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GARY E. LOFGREN
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is April 22nd, 2009. This interview with Dr. Gary Lofgren is being conducted for the Johnson Space Center Oral History Project in Houston. Jennifer Ross-Nazzal is the interviewer, and she is assisted by Rebecca Wright. Thanks again for joining us this afternoon. We appreciate it.

LOFGREN: You're welcome.

ROSS-NAZZAL: I know your schedule is busy. I thought we'd begin today by asking about your interest in science as a child.

LOFGREN: One of the interesting things that I remember, it probably stands out. When I family moved from Minnesota to California, my dad was following the jobs right after the Korean War. On the way, we drove and went through the Badlands in South Dakota, through Yellowstone, et cetera. I started collecting rocks the whole way. I think my life was preordained from that moment. I was going to be a geologist. I didn't know that at that time, but it's a funny story. I did that as a 12 year old, and then in high school I remember in the senior English class we had to write a paper on a career. One of the term papers was on a career. You go to the library, you look through all these pamphlets. I saw a pamphlet on geology. I said, "Hm." Opened it up.

Here's a guy riding horseback through the mountains. I thought, "Ah, that's cool." So I wrote it about that.

Then I got a scholarship to Stanford [University, Stanford, California], and I was sitting in an auditorium. They were telling all us freshmen that you can choose a major now, or you can become general studies, or it's up to you. If you have a major, go ahead, and declare it. You can always change. So I thought, "Hm." I wrote geology in there. I've been a geologist ever since.

ROSS-NAZZAL: It just kind of stuck.

LOFGREN: I never anticipated going on for a PhD. I just wound up going that way. The concept of research really interested me, and geology fascinated me. So that's where I wound up.

ROSS-NAZZAL: Was there any focus that you were particularly interested in once you started graduate school?

LOFGREN: Yes. I went to Dartmouth [College, Hanover, New Hampshire] for a master's degree, and then came back to Stanford for my doctorate. I got involved with a very interesting fellow at Dartmouth who was studying, of all things, the crystallization of sea ice. My tenure at Dartmouth, I was a research associate for this person, Willy [Wilford F.] Weeks. So I got involved in this. My project, which I turned into a master's thesis, which is what you usually do, was to understand how sea ice crystallizes. Sea ice does a particular thing when it crystallizes. It incorporates some of the brine, some of the salt in the seawater into the ice, but not actually into the crystal structure, because the ice itself will just reject all other foreign substances. It crystallizes as a very pure thing, but it would trap bubbles of concentrated brine from the sea ice. Depending on how fast it grows, it traps more or less of that brine. That has direct relationship to its strength.

What they were trying to determine—I was working for this Cold Regions Research and Engineering Laboratory, which is US Army Materiel Command Study of Cold Regions. They wanted to know if they could land an airplane on a sea ice shelf just knowing what the weather conditions were prior to that, and not actually going down there and measuring the strength. So I wound up being part of that project to determine that.

That got me interested in studying crystallization in general. I started applying that to rocks and how rocks crystallize. I was really interested in that aspect of geology, the detective story part rather than—some people study phase diagrams or things like that. I just wasn't interested in that aspect.

Then I came here, and built a laboratory, and continued to do that on lunar samples and meteorites. That's been my primary research focus while I've been here at Space Center.

ROSS-NAZZAL: When you were pursuing your PhD at Stanford, were you working with anyone who was attached with MSC [Manned Spacecraft Center] at that point?

LOFGREN: No. I had very little knowledge of the space program. Although, interestingly enough, again as a term paper, this was in history current-events type of thing, I wrote a paper on the Sputnik and then our first satellite. Although not at that time did I have an interest in the space program. That was just an interesting thing that interested me at the time.

My connection to the space program came as an opportunity. Jack [Harrison H.] Schmitt the astronaut was a good friend of my thesis adviser. [He] was invited to Stanford to give a lecture in this invited lecture series, and he gave a lecture about the Moon and doing geology on the Moon. This was early ’68, like February. At the end of the lecture he said, “NASA is hiring geologists.” At that time, geologist jobs were pretty scarce when I was graduating. I had one interview, and it didn’t work out. So I sent a letter off to NASA, and they invited me down for an interview. Wound up hiring me, and were going to allow me to build this laboratory I wanted to build to study the crystallization of rocks. But I very quickly was put into a group that was getting ready to study lunar samples and were also training astronauts. I had had a lot of field geology even though I had done an experimental type thesis. I had done a lot of field geology at Stanford. So they incorporated me into their group that was supporting the training of astronauts.

