Interviews of the Margaret MacVicar Memorial AMITA Oral History Project, MC 356
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Virginia Norwood – class of 1947

Interviewed by Kira Buttrey, class of 2023

June 27 and June 29, 2022

MIT Libraries

Margaret MacVicar Memorial AMITA Oral History Project

Virginia Tower Norwood (SB Mathematics 1947) was interviewed by phone on June 27 and 29, 2022 by Kira Buttrey (SB Bioengineering 2023). Ms. Norwood was at her home in Topanga, California, and Ms. Buttrey was in Santiago, Chile, taking part in the MIT-Chile internship program.

Ms. Norwood is a physicist and engineer who is best known for her important contributions to the Landsat program, which is the longest-running undertaking devoted to acquiring satellite imagery of Earth. She is known as "The Mother of Landsat" as a result.

Ms. Norwood grew up in a military family that moved frequently, and she adapted well to each of the numerous schools she attended. Her aptitude in mathematics led her to MIT in 1944; she was one of only 11 female undergraduates. As she describes in this oral history, she and her classmates were "guinea pigs"—given a surprise exam, the grading of which, they later learned, was used in developing the Scholastic Aptitude Test (SAT).

After graduating, Ms. Norwood struggled to find work that would put her mathematics degree to use. She was finally hired in 1948 by the Evans Signal Lab of U.S. Army Signal Corps Laboratories, in New Jersey. Her work there included designing a device to accurately calculate wind velocity above 100,000 feet, making long-term weather prediction possible for the first time. She was then 22 years old.

A few projects and jobs later, Ms. Norwood, along with her husband and daughter, moved to Los Angeles. There she joined Hughes Aircraft, a company she stayed with for 36 years. Her work on the Landsat satellites included designing the multispectral scanner (MSS) that has been imaging earth from space continuously since the first Landsat 1 launch in 1972. MSS data is used in a variety of applications, from environmental to geographical. Ms. Norwood's other work at Hughes included designing antennas, communications links, and optics, in addition to the microwave transmitter used on the moon by Surveyor 1.

In retirement in California, Ms. Norwood enjoys collecting and repairing clocks. She went to see the launch of the most recent Landsat satellite—Landsat 9, in 2021—and hopes to one day speak with the engineers who implemented her original "push-broom" detector design in the current satellites.

More about Ms. Norwood remarkable life and career can be found in the *MIT Technology Review*'s June 29, 2021 cover story, "The woman who brought us the world": https://www.technologyreview.com/2021/06/29/1025732/the-woman-who-brought-us-the-world/

BUTTREY: Thank you again for the opportunity to interview you for this oral history project. I really appreciated the cover story that the *MIT Technology Review* ran about you. I read it and took an interest in your work before I knew I would have the opportunity to interview you.

NORWOOD: Oh, that's nice.

BUTTREY: I'd love to follow up on some stories included there, as well as dig into your time at MIT and other aspects of your life.

NORWOOD: OK.

BUTTREY: To start off, I was hoping we could talk about your childhood. If I'm not mistaken, the *Technology Review* article mentioned that your father's army officer job meant you lived in Panama, Oklahoma, Bermuda, and Pennsylvania, all before you graduated from high school. What was it like to move so frequently?

NORWOOD: Well, yes, I come from a military family, and I've observed through the years that, for some reason, girls thrive better in that atmosphere—being pulled out of school and put it in another, and so forth—than do boys.

BUTTREY: Interesting.

NORWOOD: I've pondered that.

BUTTREY: What do you think about that?

NORWOOD: I guess girls are just more sociable. That's all I can figure. You learn how to come into a new classroom with all different people and not be befuddled by it.

BUTTREY: It seems like a good skill.

NORWOOD: Maybe.

BUTTREY: Did you have an interest in science or math early on?

NORWOOD: Yes. My father, although he was an army officer, came in from a civilian school, an engineering school, so he always talked to me about math things. Not so much science, but mostly math with him.

BUTTREY: What did that look like? What kinds of math-related things would he talk to you about?

NORWOOD: I guess I mentioned in that other thing [the *Tech Review* cover story] that he made me a slide rule when I was nine.

BUTTREY: Oh, he made it for you?

NORWOOD: Yes, and told me that logarithms added in order to get a product. He made two lines of logarithmic scales, which of course, is what a slide rule is. And then he showed me how if you slid them along, which is the equivalent of adding, you were capitalizing on the fact that you got a product.

BUTTREY: Wow, that seems very advanced for a nine year old. I'm impressed!

NORWOOD: Well, I didn't have much else on my mind, I guess. But things like that would interest him, and logic. I can remember his teaching me the idea of necessity and sufficiency, things of that sort. So they were sort of second nature by the time I got old enough to be using them.

BUTTREY: Was your mother similarly supportive?

NORWOOD: Oh, yes, very much so. She was not so well educated, because they eloped when she was a senior in prep school.

BUTTREY: What was your relationship with her like?

NORWOOD: It was a very, I'd say, an intimate relationship, especially since my father was away fighting a war for quite a while. She also had spent her life moving around, and so we just settled in Essex, Connecticut. We looked for a house to rent all through that Connecticut shore, and that was the only house we found that was suitable. I went to Pratt High School [there] for a few years.

BUTTREY: What was high school there like?

NORWOOD: The schools were reasonably standardized throughout the United States, so transferring wasn't really a problem between schools.

BUTTREY: What was the attitude like then toward young women like you who excelled in math?

