker, who was an X-5 test pilot, he flew us back, and that was the hairiest trip I ever took anyplace. It was a C-47, which is a DC-3. This airplane had been sitting in the desert for a long time, and all the seals on the windows had dried up, we found. We didn't know. We started flying back to Langley to check on the instrumentation, and we stopped in Kansas City overnight—you don't fly across the country, then, you stop. We got up in the morning and it was raining and windy and lightning.

Joe Walker called the tower and said, "What's the weather like?"

They said, "Well, it's kind of bad on the ground here, but up at 10,000 feet, it's okay." We take off, and Larry Clousing, by the way, was on this trip with us, too. He was a pilot and he was, of course, our assistant division chief. We get up to 10,000 feet, and water starts running down the center aisle. Joe Walker [was the pilot]. I walked up there to see what's happening, and the window was leaking. The water's pouring in. Joe Walker, I heard him say, he called the tower and he says, "I got news for you guys, it's not good up here." We're headed for Langley and we kept going, and we got over the Blue Ridge Mountains, and it turned cold and we started icing up. This airplane was not equipped for ice, so we had to fly, he flew as high as he could so we wouldn't ice up. We were just above the haze. Down below, if we sink down a little below, we would start icing up, and the ice would hit the side of the fuselage and make a banging noise. We were all sitting there, "Well, what the heck?" Suddenly, Clousing got up, put on his parachute—and he was the pilot that did the icing research—and went back by the rear door. We all looked at that, and so we all put on our parachutes. Fortunately, we got over the Blue Ridge Mountains, we went out over the Atlantic, and the ice broke up. They landed us at Langley with GCA. That's the Ground Control Approach by radar, and you couldn't see a thing. We're going

through all this snow, and then we land in the hangar. That was something we'll always remember.

We got there and we went in the hangar to look at the airplane. What we had, let's see, I'm not sure of this picture. You see on top of the center of the wing, here? That was an optigraph. It was a camera in there, and you see these dots on the wing, the black dots? These lights were recorded on film, and it measured the deflections of these dots. We ran all this data. Then, they had the accelerometers and strain gauges, and it was the most instrumented airplane ever, I think. The thing that got me was we went up on top of the wing, here, and you walk along the top of the wing, and it goes [moves] up and down. This was a very thin wing, and this airplane was so fast, there's a story that Chuck Yeager was following it with a chase plane, and they made a turn, and Yeager called out and he says, "Slow down, I can't keep up with you." They said it's the only time Chuck Yeager ever said something like that.

WRIGHT: What kind of plane was Yeager in, do you know?

COLE: He wasn't in NACA; he was in the Air Force. I don't know what he was flying. I just heard the story. It was probably an F-86.

The B-47 had a very thin wing, and at altitude, it'd fly very, very close, about as high as and faster than the 86 would. I went out there and I was walking back and forth, and the wing is going like this. I looked at his optigraph and I asked him, I said, "How did you fasten this optigraph?"

He said, "It's just to the fuselage, there." The thing is that the way the wing is suspended, there's two pins where the wing goes through the fuselage and then the wing rotates about the

sides of the fuselage, and the center goes up and down, and the sides are fixed, and then the wing goes like that.

I said, "How much does the wing go down in the center, here?" It turned out it was up to 7 inches. I said, "Was that taken into account when you designed the mount?"

They said, "Well, I guess we better change that." People, in those days, weren't used to this flexibility. With the project I'd been on, I was used to that.

We went through that. We approved all the instrumentation, and then I flew up to Wright Field [Wright-Patterson Air Force Base, Dayton, Ohio]. The Air Force was also testing a B-47, and I flew up to Wright Field to see what they were doing. They were not using stick wrapping. They were going to drive the elevators with the autopilot. They could program the signal and move [the control surfaces]. I asked them, I said, "How can you excite—that isn't a very high frequency."

They said, "Well, we're only going to do the short period mode." We wanted to do the structural mode, so with the stick wrapping, you excite everything. The wings fly up and the fuselage bends, and that's very important because if you put an autopilot in a flexible airplane, it's measuring pitch and these higher frequencies get in electronics, and they have to be designed to work together. I guess I better make this long story short; this was all reported in a technical report.

