NASA Headquarters Oral History Project
Edited Oral History Transcript

Edmund J. Habib
Interviewed by Sandra Johnson
Derwood, Maryland – January 15, 2020

JOHNSON: Today is January 15th, 2020. This interview with Edmund Habib is being conducted by the NASA Headquarters Oral History Project. Mr. Habib is speaking to us today by telephone from Derwood, Maryland. The interviewer is Sandra Johnson.

The last time we talked, we stopped at the time when you were working at the NRL [National Research Laboratory, Washington, DC] and you were transitioning to [NASA] Goddard [Research Center, Greenbelt, Maryland]. As we talked after that interview, we decided that the data processing would probably be a good place to start today. You were first Assistant Division Head and then moved to Associate Division Head responsible for creating, developing, and implementing one of the world's largest and most advanced data processing centers. Do you want to go ahead and talk about that transition, and how you started working for that, and explain what you were doing?

HABIB: Okay. The predecessor to data processing, we had generated the Minitrack system and along with that the telemetry receiving and recording system. Those recordings were done on what we call analog tapes at the various stations. We'd reached a point where we had 100,000 reels of tape that were all analog, which you can't use, because they're digital signals, and they've been recorded in an analog manner, and the scientists who put their life into this to get their data back were all screaming, "Give us our data, give us our data."

I was still running the calibration group of about 30 people, and one side comment on that, I think the calibration method that we reproduced, which uses the stars as a reference, gave us the super super accurate ability of determining where the satellites are.

One of the guys who worked for me at one time was Kurt Stout [phonetic], and he took on the job of trying to deduce the data, and he had built a system which was very awkward. He had 16 individual recording things that were gigantic boxes, took up a wall, and the output was going to be tape. It's equivalent to what comes out of a cash register. That was the first attempt at digitizing the data.

I was running the group on calibration and I was one of the few guys who had one of these desktop computers, and I grabbed Mr. Peter [D.] Engels, a graduate of MIT [Massachusetts Institute of Technology, Cambridge], and I said, "Let's see what we can do." In about three days we had built a box that would capture one of the signals of the telemetry. The telemetry used frequency modulation, space modulation, and digital sort of modulation.

We took one-third of that, and we built a box that would find a synchronization point and would decode the data, and we fed it into the desktop computer, which had a drum memory that could hold 4,000 words, and we built the box in about three days and we turned it on, and we recorded a whole load of data, and we printed it. That was the first time that we had a big sheet of paper with printed numbers that could be given back to the scientists.

I showed that to Dr. [Harry J.] Goett, the person who was looking into what to do, and they fell in love with it and said, "Okay, let's expand on that." At that point I got transferred in a sense. I volunteered, but I got transferred to develop devices that would decode the data and produce it in a form that the scientists could have.

There was a group of people who could build electronic stuff, and it was headed by a fellow by the name of Cy [Cyrus J.] Creveling. He was one of the original people that came out of Naval Research Lab. He had a group of about 10, 20 people that could build equipment, and he had built a converter that would take the analog tape. It was 10 racks of equipment. Two racks were the analog repeating devices, tape measurement. These were tapes that were 10 inches in diameter, magnetic tapes with about three-quarters of an inch width. Alongside the data there's also a timer so that you could get it down to the right time.

He would convert that analog tape into a digital and then record it on two digital recorders. I don't know if you're familiar with the old-time computers, but they were big giant racks with 10-inch reel tapes that you could record information. The advantage of doing this is you now recorded data into digital batches, which you could start and process and then take another batch and process that, take another batch and process that.

The analog tapes are a continuous recording. We used to say the satellite once in orbit would never shut up. They would pump data out 24 hours a day every day of the week. The recording was a continuous process; there was no way to stop an analog tape and process it, and then get another batch and get another batch. These were called STARS, Satellite Telemetry Automatic Reduction System. This was the birth of STARS I. We built that equipment, 10 racks. Several of them in house. I got to stop there because at Goddard we didn't have enough buildings, and so we rented a warehouse near the University of Maryland [College Park] and put this equipment in there and hired a company to help us operate that. It would be a 24-hour operation where you play back the tapes. All of the ground stations that were Minitrack would send in the tapes as they recorded from satellite.

You can imagine the stream. There's one satellite, but each station records while it's passing overhead, and then they'd send that tape back in. We had a quality problem that we solved. At that point we had maybe two, three, four hundred people operating 24-hours a day, playing back those tapes and converting them into computer size tapes.

Computer size we chose was an IBM [International Business Machines Corporation] digital recording. I don't know how much you know about it, but they break the data down into eight bits. That was called a byte in those days. The eight bits had an extra bit that you use as a quality of that eight bits. When there was noise present, it would have an error in there, and that was kind of an error detector. The standard tape then was nine tracks, and an additional track in there for time. On the digital it's just nine tracks. On the analog one of the tracks was time.

That started, and I was put in charge of all of that. We evolved from Cy Creveling's couple dozen guys into a large operation that was continuous 24-hours a day, and later, to formalize it we also planned to build a building at Goddard, and that building is Building 32. Initially I gave the specifications to the architects, and said I wanted to have 40 percent office space and 60 percent computer space. We ended up with a three-story building. Two of the levels were all just complete computer stuff.

After a couple years—I don't remember the time—I did this by the way starting in 1962, and 1968 is when I left it. Over those six years we evolved from the warehouses to buildings on the campus. I told the architects that when they built the building to build it in such a way we could add another floor, and that turned out to be a boon. John [T.] Mengel and Buck [Clarence A.] Schroeder, all of the guys who managed the support services group, they moved into the office space too, so they helped to run that part of Goddard. It was a beautiful building with an atrium in the middle where in the summertime you could go out and have lunch outside. That was the beginning.

In order to do this there was a satellite called OGO, Orbiting Geophysical Observatory. It stated that you could put up to 50 experiments in that one satellite, and fly it, and it's equivalent to what we call the Nimbus satellite today. But OGO was supposed to go out to about—one of them was about 60,000 miles—and measure the electronic atmosphere that far out.

One of the rules we had was the scientist who put in the experiment in the satellite, he would be the sole person that we would give the data back to. The others couldn't have it unless you got permission from him for the first two or three years. Then it became public. In order to do that, with a lot of background, we had a competition for supplying us the computer, and there were two major computer companies back then, IBM and UNIVAC [Universal Automatic Computer]. UNIVAC did the best bid, it was very anxious, but the digital tapes that UNIVAC—well, going back to bits—remember we recorded on punch cards in the early days, and IBM punch was a vertical rectangle hole. IBM was called the rectangle hole. UNIVAC made circular holes, so they were the round holes. They each competed against each other.

I told UNIVAC that when we processed and we decoded the data and we put them on tapes, we were going to choose IBM's standard, and if they wanted to win the bid they had to be matched with IBM's standard. It took about five hours, and they came back and said, "We can do that." They had converted their entire tape system to copy IBM. IBM's was a nine-track tape system. Theirs was a 10-track tape. They overnight became a nine-track tape system.

What we had done with that one requirement was we made the IBM type tape universal over the world, because the scientists were dotted all over, in Europe and the U.S. and the different universities. We said, "If you want to get data from a satellite, you had to be compatible with an IBM system." Wasn't hard to do. I guess Houston is still IBM standard on those tapes. That's what made that part.

On the first floor we put the STARS I that would convert the analog to digital. Then those tapes were moved up to the second floor, where there was a gigantic UNIVAC computer of 50 magnetic recording tapes. Because OGO could have up to 50 experiments, we were basically a gigantic decommutator, so that each experiment would get a tape that would be his data, and all of the support information, such as where was the satellite at that time and what was its attitude and what were the local environments around that satellite. That became common data. That was mixed in with their data, and they would get a batch that they could run completely. We would ship these tapes, most of them, to Goddard. We took them across the street. But the tapes went basically to all the universities who were experimenters.

