NASA HEADQUARTERS ORAL HISTORY PROJECT
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EDMUND J. HABIB
INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is December 12th, 2018. This interview with Edmund Habib is being conducted for the NASA Headquarters Oral History Project. Mr. Habib is speaking with us by telephone today from Derwood, Maryland. The interviewer is Sandra Johnson. I really appreciate you talking to us today and taking the time out of your schedule. I know you had a busy day today.

The first thing I'd like to do is talk about your background and your education. When you were going to school in the mid to late '40s, the United States was in the middle of a war. I was just curious about your choice of electrical engineering at that time and where that interest came from.

HABIB: You have to go back a little bit, when I was much younger. I was the kind of kid that tinkered with everything. I'd get a toy, I'd take it all apart and find out how it would work and then put it back together. I'm that class of person. There are a lot of people like that and that's how they get started.

I went to Catholic school up until the ninth grade. I was born in Dover, New Hampshire, and then we lived in Lawrence, Massachusetts, but when I was about 10 we moved to New Bern, North Carolina, and that's where I really call home. At that point I went to Catholic school up until the ninth grade. I was good at mathematics. I was good at tinkering. I finished my last two years in New Bern High School, and that was right about when the war was going to end. I was 17 years old.

In those days the only news we had was whenever we went to a movie and there would be a 15-minute movie report on the screen. When I saw how the Army volunteers lived, which was very raw, often sleeping in what we called foxholes back then, I didn't want to do that. The Navy seemed like a very nice clean place, and I took an exam when I was still a senior and passed [indicating] that I could handle electronics school [Radio Technician Selection Test, "Eddy Test"]. This was in 1944. I signed up to join the U.S. Navy because they had the special program called Captain Eddy [Electronics Training Program named after William C. Eddy]. Radar had just been invented in that period, and they didn't have enough technicians to repair them, and they had a school system that lasted 10 months. Five days a week, eight hours a day you went to school, and you learned electronics. You learned all of the electronic equipment that the Navy used.

I succeeded in that. There were three places where we went. One was called boot camp, and a small three-week course to make sure that you could learn electronics. I passed that, and then spent three months in Monterey [California] with the beginner's type school, and the last 10 months in San Francisco [California] in a place called [Radio Material School-Treasure Island]. That's where I learned how radio receivers, transmitters, radars, LORAN [Long Range Navigation], and all of those things.

The war ended, and I was discharged in 1946 in July, I had spent 13 months altogether in the Navy. I missed one point. I graduated in 1944 and entered Catholic University [of America, Washington, DC] when I was still 17 years old, and finished my freshman year, and then entered the Navy. When I got out of the Navy then I went back and finished my degree, Bachelor of

Science in Electrical Engineering, at Catholic University. Electronics was the big thing at the end of the war, and I became pretty good at that.

But 1949 was a depression year, and I couldn't find a job for about nine months, and when I started searching again, I had come back to Washington [DC], bunked in with some friends, and looked for a job and wasn't doing very well until a friend of mine—a lady, she worked for the [American] Chemical Society—she said that there had been an opening at Naval Research Laboratory [NRL] here in Washington, DC.

I hopped a bus, went down and applied. The opening was for actually an advanced position. Back in those days when you worked for the government you were Government Service 5 or Government Service 7. I entered as a Government Service 7 at Naval Research Lab in an outfit called the Rocket Sonde Branch. The Rocket Sonde Branch was one of those that was part of the upper atmosphere research. It had been formed at the end of the war, and the Army at the end of the war captured about 150 of the German V2 rockets, brought them back to the United States, and started using them for research.

We would put experiments in the nose and take them out to New Mexico, White Sands Proving Ground, and launch them. That was the first time that man had exceeded the balloon. Man had never been much higher than 30 miles high, and the rockets could get us up to about 150 miles high. All the scientists who were capable—this was cosmic rays and atmospheric-type scientists—were happy to develop experiments, they were very simple ones. We would put them in the nose and take them out to New Mexico and launch them.

I was what we call today the payload manager. Integration would be a better word because I would assemble all those experiments and the power supply and the wiring. I was responsible for putting all that together. That was my first job then.

We kept doing this, and then in 1955 the Upper Atmosphere Research Panel and other scientists decided to study the whole Earth, and it was called the IGY, International Geophysical Year, which was going to run from 1958 for 18 months. NRL put in a bid to produce a satellite system, and so did Wernher von Braun, he wanted to do it also. There was a big contest at that time, and [Dwight D.] Eisenhower was President. The military was heavily involved in missile development, and he didn't want there to be a military sound to the experiments that were going to take place, what we finally called the Vanguard satellite.

NRL proposed a program of putting a satellite up, developing the rocket itself—and that was the first time a three-stage rocket was developed. It was based on a rocket called the Viking, and the Viking was built by [Glenn L. Martin Company (now Lockheed-Martin)] up here in Baltimore [Maryland]. Using the Viking rocket as the first stage, the Aerobee [rocket] as the second stage, and the solid propellant as the third stage. That was the first time three stages were put together.

We proposed the three stages. We proposed the experiments that would be put in from the Upper Atmosphere Research Panel. We proposed a way to capture the data and process it. Wernher von Braun basically wanted to just be the hero who put the first satellite up, so it was more of an emphasis for that. Also NRL is a civilian organization, it belongs to the Navy, and there are Navy officers that manage it, but that's about it. There was about 3,000 people, all in experimental, particularly experiments for the Navy.

We were selected in 1955 to put the satellite up, and we had a contest as to what to call it, and ended up calling it the Vanguard Program.

JOHNSON: According to your resume, you were working on the development of the elements for that radio interferometry satellite tracking system before the Vanguard Program.

HABIB: Yes. About 1952 everybody had got hot about the missile race. In those days the stability of guidance systems didn't exist, and so we looked at guiding the missile using a radio link. It's not a good idea because radio links can be jammed. But that was the only thing going at that time.

Plus, the Navy had a program on how to develop a gyroscope that would not drift. We branched off in 1952, and we had some experience with a thing called an interferometer. It's sort of a misname, because it's based on some real science that was done by [Albert A.] Michelson and [Edward W.] Morley. The interferometer itself is we measured the phase difference of a radio signal as it arrived at two different points. If you do that then you can calculate the angle of the arrival of the signal. That would be a satellite or a rocket passing over you, and as it passed over, the angle, what you use is two receiving points, and you measure the difference in arrival time at the two receiving points. That would give you the angle.