NORWOOD: Oh, there was a certain deference or awe, and I thought it was a little silly. I couldn't spell worth a damn, and I could do math, so I just felt everybody had his strengths.

BUTTREY: Yes. It's interesting that you use the word “awe.” That's not what I expected, because while awe can be construed as a positive, on the other hand, it's

almost a little bit insulting if it implies that you shouldn't be able to do advanced math.

NORWOOD: Yes. It was surprising to me that such a large number of the children were not adept in those [math-related] things. But again, even though I was, I couldn't spell.

I had a mother who was very adept at languages. She would drill me each night with a spelling list. Do they still send spelling lists home every night? They used to.

BUTTREY: I think so, yes. I was never that good at them either.

NORWOOD: Well, English is a terrible language from that point of view, since there are no rules that hold. I rather like linguistics now.

BUTTREY: When did you start liking linguistics?

NORWOOD: Oh, dear, I don't know, after I got out in the real world.

BUTTREY: To circle back to your high school years, I've read that you decided pretty early on that you wanted to go to MIT. How did you first hear about the Institute, and what made you determined to attend?

NORWOOD: I first became aware of it when I began to think about schools. My mother thought that if I wanted to do it, that was fine, but that [going to MIT] was a little iffy. But she never tried to dissuade me.

BUTTREY: And how about your father?

NORWOOD: He wasn't around. He was out fighting the war [World War II].

BUTTREY: That must have been hard.

NORWOOD: Yes, but I can remember that, one day much later, my mother said that he probably would have not been so enthusiastic [about my matriculating at MIT]. He would have liked to have gone to MIT, but he came from a not a real well-off family. I managed to get a two-thirds scholarship, which helped a great deal.

BUTTREY: Yes, that's a significant scholarship.

Why do you think your mother said that he may not have been so enthusiastic?

NORWOOD: I've pondered that, and I don't know. Later on, he was very pleased. He was always proud of anything that I was able to do.

BUTTREY: Well, he certainly had a lot to be proud of.

NORWOOD: Well, I don't know. Fortunately, I enjoyed it all.

BUTTREY: Your enjoyment in what you do and have done comes through in everything I've read about you, for example, in past interviews you've given, in the *Tech Review* article, and in information put out by NASA.

NORWOOD: Yes, well, a lot of that is the Landsat program. That's one where I started it and went through to always making the most complex spectral device that I could with the detectors and such that were available at the time. So as the detectors improved, we were able to add spectral bands and so forth. That was always pretty exciting.

BUTTREY: I would love to come back and talk more about that. Would you mind if we first dig into your time at MIT and move up to your work on Landsat?

NORWOOD: Sure.

BUTTREY: Great. When you first came into MIT, did you have an idea of what you wanted to study?

NORWOOD: I really only knew about math at that point, and physics, because my father had studied physics. Of course, that's what you get the most of in your first two years. I don't know how it is now, but in the first two years, there were four semesters of calculus, two of physics, and two of chemistry that were all requirements. Chemistry didn't interest me at all. I mean, I muddled through.

BUTTREY: What was your freshman year like?

NORWOOD: Freshman year? Well, it was very standardized. Everyone did the same thing in the freshman year. We'd have math tests on Friday up in the drafting rooms. We were all kind of commiserating together when we had a tough question.

BUTTREY: Did the women students, however few of them there were of you, form a community?

NORWOOD: Very much so, I think.

By the way, I learned much later about the time that they [MIT administration] herded us all together in one or two of the third floor drafting rooms and gave us a test that was just sort of sprung on us. What I learned later is that the grading of that test was one of the bases for [what became] the so-called SAT tests.

BUTTREY: Oh, yes, the standardized tests needed when you apply to college.

NORWOOD: Right, well, they just started the year I went up there [to Cambridge]. They used us as guinea pigs.

BUTTREY: Just so I'm clear, was it just the female students being used as guinea pigs?

NORWOOD: No, no, no, no. There weren't enough women there! There were 11 of us [women], and they [MIT administration] would allocate two to a physics class. So they'd fill 10-250—that's a great big hall in the center under the [MIT] Dome. There'd be two of us, two women, and they'd always put us down in the front row.

BUTTREY: What did that feel like? Was it ever intimidating?

NORWOOD: No. I just thought it was a little high handed.

BUTTREY: Did you ever feel excluded for being women in study groups or by professors, or was there little difference in the way you were treated from your male classmates?

NORWOOD: I wasn't aware of any difference. We had a cadre of sort of well-off students who had gone to prep schools, and then those of us who had gone to public schools, but I never found much difference in that.

I was just thinking of our celebrities. Felix Browder was in my class. [SB Mathematics, 1946, PhD Mathematics, 1949; a mathematician known for his work in nonlinear functional analysis; received the National Medal of Science in 1999]

BUTTREY: I'm afraid I don't recognize his name—

NORWOOD: Well, he was a genius. He came in and he did all of the first two years by advanced standing. And then I think he went on to an academic life, as did his son or brother, Bill Browder. [William Browder, SB Mathematics 1954; Professor of Mathematics at Princeton University; best known for his work in algebraic topology; served as President of the American Mathematical Society]

Anyway, we had several celebrities [in our class]. You know about Mary Frances Penney, I gather? [Mary Frances Penney Wagley, SB Chemistry 1947; professor of chemistry interested in educating women; served as the first woman President of the MIT Alumni Association and the first woman to be named a member of the MIT Corporation]

BUTTREY: I don't think I do.

NORWOOD: Well, do you know the Penney's stores that are found throughout the country, or used to be?

BUTTREY: JCPenney?