JOHNSON: This is the B-47?

COLE: Yes. There's a whole string of reports on that.

JOHNSON: The report's in 1957, but what year did you start on that?

COLE: In 1953.

JOHNSON: You spent a long time on that.

COLE: This was a tremendous project. The way this worked, when we got the airplane out to Edwards, all the pilots wanted to fly it. Scott Crossfield and Joe Walker and Neil Armstrong, test pilots love to fly on airplanes, especially something new. This thing landed over 200 miles an hour, and very fast, and they all wanted to fly it. When that was over, we started our test program.

Once a week, I was up here, and Euclid [C.] Holleman was down in the high-speed station there. Once a week, George Cooper would fly us down to Edwards and we would discuss—you have an envelope that you want to cover, and we covered 15,000–35,000 feet, and various Mach numbers. It was an enormous amount of data that we could get, so once a week I'd go down there and [meet with Walter Williams and Dee Beeler] and set up what flights to run the next week and then we'd fly back home and start working on the data. [Harry Goett came with us sometimes.]

I had Stu [Stuart C.] Brown and Frances [L.] Bennion, two engineers that were working with me, reducing data. This was before we had electronic computers, and we had a staff of maybe, I guess it was around seven gals with Fridens and Marchants [calculators], and we'd set up this on computer sheets, and they would do these things. One of the things that were required in here to get a one point on this, one of these curves, by hand, took three hours. You could

imagine how many points we have, here. A tremendous amount of computing. Once a week, we'd go down and we would get more data and set up the next envelope. There were a bunch of other reports, but most of these were confidential, initially. I have a list of them here.

JOHNSON: Was it at Edwards because of the way it landed, you couldn't work on it here?

COLE: You couldn't fly it from here. Well, we did fly the airplane to Ames once, when we had a tri-annual inspection, and we had the airplane in the hangar over here, and we gave a talk on that. I'll show you that, later. I had the stuff on that. You can see how complicated this is [NACA Report 1330, *Experimental and Predicted Longitudinal and Lateral-Directional Response Characteristics of a Large Flexible 35 Degree Swept-Wing Airplane at an Altitude of 35,000 Feet*]. The Air Force was just doing this part of it, here, and we did the structural modes, here. One of these is the fuselage bending; another one is the wing bending. This is a full report, and we can't get into that, but I have a better thing to show you, here. In that same year, I gave a talk at the Institute of Aeronautical Sciences, in New York. This is the print-out of it, and I'll show you, these are all equations. The main thing I wanted to show you is these are all defining the deflections of the airplane. You can see the wings go out here, the fuselage bends.

JOHNSON: It moves that much? Wow.

COLE: If you put a gyro in the wrong place on an airplane, these peaks, like that, will throw the gyro off and it won't work very well. What I like to show is this last figure, here. We calculated the node lines. The node lines are where there are no deflections. If you put a gyro on a node

line, it's not affected by the wing—the wing and the fuselage and everything. When I gave this talk, I told them, this tells you where to sit on the 707. You want to sit on a node line because when you get into turbulence, you don't feel all this bouncing. A 707 was terrible if you got in the wrong—but you see, if you were right around the root of the wing, that's the best place to ride through turbulence. There was one humorous thing, there: when I gave this talk back there, the Honeywell engineers surrounded me and started talking. Smitty—the [Center] Director, Smitty, we call him—Smith J. DeFrance, he was back there. As soon as these Honeywell engineers started talking to me, he came over.

JOHNSON: Being protective, or wanted to know what they were asking you, or if they were trying to recruit you?

COLE: They didn't offer me any jobs while Smitty was there. Honeywell, that's one thing, you do all this work and you know it's out there and they would ask you questions. I had the Learjet people come once, and we were down the hangar there, and they called us up to the Ad [Administration] Building here and they would ask us all these questions. On the Learjet, they had a thing where the stabilizer was fluttering. We figured out how to solve that. That was the thing about NACA, was that we were the source of the information, and the companies came to us to get this information. That was our job.

JOHNSON: To do the research?