To jump to the result, we were developing that, and we had gone to White Sands Proving Ground. We had two rockets with us that day, two Viking rockets. We put a 10,000-megahertz transmitter in it. What we were experimenting was as the signal left the satellite would it be interfered with by the flame of the rocket.

That was our big experiment, and we had two chances at it. At White Sands Proving Ground you have a launch site and then you have three miles away what we call a control site. We developed a single two-point interferometer as the basis to get experimental information on the flame interference. The first one that we launched, we were three miles away, and the angle of the signal coming from the rocket was not interrupted by flame whatsoever.

When we loaded up the second rocket, we put the receiving site almost underneath the rocket. It was like 100 feet away from the launch point. Then we launched that one, and again we didn't see any interference of the signal by the flame. At that time I was a pretty good mathematician back then, and I had the job of calculating the exact angle of the radio signal to the receiving site. That involved a lot of conversions of data from the angle that's on the rocket, the movement of the rocket, and where it is with respect to you, and finally with respect to the two antennas.

That was a big experiment. I think you may have referred to that. That was about 1952, '53. About '54 people began to think about satellites, and then the IGY, International Geophysical Year, asked for proposals. NRL put in a proposal to put a satellite up, Wernher von Braun put in a proposal, and the Russians put in a proposal—I don't know any other countries that did—that they would put a satellite up.

We were chosen by Eisenhower to be the people doing that. We used this interferometer experience to build a system called Minitrack. Maybe that's what you've been reading.

JOHNSON: Yes.

HABIB: The Minitrack—I'm going to get precise—two antennas that are 500 feet apart in the north-south direction and another pair in the east-west direction. At a frequency of 108 megacycles, which was the only frequency that we could get assigned at that moment, that's the top of the FM band. Remember your FM goes from 88 to 108. The exact frequency 108 was assigned to us. The wavelength of that frequency is about 10 feet.

I don't want to get too technical there, but by measuring the arrival time and the sine wave—actually the signal is a sine wave, and the angle of the sine wave are called phase. We measured the phase difference of the arrival of the signal at the pairs of antennas, north-south, east-west. I was part of the development of that.

One of the things that I like to brag about is I built the first digital clock. It was the size of a refrigerator. In those days the Bureau of Standards was the timekeeper for the whole United States and half of the world. They transmitted it on a set of frequencies over at 5 megacycles and 10 and 15 megacycles. People all over the world could receive that signal, and they could synchronize clocks. London does the same thing, and they really were the first ones to be the time clock of the world.

There's a method that was generated during the war for airplanes to guide themselves using a radio signal and that was called LORAN. What you did was you put three transmitters hundreds of miles apart in a triangle manner, and as the airplanes fly over the U.S., they would receive these signals. One would be east-west, one would be north-south sort of. They had charts, and from the arrival time difference—that's why you needed clocks, the clocks put out time ticks electronically. By measuring the difference in time of arrival of a tick, a particular tick of the clock, you could figure out where you are in airspace. So the first tracking method was called LORAN. But in order to do all that, they had to develop a clock that was synchronized to the Bureau of Standards, and all of them were synchronized to the same time.

The oscillators that they used for that were 100,000 cycles per second, a crystal oscillating at that frequency. It was very, very stable. Double-walled ovens, and buried in the ground sometimes. The Bureau of Standards used those same things for telling time for us. The accuracy of time back then was about 1 part in 10 to the 8^{th}. I can digress a little bit. The people who set that time actually was the Navy observation site [U.S. Naval Observatory].on [Massachusetts] Avenue here in Washington, DC. They would measure the moment that a star crossed a telescope. It would be a telescope just pointed straight vertically, and when a particular star passed over the crosshairs, they would start a clock. Then 24 hours later they would stop the clock. What they were measuring was the rotation of the Earth, and the Earth became the standard reference for timekeeping. Its rotation was almost nonchangeable.

The Bureau of Standards broadcast time as an audible time tick. Your accuracy there was maybe a thousandth of a second. Digital had just begun. By the way, all of this was being done with vacuum tubes. I was given the job to build the clock for the Vanguard system, so I claim the first digital clock. It put out a stream of bits, which I called a serial decimal time code. It would put out a tick every second and a subsequent tick tick every tenth of a second.

If you counted the number of ticks in the subsequent ones, you got the time of day. Also by doing that, the only recording method we had back then was strip charts. You're familiar with EKGs [electrocardiogram]. We had an eight-channel strip chart, and we used that serial decimal time code on the base to tell time of when an event happened. That's how timekeeping started. Later on as digital bits got created, we changed it to a digital output. Someone else did that, one of my associates, but we were the timekeeping people.

The Minitrack system was developed, and I was also busy with some of that stuff making electronics. I'm going forward, and then I'll go backwards. We put those Minitrack stations in 12 different places. Most of them were on the 75th meridian. There was one here in Blossom Point, Maryland, just 35 miles from Washington, DC. There was one in Cuba, and it was before

[Fidel] Castro had taken over Cuba. It was in the airport there. There was one in Quito, Ecuador, and one in Lima, Peru, one in Antofagasta, Chile, one in Santiago, Chile. If you look at a map, that's almost a straight line that cuts through the Earth vertically.

Since the satellites were being launched from Cape Canaveral, the highest latitude that they ever would come to was where they were launched from. That's 28 degrees. As the satellite goes around the Earth in an orbit, it is detached from the Earth. It stays in that one circle, and the Earth rotates underneath it. Once every revolution of the satellite one of these stations would record the passage.

The other part is we needed to calibrate the station to know that it was highly accurate. I was given the job to develop the calibration system. We got some cameras that were used during World War II, I got a dozen of them. We put them in a tube that you could rotate in the opposite direction of the Earth, and therefore they would be in effect standing still with respect to the stars.

The pictures were recorded on a glass plate film. This was my project. This digital clock transmitted to an airplane that was simulating a satellite. It was a fighter plane, using propeller type fighter. On the bottom of it we put an antenna that was printed on a board that was 3 feet by 3 feet, so it was a printed circuit on a board. That would transmit the same signal that a satellite would. At the same time we put a flashing light in the center and transmitted the serial decimal time code, the tick tick ticks, to the airplane. It controlled the flashes of the light. Each flash of the light appeared as a new star on the film. So by using star catalogs, which are super accurate, I could locate the position of the airplane to the accuracy of the lightbulb at five miles away. The airplane would simulate a satellite, and it would fly over the station in patterns, and these would be recorded on the film plates.