NORWOOD: Yes, the retail stores. They mostly sold clothes. Penney came from that family, but she had gone to prep schools.

We also had Hugh Clark [Hugh James Clarke, MIT BO Management 1949]. I had known his sister in Philadelphia, and she pressured him to ask me for a date my first year, but we didn't have much in common. So that's about the last I saw of Hugh.

BUTTREY: Did you feel that there was an economic or class separation among the students?

NORWOOD: I wasn't aware of it. I was just aware of the outstanding cases. For example, Penney took a horse up there [to Cambridge], and that took a certain amount of money. But she was always very pleasant to me, and she invited me to her family's place in Manhattan and things like that.

We were all going to school, as I mentioned, around the clock. They gave us a half day off for Thanksgiving the first year.

BUTTREY: Wow.

NORWOOD: Yeah.

BUTTREY: Was this because of the war?

NORWOOD: Yes, they were trying to get the men through before they got siphoned off [in the draft].

BUTTREY: Did that contribute to your graduating in three years?

NORWOOD: Right, definitely. I actually took one term off. I had not done very well in my second-term physics. I was accustomed to knowing all the answers, and so I took a term off. My mother lived in Connecticut at that time, and I lived with her and went through every example in our physics book.

BUTTREY: Oh, my goodness.

NORWOOD: It helped.

BUTTREY: So up until that physics class, did you not find MIT to be all that challenging?

NORWOOD: That's right.

BUTTREY: How about after taking that term off and going through the entire textbook?

NORWOOD: Well, that gave me a very good background, which I had not had. Our high school physics was pretty perfunctory. That was in Germantown, Pennsylvania. Mostly through my high school years, I had been very much involved with the drama courses.

BUTTREY: Oh, in what way?

NORWOOD: I was in plays and things like that.

BUTTREY As an actress?

NORWOOD: Yes.

BUTTREY: Did you continue that at MIT?

NORWOOD: I played Birdie in “The Little Foxes.” That's one I remember. I had one lead, but in general, I didn't get the leads. They were always a lot of talented people around.

BUTTREY: Yes, I've interviewed a fair number of people who talk about the Dramashop productions.

NORWOOD: Really? Good.

BUTTREY: Was it a big part of campus life?

NORWOOD: Yes, yes.

BUTTREY: Do you remember anything from the plays that you were involved in? Any stories or anyone you worked with?

NORWOOD: Nothing really noteworthy, but I enjoyed them.

BUTTREY: Yeah, it is nice to have something not academic to do at MIT.

Was there anything you found surprising about your undergrad experience?

NORWOOD: Boy, not when it's put that way. Let me think. I guess I didn't really know what to expect when I went up there. I had always been in the top few students through high school. It was a little bit of a surprise to land there where everybody else in the class has had the same experience in his high school or hers. By and large, I thought they were pretty impressive students.

BUTTREY: I'm impressed that it sounds like most of your time at MIT went so smoothly.

NORWOOD: Yes.

BUTTREY: Where at MIT did you live?

NORWOOD: Well, I lived just above Central Square when I first went there, with an elderly lady whose son had been to Northwestern [University], around Chicago. She said that she would like to take in a girl student. I stayed with her for four terms. And then, is a building across the street from the Mass Avenue exit [MIT building 10] still called Bexley Hall?

BUTTREY: It was, but it was torn down.

NORWOOD: It's an apartment building.

BUTTREY: It was closed down a number of years ago, something like 10 years ago [in 2013].

NORWOOD: How could they tear it down? Dear me.

BUTTREY: A lot of current MIT students feel the same way.

NORWOOD: There were four of us who had an apartment, and it was only a one-bedroom apartment, but we turned the dining room into a bedroom. I did my last four semesters there. That was nice.

There was a Naval officer's daughter there, Hester Stickley [Hester Marion Virgin Stickley, MIT SB Chemistry 1947]. There was also a girl from Connecticut whom I knew for years, Mary Clark [Mary Margaret Clark, MIT SB Electrical Engineering and Computer Science 1948]. In fact, I went across the country and back with her later. I made good friends there [in Bexley Hall].

BUTTREY: It sounds like it.

NORWOOD: I don't know if Mary's alive. She was just about my age, as I recall. And later, she came down to the Signal Corps Labs, where I worked later.

BUTTREY: Did you recruit her there?

NORWOOD: Sort of, yeah.

BUTTREY: That's great.

NORWOOD: Most of the women were in chemistry.

Someone else I know by the name only was Paddy Vanderbilt [Emily V. Wade, MIT SB Chemistry 1945], whose father was the governor of Rhode Island. She and Mary Frances Penney, who was the Penney heir, lived together and they had a housekeeper and a maid in their apartment. So there were real differences, but they never were obnoxious about it.

BUTTREY: Did you and the other women spend time in the Cheney Room?

[Margaret Cheney was a chemistry student of Ellen Swallow Richards, class of 1873 and the first woman admitted to MIT. The already-planned reading room in 3-310, was founded in 1884 as an oasis for women students. It was named for Cheney following her early death in 1882 while on a break from her studies at the Institute, and is currently the location of MIT's Women's Community Center.]

NORWOOD: Yes, it was very important. As I said, I lived in Central Square, and so I'd walk down [to campus] and then stay there [the Cheney Room] all day. There were big gaps in your day when you didn't have a class, so the Cheney Room was very important. Is it still functioning? Do you know?

BUTTREY: I'm not sure. I know where the Cheney Room used to be, but I don't think I've ever been inside. I need to check.