That was the beginning of what I call the data processing system, and it evolved. We took the 100,000 reels of tapes, and we got rid of them. Then in order to stay ahead of time, you had to run those tapes faster than real time. We wrote some specifications and got some converting data. You're taking me way back.

JOHNSON: You're doing well.

HABIB: The method was TDMA, Time Divided Multiple Access, and the data rates were varying. Each satellite ran at a different digital data rate, like 1,000 bits per second to 10,000 bits per second. Not much faster than that. We wrote specifications that would take us up to 1 megabit per second, which would be the highest speed.

We had a competition, and we ended up with one company that won the bid. It turns out that the Air Force was way ahead of us on digital decoding of analog tapes. The company had built the recorders for EKGs. But they won the bid. By the way, as a quick background, Dr. [Michael J.] Vaccaro was the assistant to Harry Goett. Whenever you issued a request for proposals and then you put up a team together that would read the proposals, and they had to meet at least five different demands—I don't know if you've been involved in a proposal evaluation.

JOHNSON: On the outskirts of one, yes, I know what you're talking about, yes.

HABIB: This was the digital device that was going to be built by exterior that would go to 1 million megabits per second. There were four bids, and two were outstanding and two were not, with a big separation. Vaccaro said, "How did you do that?"

I said, "Well, the evaluation team." When you get a point and you vote on it, you had a scale from one to five. One, two, three, four, five as to whether they were—five was very good, one was not very good. I told my team they couldn't vote a three. See, that's an escape vote in most evaluations, because if they can't make up their mind, they'll vote three. I said, "That was disallowed. They either had to choose one or two or four or five." Vaccaro, he looked at the chart, and he saw how we separated out the bad ones with a big difference. How'd you do it? I said, "Well, I didn't allow the people to vote three." He was floored.

But we ended up choosing that company, and a marvelous machine that could run up to 1 megabit per second. Now to operate that machine, we needed a computer to automate it. We were in the process of building STARS number II. You would have a computer, and the computer would operate the whole thing. The attendant who was going to mount an analog tape would just give his serial number and what time of the day it was and so forth to identify that, and he'd mount the tape on the reel, and then the computer would take over.

It would spin that tape to find out what was the proper speed to run it at, because we always have to run faster than real time, which would choose that it could decode that data at sometimes six times the original recording rate. That would then run it and it would come out the digital tape on the digital side. It was a completely automated system.

Then I was asked by one of the Headquarters people, his name was also Edmund. But he was my boss at Headquarters. He said, "We need you to make a presentation of what you're doing down there at Goddard to Jim [James E.] Webb and [his Deputy]. The two top guys running NASA. He coached me and I put a 20-minute talk together.

We said the program we had was STARS I. We had built those machines in house. STARS II was being built by a manufacturer and a complete computerized system, automated. Their eyes were opened on that. Then we said, "And we're planning STARS III." STARS III would be the recording of all the data of all the scientists so that sometime in the future, 5, 10 years later, a scientist says, "You know that data that they got from satellite XYZ back 10 years ago, I've just figured out I could get more information out of that and so I want to play it back." STARS III would be a method with which we would store all the data on special kinds of tape, and they could go back in time up to 20 years and pick up past recordings and look for new information. That was the presentation I made, STARS I today, STARS II tomorrow, STARS III the future. They were very happy at that.

That was the data processing system. I had evolved it to that point where it was now an automated system. Then Harry Goett made a decision. I was running it as the Division Head basically. He says, "I'm formalizing the data processing system as a unit by itself. I'm putting George [H.] Ludwig in charge of it." George was a person who worked on the scientific group under the scientists, and he was one of the guys that helped to discover the Van Allen [radiation] belt. He was at Iowa as a student at that time.

That was a disappointment in a sense and a relief in a sense. I wanted to get back to dealing with satellites, that was my real goal in life, and creating more things. But I was sort of disappointed in not being chosen to be the chief. It was a disappointment period. I had to get out of a mental effect then. I went back to work with Dr. [Robert J.] Coates. Dr. Coates was one of the first radio astronomers in the country, maybe in the world.

The Naval Research Lab had a gigantic 50-foot antenna on the roof of the administration building, and that was the first radio-receiving antenna. They had discovered back in that period that stars that didn't give out light were also called radio stars, that you could detect radio signals from them. That turned on a whole new astronomy science. But Bob Coates was one of those guys at Naval Research Lab.

He was the Division Head and I was the Associate Division Head of what we called Advanced Development Division. We had five groups, each group about 30 people that would do different things. One of those was designing the first atomic clocks. We had a whole group for that. The other one that we had was an antenna group. But that was when I started thinking that Apollo had pressed us on following Apollo satellites. You had the Mercury, Gemini, and Apollo. Those three satellites, when they orbited around the Earth, with 25 stations, 3 ships, 6 airplanes, we only saw them 20 percent of their life as they circled the Earth before going off to the Moon. That was a very dangerous thing if something went wrong when we weren't able to listen to them.

That's when someone in that group came up with the idea of putting a satellite in synchronous orbit. I bid on that and I said, "I can design that one." That was the birth of the TDRSS [Tracking and Data Relay Satellite] system. I think I finished talking about data processing unless you want to ask some questions.

JOHNSON: I was just thinking about it, while you were talking, and as you mentioned those 100,000 tapes, and having to move into that warehouse and make that operation go 24 hours. That was a pretty overwhelming project to take on.

HABIB: Oh yes.

JOHNSON: Also to look forward to later as you just mentioned a few minutes ago with the STARS. That information should be available later so that as technology changed the scientists could go back and work with that data again. I was reading that I think it was 90 percent of the U.S. satellite data, scientific and application data, was all processed by the center at Goddard, before being moved on to the experimenters.

Going from that beginning all the way through to when as you mentioned it was being processed—and you built the building for that purpose—that's quite a feat.

HABIB: I was ahead.

JOHNSON: That's what I was going to say. Quite far ahead.

HABIB: I think we had the largest computing center in the country at that time, before it exploded. The banks are the ones that have the most gigantic now. I found technicians. After I left NASA, one of the jobs was helping the banking system transfer data from one part of the country to another part of the country. I was reviewing one of the banks, American I think it was, in San Francisco. You go through a high security system.

You're going down a hall and there's a barrier and you walk into it and you can't get out without having the right credentials. This is how money is secured. I go over there, and there's one of the technicians who worked at one of our sites, he's working for that bank. Our starting of making big computers, making IBM and UNIVAC the major developers in the country, I think we played a role in that too.

JOHNSON: Yes, sounds like it because that was a major operation.

HABIB: Yes. Remember I said I wanted to add a second floor if it was necessary?

JOHNSON: Yes.

HABIB: That turned out to be very important, because the other satellite that we ran was one that would take pictures of the Earth. When you put a satellite in orbit from the north pole to the south pole, the orbit itself does not move. It's standard in space. The Earth rotates underneath it. After 24 hours you've scanned the whole Earth. You take 90 minutes an orbit, and then the next one, the Earth has moved 15 degrees, 90 minutes later. You scan a different part. In a matter of about two weeks, you're now rescanning the same area.

It was Nimbus. It became Landsat or something close to that. Nimbus took photographs of the Earth. These are photographs that had to be straightened out. When you put a photograph down it's a flat sheet, 8 by 10, but you're taking a photograph of a curve. The Earth is a curve, so there's a conversion that you have to make to that photograph from curve to flat.

GE [General Electric Company] was the one I think that had the contract for that. They built the method of converting all the Nimbus data. They built it on the fourth floor where it was a photographic device. The way the satellite scans is you build a straight line of 10,000 sensing bits. This is the same as what you have in your camera today. It's called charge-coupled diodes. That's the name in the cameras.