So that became something I did for about three years there as I was building this laboratory. I spent a lot of time in training. That turned out to be an incredibly rewarding experience and something that I really found worthwhile and a lot of fun. Obviously, I was part of a large group of people who were training astronauts. It included people like Lee [Leon T.] Silver and Bill [William R.] Muehlberger and Gordy [Gordon A.] Swann. I worked mostly on the Apollo 15 mission, but I did do work with all the [Apollo] 13-17. I worked with all the crews a little bit.

ROSS-NAZZAL: Well, let’s talk about it, since you mentioned training the crews. I understand you started first with a backup crew, with John [W.] Young and Charlie [Charles M.] Duke for Apollo 13.

LOFGREN: Yes. The first time I got tapped to with the 13 crew. We had a trip to Hawaii, which sounds like a great place to go, and it is of course, but it's got some of the best exposed volcanic geology in the world. So it really is a good place to work with astronauts, because the rocks on the surface are very fresh and easy to see and easy to describe. It's a very good place to do training.

I was working with several of the guys here at MSC at the time, and so I went out with them. They needed somebody to work with. At this point we had started to do very mission-oriented training. We had the crews lined up as they were going to go to the Moon. [James A.] Lovell and [Fred W.] Haise were the prime crew. They were trained as a team. I was working with Young and Duke, and they were being trained as a team as the backup. We were planning traverses very much like they would do on the Moon. They were doing sample collection in the way that they would do it on the Moon, trying to get ready to learn how to do that.

We became far more sophisticated in the paraphernalia we had to help train astronauts by the time we got to the 15 mission. I can talk about how that improved. But yes, my first experience was working primarily with John and Charlie. They were a fun couple of guys to work with. Pressure was a little less on the backup crew than the prime crew to get ready. So everybody'd have a little more fun. But they really enjoyed learning the geology. They were very attentive and receptive to learning what was going on.

ROSS-NAZZAL: Would you tell us how you came up with planning those traverses and what went into that?

LOFGREN: Other people before me had developed the ideas. The concept, though, was you're going to the Moon. You're going to be at a certain area for four hours. So as a geologist, you'd do your photogeology of the site, the best photos that we had. You would know about where you're going to land, or where your landing target was anyway. So you would go to that area and you would choose interesting geologic features that you could see on the surface. You'd draw a circle around how far they could go. So this is the area that they can move around in. They couldn't get farther from the LM [Lunar Module] than a certain distance, and that sort of thing. So you would pick interesting points, and then you would just say, "Okay, well, we want to collect samples, we want to get samples of the soil, we want some rocks. This looks like an interesting place to do that." We picked three or four places where they could do that hopefully in two hours walking around. They didn't have any vehicle at that time. That didn't happen until Apollo 15.

The amount of area that they could traverse was pretty small. We would pick out spots, and then we would tell them to collect the kinds of samples that were obvious to collect at that site: collect a sample of the soil and a sample of the rocks. We'd already had some rocks back already. [Apollo] 13 was going to go where [Apollo] 14 wound up going, the Descartes area. We suspected that was volcanic. Didn't turn out to be quite right, but we were learning a lot about the impacts that were occurring on the Moon that we didn't really understand very well before we went. A lot more of the surface of the Moon is controlled by large impacts than by volcanism, although there is a significant amount of volcanism. The impacts play a huge role, bigger than we thought.

But that didn't really make any difference. The idea that we were trying to do with the crews was just to let them practice solving geologic problems. You got a station, you're going to go there. You want to make good observations. See what there is there to see and describe it. Then look around and collect a typical rock and maybe a couple of typical rocks. Then if there's an unusual one, you might get one of those. You don't want to focus on all the unusual ones, that's not the game. You want to get what's typical first. That's probably the hardest thing to teach. You wanted to figure out what's typical and get that first, even though some unusual ones might stand out, but you want to get those too.

So we were just teaching them a sampling philosophy. How to roughly identify different kinds of rocks. They weren't geologists, but very bright guys, and they could learn very quickly. That's something I picked up on real quick. These were smart guys and willing to learn and were very teachable.

I guess I went on a couple of trips with 13. There weren't very many. The time period where we started to get to work with the crews was pretty short after they were named and when they were going to fly. So I was on a couple of trips with them.

Then the 13 mission had its problem and didn't get to the lunar surface. I didn't wind up working with 14 very much. In fact, I don't think I went on a single trip with 14. But we got a new boss came in to work at the Space Center who was quite a prominent scientist. He came in to head up the geology group. He was already, at age 40, a member of the National Academy, which is quite an honor.

ROSS-NAZZAL: Who was that?

LOFGREN: That's Paul [W.] Gast. Unfortunately, he died of cancer about three years after he got there. In one of his routine physicals that they do for us here, they found a spot in his lung. He died like two years later. It was really sad because he was a really bright guy.