We gave a contract to New Mexico College [now State University, Las Cruces] to process this. We used super accurate measuring engines that would measure the position of the stars and then the position of the flashes of light. Relating them to where the stars are, we could figure out where the airplane was, and also where the radio signal was coming from.

It's a very sophisticated system, and this was used worldwide.

JOHNSON: Was this was something that was being developed specifically for the Vanguard Project that you were working on?

HABIB: The Vanguard Project only. Yes. One of the best astronomers, Paul Herget, who guided me, because I was not an astronomer, but I became an amateur one, he had given us the idea of tracking.

There was a similar interferometer system at the Cape [Canaveral, Florida] called [AZUSA]. But it was at a much higher frequency, 5,000. It was the basis of accuracy of when you launched from the Cape out over the ocean. It would track the rocket. This was being used by the development of the rocket people. We didn't copy it so much as I think we worked with those people.

JOHNSON: Yes. I was reading about that. Also the work with the Viking [spacecraft], the difference between putting something on a rocket and then putting it on a satellite, that's a lot of difference in weight. That was one of the drivers as far as developing this system, the Minitrack?

HABIB: Yes. The first Vanguard, I think the heaviest, it was a sphere, and it was about 20 pounds. We were in the beginning of the space system, and everything was new. We didn't have the force that they have today in launching. You can launch tons now. That always amazes me by the way. Have you heard of the Space Surveillance System?

JOHNSON: I've heard of it, yes.

HABIB: This is a military system which is an outgrowth of the interferometer for the Minitrack. One of our guys, Roger [L.] Easton, kind of a brilliant person and an associate, he came up with the idea, "Heck, if we can track a satellite that's transmitting a signal, why can't we track an uncooperating satellite"—which was Russians back then—"by transmitting the signal from the ground and bouncing it off the object and using the Minitrack idea to figure out where it is?"

We did this while I was still at NRL before NASA was formed. We put stations starting at Fort Stewart, Georgia—there was a tracking station in Fort Stewart also—we drew a line across the U.S. that is called a great circle line, and put stations on that line from Fort Stewart to Brown Field in San Diego.

We alternated with a receiving station, a very high-powered 50,000-watt transmitter with an antenna that was 400 feet long. That was the transmitting antenna. Then another receiving on the other side. We did this in a series all the way to San Diego. That's now called the Space Surveillance System. First the Navy ran it, and they used the computer systems in Dahlgren, Virginia, to process the data. We would track any object that came across that line. The sensitivity was a door handle at 1,000 miles high.

That was called the Space Surveillance System, and you might want to look that up. Later it was transferred to the Air Force, and the Air Force was the keeper of all the unknown objects and used that system up until very recently. They're building a substitute method right now.

The antenna at one of the sites had 10 of these 50,000-watt transmitters and was 1,000 feet long. It was huge. If a bird flew over it would fry the bird. That transmitted straight up in the air. Any object in orbit. That system is what's used to measure all this junk that we have in orbit. You can track that from Vanguard. That evolved, how to measure where all of the junk is in orbit.

JOHNSON: Yes. That's what I was noticing as I was reading. So much evolved from that first work that you were involved in from NRL and developing these tracking systems. One thing I was reading is that at first they were looking at an optical tracking system.

HABIB: Yes.

JOHNSON: Were you involved in that at all?

HABIB: That was run by someone up at Harvard [University, Cambridge, Massachusetts]. He had convinced them that the only way you could measure accurately the position of a satellite was with an optical system. I have a small story with that.

The optical system had an accuracy of 20 seconds of arc. Things are measured in degrees, 360 degrees, that's divided by 60 into what we call minutes of arc, and then a minute is divided in 60 again and we call those seconds of arc. The accuracy of an optical system, we're using a 20-inch lens. The lens was 20 inches in diameter. The Harvard people proposed to build 10 of them and scatter them around the world. They would be the final accurate system.

In 1958 I was in Johannesburg [South Africa]. Because I was in charge of calibration, I turned on the stations as they came on board. I was in Johannesburg and that was the last station. We had just finally launched a Vanguard satellite. One of those cameras was there and there was two astronomers running that camera system.

We had a big opening thing going on with high-powered people coming to see how things worked. First they went to the optical system. The optical system can only see a reflection of the Sun off of the satellite. You can only operate it during the evening and the early morning. I'm going to come up with his name.

JOHNSON: Was it [Fred L.] Whipple?

HABIB: Whipple. Right. That's it. He had convinced the astronomers that the Minitrack system was good enough to tell the watchers. In order to point the 20-inch camera, they had volunteers who had small telescopes, each at a different angle. When they spotted the reflection off a satellite they would yell, "I got it," and they would quickly turn the camera and point it in that direction.

He had convinced his astronomers that Minitrack would tell where the volunteers could point their telescopes and they would point the thing. We had this opening ceremony, and the astronomers gave their piece. Then they came down to my station just outside of Johannesburg. We had a satellite passing over just at that moment. I explained that we had a graph, like an

EKG, and each time the satellite moved 1 degree the phase difference would change from 0 to 360 degrees. Then the thing would pop down, because 360 and 0 are the same point. It would pop down, and you'd do another track. We call that a sawtooth display.

I explained to all the people that one sawtooth was the equivalent motion of the satellite of 1 degree. We digitized the phase to 1 part per 1,000. We were actually 10 times more accurate than the camera with the radio system.

JOHNSON: That's quite a difference.

HABIB: Those two astronomers, him and his wife, they quit and they joined Goddard Space Flight Center. That's my story on that. We were very accurate with the Minitrack system.

We had several failures. The final one that went up there was an orbit where the perigee was at 400 miles and the apogee was about 2,000 miles. Since it was a small grapefruit size ball there was hardly any drag on it. The prediction is that it will be several thousand years before that thing falls down. It's still up there.

The Minitrack system, because it was developed in vacuum tubes, they kept using it for about 10 or 15 years, almost 20 years, and then it's now been destroyed. We don't use it any longer. We have better methods now.

JOHNSON: Let's go back and just talk about the team that you were working with at the time. Maybe who you were working under and how many people you were working with. You mentioned that you were working with an astronomer that helped you understand how to do the calibration or helped you with that. But just some of the information about your team that you were working with in that early time.