NORWOOD: It had a kitchen and a big lounge, an office, sort of, and then a locker room. It stretched out along that upper hall. No, without that, we would have been cooling our heels for long times. The library wasn't very good. Yes, that [the Cheney Room] was very important to us.

BUTTREY: Was it a social gathering place?

NORWOOD: Yes, and also where we could study. The kitchen was very much dominated by the fact that we had, I don't know how many, but perhaps 12 or so Chinese girls. The girls from China were in a special course.

BUTTREY: Oh, I didn't know that MIT had Chinese women students at that time.

NORWOOD: Yes, they did. I never knew quite what the arrangement was, but they all stuck together. They didn't speak English very well, in general, and so we would just sort of smile and say hello to each other. I didn't know any of them, and they seemed all very shy.

BUTTREY: It seems incredibly difficult to not speak English and be a woman at MIT at that time.

NORWOOD: Right, definitely.

Do you live on the campus, or where?

BUTTREY: For my first two years, I lived in a dorm called Burton Connor.

NORWOOD: Was that in Cambridge, or across the river?

BUTTREY: It's in Cambridge, on Dorm Row. Maybe a quarter mile down from where Bexley Hall used to be.

NORWOOD: Yes, OK, I know what it is.

BUTTREY: One of my favorite parts of my MIT experience has been having a community within the dorm. Similar to the Cheney Room, my dorm has kitchens and lounges, and it was a social area.

NORWOOD: Well, we didn't have any dorms, of course. The closest thing to it was a bunch of girls lived over in Back Bay in a house. That was later, and it was sort of treated like a sorority. They didn't call it that then, but other places, like Wellesley, have sororities.

BUTTREY: What made it like a sorority?

NORWOOD: That they were girls living together in different stages of their education. The fraternities, I didn't know much about what the girl's place was like, but the men would keep old exams and really helped each other in fraternities.

BUTTREY: It seems like you're at a real disadvantage as a woman in that time, who can't join a fraternity and have that academic help.

NORWOOD: Exactly.

I married my M21 [second-year calculus course] instructor, by the way.

BUTTREY: How did you meet?

NORWOOD: He was in the math department. He was an instructor and a graduate student. There were three men in that category. We just hit it off, and we got married the week that I was graduated.

BUTTREY: What was his name?

NORWOOD: Lawrence Norwood. He came from Stanford. His bachelor's degree was from Stanford, and then he left MIT and went to Yale, where I joined him after I was graduated.

BUTTREY: If I'm not mistaken, did you also take graduate math classes at Yale while he was teaching there?

NORWOOD: Right. They were very nice to me. We could not have afforded the tuition, but they allowed me to sit in on courses.

BUTTREY: What motivated you to sit-in on those courses? Was it just a love of the subject, or were you trying to improve your education for some job or career goal?

NORWOOD: You know, I never thought in those terms. I just knew I'd been going to school all my life and so I just continued.

BUTTREY: I think that's great.

NORWOOD: It was just what someone did. Yale was very, very obliging because they knew we couldn't afford their tuition.

BUTTREY: Was your husband encouraging of both your graduate math classes and all of your later work?

NORWOOD: Oh, I think so. He died in 1980, by the way. And I married again for another 30-odd years.

BUTTREY: What was your job search like after graduating and moving to be with your husband at Yale?

NORWOOD: Well, after I got my degree, my family was in Germany. We got married, and I moved down to New Haven. And as I said, Yale was very good to us, in that they'd let me audit all the courses. My job hunting was really rough, though. There weren't any professional jobs aside from the school at Yale, or in New Haven.

BUTTREY: Were there no professional jobs for anyone, or were workplaces unwilling to hire women at this time?

NORWOOD: I think there was a little of that. But there just wasn't much around in that town [for anyone]. Later, I went to the Signal Corps Labs [a research and development center of the U.S. Army Signal Corps, located in New Jersey], which was a very good move for me. They were just great.

BUTTREY: How were you introduced to the Signal Corps Labs?

NORWOOD: Well, my father was a Signal Corps officer. Lawrence and I both went down to spend Christmas with my parents in Fort Monmouth, where we went to a party and met another Signal Corps officer, who had been a colleague of my father's. He said, “Oh, you should go get a job at our labs. They're wonderful.” And they were. I started out in what was called weather radar. My whole job was to think of things you can do for weather prognostication using radar. That was great fun.

BUTTREY: The way you talk about it, it sounds like it was. If I’m not mistaken, while in that job, at the age of 22, you designed a device that could accurately calculate wind velocity above 100,000 feet, making long-term weather prediction possible for the first time. That's incredible. Do you remember any of what your design process was like?

NORWOOD: Yes. I didn't realize the value of getting the data—the wind data from the ground up as far as there was air, really—until I had joined that group called Weather Radar. Do you know the basic idea of a corner reflector?

BUTTREY: I know the basic idea, but would you mind explaining for anyone reading this?

NORWOOD: Well, imagine the corner of a room; in other words, three planes coming together at right angles. If you have a cut-out of that corner, then a radar beam going in, if you try to track it through, it hits the side. Equal angles means the beam goes off to another one of the three flats, and then the third one, before it comes back—so it makes something that you can track. If you just put a balloon up that's a reflective, then, when the beam hits it, it splatters out in all directions and loses force. A corner is a way to trap the beam so it comes back where you want it to.

BUTTREY: How did you think to use that design?