For satellites, you build just a linear string of them, and you build seven of them, each one with a different filter. As the satellite was moving from south pole to north pole, the scanning mirror would move from left to right, and the next one would be another line next to right, next to right. As the satellite moved forward, that would be the continuum. You were now taking pictures of the Earth in seven different colors, which allowed you to isolate what was it taking a picture of.

One of the examples is tobacco. In Maryland and Virginia and South Carolina, North Carolina, tobacco was the thing. You would like to know how much tobacco is being generated. You would first have a good farm that had tobacco that was ripe, and you'd take a picture of that in those seven colors. That would be a signature of tobacco. You get a different signature of rice. Later on after you'd scanned for two weeks, and you took the whole world, you could then decode how much tobacco is being generated in the whole world. The same thing for rice.

I remember one of those years we found out that the Chinese were not able to create as much rice as they had been due to weather events. We could then use that Landsat information to tell our farmers, "Hey, grow more rice, there's going to be a shortage over there." That was one of the useful things of the Nimbus satellite.

JOHNSON: Definitely useful.

HABIB: It has to do with cattle farming, chickens, the whole works. That was all processed up on the fourth floor.

JOHNSON: Okay, that extra floor that was built.

HABIB: Yes. The pictures were processed. Of course you had the digital part of it so you could look for certain signatures. I didn't realize trees get sick when they're getting ready to die, their temperature changes. By satellites we could take the temperature of a forest and find out that there was a disease going on and that trees are going to be dying. That was one of the things. Data processing and doing it the way it evolved became a very important thing in the world.

I was part of all of that. I didn't have my PhD. I had taken a lot of graduate courses at Maryland, and I gave myself one of these things where you worked three days a week and you went to school two days a week. I continued, I got all my work for a PhD done at Catholic University [of America, Washington, DC] but never wrote the thesis. The theses are the things I did.

I had taken several kinds of courses. I was adept at math, at digital things. I took a course in how to design a digital computer back then when they were very raw. In 1962, I can still remember—1961 or so—someone had brought a document in which was an early crack at a request for proposal to build a telescope in the sky. Nancy [Grace] Roman I thought was the person who brought that document in. She has just recently died. But I was close with her. I was one of the guys that developed the requirement for the OAO [Orbiting Astronomical Observatory].

The astronomer was Jim [James E.] Kupperian. Jim was a very brilliant guy, and he was the astronomer at Goddard Space Flight Center. He also had a good knack at digital, and I was from the support side one of the key digital guys. I'd had enough instructions in that and knew a lot about it. In the specifications we said that there would be a computer on board the OAO. You would give commands to the satellite that I want you to point a certain star. Can you picture that?

JOHNSON: Yes.

HABIB: Okay. The OAO had six tiny telescopes, and these six were up and down, left and right, and north and south, east and west, and vertical. They're plastered on the outside of the satellite. They would lock on to stars that are very bright because it's a small telescope. The kind you would actually use as binoculars almost.

Once they locked on to a star in the sky, you could then with respect to that move the satellite to look at a star you wanted to study. The reference was these six telescopes and the target would be one that you would choose. Physically if I put one hand pointed up in the sky to my left and another one sort of in front of it toward the right, and I told you that this left arm had a vertical angle of such and such and a rotation of such and such, that was two dimensions. And if I did that with the second arm that was two dimensions I got from that, I could tell you where my head was pointed.

That's how Hubble [Space Telescope] works and how OAO works. You have to have guide stars in order to point the satellite. I went back over some data, and I found out that once you locked on to these stars you could hold a position accurate to one-tenth of a second. Measure angles in terms of 360 degrees, divided into 60 minutes, and 60 minutes each minute divided into 60 seconds of arc. Its astronomical accuracy is a tenth of a second of arc, and you could hold that satellite pointed at a star steadily.

The star's light you couldn't see with your eye, you couldn't see just looking through even a giant telescope, you had to stay looking at that spot until you'd receive enough photons on the film that you'd develop the picture. This is how the Hubble works. Hubble has actually taken pictures of the beginning of space, which is billions and billions of miles away, by looking into an area that has nothing. Then after 6 or 20 days, they discovered there were a huge number of stars out there that are beyond our viewability by taking time shots.

OAO was the first satellite to attempt to do that. It used a mirror about one meter, and it was going to have a memory on board where you would record data, digital memory that IBM would build, and a digital computer so that you could transmit commands to the satellite and say, "Now I want you pointed at this star," and it would operate itself and zoom over and take a look at that point.

The first OAO, besides doing the data processing and the other stuff, I was also helping out as an engineer on the OAO because of my digital prowess. In the end we came to the conclusion that IBM was not going to meet the schedule with the computer, they were behind schedule. I'm now talking OAO. OAO now would not have a computer on board, and that was going to be disastrous.

What I came up with was we would put the computers at each Earth station, and we would do the computation of the guide stars, what guide stars and what angles they should use, with a gigantic 9099—I forgot its name—computer at Goddard. It would compute the proper angles that the smaller telescopes would have to go at to point the satellite at a target.

This information would be sent down to the ground stations every morning, or once a day. There would be enough information for running a 24-hour operation at all of the different ground stations. I found out it takes about 100 minutes to go around once. When it appears over a ground station, you only get to see it anywhere from 5 to 15 minutes. In that amount of time the Earth station would have to dump—we were going to record the data in that memory. Memory looked like a big trash can. It was a circular drum. You would have to send a command to the satellite to dump the data and then the ground station would then have to turn on and beam the next set of programs for the satellite as it passed over. All this had to happen in the next 5 or 15 minutes. At the same time as the satellite was moving, we had big dishes now at the stations, you had to control the movement of the big dish. That was the birth of automated ground stations.

To use the computers, we still were in the early days of small computers. General Mills, which makes cereal and Wheaties, the little round circle, they had a group of guys that were designing a stand-alone computer. It was equivalent to about two racks of equipment. They used germanium back then instead of silicon transistors. It was the first transistorized computer. We bought seven of them and put them in each ground station, and those computers that had 64 plug-in cards that were really the basic of the computer. Thirty-two of them would run the computer itself, and then the other thirty-two we could write different programs, such as how to convert information to how to point the satellite, and things like we could say, "Go for this satellite." We could write a process into this plug-in card.

These were the birth of what we do today. When you buy a laptop you get a computer with it. In that computer there are fixed software programs, they're commands, and those commands allow you to write bigger programs. They're built into the computer part to make life easier. This was the birth of that class, that is we could give commands—I'm getting beyond myself. But those, we called them the General Mills computers, because in those days, memory was called core memory. Core memory were little magnetic rings. Everyone says, "The Wheaties computers are out in the Earth stations."

I had some brilliant guys working for me who knew how to program that computer, and they left me behind. But that was the beginning of automated tracking stations.

JOHNSON: Were there any major disruptions in that? You were mentioning that they had those few minutes every time the tracking station picked up the satellite to dump the information, program the next information. Do you remember any significant disruptions or any problems that you had to work through?

HABIB: No, I think because we had stations all over the world, and we had that straight down on the 75th meridian, and the OAO, and I found out today that the Hubble are at a 28-degree angle to the Earth. I was reading the question, why can't I see the Hubble? I'm in Washington, DC. We're at 38 degrees. The satellite doesn't come that far north, so the satellite orbit is a circle at a

28-degree angle to the equator. You have to be down in Florida to be able to see the satellite come over you.

We had enough stations that we could catch every turn, rotation of the satellite. You could dump data from it every orbit. Now I had left the program by then, because I was working on data processing. I was only at the beginning of the OAO. What I've found out, there have been four of those OAOs. The first one failed right after launch. I remember I was on the committee to find out why it failed.