But anyway, he was the one that assigned me. He said, "I want you to be my eyes and ears for training Apollo 15." I thought, "Whoa, this sounds kind of neat." Gordy Swann was the USGS [United States Geological Survey] lead for Apollo 15. I was imposed upon their team. They looked at me like, "Who's this guy from the Space Center? Does he know anything? Is he just going to be somebody, a klutz, we have to deal with or is he actually going to be useful?" I had enough field geology. I showed them quick enough that I was actually going to be useful, that I could help out.

Lee Silver played a very prominent role with Apollo 15. I had had the experience of working with two very fine field geology professors at Stanford. They have two really good ones. But Lee Silver was every bit as good or better at doing that and was a very impressive guy as a teacher of geology in the field and how to bring out students and get them interested.

Lee had already had a week where he had gone with the crew to the Orocopia Mountains in southern California. It's in the desert sort of in eastern California. He went out there with the prime crew and the backup crews, Dave [David R.] Scott and Jim [James] Irwin and then Dick [Richard F.] Gordon and Jack Schmitt, the backup crews. He was out there with them for a week and that really got them started. Dave Scott was a very motivated guy, and he knew he was going to be on the lunar surface for three long EVAs [Extravehicular Activity]. He understood that he had to know what was going on. He had to have some geologic background, or he was going to look silly. So he was really dedicated to doing this and learning.

I was a rookie there, I didn't set this up, but between Lee Silver and Gordy Swann and Jack Schmitt, they said, "Okay, we're going to do a field trip a month. We're going to be using astronaut time a couple days, maybe three or four days each month." We set up those trips, and I got involved after the first couple. Basically went on every trip after that and became part of the team. It was a team of about 25 people. Not everybody went on a given trip. We might only have 8 or 10 guys on a given trip, but the USGS pool of guys was at least 15 or so people. I can't remember the number exactly, but it seems like that many; that may be a large number.

We would do the same thing we did on 13, only we had more time to do it, obviously. We were going to have like 20 months to do this. We were going to run like before the launch, so we ran like 18 field trips compared to like 3 or 4 for 13, and 14 had 5 or 6. This was a real quantum jump in the amount of training that they were going to get. We probably wouldn't have gotten that many trips except Dave Scott insisted on it. He told his schedulers back home that he was going to do this once a month and that was that. They could work all the other training he needed around that. I'm sure we wouldn't have gotten that kind of time with the crews had not the commander really wanted to do that. So that was evidence of his dedication to doing this.

These field trips were really hard work. That's the thing that really impressed me. We would routinely have 14- to 16-hour days. You're up at the crack of dawn. You're out in the field by 7:00 a.m. You may not get back to the hotel till 7:00 p.m., then you have dinner, then you have another debriefing before you go to bed. So these were long hard days. We would do two, maybe three of those. Usually a couple of those days is all we would do. Then they obviously had travel time to get there and go home.

Except for Hawaii, we were actually out in Hawaii for I think nine or ten days. We ran like three hard days, then we gave the crew a couple days off, and then we ran three more hard days. That was fantastic. That was the trip that turned the corner. They really got good out there, and that was halfway through the training. But we went to a variety of areas.

Apollo 15 was the first mission that was going to go to a much more complex site. The geology we had was at the edge of this big Imbrium Basin, which was a 1,500-kilometer-diameter basin. I think, somewhere in that ballpark. We were going to be landing on the basaltic volcanic rocks that dominated the center of the crater, but we were right next to the mountains at the rim. This was the first chance we were going to have to collect primitive lunar crust. So far, we hadn't really done that. We knew it existed. This was the first time we dared land close to the mountains, that the mission controllers, mission people said, "Okay, we've got really good with this landing thing now. I think we can land near a mountain." That was a big deal, because we came over Hadley Mountain, which was pretty high. I forget exactly how high it was above the mare, but about 11,000 feet, and then plopped down right on the other side of it. Then there was a big little less than one-and-a-half-kilometer-wide valley bounding the other side. It was a rille. We think they're a volcanic feature, but it's still a little open to question. They're probably basically a volcanic feature related to the lava flows, but it's sometimes hard to tell for sure.

So they had to land in this area in between the mountains and the Rille. They had to come over that mountain and plop it right down, which they were able to do. They landed very close to their target place. Let's see. We had two fundamental objectives, which were looking at the volcanic rocks and collecting the pristine primitive lunar crust, the first part of the lunar crust that formed.