NORWOOD: Well, that had been used for all kinds of things. For example, to mark the edge of runways. When a plane would be landing, it would have a radar beam and it would look for these corners that were lined up along the runway. But if you just had one of those corners, then there'd be a long time when it wouldn't be facing you, and you couldn't get back information.

I devised an intersection in which you had these returns from all around the device that was going up. I put it under a balloon, and then I put a fishing spinner on it, so that it would move around and assure you that at some time you'd have a return.

It was pretty obvious, but nobody had done it.

BUTTREY: Well, I'm glad that it was obvious to you. It seems it was not obvious to most!

NORWOOD: Yes, I guess not.

BUTTREY: Am I correct in thinking that this technology was patented?

NORWOOD: I did get a patent on that, yes.

BUTTREY: What was getting the patent like?

NORWOOD: Pretty straightforward. You just had to write descriptions. We [the Signal Corps Lab] had patent attorneys who were up at Fort Monmouth, and they helped. Some of them were very ignorant about radar and reflections and all that kind of thing. I don't know where they were in high school. But once they got the idea, they were happy.

BUTTREY: I would imagine that it's a particular skill to translate these technological things to the lawyers.

NORWOOD: Oh, yes. It's a little frustrating.

By the way, I just remembered that when I was preparing to talk to you, I wrote down the [names of the] women that had been at places where I worked. They were very few. Surprisingly few.

BUTTREY: Was it surprising at the time, as well as now?

NORWOOD: It was to me. Yes.

BUTTREY: So were you working with any women when you were at the U.S. Army Signal Corps Lab?

NORWOOD: Well, various people, but I never worked directly with a woman. Jenny Bramley [Dr. Jenny Rosenthal Bramley, physicist at the Signal Corps Engineering Laboratory; known for her work in lasers] was Russian, and a very nice woman. I kept track of her for quite a few years. I suspect she was a

few years older than I, and I would doubt she's alive now. Her name was Rosendahl in Russia. Then she married a man named Bramley, in this country.

BUTTREY: And she worked at the U.S. Army Signal Corps Lab?

NORWOOD: She worked in the labs, yes.

BUTTREY: Did you ever work with her?

NORWOOD: No, it's interesting, I was the only woman [on my teams]. There may have been a meteorologist whom I never met in another area. Jenny had spent her life in the same situation, and so she came down to meet me in my office. She was very nice, and I did bump into her at conferences for a few years after that.

Then there was a young woman from what was then Carnegie Tech, or Carnegie Mellon University, they called it later. Anne Black was her maiden name, and she worked for me for a while. She did computer stuff for me, especially when I was working on the Landsat.

BUTTREY: Was that a coincidence, or did she seek you out as someone she wanted to work for?

NORWOOD: I suppose it was pretty coincidental. For some reason, the Signal Corps Labs made it very difficult for technical women to get what was called a professional billet. They usually stuck women into running a Marchant computer. When I needed that done, I sure as hell didn't want to do it. So I asked for her [Anne] because I knew she was smart.

BUTTREY: What did the Marchant computer entail, and why do you think the women were stuck there?

NORWOOD: It was an adding machine, in effect, and you could switch it to back and forth, sideways. You've seen calculating devices, have you not?

BUTTREY: Yes.

NORWOOD: Now they're little handheld things. But in those days, this was before Hewlett-Packard and Texas Instruments made their little electronic ones. You'd punch in numbers and then turn a crank. You should look at a Marchant device someday. I bet there's some around in—

BUTTREY: Yes, I bet I could find one at the MIT Museum, or in some basement.

Another woman I wanted to ask about was Frances Whedon [SB Physics 1925; American meteorologist with the United States Army; two-time recipient of the Meritorious Civilian Service Award]. If I'm not mistaken, from the article about you in the *Tech Review*, she was a U.S. Signal Corps meteorologist and also happened to be an MIT alum.

NORWOOD: Yes, it was sort of interesting when I was trying to get data for what altitudes would be valuable and that kind of thing. I didn't know much meteorology, so I arranged to go to Washington, and she was very nice to me.

Apparently, she hadn't been very nice to the men that came to her asking for stuff. She kind of took me under her wing and got me reams of actual data of radio signals going up so I would know what rates they were going at and how fast they'd get out of range and that kind of thing.

BUTTREY: Do you remember any of your conversations with her, or what she was like?

NORWOOD: She was a little brusque. But as I said, the main thing that came to my mind was that various men said, “Oh, you don't want to talk to her,” and then when I did talk to her, she was very helpful. Again, she hadn't been so helpful to the men, I gather.

BUTTREY: Do you think she felt some sort of camaraderie with you?

NORWOOD: I do.

BUTTREY: For being women in this very male-dominated field?

NORWOOD: And she probably hadn't met very many women from MIT, because she had graduated in the late '20s, and I don't know if she ever went back.

BUTTREY: Do you recall whether you talked about MIT with her at all?

NORWOOD: Not much. It was pretty much business.

BUTTREY: Later on in your life, once you began working at Hughes [Hughes Aircraft Company, the major American aerospace and defense contractor that was founded in 1932], you worked on many interesting and historically relevant projects. One that stuck out to me was the scouting device for NASA to report on moon landing sites, which allowed Surveyor 1 to reach the moon and land intact. I was wondering what it was like to be at Hughes watching the subfeed showing the command center at the Jet Propulsion Lab at that moment.

NORWOOD: It was very exciting. It was great.

Of course, JPL [NASA's Jet Propulsion Laboratory, a federally funded research and development center primarily researching planetary robotic spacecraft] was very dominant around town. We won the Surveyor [design contest], which was the moon first moon lander, competitively. TRW [a U.S. aerospace and automotive company eventually bought by Northrup Grumman] was our main competitor.