It turns out that when the satellite is on the ground it's in an atmosphere of air, and when you launch the satellite you don't want to turn on the electronics right away because it's still letting all that captured air blow out. You haven't reached a perfect vacuum. Because it's astronomy, some of the sensors operate with 1,000 volts. You have this vacuum tube which multiples the number of electrons. But that operates that at a high voltage.

What we found out was we had turned on the satellite electronics too early, and arcs were forming in the electronics and burning out stuff. The fix is to wait a day or two before you turn on the sensing electronics. But that caused that first satellite, the first launch lost attitude, and it was running on batteries. Once the satellite gets up there you run it on batteries because you haven't put out your solar panels yet. Then you have to rotate the satellite so that the sunshine will shine on the solar panels. OAO number 1 died within three days, ran out of battery, and we couldn't turn it around enough to get sunlight on the solar panel. That was that failure.

The second one operated okay, but it was about two years later before they launched it. The third one, it never separated from the second stage, so it was a dead one. Only two really worked of the OAOs. But the data that the astronomers got back was so astounding that they said, "This is the way we got to look at the sky." That gave rise to the Hubble.

JOHNSON: I was reading they did find some things that were unexpected.

HABIB: Yes. I read that too. But a part of it has to do—remember we had this satellite that discovered other stars with planets around them, the planetary one. What they did was they pointed it at a single area of space, and they never moved it. They had to use the same stuff we were talking about on OAO for holding it dead still. Just keep watching because at some moment the star would dim, one part per million. You're looking at a star. That's the sun. A planet crosses over in front of you in the direction you're looking, it would block out some of the light from that star. The star would dim one part per million, and this scientist who kept pounding away at NASA and Goddard, "I can do this, I can do this, I can measure that one million change in light intensity," they didn't believe him initially, and then were astounded. We're now discovering that there are stars out there that have planets that may emulate our own. That's how those things go.

OAO I guess led the way. I was one of the first engineers working with Jim Kupperian. We were like brothers. Kupperian was what we call the project scientist. I would be called the project engineer on that one. I had to do that in addition to other things that I was doing.

JOHNSON: That's interesting, because we've talked to other people about those relationships between scientists and engineers, and how well that worked, or how well it didn't work.

HABIB: I could talk about that.

JOHNSON: Yes. If you have any anecdotes. You said that you were very close to him. How did you make sure that that was something that you and your team could do?

HABIB: First of all, they picked me out because I was kind of a jack-of-all-trades, to get on the OAO, and also, I had taken an astronomy course, and I had to understand astronomy because the calibration method we used, we used the star background as the reference. If we go all the way back to Minitrack, Minitrack needed to be calibrated. Paul Herget—I think I brought him up before—was the astronomer from Cleveland. He had told us that if you want to calibrate your stations, you put a camera at the intersection of the north-south-east-west line right at that. I actually put the focal point of the camera on that X, so as you moved the camera you didn't laterally move it. You rotate it on that X. You point the camera straight up, and you use an airplane with a flashing light. That flashing light was only on about 50 microseconds, it was the kind of flashes that we use today. It would appear as a ninth magnitude star. It mimicked the star background.

I went over this before, but I had this code called the serial decimal code. Serial decimal time thing. It put out clicks every second. It put out additional clicks every tenth of a second. But the number of additional clicks would tell you the time of day. I transmitted that signal to the airplane, and that would trigger the flash that was in an antenna that was just 3 feet by 3 feet. It was a printed circuit. In the center of the circuit was this argon flashing light. It would come on in unison with the time ticks. The film was a glass plate 8 by 10 inches, and the camera was an 8-inch lens. They used to be reconnaissance cameras during World War II. It was a big camera, and it was sensitive to ninth magnitude stars; it could record them.

You would have this 8 by 10 glass plate and you have these star dots all over it. Then you'd have this string of lights that would be the movement of the airplane. Tick tick tick tick tick tick tick. Dots. From that you could calculate at what moment of the day the light flashed. That would tell you the position of the stars at that time of day. Remember the Earth is always rotating, so the stars aren't standing still.

With all of that I could determine the position of the airplane to the size of a lightbulb at five miles away. That's the calibration method. To get the catalogs of where the stars are and to deduce all that data made astronomers of our group. We had to learn astronomy. I took an astronomy course.

That brought me into the OAO Program, so I helped to write the specifications with the digital part, which is we're going to have a computer and it can automatically point the telescope, so forth, in space. That was the goal. There's the relationship from what we did at Naval Research Lab, that was where we did all the early inventing, and it flowed into how to deal with a telescope in space.

Harry Goett had a report that came out every Friday, and every Monday we would get that report, and they would be beating the hell out of us, the scientists. Why haven't you finished processing this data? Why can't I have my data? Why are you guys taking too long? Have you been to Goddard?

JOHNSON: Yes, I have.

HABIB: Okay. When you enter in the gate that's the main street—forget what it's called, but it's the street. On the right-hand side were all the support services. On the left-hand side were all the science services. We were divided. Jack [John W.] Townsend [Jr.] ran the science guys and Jack Mengel ran the support services guys. They were the two subdirectors.

We would complain that they said we didn't do something, and we had done it, and we were on time, and we were building the computing, the data processing system, as fast as we can. We were doing all that work, but the scientists were still pounding away at us. We complained to Harry Goett. You know what he did? Brilliant guy, he issued the report out on a Thursday. By Friday we would go have our meetings, he would have a review every Monday morning, and anyone who had something to say could go there, it was open house. But it was in his office.

Monday morning we would be just beginning to complain about what the scientists said against us, and we're busting ass. He put it out on Thursday, that gave us time to read it and figure out how to answer that one, and so we had answers. You know what? The scientists stopped complaining, because we could fire back at them. That was Harry Goett.

The other brilliant thing he did was he gave the job to George [Ludwig]. I had developed the data processing system. Mind you, that was a good thing, because I later developed the TDRSS which I'm going to cover. But when he did that, I was chagrined, and I was disappointed, and I went back to school, just to get my oomph back. I was sort of depressed. I said to myself, "There's only one way to get out of depressed, go do something." That was go back to college. I got out of depressed. I created the TDRSS as a result.

Later Harry retired, and he went to work for Loral. In my resume I show where I worked for Loral in building a special kind of satellite. Harry Goett lived in that area in California. Mountain View is the area. I'd go have lunch with Harry. My father had passed away when I was 52, and Harry Goett was Catholic with five children, and I was Catholic, and I had five children. We kind of were buddies, but I didn't know him that well back then.

I would go have lunch with Harry every other week while I was on the west coast, and finally I said, "Why did you appoint George Ludwig?" He was a very egotistical guy. He would go to meetings and say, "I did this and I did that," when he had a group of 150 people. I never did that. I always said, "So-and-so did this and so-and-so did that." That's how I would report things. I sort of acquired a dislike for George Ludwig.

I asked Harry, "Why did you appoint George Ludwig?"

He said, "I needed self-starters." Now that told me a whole story, that if you are up at the highest management level, he didn't want me to waste time being a manager and running an operation that was humming away. He had identified the people who create, and he would turn them loose, and that's what he had done with me.

JOHNSON: It made you feel better.

HABIB: Yes. I think the class of guys you have out there at Houston, they came out of [NASA] Langley [Research Center, Hampton, Virginia]. The Langley people as I've known them were that kind of person. That is they were always creating. The management people were sort of out of their way. Management is one thing you can be, me, I just wanted to start. I only wrote two applications for patents. I never patented, because I was jumping from one thing to another. The Goddard Range and Range Rate System, I built it myself personally. All the electronics. That today I think is the mainstay way of tracking satellites. I found out that JPL [Jet Propulsion Laboratory, Pasadena, California]—I didn't realize, but I read an article, I get the JPL newsletter every month. They used a method called pseudorandom ranging where they send a 5-megabit-per-second signal that the ones and zeros are random, what we call pseudorandom. It's a code, and you can lock on to that code because you know what the code is, and pile up all of the 1 million bits, 1 million ones, and get a signal. That's how you decode it. They use that for measuring.