HABIB: I worked under Buck Schroeder. It's actually Clarence [A.] Schroeder. He's the one that put me in for that award in 1970 which I sent to you [AIAA Aerospace Communication Award]. Jack [John T.] Mengel was the head of our group when it started. Homer [E.] Newell who eventually became the top scientist of NASA was our branch head.

The branch had technology people that was under Jack Mengel and scientists. I had written it down on a paper, some of their names. They've been coming back. But there was a cosmic ray scientist and an atmospheric scientist. We were a group initially, must be about 50 people originally. The branch that I had, eventually I had 30 people. Because we used an airplane to simulate a satellite, we actually had our own little airplane force. We used airplanes. When we calibrated in Australia they provided an airplane. When we calibrated in Santiago the ministry there would provide an airplane.

I have one other nice story. When star catalogs are being developed, the astronomers take pictures of the stars and they watch the very minute movement. They stars are so well measured now that it's the ultimate accuracy. It's fractions of a second of arc. They publish their books on that.

The problem is they can only see the stars that are below their telescopes. You have different groups in the world developing star catalogs. Since we were the first group that did this all over the world—we did them in Australia, we did them in London, England, and we did them on that line that I mentioned to you—we needed start catalogs. One of the guys who worked for me, he assembled the star catalog by writing to the different astronomers and getting their copy of their star catalog. In the end at NRL we put the first universe catalog together. It was about 10 inches high of paper.

Those were the days that IBM [computers] used only punch cards. At summertime I would hire students. First when NASA was formed, we got a bundle of money, and I gave some to the Naval Observatory on Massachusetts Avenue, and had them convert this 10 inches of catalog into punch cards.

Stars are measured in terms of magnitude, and the catalogs at that time were limited to about 9th magnitude. We can't see that with our eyesight, we barely can see a 5th magnitude. There were 300,000 stars. They converted the catalog into 300,000 punch cards. They had to punch them three times to make sure they made no error. That became the first, in effect, punch card digital catalog of the stars.

Then there was no tape-recording in those days, so at one point that catalog, those punch cards, I made four copies of punch cards during the summer using the students. Picture punching 300,000 cards four times. I gave one back to Paul Herget. He was the astronomer at [University of] Cincinnati [Ohio]. Then at some point the punch cards were converted into magnetic tape and that tape was given to the Library of Congress [Washington, DC] and that was the beginning. People could now get a universe star catalog. That was one of the products of the program.

JOHNSON: Probably not something that people would normally think of coming from the Vanguard Project.

HABIB: Right.

JOHNSON: That's interesting, and I appreciate you adding that.

HABIB: We had maybe 150 people in the whole Vanguard Project. No. It had to be more than that. It was maybe 50 or more down at the Cape. So we had a group at the Cape, and the group up here at NRL, which later got kicked out of NRL. Once we became NASA they couldn't house us anymore and so we built our own—first we went into some barracks building. Do you know where the Nationals baseball team plays?

JOHNSON: The Nationals? Yes.

HABIB: Yes. Where that was was some barracks that were used during World War II, and we moved into those barracks for about a year while we built Goddard. The barracks are gone and there's a ball field there.

I had written some notes just before. Calibration system, astrographic star method, and the Space Surveillance System was an outgrowth of that. Then at some point, and it's not clear, I developed something called the range and range rate system. Called the GRARR, Goddard Range and Range Rate. I wanted to use that system, it's super accurate, when we were doing going to the Moon. JPL [Jet Propulsion Laboratory, Pasadena, California] had developed a competing system called pseudo-random ranging [range tracking system]. Are you familiar with that?

JOHNSON: Yes. I've read about that.

HABIB: Okay. Harry [J.] Goett was head of Goddard Space Flight Center. He and I would go down to Headquarters and make a presentation to the fellow in charge. He'd come and propose the pseudo-random system.

The pseudo-random system is a wideband system, so that means you have to deal with the filtering problem, whereas the range and range rate, the bandwidth was one cycle, one hertz, so there's no noise to deal with. We tried to convince them that that should be used on the Apollo. But the fellow in charge, I won't use his name, he said at one point that he didn't want to choose Goddard. He chose JPL's method.

When they installed the system in the Apollo, as I was told, the pseudo-random was supposed to be so low a signal you wouldn't be bothered with it, but it was very bothered every time they tried to use voice. So we ran the whole Apollo Program alternating between tracking and voicing. Where if they had adopted mine, they're two separate systems and they would not interfere with each other.

Eventually now we're Goddard, and we flew the first—help me with the word.

JOHNSON: Geosynchronous?

HABIB: Geosynchronous, yes. But the satellite itself was called [Syncom]. Al [Alton E.] Jones and I were roommates. There were five of us who rented a house. After Goddard was formed, we decided to get into the communications system. There were two competing systems. One was called low altitude and one was called synchronous orbit. Al Jones was in charge of the synchronous one and someone else was in charge of the low orbit.

The trouble with the low orbit for a communications system is you would have to have at least three gigantic antennas at every station that was going to—this is for telephone and video, television communication I'm talking about. It would take a lot of antennas at low orbit, and the satellite would be zooming across the sky, so you would only see it for about 10 or 15 minutes. Every 10 or 15 minutes you had to be switching antennas. When one was disappearing you'd get the next one coming up.

We proposed that with the sync orbit, we could figure out where the satellite is in a very exact manner, and then the sync orbit would be the way to go. Al Jones was in charge and I went to Al and I said, "Listen, Al, if you let me use the Goddard Range and Range Rate, I don't put any electronics, I will just use the same transmitter that you're using for the TV, and put the signal through it, and we can figure out where the satellite is."

The first sync orbit blew up. The second one was found so accurately, and the fact that we could keep it in that sync position, that they dropped the relay satellite. The second relay satellite, which was going to be experimental, is now hanging in the Smithsonian [Institution, National Air and Space Museum]. This is the birth of sync orbit.

The development of the Goddard Range and Range Rate and the sync orbit were hand in hand. I can't swear to this, but I believe every satellite that's up in sync orbit uses my method. It's called sidetone ranging.

JOHNSON: Do you mind for a minute if we go back to Vanguard? I just had some other questions about what was going on at that time. One of them was about the schedule, because this was something that was being attempted for the Geophysical Year. There was this element of trying to get things done quickly. Was there a lot of pressure on you or the groups that you were working with to get things up and running quickly?