COLE: Yes. These reports, I should mention that to put out a report like this, [Gerald E.] Nitzberg was the head of the editorial, and he set up editorial committees, and on the editorial committee, you had the author, and then you had an expert senior scientist on the field, as the chairman, and then they liked to get somebody in between, and then a junior, somebody just starting. The junior member would usually want to change the grammar, and then, of course, the others would question your mathematics and all that, and so forth. Editorial committees were a major, major thing. NACA just did not put out false information—everything had to be checked and rechecked.

JOHNSON: How long did it take for a report this size, which is a pretty good-sized report?

COLE: To publish? Sometimes, it'd take about a year before it was published. They were a little faster when it was confidential. Confidential reports were thinner. With this, this is a confidential report, here, and with this, parts of this were put out as thinner reports. Leading up to this would maybe be three or four reports.

JOHNSON: The memorandums were smaller and then the note was the larger document, usually?

COLE: Yes. One of the comments I got one time was they wanted my appendix. There was an MIT professor that wrote a paper on my Appendix A [NACA Technical Note 4147, *Measure D and Predicted Dynamic Response Characteristics of a Flexible Airplane to Elevator Control over a Frequency Range Including Three Structural Modes*], only he didn't know it. He did it independently. Somebody said, "Hey, that is just like your Appendix A." I thought, "Oh, wow,

that's nice." [Appendices A, B, and C derive equations of motion in matrix algebra including three structural modes.]

JOHNSON: At least you had your work validated, didn't you?

COLE: We were ahead of him.

JOHNSON: We were talking about the length of time that it took for that B-47 project. It was quite a long time.

COLE: Actually, we just finished it in 1957, and about that time, there was talk of they were going to form NASA. They were talking about moving the flight research to Edwards. I really didn't like that because I had been to Edwards so many times, and part of that was one time, at Edwards, they had a lot of guys lived in Hollister, [California], which was about 15 miles, 20 miles away, but a lot of the junior engineers lived in a Quonset hut out on the desert. I was down there for a month one time.

JOHNSON: It's a little warm down there, isn't it?

COLE: The desert is dreadful. When the sandstorms start, it takes the paint off their cars. The other thing that disturbed me was that all of the guys that are working out there, in college, I was one of the top ping-pong players at UW, and practically all those guys could beat me. I went down there, all they did was every night, the only thing they did was play ping-pong.

JOHNSON: They didn't have anything else to do.

COLE: Yes, there was nothing to do. It's not the greatest place to work. That's when I decided, they said they were going to move down to Edwards, and that's when I made a move. I moved to structural dynamics here, and I don't know if Glenn [Bugos, Ames historian] gave you a copy of my book?

JOHNSON: No. He mentioned that you had a book, but no, I don't have a copy of it. I think he was supposed to leave it in his office this morning, and then we couldn't get in there.

COLE: That comes later. The other thing down there was I stayed at a motel one time and they said, "Be sure you get a heated pool." Why do that? The desert is very dry, and I went out and dove in the pool, and I almost froze to death. It was cold—can you imagine, you're out in the desert and all that heat, and you got to have a heated pool because the evaporation, the humidity is practically zero.

JOHNSON: How did you fly back and forth? On what kind of plane did they fly you back and forth when you were working on that?

COLE: That was a C-47, or it was a DC-3. George Cooper did most of the flying, but there was [William H. "Bill"] McAvoy and Larry Clousing, and they used to fly us back and forth. I don't

know how much I can say about the flight research. Would you like to hear about any of the other projects?

JOHNSON: Sure. You mentioned, like 1957-58, and that transition, if you want to just talk about that transition?

COLE: This project was wound up just about the time NASA formed. I was giving talks. I don't know, if you wanted, I have an extra copy of this if you want it.

JOHNSON: Yes, that's great.

COLE: Before I get into this, I got to tell you about this. You have this mode, the airplane goes through a mode, and it's an oscillation. There are different things. In the lateral thing, there's a thing called Dutch roll, where the airplane goes like this. There's a story—Chuck Yeager was flying on one of them, it's the 707 that became a commercial airliner, he was flying on a 707 and the pilot got into a Dutch roll, and everybody was getting sick. He went up to the cockpit and kicked the pilot out and took over. He knew how to stop the Dutch roll. You get into these modes and you can't stop them. Autopilot can control that, but sometimes, the pilots are flying it and they get into these things and they can't get out. To get this, you have to know the moment of inertia of the airplane.