We built models of our own designs, and they turned out to be better. It had to be a soft landing, so it was very important to focus on the landing design. We had three beams that were pointed downward. They were adjustable, so that with feedback loops you could keep the thing level. We landed about three of them on various places on the moon. One of them we liked in particular because it was on an essentially flat area, so that was the area we chose [for a future moon landing].

BUTTREY: That's incredible.

NORWOOD: It was fun.

BUTTREY: When you say it was exciting to watch these, was it also a relief?

NORWOOD: Oh, boy, yes. I can remember going out the night before at my house in Mandeville Canyon, in Los Angeles. It was a full moon. I remember looking up and saying, "that's my moon." I was very young!

BUTTREY: How young were you?

NORWOOD: When? it was '66-ish right? And I was born in '27, so 39 or something like that.

BUTTREY: That is an incredible accomplishment for any age.

NORWOOD: Well, Hughes was very excited, I can tell you. We had a lot of very good people at Hughes because they gave everyone his freedom to do what he liked. Then [in 1985] we were purchased by General Motors, and they wrecked it.

Before the GM purchase, we [at Hughes] had quite a few people from JPL. It was a buyer's market in those days. There was a lot more need than really good people available.

BUTTREY: At Hughes, if I'm not mistaken, you progressed to leadership roles where you were managing large teams. What was it like to manage so many people? Did you have a particular method or style?

NORWOOD: I didn't really like managerial roles, so I avoided them. I usually would try to be staff. As soon as you get into the managerial roles, you lose track of being able to do anything in the engineering sense, so I didn't like it.

BUTTREY: You've gotten a lot of press in recent years for your work on the Landsat satellites, for good reason. Just to rehash some of the details: Your innovative multispectral scanner (MSS) design [a digital image capture technique with better precision than visual analysis of analog images; it allows for the identification of the material being imaged] currently allows for countless applications from the scanned images of Earth. What did the design process look like?

NORWOOD: The idea just sort of grew. In airplanes [at the time], they would just fly a full spectrometer, which we couldn't do [due to space constraints]. We had to break it up into bands in order to get enough energy returned. What I had to do was try to get useful data with fat bands, but many fewer of them.

That's why I was always eager to use the best detectors, the latest that were available. We were always on the leading edge of detector research.

BUTTREY: What did people at NASA think about the banging mirror design of your MSS? I know that it was unconventional.

NORWOOD: They were skeptical as could be. Because at first, they didn't really understand it, but the idea of anything in air making that much noise was not very satisfying. There are things you can do in space that you can't do either in a gravitational field or an atmospheric field. So it capitalizes on the fact that it's weightless and airless.

BUTTREY: That sounds like a great design.

NORWOOD: It worked.

BUTTREY: When designing the MSS prototype to show NASA, I found it notable that you sought to conduct a user base design study of different resource managers at USGS, so that you knew the data would be something that people would actually find useful. How did you think to contact those different resource managers when others were not doing the same?

NORWOOD: Well, what was interesting to me was the pride with which the users came forth and said, "Oh, we figure we can do this or that." And since they were in

their specialty fields like geology, or the Purdue people were agriculture people, they thought of things that never would have occurred to me. They had some background in it because they had done a lot of this sort of thing with aircraft. But aircraft doesn't have the advantage of the two factors that I mentioned. For one thing, the direction of the plane that had the sensor on kept shifting around, so there had to be a lot of oversight on that. And not being in a vacuum made calibration very hard.

BUTTREY: Were these people coming forward with different applications of the data before your first design, or after data had already been captured from space?

NORWOOD: Oh, yes, yes—before. I solicited it because I knew about the fact they had been picking up air data from aircraft. And so it was a natural thing to go to the people like the Purdue people in Indiana, and they were probably the most experienced in using the data. They were just delighted that they didn't have to do all the machinations to get to the data uniform.

Space is a very good place to put such a sensor, it turns out. Even though it is so darn far away.

BUTTREY: Did any applications or analysis of the data surprise you? In other words, did anyone use the data you collected in unexpected ways?

NORWOOD: Oh, I guess. Not the method of using the data, but the fact that they felt the data was worth collecting. There is an interesting aside: Shortly after we launched, the Russians had a crop failure. We didn't know about that in this country. And had we known, as a little adversary, we would have probably charged them more money.

I found the Russians very interesting to talk to, by the way.

BUTTREY: Why was that?

NORWOOD: Well, they were not any good at miniaturizing in those days. I remember one elderly [Russian] man who had a house on the Caspian. He said to me, “We couldn't build anything like this in space—I mean, to work in space.” The approach was to encapsulate great big pieces of equipment, making the environment in their spacecraft. Sputnik was like this, by the way—like the lab on the ground.

BUTTREY: Do you think that the U.S. approach represented a difference in culture in the space community?

NORWOOD: Well, we were very advanced in miniaturization and that sort of thing.

BUTTREY: It's so impressive that some of your early designs were implemented many years later. It speaks to their ingenuity.

NORWOOD: The push-broom. [A satellite scanner design in which thousands of detectors sample every line in the swath being imaged, without a need for mirrors.]

BUTTREY: Yes, I was referencing the push-broom's launch in 2013. [Landsat 8 implemented the push-broom design for the first time]

NORWOOD: I would have loved to flown a push-broom to start with, but that was completely out of the question. They couldn't make that [detector] array that would cover the whole swath [of Earth].