In the training, we went to two kinds of sites. We went to volcanic sites like Hawaii and a couple of others. But we also went to sites where they would see the kinds of rocks we expected to find as part of that primitive crust. That's a rock more akin to—people think of granite as a rock that crystallizes deep in the Earth. Well, it's not the technical granite that the geologist thinks of, which has compositional implications. This is a rock that is all particularly one kind of feldspar. It's an anorthosite, which is rich in a calcium aluminum feldspar called plagioclase or anorthite. We went to places where they could look at those kinds of rocks. There was a place in southern California in San Gabriel Mountains. There was a place in northern Minnesota. There's a big complex of anorthosites there. In the San Juan Mountains in Colorado we looked. They weren't anorthosites, but they were granitic plutonic type rocks. We wanted them just to have seen some of those kinds of rocks, because we were hoping that they would get a chance to sample them.

Sure enough, actually they did. People have probably heard of the Genesis Rock. That's the one they found that really was part of that primitive crust. What was rewarding was that Dave recognized what it was immediately when he saw it. He picked it up and looked at it and said, "Well, I can see the twinning in this feldspar. I know what this is. This is what we came for." Some comment like that in the transcript. So everybody was all excited about that. They did an excellent job of sampling.

The things we tried to accomplish in the training were to teach them to be good observers of the geologic landscape. These are guys that are trained test pilots, they're trained to know what's going on around them, to observe what's going on around them. But looking at the rocks and looking at the landscape is a little different thing than they were used to looking at. So we had to teach them how to do that in some kind of systematic way, how to describe it, and also to help them develop a vocabulary that the geologists had in common with them.

Our technique was not to try and change their vocabulary too very much or to give them the full technical vocabulary that a geoscientist would use, but to learn the way they described things. They picked up a bunch of geologic terms over the 18 months they were training, but we made no great effort to insist that they learn all the technical terms for what they were describing. Just let them do it and let them get used to doing it and let them get good at it. Then we would learn the words that they would use and what they mean.

I'll explain in a minute how we did that. So that was a prime thing to teach them, to develop a vocabulary for describing what they were seeing, and to develop that common vocabulary with the scientists. The technique we used I think was really quite good. It did evolve and get better over time. But we would make up these traverses like we did on 13. They were more extensive now, because we knew that they were going to go out on the surface for like eight hours. So we didn't plan an eight-hour traverse, because we couldn't get all that done in a day and do a debriefing as well. But we would plan a four-to-five-hour traverse with several stations. We would set it up very much like it was going to work on the Moon.

We would have the crew going out and collecting rocks. We would have them set up with radios. They would be talking to a couple of geologists who could not see what they were seeing. They were sitting in the "science back room" someplace back near the base of where we started. We also had the CapCom out there, the guy who would be the real-time CapCom for the mission, in this case Joe [Joseph P.] Allen. So he was on all these trips, and he served that function on all of these trips. So he was learning the vocabulary as well. He was learning how they were going to do things and work in the field, because he did every EVA. He was the CapCom for all three of the EVAs. So he had to know what kinds of things they were supposed to be doing.

He would be talking to the crew, and there'd be a couple of geologists sitting there with Joe. They had the same maps the crew had. They'd listen to the crew's descriptions, and then they would make notes on what the crew saw at a given point and a given station. We'd have predetermined stations. They would try to find these stations. They got pretty good at navigating their way around and finding things. They would go and then they would describe it carefully and collect samples. Talk back and forth their geologic observations.

So this would be a four or five-hour exercise. Then we would stop and have a little lunch. Then the geologists who were sitting in that back room would get together with the guys, the crew who were walking out there. We would always have one or two geologists walking with the crew in the field. Lee Silver often did that. I often did that. We would see in real time what they were missing and what they were doing right and doing wrong. But the first thing we would do is walk out with the guys in the back room and let the guys in the back room see what the crew had been describing and then tell the crew how well they did it. How good a picture they got of what they were trying to describe. So that conversation would go on. Then Lee would pipe in and tell them the things that he could see that they missed.

So that was the general technique that was used. We did that over and over again. So doing that, I don't know how many exercises we actually had. It was like 18 field trips. We probably had 40 of these kinds of exercises that we did. I'd have to go back and count them. I don't know the number, but it was a lot. Every one of these 18 trips was at least 1 or 2 traverses, some maybe even 3 or 4. So it was well over 30.

So they had lots of time to do this. That accomplished very well this ability to describe and to communicate with the geologists. These were the geologists who were going to be working with them in the real mission as well. So it allowed the crew to get to know the guys back and forth and develop some rapport with the guys that they knew they were going to be talking to and would be sitting in the back room in the real situation. Joe Allen as well got to learn this whole.