You can imagine what Boeing does, the moment of inertia, you've got to take all the masses of all the structure and everything in here and measure the moment of inertia about the center of gravity. They had books and books of this stuff, little part, every part, every nut and

bolt that went in there is in this book. They take all this stuff and they add it up and they get the moment of inertia of an airplane. For flight research, what we used to do, like the F-86, you know what it is? A swept-wing fighter. You put it on knife edges and then you put a spring on the nose, then you oscillate it. From that, you can calculate the moment inertia, and you're really measuring the moment of inertia. I decided we should do that with the 747. It's 80,000 pounds and it's got all this flexibility. Frances Bennion was the one who helped me on this, mostly. She did a lot of the calculations. Then, we had the gals on their Marchants and Fridens, going like crazy.

JOHNSON: Was she a mathematician, the one you said that helped you?

COLE: Yes. I introduced matrix algebra, which I had taken at Washington, into this thing, and we calculated all these modes. Here's a diagram [NACA Technical Note 3870, *Measurement of the Longitudinal Moment of Inertia of a Flexible Airplane*] showing—here's a knife edge—this is just a string diagram. This shows the wing, here, and then the fuselage, and has a line, and then there's a spring in front. Here's the hitch to this thing: you have to do it indoors because you can't have a wind effect. Down at Edwards, we didn't have a hangar big enough for a B-47. We had it outside. We went to the Air Force and wanted to know if we could borrow a hangar, and they said they had a hangar which had their secret airplanes in it, and they said, "We will move those airplanes out of there and give you access to this hangar, but you have to be in and out in 1 hour." We went through all these calculations and we figured out the optimum way. The spring we had on the front was a railroad spring, you see this thing, the steel is that big

around and it's about 1,000 pounds per inch spring. We built all this stuff, and then we had knife edges, here. This is 80,000 pounds, and just thinking about this, I feel—

JOHNSON: Yes, tense.

COLE: We had this all figured out and we roll the airplane in there, and there were four points on the wing; an airplane has lift points that you're allowed to lift with. There are two on the fuselage and four on the wings. We decided, after figuring the optimum one was to put the knife edges in-board and then a spring up here, there was a lift point here. What we had to do was roll the airplane in, we jack it up on lift points that we're not using for the test, and then we put the knife edges under there, and the spring, and we lower the thing down on these. This has got the knife edges and spring, and the idea is that to get us started, we took about 10 people and we all pushed in sync. It's like pushing a swing, you keep pushing it, and it builds up this motion. Here, we got all this stuff set up and 10 of us were pushing up and down and the airplane is oscillating like this. This is great. Then, we say, "Let go," and the thing goes down, and the thing goes, "Clunk," and stops.

Everybody was silent, and then Joe Walker, who was a test pilot, he let out this big "Ha-ha." I grabbed a couple of mechanics, I said, "We got to line this thing up." I went over and looked at it and it seemed like what had happened was the shaft was touching the metal edge there, but we only had an hour, we wouldn't lower the thing down. One of the mechanics ran over and got a sledge hammer and started banging this on the thing and got it to where there was enough clearance, here. I designed this thing, and I should have had more clearance. It was my

fault. You got it lined up, and then we did it again, and it oscillated. We got all the data and that's in this report. We got the moment of inertia of an 80,000-pound airplane.

JOHNSON: And you did that in an hour?

COLE: Yes, and then we quickly took it down and took it out, and they slammed the doors on us. One hour. I don't know what they had in there, but they had something they didn't want out in the open. That completed the B-47 project, and it's all these reports out there. We had reported to the IAS [Institute of the Aeronautical Sciences]. Have you had anybody talk about the tri-annual inspections?

JOHNSON: We've had some people mention them, but it looks like you have some documents there.

COLE: This was 1955, and we flew the airplane up here, and it was part of the display. I'll let you have this.

JOHNSON: Are you sure?

COLE: Sure. I have a couple of them, here.

JOHNSON: We can send them back to you if you'd like to have them back. That's not a problem.