I found out that when the satellite passed Pluto not too long ago, I thought they were using my method, which was tone ranging. It turns out they were using the pseudorandom, because the paper that I read said that the pseudorandom blah blah blah. Mine was super efficient. All you did was transmit a tone. If you transmitted 1 megacycle per second, you could build a filter around it of 1 hertz, so that means you eliminate all the noise. That's a different story.

Okay, OAO, I looked it all up, and there were four of them, and only two really worked. The last one was a really fine one that had all kinds of X-ray, gamma ray, and ultraviolet detectors. Like you said, they also found things that they didn't know were there. That's OAO.

At the beginning of the space business, Mercury was part of Goddard. Harry Goett would spend two days a week at Langley and three days at Goddard. When they came around, they had to have a computer for Apollo, and so he assigned me because of the computer argument that we had with IBM to the guidance system of Apollo. I didn't spend very much time on that, but I did help out on that group.

Apollo had a dozen different groups it was divided down into. Escape and return and so forth. There were programs on each one of them, it was a big big deal. I'm amazed at how it all worked together. Harry Goett and I, we proposed to use the Goddard Range and Range Rate on Apollo. But the fellow who was in charge of the research at JPL was also in charge of deciding what tracking system would be used for that, and so they ended up with the pseudorandom ranging on Apollo for the whole mission, all the time. Goddard Range and Range Rate was not used. But it worked. But the pseudorandom ranging, as I understand it, would interfere with voice communication, so they couldn't do ranging while they were talking.

All right. Let me go back to TDRSS. I wanted to design a satellite. TDRS was going to be a relay satellite. Also Harry Goett I think arranged for me to get all kinds of security clearances. I had everything. That's when I found out that the secretive services were already transmitting at 3 megabits per second information from their satellites.

Fastest we were going was about 25 megabits per second for data. I had available to me a frequency bandwidth of 600 megahertz. It was me and [Paul F. Barritt]. We wrote the first paper on TDRSS, and the first thing we wrote was the specification of what should it do. One was it needed to get back very high rate data and video, so that would require a dish type antenna on the satellite. That was the time when Headquarters had discovered that when they start a program there's always one gadget that was not available yet and would really set the timing of when you could launch it. So, they started a program where they gave us advance research money.

I used part of that and gave a contract to Radiation, Incorporated. They were in Florida, and they were a good class of people. Today they make printers. They've got a different name [Harris Corporation]. But Radiation had designed an antenna that you could fold and unfold. Back in those days when ATS [Applications Technology Satellite] built an antenna, it was going to be opened in zero gravity when it's in orbit, there's no gravitational pull. But on the Earth, there's a gravitational pull, so the only way they could test that the antenna would open properly was to use strings and weights and a big room and simulate zero gravity to see if the antenna was proper.

But they had a method at Radiation where it opens like an umbrella, and instead of your finger pushing the middle button forward in an umbrella when you open it, it was an electric motor. The whole antenna was folded just like an umbrella and would open like an umbrella, and it would be so accurately curved that you could operate at 15 gigahertz, very high frequency, which meant the surface had to be a parabola perfectly.

I funded Radiation to design that antenna to operate at the frequency we were at. I had sort of known secretly they had built one that operated at even a higher frequency. The antenna then that is now on the TDRS was developed before the TDRSS was developed. I borrowed that antenna.

Then the other service we had was the TDRSS had to operate up to 20 or 30 smaller satellites that would be below it, so we needed to develop pencil beams. You can use a technique called phased array. That is you put an array of antennas on the satellite and then you have a phasing method that you could develop a pencil beam and lock it on to a moving satellite that's underneath you.

The problem was we were still somewhat in the vacuum tube stage. You couldn't develop the electronics, multiple parts of units. Today I understand they track up to 20 satellites simultaneously, which meant you had to have 20 different phase developments. To build that and put it in a satellite would be awkward.

I had enough math that I could write the equations of frequencies, so I wrote these equations, and came up with a method where I would take the 30-element antenna—that's what's flying now on the TDRS. Each one was a rod. Think of it. The output of that antenna, you would put a preamplifier. That amplifier at the frequency, which was somewhere around 2,000 megahertz, you would have established a signal-to-noise ratio. Now I needed to relay that output of the preamp to the ground, and then reproduce it on the ground. You would have a crystal oscillator that would produce 30 different channels. Each channel was 10 megahertz wide. I took 300 megahertz and divided it into 30 different units, each one 10 megahertz wide, and assigned that 10 megahertz to that antenna element. There are 30 signals, one representing each antenna element with a 10-megahertz bandwidth being transmitted to the ground. Those carriers were developed from a certain crystal oscillator.

You transmitted that crystal oscillator to the ground. If you did that you could then reverse the operation and basically be at the back end of each antenna as though you were in the sky. I gave that a name. Actually I came up with that idea and then we had a whole branch of antenna people, and they took over.

We simulated it. We did a contract to [Airborne Instruments Lab] up in Long Island. They replicated that idea—a quarter of the idea—in an anechoic chamber. Yes, the whole system would work that way, so that was proved that the idea would work, that you could recreate the output of each element on the ground. The name of that thing was called AGIPA and it was [Adaptive] Ground Implemented Phased Array.

Because there are 13 TDRSs up there and they all are using that method, except for three I understand. Now the word A was adaptive. When you are pointing an antenna—and let's think of it as a pencil beam—it has a shape of a round top. Have you ever seen antenna patterns? You have the beam and then a smaller beam on the side?

JOHNSON: Yes.

HABIB: Okay. You don't want to point the main beam at your target because there's also a lot of noise, in this case at 2 gigahertz Russia has 10,000 radars running at that frequency, and they could jam you. What we do is what we try to point off a little bit, and we try to point the antenna so that the ratio of signal strength to noise is the best. It turns out that you don't point the center of the beam at the target, you go off the target, because you're trying to reduce the interference noise. That's what adaptive meant.

I've now done a lot of research on where all that went. The first TDRSs, they only needed two. You built the ground station at White Sands [Test Facility, New Mexico]. I wanted to build the thing at Goddard because that's where the data processing is. But today the data appears at White Sands. Fiber optics today though, we have high-speed transmission that they can send it all the way to Goddard. But initially they were using another satellite to retransmit what they'd gotten, data back to Goddard, or to the experimenter.

JOHNSON: Why did they decide to use White Sands instead of Goddard?

HABIB: That was the guys. I started to say earlier. Jack Mengel's group was divided into two groups, one run by Ozzie [Ozro M.] Covington and one by Jack Mengel. When Apollo was going to go to the Moon and when manned flight started, we knew that we were going to have to have a different kind of ground station. Minitrack was an interferometer and it works with the kind of satellites that were flying, but with men and voice communication necessary and so forth, we said, "This is going to be the manned flight service operation."

We had the science operating group, and I stayed in that, and we had another group called the manned flight support services. They built their own telemetry system, their own capture of voice, their own tracking method using radar initially. That was for the first two, Gemini and Mercury. That was a different group.

Then when the Apollo Program was closing up, just before that they said, "Well, let's build satellites at synchronous orbit so that we go down on the manned flight." They were thinking only manned flight, so they came up with this idea of putting a satellite in synchronous orbit. I bought that idea and said, "No, we'll apply it to everything. We build a satellite that will support man," and that's the two dishes out there, and the other scientific satellites would have the multiple beam system, where each satellite had up to 20 beams. At that time I thought it was going to be 30, but today it's 20 beams per satellite. With two satellites you can service 40 different satellites in low orbit, and you could service man, and as it turned out, the [International] Space Station too, with the big dishes.

The big dish by the way was a dual frequency one. It also operates at 2 gigahertz as well as 12. But I understand that the newer ones went up to 30 gigahertz and the multiple one services 20 at the 2 gigahertz. That's TDRSS.