BUTTREY: Would you mind briefly describing the push-broom design?

NORWOOD: Well, we figured we could use 100-foot spot size on the ground [to image]. Initially, the design team just thought they would have a device that rocked sinusoidally, but if you think about that, there are times with very long dwell times. Then when you're doing your transitions from plus to minus, the windows are very narrow. [With that design] you don't get much energy in there. The main advantage to having the sun synchronous orbit is that you do get energy in each spot that's usable if you do it right. But you have to sacrifice a lot in using just a few bands instead of all the frequency that's available.

In other words, you have to do with many, many fewer components, but you had the advantage of always having the same sun angle, so the data were very similar day to day. They were in a similar range.

BUTTREY: So did it take until 2013 for this original push broom design to be built because the technology wasn't there yet?

NORWOOD: Correct.

I've tried to get a chance to talk to somebody who's done it. You have to calibrate those sensors—the amount of light in, and the signal out. And you can imagine that early on, the detectors weren't at all alike, so you'd have one detector that would subsist on very little reflected energy and another one required a lot.

That [technology] had to be developed to the point where they were in the same range, at least. There's an awful lot of detectors across there. As I said, I would love to talk to somebody and find out how hard it was to calibrate it. We had to put the detectors in an airless chamber in order to get those returns, in order to know what the amplification of the circuits behind each detector was.

BUTTREY: I hope that you do get the chance to talk to someone who's implemented that.

NORWOOD: I don't know where they have their chambers. Do they have them in New Jersey?

BUTTREY: I don't know.

NORWOOD: I don't know either. But you spend an awful lot of time with that, your device, and they're big. It's a big piece of equipment sitting in a vacuum chamber, and you also have to have a known source in order to tell what the detector is going to come out with.

So it must have been a real job. And since I've sat for days outside the darkroom with only 24 detectors, I'm quite aware. Thousands across, sounds to me, formidable.

BUTTREY: To me, as well.

NORWOOD: There was one thing that I found sort of amusing, when I first started to do this, the logical place for me to get my detectors was our bunch in Santa Barbara and the people in Culver City in two different divisions.

One was responsible for the scan mirror, which is a whole tale in itself, and the other for the telescope. And my management said, "You must be insane. You can't get three groups to work together." They all seemed like nice people to me, so I said, "Yes, you can."

BUTTREY: Were you the one to facilitate that working together?

NORWOOD: Yes, I had to tie it together. Because people in those various areas were so specialized, they didn't understand the complete instrument.

BUTTREY: That sounds difficult, translating between different disciplines.

NORWOOD: Yes.

BUTTREY: What was it like to see the first MSS data from space translated into images?

NORWOOD: Oh, it was very exciting. We launched from Vandenberg Air Force Base [north of Santa Barbara, California, now called Vandenberg Space Force Base], as that's the only way you can get into near polar orbits. I was actually interviewed very briefly on the radio. A woman who lived near my friend came out and said, “I heard your lady.” She was all excited.

BUTTREY: Understandably.

NORWOOD: So was I.

BUTTREY: I'd imagine that kind of interview would get people, and maybe especially young girls, interested in space and in science. I know that when I saw or heard interviews like that growing up, it did make me interested in astronomy or science, or biology, whatever the topic was.

Something I've been wondering about is how you and your husband managed having three kids while you were both working. I know how intensive your job was. Did you have some sort of childcare, or how else did you make that work?

NORWOOD: Well, I was very lucky. I hired a woman when my first child was a baby. She was a Papago Indian. Are you aware of the Papago tribe down in Arizona and New Mexico? It's a huge reservation.

BUTTREY: I don't think I've heard their name before.

NORWOOD: Their Indian [nation] name is Tohono O’odham. They were called Papago Indians because that's what the Mexican people could handle more easily than the Indian name.

Anyhow, I hired her [Lena]. Her husband was from another tribe, and then he wandered away. She worked for me until '78, and I hired her back when my now 65-year-old daughter was one—just a babe in arms. So she effectively worked for me almost all of my children's childhood, which was great. She was intelligent and a little stern, but that's all right. I could spoil them.

BUTTREY: Did she live with you?

NORWOOD: She did not live with me. She lived in Inglewood, and I was in what was called Westchester here. She came in the bus every morning. If she were late, it

could be a real annoyance. I would have to wait around for her, but she very rarely was late.

I think the only dramatic time was when there was an accident and the bus couldn't get through. But Hughes was very good in allowing people to have their own hours, and as well as picking their own jobs.

BUTTREY: That's very good to hear.

NORWOOD: It was a great place to work. It's all gone now.

BUTTREY: What was your husband's job at this time?

NORWOOD: Similar, he was a Stanford man. Older than I.

BUTTREY: How did you negotiate where your jobs would be?

NORWOOD: I got disrupted twice because my then-husband didn't like his job. I left the Signal Corps Labs because of him. He was a Californian. We came here to Sylvania, up north, in Mountain View. And then he got disgruntled with that, and I decided to come to a place like L.A., where there were a lot of companies doing my kind of work. So I didn't move around here much. I moved to various different Hughes labs, but I stuck with Hughes for 37 years.

BUTTREY: It sounds like Hughes was a great niche for you.

NORWOOD: Right. Yeah, it was a very good place to work.

BUTTREY: If you don't mind taking a step back, what impact do you think your MIT experiences have had on your life and career?

NORWOOD: The only thing I can think of is that we, women, were in such a minority. There were only 11 or so—11 women in my entering clas—and so we were sort of all odd to start with.