HABIB: We made a schedule. That schedule was what you tried to keep up with. But no, as I understand it, we did everything, designed the three-stage rocket, the interferometer system, the tracking method, and the accumulation of the data that the satellites transmitted all in about three years with about $130 million. That's one thing that came out of it.

We were sort of in a race. They were in a race, I didn't know it, but we were in a race with Russia.

JOHNSON: That's what I was going to ask you about. How aware were you or the people that you were working with that this was a race even though it wasn't advertised that way?

HABIB: There may have been people who were accessed to the CIA [Central Intelligence Agency] data of where the Russians stood. So the upper bosses knew it, but I did not know we were in a race.

JOHNSON: Were you aware that the Russians were working on a satellite at all?

HABIB: We were so occupied with what we were doing. We loved the job. I used to say, "They pay me too!" We worked night and day to get things done on time and it was a burden probably on our families. But we loved doing it. Everyone was gung ho on the thing, because it was the first time anyone ever attempted these things.

Wernher von Braun, he was chagrined. He wanted to be the first guy to put a satellite up, and he built the rocket system that they finally used, and it's sort of a secret. He was ready to go. What he did was he assembled—the V2 became—we gave it a different name and a little stronger rocket engine. The Jet Propulsion Laboratory, the name means that. They were doing design work for the military in propulsion. They had built a batch of these rockets that were like 10 inches in diameter and 10 feet long.

We would meet them every time we went to White Sands because they were testing them. If you look at the photographs, Wernher von Braun, who put the first U.S. satellite up after the Russians did theirs, he strapped 10 of these 10-foot guys together and that became the second stage. Then used three more for the third stage, and then one more which held the satellite, was in orbit. He launched that. He had not proposed, as I understand it, a good science program, and NRL was chosen because it had this Rocket Sonde group with all these super scientists there.

The Van Allen belt was sort of an accident finding. We actually—not myself but another group at NRL—they built the electronics that was going to go in the Vanguard satellite, and one of those was the cosmic ray detector. When the Russians put up their satellite, and [James A.] Van Allen was from Iowa, he came and asked for the equipment, the electronics that were going to go in the Vanguard satellite, and moved them to Wernher von Braun. In effect we at NRL had built that equipment for him. He did the detector.

That flew on the first U.S. satellite, which was Wernher von Braun's rocket.

JOHNSON: The Explorer 1 satellite.

HABIB: Yes, and then we collected the data, and when they were processing the data, the story that I heard was there were no changes in the signal, which would tell them the telemetry, how intense things were. One story was a technician mentioned to Van Allen that when he brought the test radiator too close he got the same effect, and all of a sudden the light lit and they said, "My God, the detector was saturated." That's how the Van Allen belt was discovered.

JOHNSON: During that time you were working on this tracking system, I was reading that the TV-0 test of the Vanguard was the first time you were able to test that Minitrack transmitter.

HABIB: We had a lot of flights with airplanes.

JOHNSON: Yes, right. But this was the first time actually on a launch. Is that correct?

HABIB: Yes. We had two stations downrange from the Cape, Grand Turk [Turks and Caicos Islands] and Antigua [Guatemala]. I went to Antigua to turn that station on. But we didn't have good communications. Back then it was teletype. We had one launch that I went down to the Cape to help out on the tracking of it, and Milt [Milton W.] Rosen, that's the name I was trying to remember, he was head of the rocket business. The calculator had—have you ever played mumblety-peg?

JOHNSON: Yes, I know what you're talking about.

HABIB: Okay. The first computer was a mumblety-peg program. What you did was you put pegs in holes for what command you wanted and more pegs for where the memory would be, where it would be stored. We had that computer down at the Cape. When we did one test launch, I got a voice connection to the guys out at Antigua and they read me back some numbers, and I put them together. Then I tried to compute it, and I came up with no, it didn't make orbit. It was one of our first attempts.

It appeared to me that the rocket was moving at about a 60-degree angle going straight up. Later the company in Baltimore [The Martin Company], they analyzed, and they discovered that a pinhole had occurred in the wall of the rocket engine, and so some of the spray was coming out sideways. That tipped the rocket up to the 60-degree angle. That sawtooth form, I became kind of a magic act guy. I knew what the sawtooth should look like if the thing was moving horizontally over Antigua, and it wasn't. It was moving in a slower manner, so I said it had to be going vertical. Those are some of the things that you can get out of that Minitrack system.

Going back to the people. There was Buck Schroeder. He was head of one group and I was in that group. He developed the clock and the tracking method. There was another group that was the RF [radio frequency] group, and that was Roger Easton. That's an important name, because Roger Easton eventually developed GPS [Global Positioning System]. He got the Presidential Medal [National Medal of Technology] for that.

I gave him the idea in a way. I told him that it would be much easier if we could put the clock in satellites and synchronize them. The Goddard range and all the other methods required a response from a satellite. You transmitted a signal to it and it turned it around and repeated it back to you. So from that you got twice the number for how far away it is. That's how most things worked. But if I could put an accurate clock in the satellite it would be synchronized timewise with the ground stations. So you could measure how long it took for a signal to come from a satellite to the ground. That's how GPS works.

Roger Easton stayed at NRL, he never joined Goddard, and I joined Goddard. We were very close friends. He spent 10 years developing the clock, turned out to be atomic clock, in satellites, and how stable they were and could you synchronize, and then will they be all synchronized together, and all that. He developed that concept.

JOHNSON: When Sputnik [Russian satellite] flew was that the first awareness that you had that the Russians were working on that?

HABIB: Me personally at my level. I think all my associates too, because I'd never heard anyone talking about them.

JOHNSON: From what I read, they were in meetings for the International Geophysical Year and one of the Russians, Sergei Poloskov, had actually done a presentation and indicated that they were getting close and while the meeting was still going on I think the next day they actually flew.

HABIB: I can tell you about that.

JOHNSON: Yes. If you have any stories about that time, because it's pretty interesting because of everything that was going on. You had mentioned that 108 frequency. Of course Sputnik was much lower frequencies.

HABIB: Yes. Let me talk about that. Our calibration system was a camera that was exactly at the intersection of the east-west and north-south line. The actual rotation of the camera was designed so that—the one that was going to take pictures of the stars.