Now the problem that I had was the program manager was from Austria, and he was self-minded. He wanted to build a satellite that was a spinner. Are you familiar with the spinning satellites?

JOHNSON: Yes.

HABIB: At the very beginning of going into space, what you had was a satellite that spun like a top. That would maintain the given attitude that you wanted. Then the upper part was called the despun table. On that table you built your dish that just looked at the Earth, it would not spin.

You had to transmit signals through rings in order for power to transfer from one part to the other. The spinning satellite, the first communication satellite was a spinner built by Hughes [Space and Communications Company]. There were two guys at Hughes that got the first medal for creating the idea of a spinning satellite.

A lot of satellites were built with the spinning thing. But this guy at Goddard who was my boss at the time, he wanted to build the TDRS as a spinner. I felt that could not do. It would have to be a three-axis-stabilized satellite, and the experts at that were at JPL, because they built three-axis satellites for deep space.

I gave a contract to JPL to design the TDRS. The TDRS that flies today is their design. I had given the specs, the two dishes and the multiple support services at 2 gigahertz at the multiple antenna, the phased array.

To get around them I had this little story. To satisfy him we designed a spinner that would operate at 136 gigahertz. It wasn't big enough to support man at the time. It had Yagi antennas. It's an odd-looking thing. I have in my house a 2-inch volume which is a design of that satellite. We designed it, we put together a crew of engineers and we designed a spinning satellite that would have antennas that could look down to the Earth. But we never built it. Rudy [Rudolf A.] Stampfl was one of the first people to come down from Fort Monmouth [New Jersey, U. S. Army Research and Development Laboratories], and they built the TIROS [Television InfraRed Observation Satellite] that was the first weather satellite, and he was part of that group that came down from Fort Monmouth. They changed it to Al [Alton E.] Jones. Are you familiar with Al Jones?

JOHNSON: I've heard that name, yes.

HABIB: He was my roommate. We were five guys, which included my brother, that rented a house. Al was in charge of the Syncom Program, which was the first synchronous [communication] satellite. That, using my ranging system, proved that we could determine where the satellite was to 25, 50 feet accuracy at 22,000 miles high. I went to Al. Al was then assigned as in charge of what turned out to be the TDRS. He was very approving of that one. He was my roommate. We schemed together.

The TDRS, I'm extremely proud of it, because I wrote there are four things that it uses that are used today. You've arranged a phasing of all 30 elements, so they form a pencil beam, and that pencil beam has a 10-megahertz bandwidth channel. Then how do you isolate the next guy? The thing that was being invented back in those days, they created the idea of CDMA. Your cell phone right now operates on Code-Divided Multiple Access. There's several ways you can divide bandwidth. By frequency. You can assign a carrier to one guy and a different carrier and a different carrier and a different carrier.

Or you can assign the same carrier but time-divide them. That is let's say you had a unit of time and you divide it into 20 units. The first unit that comes in time, that's a channel that somebody can use. The second one is channel two, channel three, channel four. If I'm on channel five I have to wait until the fifth timing comes up before I transmit. You divide people by time, and that's called TDMA. Then the other method was you used coding.

If you have a digital stream and you multiply it by a certain code it looks like noise. Then if you have another stream and you multiply that by a different code then that looks like noise, and together they're noise. You can do this 20 times, so you can divide it into 20 different codes and they're all noise. But when you're receiving that bunch of noise you can multiply the bunch of noise by one of the codes, and that would pop out that channel, because it would lock on to that code and pull it out of the background noise. That's called Code-Divided Multiple Access, CDMA.

The company [Qualcomm], they're on the west coast. They created that idea. They had brilliant engineers that were MIT guys. They came up with the CDMA method. They convinced China and the U.S. to use it for cell phones. When you use your cell phone, you've been assigned a certain code, and your neighbor who might be right next door, he's got a different code but he's on the same frequency, and you don't interfere with each other. You see how clear the voice is when you use your cell phone. CDMA. But TDRS was the first satellite to use CDMA.

So I claim that we were the first ones to use it in space. It's code division. We were the first one to use Adaptive Ground Implemented Phased Array. We were the first one to use the tracking method, which was an adaptation of the Goddard Range and Range Rate, but it's a four-way system. In other words you transmitted the tones to the TDRSS, and TDRSS relayed them to the flying satellite, and the flying satellite echoes that back, that's a four-way trip. And then you also send a different frequency band to the TDRS by itself. If you can subtract out the TDRS position, you now have the position of the flying satellite. The Goddard Range and Range Rate is a four-way system.

Then the ground station being in White Sands was a good idea, and it was chosen by the group of people who were in charge of tracking Apollo. There's one reason. When we started the Apollo Program, Jack Mengel didn't have enough people to build two different tracking systems, so he needed people. Ozzie Covington was the name of the guy who ran the group at

White Sands Proving Ground. He hired Ozzie and Ozzie got most of the technicians that worked at White Sands to work for Goddard. They came from there.

Most of the guys, there were very few classical engineers like myself in that group. But they were mostly technical people. Highly good technical people that ran the Apollo network. They came from White Sands, and they wanted to go back home. That's why they chose White Sands. But there was a better reason that I didn't realize. It never rains there. So you don't have to hide the antenna because it won't be drowned out by big storms. It will when there's a hurricane or something, but that's very few. They chose the right place to put a ground station, but the problem was that's where all the data is. You now had to get it back to where the users are, and that meant using satellites again, so everything had a double trip, and it still does. We had the data processing at Goddard and the ground stations were 2,000 miles away.

But today with Internet and everything else, it's not a problem. You can just put the stuff on the Internet. With 5G coming up, they say it's going to be super fast. It's going to beat out sending stuff to space again.

JOHNSON: One of the things I noticed on your resume, which I thought was interesting, was that you were considered the father of TDRS. That is quite an accomplishment when you talk about what it's been used for and the whole Shuttle Program and how that changed.

HABIB: Goddard just gave me a medal for that.

JOHNSON: Oh yes. I was going to ask you about that, because you said you just got another award.

HABIB: It's now been about six months. I didn't realize because I don't go back to Goddard that often inside. The entire Building 12—and that was the original building where Bob Coates and I ran the advanced research, Building 12, ran it on the second floor. The entire building is TDRSS now. TDRSS is the biggest thing going on. I think I have decoded why. Thirteen TDRSs have been flown. Three of them have been put to bed. They're the oldest ones, and they've shut them down. There are 10 operating up there.

NASA doesn't have that much demand. It turns out that during the design of the TDRSS the military also started—I think it was the Air Force—to do the same thing. Congress said, "We can't be supporting two of the same thing." There were meetings that I would go to with the military people, and we'd talk about what we were doing. But then I stopped going to these meetings.

I think what has happened is there is an alliance between NASA and the military, and one of the statements that I read was the pencil beams are mostly being used by the military. If you have 10 operating satellites and each one has 20 free beams, that's 200 beams you could operate around the Earth. I have a feeling that you can also manage the drones that fly. There is a classified part of the TDRSS that's going on. That isn't talked about but it's there. It's done economically. That is it sounds like NASA is running the show. But I know that very early after the first set of stations were built at White Sands a second one showed up, and that's the military one. But now I think there's three of them.

I still am on a committee that selects who will get the next award. I got the award in 1970. Then for a while I was in charge of giving that award out. I was the third person to get the award for the AIAA [American Institute of Aeronautics and Astronautics]. We have recently selected the new award winner. I don't know if I can talk about it yet or not. But TDRSS is involved.

JOHNSON: I noticed when I was reading about that award in 1970 one of the things you were awarded, besides a small monetary award, was the ability to pick someone for a scholarship. Is that still part of that award?