COLE: I don't know—I got so much stuff, and I have a lot of this. One of these, I think I have several copies. We had a talk that went with this. Everybody around the Center here, they had talks they gave and congressmen showed up, and then you had people from industry. You've probably heard about the inspection?

JOHNSON: Yes, that they would have a lot of times, celebrities or famous people would come through.

COLE: All kinds of people. I think [Henry J. E.] Reid was the Director of Langley. Yes, Reid was the Director. We made a model when we had it on springs and we have a driver and we'd oscillate it and the wings flap and so forth. It was kind of neat, but I don't think it's shown in here. The airplane was here, and the wings from push-down to pull-up, the wingtips would flex 16 feet, from pull-down to push-up. The figure you usually hear quoted is 5 feet, but that's not in the extreme maneuvers that we were doing.

This is Ames, and this shows Ames is mostly high-speed. Here's your project. Some of the things we do in wind tunnels, this vapor screen. I never did see one of those, but it's something, you can see the vortices and everything. We had things like a shadowgraph, where you can see the turbulence, and of course, shock waves. The 14-foot transonic wind tunnel was where I went in structural dynamics, and that's what my book is on. That was what was put out for the tri-annual inspection.

JOHNSON: All the different projects that were presented, did they all make these books, or was this something that y'all decided to do on that?

COLE: I think there were more than that around—more talk. Every branch had a talk. Some of them had displays. For the congressmen and all the other people that showed up, everything was straightforward. The last day, we had one for just the Ames people, and so we all got to go around and see all the displays. What we did, we hammed it up.

JOHNSON: You had more fun on that last day?

COLE: Yes, it was a fun deal, and it was full of laughs. With ours, we put a squeaker on our flexible airplane, and it went, "Squeak," like a squeaky door.

JOHNSON: You stayed with NASA, right, when the transition happened?

COLE: Yes. I wanted to stay at Ames, and I thought that flight research was moving. Flight research developed into—they started developing simulators. Most of the guys I know that stayed with flight worked on simulators. Have you ever seen a simulator? Okay, you've been on one where you fly?

JOHNSON: I haven't really been on them, but I've seen them.

COLE: That was the thing—Ames had a 4-degree freedom simulator down here, and everybody who came here wanted to fly on it. When I was here, I have had a committee I was running, and

everybody wanted to fly the simulator. You can set up different airports. I really don't know that much about it.

JOHNSON: You switched and you went to a different area, though, when NASA took over?

COLE: I went to structural dynamics, and that's a longer story than this. That's right up to today. It wasn't all at Ames. The other thing at Ames, we had a baseball team, we played football, we had a ski club. This area is so great for recreation, and I did a lot of skiing. I skied almost every weekend. Friday night, we'd drive up to Dodge Ridge, which is fairly close, here, about a 2 ½ -hour drive. Ski in a weekend, and come back Sunday night.

JOHNSON: There were a lot of activities that involved the families, too, I would assume, during the NACA time.

COLE: Yes, we had picnics, and of course, the individual branches, we had annual parties. With NACA, I was a bachelor, so actually, I did things like I toured Europe. My model airplanes, I was on the US team that flew the world champs in Germany, and so I went to Germany and then I toured Europe. I bought a Mercedes. Is this being recorded?

JOHNSON: Yes. It's okay.

COLE: Okay. There was one time at Ames where they were short of funds, so I said, "Okay, can I have six weeks' leave without pay?" They said sure. I spent six weeks touring Europe, and I

was writing articles on model airplanes for a German magazine. They showed me around and helped me buy a used Mercedes. I bought this Mercedes 190 for $1,600. It was a sedan, and it was a used car. It was two years old. They took me there. Alfried Gymnich was the editor of *Der Flugmodellbau*, and he took me to this place. The Germans are very precise about everything, and they have all these used cars, there. They call them pre-owned, now. I looked at this one and he had a price on it, I asked him, "What should I bid on it?" He didn't understand. I said, "In the U.S., we buy a car, we offer them a little less." He said, "How can you do that? That's what it's worth."

JOHNSON: There's no haggling, huh?

COLE: He said, "If you want another, I got another car."

JOHNSON: How did you get the car back here?