There was a Physical Society meeting taking place in George Washington University. Lisner Hall. Someone had arranged for the top scientist. One of them was Brognarov. We were giving them a tour of the whole station down here at Blossom Point about 35 miles south of here. My turn came up. The camera was inside of a hut with a sliding roof. You'd slide the roof backwards and that would expose the camera.

I was giving my talk as to what the calibration system does to these guys, and they understood. Two Russians. I've got a photo of that; two Russians and one Iranian. So I give them this thing, and the photographer from NRL was standing on the roof and he says, "Hey, Ed, point up." So I stuck my finger up and pointed up, and everybody looked up basically at the camera guy, but he snapped that picture. That picture later showed up on the cover of a *Sputnik* magazine. I have it. I can't find it anymore, but I have it somewhere.

The way I got the magazine is when I was giving that demonstration in Johannesburg the astronomer, who was not part of Vanguard or Harvard, he says, "You know, you look familiar." The next day he came back with this magazine, apparently he had access to the Russian magazine, and the name of the magazine was called *Sputnik*, and there was our picture right there looking up at this guy.

So that was the first time—I had no hint—the very next day they launched Sputnik. After we gave them the tour, and then the next day. Those people knew there was going to be a launch. That's when Sputnik was launched, it was the following day of that big Physical Society meeting. Does that clarify what you wanted?

JOHNSON: Yes. Because it was interesting to me when I was reading about it because the person Poloskov that was talking basically told them I believe, "Maybe you can help us track it," or something like that. It was kind of an offhanded comment.

HABIB: They laughed at us. But they came up on two frequencies, 20 megahertz and 40 megahertz. Now those two are related. On the 50th anniversary of Sputnik, there was a big to-do here in Washington, DC. I paid 50 bucks to go to an affair at the Russian embassy after it. One of the reporters there sort of clarified something.

Each one of them was going beep, beep, beep, beep. You heard that. Why did it go beep, beep? We never—but I think I know why. They probably had one battery in it, and they switched the battery back and forth between the two transmitters. The other stories he told were when they launched the second one with the dog in it, who was the premier of Russia, [Nikita Khrushchev], he had not paid any attention till suddenly he realized my God, the whole world is jumping up and down, we really did something important, get those guys back up here. So he gets his chief guy of rocketry and he says, "Go put another one up." They got another one ready. He said, "What are you putting up? Put a dog in."

"Where do I get a dog?"

"Right down here in the street. Just grab one." That's the conversation that was related by these reporters during that 50th anniversary.

I think we were very puzzled as to why are they switching. Now we worked on the 40 megahertz, and here comes Roger Easton again. He's a genius. We built some new antennas at the shops at NRL. Did that overnight. We took those antennas and put them on the same pads that the 108-megacycle antenna was on. Now we could receive the 40-megacycle signal. Then he built a converter that would convert the 40 to 108 and we fed it into the Minitrack system, so in a matter of a week or so we were tracking that satellite at 40 megahertz.

JOHNSON: I can't remember who said it, but somebody said it was the wettest dry run in history. I thought that was interesting.

HABIB: That would be Roger Easton. He has that kind of humor.

JOHNSON: It's just interesting that you were able to try everything out and find out that it was working the way it was supposed to by using a Russian satellite.

HABIB: Yes. But the problem we had was calibrating it. It was 40 megahertz. I got a 40-megahertz transmitter, I got the Air Force to lend me a helicopter, and I added voice communication to them, and I tried to make them stop at 5,000 feet altitude and try to come at the very point where the cross occurred. This was kind of stupid of me at the time, but I kept trying to guide the helicopter to this cross where the two met, and then I would yell, "Zero," and they would put a mark on the recordings, the sawtooth recording. That would be the calibration method.

I did this and I kept trying to. We did this several days, and then one day I looked in the spotting scope and the airplane was this size and then I turned around to speak to somebody and came back, he was double that size. That meant he had suddenly dropped from 5,000 feet to 2,500 feet. I called to the pilot and I said, "Are you in control of the helicopter?"

He says, "I've never been out of control of a helicopter in my life like this."

He did one gigantic circle and ended up landing on a farm. He avoided a crash, and he did something they're never supposed to do. He revved up the engine to beyond the red line on the propellers. You usually would break propellers or ruin the engine when that happened. But he did that at the last second so that when he hit the ground it wasn't too hard, and he was about five miles away in a farm.

That scared the hell out of me because I almost killed some people. After that what I did, I says, "Okay. Just drive straight." They got what I called the banana helicopter that had propellers at both ends. They switched to that kind of helicopter and then it would just stand straight across. Through my spotting scope, when I saw they were in the middle, I would hit a mark. So, yes, we were tracking them, and I was very involved in it.

JOHNSON: I also read that they were using ham operators [amateur radio operators]. This was international across the globe.

HABIB: Paul Herget was an astronomer. IBM had offered—this is how they got the contract—IBM had offered to compute the orbit of the Vanguard satellite. It was the first time that a big, gigantic computer was put in use. It was called the 704. They built a building on Pennsylvania Avenue at 6th Street. Have you been to Washington often enough?

JOHNSON: Yes.

HABIB: Okay. So at 6th Street. They called it the Vanguard Computing Center. They had about 60 people writing the software. Astronomers were the only ones who knew the mathematics of orbit. But their orbits were thousands of years for one orbit. Suddenly our orbit took 90 minutes. Suddenly the math has a different problem. Things change rapidly.

He was in charge of that, and we were still writing that software, when Sputnik went up. Then all the amateurs around the world started sending in telegrams, which came in to the back room of that Vanguard Computing Center. Paul and I would sit there, and we'd plot it on a Mercator projection. He was smart enough that when he saw this little sine wave on a big chart he could estimate what the orbital elements were. He would put it out the front door. He would give it to the reporters—to our reporters—and they would put it out that the Vanguard Computing Center had just computed the orbits of the Russian satellite.

We hadn't. The software wasn't ready and we were in the back room, Paul and I. He's estimating. He's using all that information from the amateurs and putting a plot on the—because they were all around the world, he could get a good plot—plot that sine wave, and then give an estimate of what the orbital elements were. That's what you were reading.

JOHNSON: The use of the ham operators and the amateurs. I'm sure it was exciting for them too.

HABIB: Oh yes. We started funding some of them. Those were great times. I'm glad you're talking to me. I was in the thick of things there.