HABIB: See, I've always belonged—it used to be called the American Rocket Society. It changed its name to AIAA, American Institute of Aeronautics and Astronautics. I've been a member of that from the beginning. There's a crew of people that meet twice or three times a year to set up what the next conference is going to be like. They hold a conference once every year. It used to be a big conference, but it's kind of dying out now. But I'm a member of that committee of the big conference, the committee that runs it. It's got subcommittees, and one of them was who selects the winner, the next guy. I've been a member of that all along since 1970, I haven't given it up.

As it turns out, it's hard to get guys who are familiar. I found out now that the last—we were supposed to have like five people who select, and we were missing a couple of guys, because they were the guys who supported people. You can't get the support guy to be the voter. This past time there were three of us who made the selection, and I was on that. You'll see who it is.

JOHNSON: Okay, I'll look forward to seeing who that is. One of the things I wanted to talk about is when you left Goddard and actually went to NASA Headquarters for a couple years for a special assignment as Manager of Advanced Communication Satellite Concept Development.

HABIB: Yes.

JOHNSON: You want to just talk about those couple years?

HABIB: There was a time when the communication satellite people along with Europe wanted to put up a satellite that would talk to an airplane that's going from continent to continent. I've forgotten what it was called.

The Europeans, they were the major runners of it. Who runs airplanes now? Government.

JOHNSON: You mean the Federal Aviation Administration?

HABIB: Yes. There was always a contest with who would run it. When this happened it became a contest between the guy who was running the communication thing, and I was just a member of that group, and the guy who ran the aviation wanted to be in charge of deciding what kind of a satellite it would be. His name was [David J.] Israel. The guy who was at Goddard, he wanted to be the guy that dictated what the satellite would look like, because that's NASA's job.

They competed with each other and the end result is we never built the system to support airplanes in flight. Only just now I'm beginning to hear that they're going to use satellites. Airplanes are now able to allow you to have Internet connection all the way, right?

JOHNSON: Right.

HABIB: They're beginning to turn that system also into the support of aircraft as to where they are and the operation of the aircraft itself. That was talked about when was I there [1972-1974]. Way back in '72 we were talking about how to make a safe flight, U.S. to Europe. It died because of two things, one was competition as to who would run it, and this is my take on it. The group that was going to fly the satellite or devise the satellite was COMSAT [Incorporated].

COMSAT was a U.S. group, and everything they tried to do, they would operate it at 4 and 6 gigahertz. That's where the first communication satellites were built. The problem with that is it's the wrong frequency to operate FAA. They have their own frequency band they want to work at. The 4- and 6-gigahertz bands were selected in a hurry, way back at the beginning of communication satellites. Bell Telephone [Company] had built the first satellite, and they needed components to put in the satellite and they wanted to do it in a hurry. This is called the first communication satellite, and was built by them.

Bell Telephone chose the same frequency they use for microwave towers, 4 and 6 gigahertz. Now every time you built a ground station that was communicating to satellites it would interfere with the telephone system that was tower to tower. You had to always make sure that you weren't bothering them.

The guys at COMSAT labs could only think one frequency, 4 and 6 gigahertz. They forgot where it came from, they forgot that every time you built a station you had to go and coordinate the thing, or you built a satellite you had to coordinate it, that you weren't jamming somebody else. It was a selection of frequencies that was done in a hurry and became permanent, and it's the wrong thing.

I think this whole idea of putting communication satellites to service airplanes just died because it was too cumbersome. The airplanes operate in the 200- and 300-megahertz bands. If you operated it in their band, it would be more attractive. The other part was competing with my NASA guy wanting to say, "I'm going to pick out how it's done," and Israel on the FAA saying, "No, I'm going to pick it out." The whole idea died. So I was disappointed. But there was a more personal reason. In 1971 or close to '72, I volunteered to work for Congress. Congress is the one that puts out the money to build stuff. What's that called? That Committee.

JOHNSON: The Appropriations Committee?

HABIB: Yes. One committee decides what they would pay for building in the budget that's done every year. The other one would be the money supplier. At one of the air bases there was a guy who raised a complaint to his representative in Congress, and that guy said to the unit running the Committee, "Go look into it. Have the staff look into it."

Back in those days, most of the money was for how to construct buildings. The support group is supported by the FBI [Federal Bureau of Investigation]. The FBI assigns guys to go in and investigate whether this building, this aircraft, or so-and-so should be built. They report to the committee the result. They were given the job to find out why was this guy complaining. It was a technical question, and they needed technical people, and I was kind of loafing around, and I volunteered. It was 10 months. I was assigned to the Pentagon for 10 months, with a promise that I could always come back to my original job.

While I was gone, there was a reorganizing at Goddard, the manned flight people and the non-manned flight people were welded into one support service. At that time I had transferred myself to the people who designed satellites at Goddard. The one guy who took it over didn't know me very well, and he was told he had to cut the number of employees. When I came back from the FBI group, he says, "I'm laying you off."

I said, "You can't do that. I just started working for Congress, and I'm going to go talk to General [Jacob E.] Smart and tell him you're going to lay me off." He started shaking. He was doing the wrong thing.

He said, "Okay, you're not laid off." At that point it wasn't going to be a very good agreement, so I decided that I would transfer to Headquarters, after the communication group. That's how I went there.

But then there came a moment when—now mind you, all this started at Naval Research Lab. One of the key guys at Naval Research Lab was now a vice president in COMSAT, the company COMSAT, which had headquarters down there in L'Enfant Plaza. He kept saying to me, "Come on over here." After we stopped Apollo, we were also laying off a lot of people. My first child, my son, was getting ready to go to college, and government salary, at that point I was earning the highest salary, it was $36,000 a year, and I think I was equivalent to a GS-16. He kept saying, "Come over here and work."

I said, "Well, make me a written offer." He kept doing this, doing this, until the time was just about to run out at the end of February. I said, "You got to give me a piece of written paper that you're offering me a job." I got that job, and it was $2,000 more than I was making, but I had 25 years of service. See, I was also a veteran of World War II. When you add all that up it came to 25 years. If they're RIFing [reduction in force], then you can meet one of two gates. You can be 55 years old or have 25 years of service and you can take an early retirement. I took the early retirement in 1974 and went to work for COMSAT.

JOHNSON: Then you had a long career after that, from looking at your resume.

HABIB: It was good, yes. At COMSAT, I was assigned to the vice president of research and engineering. Then I got an offer from American Satellite [Company]. It was a brand-new company with a brand-new goal of making—the linked communications in the U.S. was by towers. Radio signals sent from tower to tower to tower. It would take 20 towers to link the east coast to the west coast.

You could put what was called a communication satellite up in space and in one hop you could connect the east coast to the west coast, and there were companies that were beginning to build that, and one of them was Fairchild [Communication and Electronics Company], with a subcompany called American Satellite Company. They offered me an engineering job. That's when I started working in that field.

I spent four years with them, and then the idea of broadcast satellite was born, and Bill [Wilbur L.] Pritchard, who ran a consulting company, had also put a bid in to the FCC [Federal Communications Commission] that "I'd like to build a communication satellite that will transmit 10 channels directly to the home." That was the idea. He made me an offer and I became a vice president of that company called SSE [Satellite System Engineering].

It turned out that nobody would fund. You needed $500 million to build a communication satellite. Nobody was willing to risk it, it was too early. Of 10 people who proposed to do it, nobody got it. But finally Hughes said, "Ten channels is just not enough." Back then it was grandiose to have 10 channels. On the ground we had 30 channels, on cable. Finally Hughes came up with the idea of compressing the signal, and they bought a company that was called Compression something, and so now they could pack 10 analog channels in the same space as one. You could now have up to about 130 channels from a satellite.

That's what made it. Today have you got a rooftop antenna?

JOHNSON: No.