COLE: They just put it on a ship. There was a little seawater that got into mine. Wasn't too bad. They deliver them up in San Francisco, in a warehouse, and you show up and you have to get it started. You have to put the liquids in and everything. I had this little 190, and I still have it. Later on, when I got married, we went on our honeymoon in our Mercedes. I didn't get married until we were in NASA. My wife won't let me sell it—there are a lot of people that want to buy it. It's sitting in my front yard now, but I drive a [Toyota] Prius.

JOHNSON: A little more practical.

COLE: My kids learned to drive in this Mercedes 190. It's got a couple of hundred thousand miles on it.

JOHNSON: Yes, I can imagine by now.

COLE: We used to give talks, here.

JOHNSON: You mentioned that, that you did that.

COLE: I was giving a talk in the auditorium over here on a B-47, and in NACA, you prepared a talk and all these slides, and then you memorized it. You had to memorize it, and then we had all these rehearsals. Smith J. would be over there, listening to me, and Harry Goett, and of course, all your buddies and everybody. You would rehearse in front of them. I was giving this talk, and then you come in, when you're ready to give it at the conference, and here's this auditorium full of all scientists, most of them with foreign accents, which makes the question period rather difficult. I'm going through my talk, and I had it memorized. The trouble with memorizing is that you kind of go along and you're doing it by rote, and you're not thinking. I'm going along and this slide came up.

I introduced the slide and I was talking about introducing a slide. I had this slide that came up on the thing, and I looked up there, and it was the wrong slide. Then, I looked down at Harry Goett, our division chief, he was twitching in his chair. I looked over at DeFrance, and DeFrance was kind of wondering what I was going to do. Then, I realized what I had done—I

had skipped, in my talk, a little section, and I had introduced the slide following that one. I said, "Next slide," so then the right slide came up. It turned out to be a terrific deal because the first question that came up on my talk was what the slide that I had skipped.

JOHNSON: What is was about?

COLE: Yes, they asked about that, so it was slide number seven, as I remember. I said, "Could you put up slide number seven?" Then, I answered the question.

JOHNSON: You covered it.

COLE: You're up there and suddenly, fortunately, I got through that one. That's enough on the talks, I guess, but the talks I gave for IAS and so forth went very well. Those weren't as complicated. Some of the talks we gave, memorizing was difficult.

JOHNSON: I could imagine because it's very detailed information. A lot of technical information.

COLE: When you have a lot of slides, it's harder to memorize. Memorizing is not my good points.

JOHNSON: Did you ever work on anything here at Ames after it changed to NASA, and then the whole build-up for the space program? Did you work on any of that?

COLE: I forgot to tell you about that: the last thing we did, NASA was 1958, John [C.] Houbolt, I don't know if you've heard of him, John was one I knew well through the times. We had a lot of stuff together. He's the one who picked the way to land on the Moon. They were going to have one vehicle that landed on the Moon, and he talked them into making an orbit and dropping an orbiter down. Houbolt came out to Ames and Smith J., Smitty, asked me to go along with John. We went to all of the manufacturers in Los Angeles.

Did I mention Ed [Edwin P.] Hartman? The WOO office, Western Operations Office, was run by Ed Hartman. He's written a couple of history books that I couldn't find. They're around somewhere. We would go to Los Angeles, and it was a little office, and he would take us around. He would drive us around LA. He taught me how to drive in LA. It was scary, but Ed, he knew how to maneuver through all that stuff and he told me, "Never cut anybody off, they'll pull out a gun and shoot you." Ed Hartman would take us around the manufacturers.

John Houbolt and I went down there. The one I remember the most was Hughes Aircraft. The difference was NACA was going from an advisory committee to a space and aeronautics administration, so we were going to be letting contracts to all these manufacturers, so they weren't asking us questions. They were telling us what they could do. John and I went down there to Hughes Aircraft. I'd never seen so many Ph.D.s in my life. They had at least 20 Ph.D.s that showed up when we introduced all this, and then they had a luncheon for us.

I can't remember who the head of that was. It wasn't Howard Hughes; the name slips. Before we had our lunch, he said, "Our practice here is everybody to earn their lunch had to get up and tell us what their most pressing problem is." I can't remember what I said, but I remember, I had one.