While we couldn't match the geology from the Moon obviously, being on Earth, we would kind of focus the objectives for the field training in the same mode as we had objectives for what we were going to try to accomplish at the Apollo 15 landing site. So while we were doing all this, they were kind of learning what the real objectives were going to be when they went to the Moon, because we would always relate what they were doing here to what they'd be doing on the Moon. So they understood that while it wasn't exactly the same, they understood why we were going to these kinds of sites, and what we were trying to accomplish by having exercises at these sites.

So that gave them just a general feeling for how you do geology and how you can relate. How doing a geologic exercise, while it's not exactly what you're going to do on the Moon, builds that fundamental knowledge base that allows you to do what you need to do when you get there.

The other thing that we did very systematically, we developed specific procedures for them to accomplish the sampling precisely. We had very detailed sampling procedures, the way they would document the samples with their cameras. They had several different kinds of samples that they were supposed to collect. We had rocks obviously. Three-fourths of the samples they brought back were rocks, roughly, and soils. We would collect soils. We also had some special kinds of samples where we had these tubes that we would drive into the soil with a hammer and get a section of the tube in sequence, and not just a shovelful. We would dig trenches and collect a sample maybe 12 inches deep under the surface. Dig a trench maybe 12 inches or so deep, and collect a sample at the bottom, and one time we even took a core from the bottom of a trench rather than from the surface. So we had all these different sampling techniques.

Apollo 15 for the first time carried a whole new sampling device that was conceived of after we went to the Moon and we realized that this would be a good sampling tool. I have to give credit to the engineers who allowed us to develop this sampling device and get it on a mission in pretty short timeframe. But it was what we referred to as a rake. It actually turned out very well-designed. It was like a scoop, but with tines. It wasn't a solid scoop. It had these fairly thick wires, eighth-of-an-inch-diameter wires about a centimeter apart. So that when they dragged this through the soft lunar soil, you'd pick it up, all the soil would fall out, but the rocks bigger than a centimeter would remain in there. Those are the ones that we wanted to collect more of, because we were looking for variety, and we thought the most variety might be in these smaller samples that could have been bounced in from farther away.

That turned out to be a very useful kind of device for sampling. They would practice that, although most terrestrial geology is not suitable for using that tool. The soil gets very hard and crusty, and on the Moon it's not hard and crusty. So you have to have a special place to practice with the rake. We had special procedures for collecting rocks. We would take a particular set of photographs. For collecting soil we would have a particular set of photographs.

In all of their traverses, they would use all of these techniques all the time to collect samples, so that the sampling became just really second nature. They knew how to sample without having to stop and think, "Oh, what do I do now?" It became so ingrained, so automatic that they knew they were going to collect a sample, "This is what I do." They didn't even have to think about it.

They carried a little device that they would set on the ground by their sample. Then they would take a picture looking down Sun with the Sun to their back. Then they would do these cross Sun photos. So we had the set routine. They'd go through the set routine. So that became very much second nature. They had to learn this and get this ingrained so they could think about the geology and not have to think about so much what they were doing. We knew that would be important as well. That worked out very well, too. I've been watching a lot of the video recently, for a reason we can talk about later. But you watch it, and you realize that they had this down. Because Dave would be sitting there describing what he's seeing. He's busy collecting a sample. You can watch him on the TV and you know he's doing it. If you weren't watching the TV, you would think he was just describing and not doing anything else. But he was busy doing the things he needed to do while—he wouldn't stop and concentrate on doing this. He could do that second nature and still be looking around him and describing what he was seeing. That let us know that he really did absorb all that training and really use it well.

Doing those techniques over and over again, I think the guys just got very confident in what they were doing. They felt like they could go up there and do a good job. They knew they could do that. There wasn't any trepidation about saying something. They weren't shy about describing what they were describing because they had the confidence that they could do that.

By that time, too, we had three missions' worth of rocks. I took them in the Lunar Receiving Lab, and showed them rocks, and let them look at the various kinds of rocks that we had collected from the Moon. So they got a feeling for what they really looked like. I think that was very useful. I don't know how many hours we spent doing that, probably eight or ten over a period of months. We would have liked a one-hour, hour-and-a-half session. We had about four or five of those over the months prior to the mission. Let's see. What else can I say about that?

ROSS-NAZZAL: So you had course room instruction as well. Did you offer classes?