HABIB: The rooftop antenna, that was how it was born. The consulting company didn't do so well, so I went back to Fairchild and worked for them. They made me the president of a company that was failing, they were already $1 million in the hole. It was a very small construction company. It's a long story.

JOHNSON: Yes, and a long career.

HABIB: The best one was the company that when Russia became democratic, then a group of guys, just three or four guys, decided that they could fly a Russian communication satellite very cheap, because Russia didn't know how to price things. In the communism system, everyone was a government employee. They didn't know how to compete and price things.

They got a contract that they would put six satellites up, Gorizont [geosynchronous communication] satellites or equivalent, using a Proton rocket. Proton rocket now sells for $60 million a shot, just the rocket itself. For $140 million they would put six satellites in orbit. They needed an engineer and I volunteered.

JOHNSON: Was that Rimsat?

HABIB: That's Rimsat. That was a nasty problem because there was some hanky-panky going on that caused it to fail. But the other one that made it fail was we were succeeding. We sold some channels on the satellite and I was running everything. I was spending half my life in the Philippines where I made a headquarters there and that's where I transmitted to the satellite. I rented an antenna from the Philippine telephone company there to communicate to this Gorizont satellite. But what happened was the business was beginning to fly. The customers were in India, and it was the beginning of India broadcasting television to the home, and I helped them start that. It was called Sun TV. That's one of the big companies today.

The Russians said, "Wait a minute, that's pretty good. We're going to take those satellites back that we gave you."

"You can't do that, you sold them to us."

"No, we didn't sell them to you." They started writing to our customers and said, "Send the money to Moscow, don't send it to Fort Wayne, Indiana, or we'll shut you down." The customers ended up doing that. Our company went bankrupt.

But that was the best fun, because I traveled to Russia and in the super secret places where they initially had been building—they were building a copy of TDRS. I saw the model of it sitting in one of the plants.

I'm going to give you one last little story. This is classified sort of.

JOHNSON: Okay.

HABIB: I was visiting JPL, had a good friend there, and he wanted me to explain how the Goddard Range and Range Rate worked. He wrote a whole chapter in a book about it. Then later he says, "I got something I want to show you."

We go down to where JPL is located, outside of Los Angeles. We go down the road, and we enter something that looked like a garage, but we go upstairs, and there's a super secret place out there. He gives me one badge and we go 30 feet, and you take that one away and he gives me another badge. He's got one of these oscilloscopes that shows signals that they're picking up. They were picking up a strange signal, and they can't decipher it. It has a whole bunch of peaks in the signal. Have you ever seen a scan like that that they show you what the spectrum is like?

JOHNSON: Yes, I believe so.

HABIB: It's called a spectrum analyzer. You get these little like Christmas trees up and down, which are all of the different frequencies they're looking at. He had this scan up there, and he said, "It's Russian, and it's way out deep in space, and we can't figure out what that is." Took a look at that. I said, "That's my Goddard Range and Range Rate. That's what it looks like." That's what it was.

JOHNSON: That's funny.

HABIB: Russians had—well, we were open and we would write papers. We don't make it a secret at Goddard. The Goddard Range and Range Rate. They had copied it. JPL was still using spectrum distribution, and the Russians are smart enough to pick up the Goddard one.

All right. That's one of my stories.

JOHNSON: I'm sure from your career you have a lot of those types of stories or interesting little tidbits. That's pretty amazing.

HABIB: Let me tell you something I was dreaming about last night.

JOHNSON: Okay.

HABIB: The beginning. You want to know how the heck this all started, the beginning of it. I'm not sure we covered it very well. When I graduated from college, I couldn't find a job, so I worked for Montgomery Ward for eight months. Then I started looking again, and I came back to Washington. I was about to give up, it was hard to get a job in 1949. Wow. Yes, 1949.

Then this one woman I knew, she was a friend. She worked at the Chemistry Society, and she said, "I heard there's an opening at Naval Research Lab." Have I told you this before?

JOHNSON: Yes. I believe you mentioned that in the first interview.

HABIB: I went out and the person had died very suddenly, and they needed a replacement. Okay. That group, what we did in those earliest days, we weren't tracking satellites, we were launching rockets. There are stories there. Did we cover that?

JOHNSON: You did talk about it. I don't know if you covered everything you wanted to. But we did talk about those days.

HABIB: Yes. We were using the German V-2 rocket. Aerobee rocket and all that. Okay. We've covered all that.

JOHNSON: But, if you go back and look at the transcripts, either one of them, and you don't feel like we covered it enough, we can always come back and do this again.

HABIB: Okay, yes.

JOHNSON: Once we get it back to you, then you can look at it. If there's anything you feel like oh, we should have talked about this more in depth, then just let me know. It's up to you. You know your history.

HABIB: Okay, let's stop then. Let me just tell you one last thing.

JOHNSON: Okay.

HABIB: The medal that they gave me is a little disk that has an emblem of the TDRS satellite on it. It says that this medal flew on the last flight of the Shuttle. They had flown apparently a bunch of little medals of different kinds, and they flew them on the last Shuttle so that they'd have something to do, so I had that piece. That little round disk. One other guy was honored at that same meeting by the way.

What happened was I left TDRSS and went on to do some other things when I retired. This guy, he continued the process, so he's the one that carried it on, I would say. But TDRSS was already completely designed and claiming to be the father of it is I think okay.

JOHNSON: Yes, I think so too.

HABIB: It's the design that I was the expert on. I've been saving papers here at home, and I just found a whole batch of my notes. I was a damn good mathematician. I couldn't do that today, I swear. But it's called vector analysis, and the one thing I did tell you about was we were doing a classified experiment at White Sands as to whether the flame would interfere with the signal. I don't know if you remember that.

JOHNSON: Yes.

HABIB: To do that you had to do what you call coordinate transformation. To that, I had taken analysis from Homer [E.] Newell. He was the Chief Scientist at NASA when it was formed. But Homer Newell was a branch head at NRL, and he taught a course in vector analysis, very very complex stuff. I ended up knowing it, and so this says that if you want to know whether the flame and the signal are interfering with each other, you had to know what the attitude of the rocket was. To do that, you had to read the gyroscope numbers. Then the engine itself was tiltable. You needed the data, which way was it tilted at that moment that the signal was coming down. Then you're back three miles away listening to all this, so now you got to know what was the angle for you to pick up the signal. You had to put this all back into the rocket's own dimensions. That's the math I was good at.

JOHNSON: That's good that you saved that.

HABIB: Oh, I do have one more, I was going to mention this. We flew an airplane to calibrate the station, and what we asked the pilot to do was to make a run directly over the middle, and then to move over 10 degrees and do another pass, and then move over another 10 and another 10 and another 10. We scanned the whole area that was covered by the Minitrack system.

To do that, you had to know where to fly in space. I built a miniature interferometer. It was two antennas jammed together, so the baseline was really one wavelength. We processed that signal, that phase difference signal, being picked up by each of the antennas, and we put it on a meter. The meter would be like a voltmeter. It would go from one end to the other end.

I arranged it so that when the meter was at the center, he would be flying through the middle of the pass, dead center. I transmitted this signal to the airplane and put a meter on his console, and I said, "Just fly so you keep the needle in the middle. You'll be flying right over dead center." That was an invention just all by itself.

We wanted him to move 10 degrees over. I would tilt these two antennas 10 degrees, then say, "Do the same thing, keep the needle in the middle," and he would be 10 degrees off, 20 degrees off. This pair of antennas was on a seesaw that I could tilt left to right. As I tilted it, he flew through the middle of that pair of antennas.

That came to me just like that. Let's guide the airplane. You could use that method any time you wanted to have an airplane fly in a certain path. That's a fallout of NRL.

JOHNSON: I do appreciate you adding that and talking to me again today.

HABIB: Quite enjoyable. You must have a good job.

JOHNSON: Oh yes. I tell everybody I've got the best job in the world.

[End of interview]