JOHNSON: You were, and like you said, you all were busy working hard on what you were trying to accomplish, and you weren't necessarily paying attention to what was going on outside of that, and then Sputnik kind of changed everything. It's been described working on the Vanguard Project after Sputnik was a little like working in a goldfish bowl because all the attention was on the Vanguard Project in the hopes that you would salvage that American pride that we lost when the Russians beat us to space.

HABIB: I was slated to give a talk at the [Cosmos Club]. It's a club in Washington, DC. This club where famous people can go and sleep overnight. They had an auditorium, and I had been scheduled to give a talk. Honest me, I started out, and I said, "Well, I guess we goofed, we didn't know that they were ready to launch," or something like that.

The only thing that a reporter got out of it was I guess we goofed. That's the word he used in the *Washington Post* the next day. There was a society back then called the [American] Rocket Society and I belonged to it. It's now called AIAA [American Institute of Aeronautics and Astronautics]. But those were heady days. We just kept going.

What Roger Easton also did was when we were developing the three-stage rocket—and we first tested the first stage live and dummy second and third, and then we went to live second and live first and dummy third. These were called TV, test vehicles, TV. When we got to the three-stage, he says, "You might succeed."

We had a lot of instrumentation and very little weight left over, so he built this what I called a grapefruit satellite, a small satellite, and just put a 108-megacycle transmitter in it. He had that ball ready. "When you guys go with the third let's put this in, you might put it in orbit."

People at Fort Monmouth [New Jersey] had just been playing around with solar cells, and one of the guys came down to NRL and says, "How would you guys like to have some solar cells?" Heck, yes. Those cells were then plastered on the outside of the little ball. He put a second transmitter in there and says, "This is scientific. The frequency will change with temperature. The outside, that'll tell me the temperature on the wall, as well as the other one would tell me the temperature inside." That was our first Vanguard, and that's the one that's still flying. The little grapefruit.

The big fiasco we had was we were ready to go with the three-stage and something happened at the engine. It exploded. You probably have seen the video of it.

JOHNSON: Yes. I was going to ask you about that failure coming after the Russians and their successes.

HABIB: Yes. I'm not sure whether that was going to be before or not.

JOHNSON: TV-3? Is that the one you're talking about? The Vanguard?

HABIB: Blew up.

JOHNSON: Yes. That's the one that came after Sputnik. Yes.

HABIB: We rushed it out. It tips over and the nose cone pops open and out rolls the grapefruit satellite. Roger Easton's buddy, he has since passed away too, he ran out and grabbed the ball and took it home. It was still beeping. That satellite is the one hanging in the Smithsonian.

We went on the 50th anniversary—he finally gave it to the Smithsonian and they put it in a storage place. Then they wanted to find out if the thing would still run. We all had a little meeting upstairs in the Smithsonian, I'd never been up there. They very carefully with gloves and everything else opened the thing up. Sure enough, the batteries were still in there, there was no corrosion or anything. These were NiCad batteries. It was interesting, 50 years without corrosion.

I got another one for you. In my resume you see I spent some time on a project called Rimsat, [Ltd]. It means Pacific Rim. A private company formed by some guys in Indiana. I was the chief engineer on that one. We were having meetings in Krasnoyarsk [Krai, Russia]. It was about a four-hour flight from Moscow. We were buying satellites from Russia. Rimsat. They were Russian satellites called Gorizont. It's in my resume when you read it.

We were having sort of a get-together dinner, and each one was asked to stand up and tell a story. When it was my turn, it had to be translated. There were a lot of Russian engineers in there. I told a story of when I was doing the demonstration when the rooftop was rolled back and the guy took that photograph. One of our people said he was watching the faces of the Russians, and tears came to their eyes. So I related that story of taking a picture, and my picture appeared on the first page of *Sputnik*. I think that was the first issue too.

JOHNSON: Once Sputnik flew and then there was a lot of—

HABIB: Before we got started.

JOHNSON: Yes, but there was a lot of finger-pointing politically. All this going on obviously a long way from your work. Then there was the idea that they were going to create NASA and the civil program. Did you have any idea?

HABIB: I didn't hear that. We just kept plodding along until we finally put—you know when we launched ours? On Saint Patrick's Day. That's because the head of the Vanguard Program was Irish. [John P.] Hagen.

JOHNSON: It's interesting because I hear this a lot from especially the guys that worked on those early programs like Apollo. What you were talking about, you had your head down, you-all were doing your work, you weren't necessarily aware of everything that was going on around you. But did you have any idea at the time, working on Vanguard that this was going to open up spaceflight? Do you remember having thoughts about what was the future beyond Vanguard?

HABIB: Not me. I was still young. I was in my early 30s. I was just so busy creating. That was very satisfactory for me as an engineer. My mind just clicked on a lot of things. I'll give you one other one that I should say.

After the first ball went up then we began to get better and people began paying attention that with a bigger rocket you can put bigger experiments in, and the march started there. We collected data from all these satellites. We had 100,000 reels of tape unprocessed, and this takes you back to how raw we were. One of the guys who used to work for me, he went and bought—and the telemetry system was very raw. It was designed by another group at NRL. When you have telemetry, you break up time into units. It was 16 units. So 16 bursts of a changing frequency. Frequency was related to 0 to 5 volts, and 0 to 5 volts would be related to the intensity of cosmic rays. That's telemetry.

They built a thing that would change the frequency in accordance with the voltage and there were 16 channels, so 16 different measurements or instruments could be taken care of. They didn't have a starting point. Then they got smarter and they said, "You know what? We could also change the spacing between each burst." So all of a sudden, the thing became nonsynchronous because they were changing the spacing. It wasn't a constant frequency of bursts. You would have 16 more channels.

Then they did one more, I forgot, and that had not been processed. This is 1962. There's 100,000 reels unprocessed, and I'm one of the guys that has a desktop computer. It was called a Librascope. It had a drum in it that could store 4,000 words, and a keyboard.

So I grabbed Peter [D.] Engels. He was an MIT [Massachusetts Institute of Technology, Cambridge] grad. I had the best guys working for me. I said, "Let's build a guy that would detect the signal and convert it to numbers." Digital numbers. In a matter of three days we had a thing working that would lock on to the signals and it would convert the burst rate into a number, and we stored that number in a 4,000-word thing, and then I printed it. That was the first time we had printed data. On my desktop computer.

JOHNSON: That was very early on for a desktop.

HABIB: Yes, 1962. They put me in charge of developing the data processing system.