LOFGREN: Yes. Once we started this mission-oriented training, we didn't do a lot of classroom training. Most of it was in the field. The sessions with the lunar samples were classroom training. They had the ALSEP [Apollo Lunar Surface Experiments Package] experiments, the Apollo Experiments Package that they deployed on the surface. There was a package, I don't know, of eight or ten experiments that they laid out. At least once, the investigator for a given experiment would come and describe that experiment to the crew. So those were classroom type activities. We didn't practice the deployment of those kinds of experiments on our field trips. Those were usually done either here at the Space Center or in Florida [Kennedy Space Center] prior to launch. Those were done in a controlled environment, because it was just too complicated to carry these complex experiments out into the field and work with them.

So that training was all done in a very special—an environment close to home. So they would be taught about that, and then we would have sessions where we would talk about the mission objectives, especially as we got closer to launch at the Cape [Canaveral, Florida]. I remember going to the Cape and having briefing sessions a couple of evenings after their all day of training. We'd sit down after dinner, and talk about geology, and talk about the traverses they were going to do, and just give them background information. By that time we had laid out very detailed traverses. Gordy Swann's team basically did that. We would work with them and just go over the objectives so that they really understood them, had an overpicture. Obviously, we would give them the details. When they went to a station, we would remind them what they were going to do. Joe would do that. But give them an overview, a good over feeling of what they were going to encounter and what we wanted them to do.

There's another aspect I should talk about a little bit too. For the first time they were going to have a rover, a vehicle, to move around on the surface. We did not have a rover for all of the training [paraphernalia to do all of these] exercises. We could not use a rover. It just wasn't feasible. We didn't have one. In Hawaii, we rented some all-terrain vehicles that we used like a rover. That worked quite well. These open things that you can just sit in. They're not meant to drive on a highway. They really are off-road devices. Those worked well.

The USGS did put together a very good simulation of a lunar rover, which we used. The last exercise they had was at Flagstaff using that rover and communicating back to the real mission control with the real flight controllers. That was like a full-up sim. But a couple other times we used that same rover. We had an exercise in New Mexico near Taos. We were looking at the Rio Grande River Gorge, which was of similar dimensions to this rille I was talking about on Apollo 15, which they were going to look at. This Rio Grande Gorge is full of lava flows like we expected the rille to be full of lava flows. They would be looking across the rille about the same distance they were looking across the Rio Grande Gorge at lava flows. So it was a good chance to just see what lava flows would look like from a distance.

They had a 500-millimeter camera that we decided to use based on the fact that we were doing this thing and a telephoto lens would be very useful. So they practiced using that when we were in New Mexico. The USGS brought the rover from Flagstaff up there, which was a reasonable distance. Still a significant distance, but they were able to bring it up there. We used it there. I think that was the only other time we used—they referred to it as the Grover. I'm not sure—I remember the story but I can't remember it right now how it got its name.

ROSS-NAZZAL: If you do remember, put it in the transcript.

LOFGREN: Yes, I think it was actually named after the guy who helped build it [The Grover], but I can confirm that. So anyway, we did do a number of exercises with a vehicle, but we did not consider that critical to their training.

They definitely needed to learn to work with a vehicle, and how much more distance they could cover with a vehicle, and how to think about describing while they were driving, because working with a vehicle is different than walking on the ground. But they could learn how to observe and how to collect samples in just walking traverses. So I'm going to say that only a third of the traverses during this training period did we have a vehicle, and the other two-thirds—and I could confirm those numbers, but we just did walking traverses, which we felt were perfectly adequate for learning how to observe and learning how to collect samples and developing this common vocabulary.

All those exercises would do all of that. A third of them to work with the rover I think was enough. They got a feeling for how they would work with a vehicle. It's pretty obvious how you work with a vehicle. It doesn't take any great intelligence to figure that you can drive farther between your stations, you make some more observations. But you're still going to do the same number of stations, and once you get off the rover, it's the same thing as when you were doing the walking traverses, so that part doesn't change.

The rover just allows you to go farther and to get more interesting places. That certainly turned out to be true at the 15 site. We wouldn't have gotten to collect the Genesis Rock had we not had the rover. They were going about seven and a half kilometers from the LM to where they collected the Genesis sample. That would have been beyond their walking circle, or right at the limit of it, although they could never get beyond their direct walk back capability.

So the rover turned out to be a real boon for carrying the samples back to the place to have the tools. [A] way to carry the samples back to the LM. The rover was an invaluable tool. The three eight-hour traverses would have been much less science quality without the rover, for sure. That clearly was a critical part of the mission. But I think we got the right mix of working with and without a rover.

ROSS-NAZZAL: The crews, when they went on these field trips, were they just in plain clothes or were they wearing their suits?