JOHNSON: That was bothering you?

COLE: Everybody got up, and every Ph.D., they had all these things, they were ready to get all these contracts. I had one that was different than everybody else, but I'm sure they went back and figured out a way to do that.

JOHNSON: When you went around to all those different places, what were you looking for? What were you and John Houbolt looking for?

COLE: We wrote a report—and I don't know where it is; I couldn't find it—and we told what the manufacturers could do for us. NASA eventually did that. Everything was contracted out. Our machine shop, contracted out their stuff, our machinists began writing specs [specifications] and stuff like that. The model shop gradually faded away. To get anything done, you had to write specs and have somebody do it for you, and it delayed everything. That was a part of what was so good about NACA, was that we did everything in-house here. When I wanted a model or something, I would go over to the model shop and I'd talk to the guys who were doing it, and while they were building the thing, I would go over there and we would talk. If they had a problem, we would figure it out. It was real quick. You didn't have to write a bunch of specs and so forth. The people they had at the Center here were very, very good. A lot of that carried over into NASA. A lot of the same people were here. The model shop, for example, I had them building space vehicles. We can talk about it separate—that wouldn't be into this. That's a real long story.

JOHNSON: If you promised your wife you'd be home by 11:30, we probably don't have time to talk about it.

COLE: Yes. I pretty well wrapped it up. I can't think of anything.

JOHNSON: How long did you stay with NASA? When did you retire?

COLE: I left NASA in 1971. I was here 20 years. Under [President Richard M.] Nixon, NASA went through a restructuring. It turned out that we had a structural dynamics branch here, and Langley had a structural dynamics division, so to cut out duplication, they cut our branch. They offered me a job to do the B-1 bomber, but I had a hot project. I used to work with Headquarters, and they had the money for me to continue my work. I went to Nielsen Engineering [& Research, Inc.], and I got a contract from Ames to do what I was doing, continue my work. That worked out very well. I've written a book on what came out of that.

JOHNSON: You got to work on what you wanted to work on, but just as a contractor instead of a federal employee?

COLE: That was the thing, that many engineers would come here and talk to me, they'd say, "How do you get to do all this and finish and get a report and everything?" A lot of them would say, "I get started on a project and the finances drop out and they cut it off." Here, they just let

you go, as long as you had the ideas, and you could finish. It was up to you to decide it was time to quit.

JOHNSON: During the NACA times?

COLE: Yes. That's what I decided with Randomdec, which was a patent at NASA, and I went out and developed that. I'm still working on it—I wrote my book, and at 92 years old, I published my book [*Randomdec in Retrospect: Including new information on triggering*].

JOHNSON: That's amazing.

COLE: Yes. It's now on Amazon, and it's sold throughout Europe. I'm working on Volume II. That's a long story. I'll show you that when we're through with the—yes.

JOHNSON: Is there anything we haven't mentioned about NACA that you have there on your notes that you wanted to talk about?

COLE: The problem with this, I didn't get to rehearse it.

JOHNSON: It's fine. You've done great.

COLE: Last night, I started thinking about doing more on that, how I was working for NACA before I even got here. I was lucky to get a quick start that way. I probably left something out,

here. There were so many wonderful people I had, who I worked with. There are all the reports and scientific advances. Did I mention, one thing they told me—and I think it's in this *NACA and You*—have you seen that one?

JOHNSON: I haven't seen that.

COLE: One of them told me you can advance to the highest level as a research scientist as you can in administration. I was fortunate to stay entirely in research right until NASA was formed. When NASA was formed, I started being put on committees. That was another reason I changed, I wanted to continue my project.

Scott Crossfield, Neil Armstrong, they flew me around once. Neil Armstrong, he was the shyest, I never would guess he would go to the Moon. He was a test pilot at Edwards. Nice, very—I wouldn't say shy, but reserved. He didn't say anything without thinking about it. He was very good. Scott Crossfield, he was wild. We had some wild parties when we were back at Langley, but that's not part of this. I think I've pretty well got it.

JOHNSON: We appreciate you coming in today and talking to us about the NACA. This has really been great.

[End of interview]