JOHNSON: That's definitely something we need to talk about when we get together again because that's pretty interesting, all of that early work. You'd mentioned the IBM computer and everything. All those early days and the punch cards. The evolution of that technology is just fascinating.

HABIB: What's amazing is we did all that with vacuum tubes. We always found a way to do something. The idea of the digital clock the size of a refrigerator.

JOHNSON: You mentioned before about how quickly everything you did happened—I was reading that the program, from start to finish, was two years, six months, and eight days, and it was developed from scratch.

HABIB: Yes. We had the Viking rocket but it wasn't big enough yet. That's our starting. But we had an Aerobee rocket also. Those were the two. The V2, the Viking, and the Aerobee were the three rockets we used.

JOHNSON: The Aerobee, I read that that's the first time a photo was taken? It helped convince people that you could predict weather by using those types of photos.

HABIB: Let me correct that. I have here what is called a gun camera in my house. When we launched any Viking we usually installed a camera. The gun camera was developed during

World War II so that when a fighter pilot pulled the trigger to shoot bullets the camera would come on and record his hit, and it would stop.

We took these cameras and we built them into another box that would survive. We used color film, 16-millimeter color film. I was in charge of these kinds of instruments, besides the scientific stuff.

The camera was put on a device—it was on a Viking rocket, the nose of it, but the nose of it could rotate, because it was going to look at the Sun and they were going to take pictures of the Sun. Not with the camera, but they had a different instrument.

The rocket misbehaved. I'm saying the whole rocket did, because I believe that's correct. What happened was it started rotating very slowly. Each time it rotated it would tip a little bit.

Have you ever thrown a top on the floor and watched it precess? It's what is called precession. It would precess. This gun camera did a rotation, and on the second rotation it was pointing downward a little more, and then downward, and then downward and downward.

We got that film, and one of the guys in charge, his name was Otto [E.] Berg. Otto Berg has recently passed away. He lived near me. He took that 16-millimeter film that was developed and he took each picture of it and he put it together as a puzzle. It took him three months. When he finished, he had the picture of the first hurricane. That was over the Mexico and California area. That was the first time I think people realized that the hurricane had a form.

JOHNSON: And that this type of photography could be used to track weather patterns.

HABIB: Yes. That was a Viking rocket back then, and it was an accident. That's what started the development of the weather satellites. The satellites are called TIROS. The group that worked for the Army, they had joined Goddard and NASA, and they were developing all those photos that were taken. To this day.

JOHNSON: As you mentioned before, in 1958 once NASA was formed then the Vanguard group was transferred to NASA. Of course the new Administrator [T.] Keith Glennan, I think his first official act was to delegate that back to the NRL, at least the way the management was, since it was already being run through there.

You mentioned that you had to move to those barracks. Was that right away?

HABIB: Yes, we spent about three months in our regular offices at NRL. NRL was expanding, and they said, "You guys got to get out of here." Then we found the barracks. There were still some military people on the first floor, and we were on the second floor. I was building a box that would carry 10 glass plates halfway from Australia to here and the glass wouldn't get broken. My staff played a joke on me.

We made this box and we put the plates in there and we bolted the whole thing together and I said, "Okay, now let's test it." We drop it on the floor. They would go back and unscrew all the screws, and damned if all the glass wasn't busted. So then we'd do it again—well, I think we did it the first time and it didn't get busted. We did it again and it got busted.

By then because we were hammering it on the floor, the military people from underneath started coming up and saying, "What the hell is going on up here?" It turned out that Peter Engels, the MIT guy, was playing a joke on me. When he opened the package, he would take a screwdriver and hammer the whole glass.

The stuff never broke. We could ship all around the world and 10 pieces of glass would not break. But they had me going for a while there.

JOHNSON: I think we've been going almost two hours. I think we can start wrapping up for today. But one of the questions I wanted to ask goes along with that, because you were working with a team. There's always that feeling of camaraderie and that feeling of teamwork. Maybe just reflect on that a little bit. What did you learn? You were relatively young when you started. So what did you learn about this teamwork? Because I think Dan Mazur said working on the Vanguard and that whole team and that project, it was a way of life, it wasn't a job. You alluded to that earlier. For a minute maybe reflect on that teamwork and what you learned from that project.

HABIB: Dan Mazur was my father image. I loved that man. He ran the team at the Cape. His personality just runs all over you, because he was never, "You got to go out and do this, and you got to go do that," he would just leave you to figure out what to do.

You love a boss like that because the type of people we had were all innovators. Dan ran the group that designed satellites. I ran the group that did data processing. I ran the group that calibrated things. I had a lot of freedom, by the way. Harry Goett put me on the Apollo Program too, because I was the Chief Engineer on a thing called OAO. Orbiting Astronomical Observatory. I was the Chief Engineer on that one.

I had multiple jobs because people, I guess they loved working for me. I didn't guide people in detail, I just turned them loose. The OAO was supposed to fly a computer as well as a memory. The memory was about the size of a round trash can, a big one. The computer they never got done in time. So on one of the visits that I made, I figured they would never make the schedule. So, we flew the OAO without a computer. That's another story. Let's come back another time.

JOHNSON: I'll make a note of that.

HABIB: Because we did some big things. Nobody knows about the OAO anymore. They all got the Hubble, like the Hubble was the only thing we thought up. The OAO used a lens, 1 meter. The Hubble uses approximately 3 meters. It's much more powerful.

But the reason he assigned me to Apollo is because of my experience with trying to develop a computer, and Apollo could not fly without a computer. So the experience of IBM on developing a computer I guess fed into Apollo.

The other thing was manned flight initially was part of Goddard, because it didn't have a home yet. Harry Goett would spend two days a week in Langley [Research Center, Hampton, Virginia] and three days at Goddard, and he would drag me into the Apollo, because I was one of the doers. He was a wonderful Director, and everybody wanted to work for him. That's really what makes a team. I had an old saying which says good people pick who they want to work for, and we had a bunch of them.

JOHNSON: It takes a good team to accomplish what was accomplished, that's for sure.

HABIB: Yes. The same goes for the Langley guys who started manned flight.

JOHNSON: Right. We've gone a couple hours, and I think that this is probably a good place to stop. We can pick up the next time we talk and start about those projects you worked on once Vanguard was over, some of those early projects.

HABIB: Now you've met me. I'm a talker.

JOHNSON: That's good. That's what we like. That's what oral history is about.

[End of interview]