LOFGREN: Yes. They did some suit sims [simulations] back in the buildings, where they were working in pressure suits so they got used to how difficult it was to move in these suits and how difficult the gloves were to work with. But they did all that right here at Johnson—at Manned Spacecraft Center or in Florida as they got closer to the missions. But there was no reason to make their life difficult in the field. So no, they worked strictly in shirt sleeves or jackets when they needed them. That worked fine. There was no reason to work in suits all the time, none whatsoever. They had plenty of time in suits to learn what that would be like. It was miserable enough. It was difficult to work in those suits, even on the Moon. It was easier on the Moon than it was on Earth, but it was still difficult. They had to adapt to working with them. They couldn't bend over and pick something up easily. If you've watched the videos, you'll see the special techniques they developed for picking something up they dropped on the ground. It was pretty unique. But everything was in shirt sleeves.

ROSS-NAZZAL: Now I understand you worked in the science room for this mission. Can you tell us about that?

LOFGREN: Well, that's another interesting story. I didn't work in the prime science back room.

ROSS-NAZZAL: Oh, okay.

LOFGREN: I was kind of a rookie. I wasn't part of Gordon Swann's team formally. They only had like 6 guys of the 20 or so people who were involved, or 25 who were involved in the training. Only about six or eight guys were actually in the back room. So that was a pretty exclusive group. But not being there and being here on site during the missions, starting with 14, the group in our science building, there was a group of scientists, and I was involved in training by that time, but most of the other guys just were involved in working in the Lunar Receiving Lab or were here for other reasons. But we had a group of scientists.

We decided to have our own back room. Well, we didn't call it a back room initially. We just decided we wanted to get together as a group. We got the TV piped into that conference room over in Building 31 and just wanted to watch the mission. We had maps. We had the traverse maps laid out on the table so we could follow what they were doing and just listen to them and just enjoy watching the mission, with the TV being an important part of that, particularly with 15.

But on 14 it was interesting. We had our group. We were probably eight or ten people or so sitting in that room. So this was a pretty relaxed environment. There's no pressure. We weren't doing any job. Nobody was asking us questions. So we were able to follow very closely what was going on. As the 14 crew got close to Cone Crater, we realized that the real back room didn't know where they were. They had lost track of exactly where they were, probably under the pressure of doing all this, but we realized exactly where they were. So we managed to get the phone number over there and call them up and tell them what was going on.

So what that did, it was realized having this sort of second group of guys who aren't under pressure to perform in a certain way, they could sit back and watch the mission in a more relaxed manner and get more absorbed, and we wound up being in this other room sort of a place where they could call up and ask questions back and forth. Being there in this more relaxed mode, we might have a little different view or have been able to pay attention in a way that they couldn't, because they were under these real close constraints.

So it worked out that we contributed to the real-time back rooms. There was actually several back rooms. There was a back room for the field geology experiment. There was a back room for all those experiments where the scientists who were doing those experiments, they sat in yet a different room, and so they could be consulted while their experiment was being deployed. If there was a question, they were handy there to answer questions. There was a similar back room for the experiments that were on the Command Module that was circling the Moon. There was two or three science experiments going on in there. So there was a back room for those people. The orbital science around the Moon, the ALSEP package, the surface experiments, and for the geology experiment, for the traverse planning. All those worked in a similar way. But with the other two, the experiment ones were more focused for particular guys when their experiment was deployed. That's when they were on tap. But there were a lot of people involved in this.

Then after the missions were over, the team wound up over in the LRL [Lunar Receiving Laboratory] working with the samples. Curation people were documenting the samples, numbering them, weighing them, doing all the kinds of things you do to curate the samples. But the field geology team was over there wanting to put those samples back into the context, developing little mini geologic maps for each station that the crew went to. One of the guys spent basically his whole career trying to determine the surface orientation of all the samples where we got good pictures. He would take the rock and go to those pictures and figure out which part of the rock was facing up. This actually was a fairly important thing to learn, because scientists who study the Sun wanted to study the penetration of the solar cosmic rays from the Sun into these rocks. They wanted to know exactly how that rock was sitting on the surface.

Eventually we got smart enough to figure out through studying certain short-lived isotopes how long that rock had been sitting on the surface, how many million years that rock had been sitting there. While these rocks were anywhere between 3 and 4 billion years old, they had actually crystallized from the lava 3 or 4 billion years ago, most of them had only been sitting on the surface for a few million years, a very small fraction of that time. So the surface was constantly being bombarded by meteorites and the new rocks would be bounced up on the surface at some point. The rocks that were on the surface when we went there, most of them had been exposed for less than 200 million years at the most, and that's a small fraction of 4 billion. So that surface, while static in many respects, was still a dynamic surface, which was still constantly being impacted.

ROSS-NAZZAL: Tell us about your recollection of hearing that they had found the Genesis Rock at that point. What was the feeling in the room?