BUTTREY: Did being one of so few women at MIT prepare you for being one of the only women at Hughes and other places you worked?

NORWOOD: It probably did. I didn't think about it at the time, but I was accustomed to being in a minority. My fellow students found us a little bit odd.

BUTTREY: From the *Tech Review* article, I also got the impression that the fact that you had an MIT degree was surprising to many of your colleagues later on. Was that the case?

NORWOOD: Perhaps. Even though my mother didn't entirely agree with me, I only applied at MIT because I felt that having a name school behind me like that—it was even more of an oddity at that time [to go to MIT]—would be valuable to me. I'm sure I'd get the same education or figure I would, but I felt that having that name [MIT] behind me would be valuable. And I think it was.

BUTTREY: Yes, that's interesting, and I think a lot of foresight to have as a high schooler applying to college.

NORWOOD: Well, of course, in high school, I was also a real minority. I was the only woman taking trigonometry, I remember.

I guess I've mentioned, I went to 11 grammar schools and five high schools in three countries. So I was accustomed to flipping around. I remember that in those days, everyone in science had to take solid geometry. When I signed up for solid geometry, the teacher came to me and said, "You don't have to come to class. You understand all this sort of thing. So don't worry about it."

BUTTREY: Did you still go?

NORWOOD: No, I didn't. It was kind of dull. Solid geometry is, after all, just obvious. So I didn't waste much time on it. He gave me what was called an H, I think, for honors. I may be getting that mixed up with MIT.

MIT had funny grades then, and I don't know if they still do, but they had Cs and Ds, and then they'd give out roughly one "H" for "Honors" for several sections. It was a weird grading system, different from every place else in the country. Do they now use the standard A, B, C, D, E, F, G? Do you know?

BUTTREY: We have A, B, C, D, F—or you can also take a class on pass or fail.

NORWOOD: I see.

BUTTREY: How have you spent your time since your retirement? I've heard that you have quite a few hobbies, like birdwatching and driving sports cars.

NORWOOD: Mainly clocks. I took up clocks toward the end of my career, and I find them fascinating. Antique clocks, mostly. They've got three aspects. There's the artistic, which I'm not, but that's part of clock making. And then the mechanisms, which I particularly like. And there's the history, which I find interesting. And I find the clock people very nice.

BUTTREY: Do you collect the clocks and then work on the mechanisms?

NORWOOD: Right. We have a very strong association, the American Association of Watch and Clock Makers. That's all amateur; that's not commercial. In fact, clocks are going out of fashion, as you may be aware of. I still wear a wristwatch, but a lot of people don't. They have a little computer calculator in their pocket.

BUTTREY: How many clocks do you own? And do you have a favorite that you've worked on?

NORWOOD: Well, I have about 50 that are going, and then I have bits and pieces of some. As I said, I very much enjoy our [association's] meetings. We would meet about eight months of the year. I find that the people are very generous and very helpful.

BUTTREY: That sounds like such a nice community to be a part of.

Have I heard correctly that you're also still going to satellite launches at Vandenberg?

NORWOOD: I've only gone to launches of Landsat.

I did a design before the multispectral scanner, another multispectral sensor that was never built, which was an ocean color mapper. It was a very easy design. Because the spot sizes were so big, one had a lot of energy to play with in each band.

I've never met anyone who's used the darn thing, but the idea there was to map the oceans of the world: what kind of life was in each area, and the temperatures—such as the Gulf Stream.

BUTTREY: Oh, that sounds like very interesting data.

NORWOOD: Yes, it was. I don't think I ever got enough money from NASA or anyplace else to build one, but it's an easy satellite from the point of view of having enough energy for each spot to be able to do all the things that you want to.

BUTTREY: Is that ocean satellite something you'd like to see built in the near future?

NORWOOD: No, I don't have much of a feeling about it. It was such a natural at the time, but I designed it a long time ago. Before the MSS.

BUTTREY: Oh, wow, very early in your career.

When you go to the Landsat launches, do people know who you are?

NORWOOD: Well, the one most recently [September 27, 2021], which is quite a while ago now, there were people there who had been using the data and they seemed to be excited to meet the designer.

I've only been to the first launch, which was in '72, and then this later one, so I haven't been to many launches. The launch itself is sort of interesting, but it's days before they get it where they want it, to use it. It is the thing you see in newsreels all the time: just the rocket sitting there and shaking and going off. It's the least exciting part of getting into orbit.

BUTTREY: I wouldn't have guessed that, but it does make sense.

As we wrap up, is there anything about your time at MIT, career, or life in general that we haven't covered that you'd like to talk about?

NORWOOD: I really can't think of anything that I haven't commented on already. I really did like MIT. I liked the people. I liked everything about it.

BUTTREY: That's so good to hear.

NORWOOD: One thing is that I took a reading course with Dirk Struik. Do you know who he is? [Dutch-born American member of MIT's Mathematics faculty from 1928 until 1960; famous for his contributions to mathematics and the history of mathematics]

BUTTREY: Oh, yes—

NORWOOD: He retired and died, oh, 20 years ago maybe. [Professor Struik died in 2000] Anyhow, I had quite a few courses from him, including a reading course in mathematical logic. It was fun.

BUTTREY: What was he like as a professor?

NORWOOD: Oh, superb.

BUTTREY: Well, thank you so much for taking time for this oral history project. It's wonderful to have had a chance to speak with you. I've really enjoyed hearing about your life firsthand—you've had such an incredible life.

NORWOOD: Well, I've been very lucky, I think. It was nice to talk to you.