LOFGREN: Well, it was wow! The enthusiasm that Dave had, which was clear when you were listening, was just—everybody was "Whoa, yes." They were excited. We had had lots of lavas. We knew we were collecting more lavas on 15 the mission; they were describing them. On the first EVA we went to the front. The LM landed, like I said, about six kilometers from this portion of the mountain that came down to the mare surface. We couldn't get up on top of Mount Hadley, that was way too big and too far away. There was this ridge that came down off of Mount Hadley and actually was terminated at the rille that was the target place to try and find some of this primitive crust.

The first EVA, we went down right along the edge of the rille down to this ridge, but didn't really find anything that was obviously primitive crust. The rocks looked a little different. We were getting breccias. We weren't getting basaltic rocks. Obviously these breccias were part of the impact process. We expected to find the primitive crustal rocks as part of breccias most likely. We got a few breccias. But there weren't many rocks at all. This was a site that was just very pulverized and didn't collect a lot of rocks.

So we were really edgy. We were thinking, "Well, we may not find anything." This was disappointing, what we found at this station number two on the first EVA. So we were apprehensive. The second EVA's job was to go back to that front farther away from the rille and up a little higher. We knew we had one more chance to meet that objective. So they got up 100 meters or 100 some odd—100 meters or a little more above the mare plain. The rover climbed right up there pretty well. It got in some pretty steep slopes actually. Between the two stations they had out there, the slope was about 15 degrees. That doesn't sound like much, but just think that the steepest roads on a mountain is only like seven degrees, and some of those can seem pretty steep. If you're driving up a slope that's 15 degrees, you would think you were driving up a steep slope in a car. They were driving up a steep slope in a rover, and they got out of the rover at one point, and the rover started to slip back down the hill a little bit. So they had to go stabilize it. They didn't want their transportation heading on down the hill.

But the first station on the front had more rocks, but didn't produce any obvious pristine crustal rocks either. So by that time we were getting pretty apprehensive that we were going to get what we came for. Dave finding that piece of anorthosite was probably serendipitous to some degree. We moved over 100 meters or so. They chose to go to another [spot]; we were looking for the Spur Crater, because we were thinking this crater might have ejected some rocks from a little deeper. It wouldn't be just the ones lying on the surface, and it had more rocks around it. We could see that from the photos. So the objective was to get to the Spur Crater. But once you get on the surface, it wasn't so obvious. You could see them in the photographs, but once you're out there on the surface it's not so obvious where they are.

They got up on the front and they stopped and they sampled, which didn't produce anything much that turned out to be interesting. They saw this big boulder off in the distance. They said, "Well, go look at that big boulder." It was a couple of meters. So they drove over there and they collected one sample there, and then they saw the crater that they really wanted to go to they thought. And it was right. It was the crater we wanted them to go to finally. They saw that. They went over there, which was another 50 meters or something from where they were.

That's where they found the anorthosite, the Genesis sample, as probably part of the ejecta from that crater just like we had hoped. But he was wandering around. The first couple samples he picked up were breccias and soil breccias again. Then he just saw something white kind of glint in the Sun. He says, "Well, that white is—we know that what we're looking for is white, so let's go look at that." It was a chunk of rock about a little bigger than the size of a fist or a little bit bigger. It was sitting like up on a pedestal. Actually it was in a breccia. The breccia was beginning to come apart. So this piece of anorthosite was sitting up on top of it, about three or four inches off the surface. He saw it and picked it up, and once he picked it up and looked at it close he realized what it was right away.

So the excitement was just electric at that point. God, thank goodness we're going to find at least one. He picked up a couple other samples at that same station that were breccias, but that had some interesting stuff in them too. Among the fine things that we picked in the rake, we found some other samples that turned out to be important samples at that site. They weren't so obvious. You're scooping up these little rocks in the rake and throwing them in a bag, but you never really look at them. They're small. They're golf ball size, big marble size to golf ball size rocks. They're all covered with dust because they're buried in the dirt, so you can't really tell what they are very well. A few of those turned out to be quite interesting. But clearly we knew we had one really good one. So we were excited about it.

ROSS-NAZZAL: So how soon after they came back did you get a chance to look at those rocks? I found this photo [S71-43203]. I thought maybe you'd like to talk about that, because according to the description you were recording actually their recollections.

LOFGREN: I just wish I knew where that recording was.

ROSS-NAZZAL: And that was another question for you.

LOFGREN: Yes, I remember this very well. In fact, we have a movie of this. There is a 16-millimeter movie of this activity.

ROSS-NAZZAL: Oh, is there? Okay.

LOFGREN: I recently worked with the video people here at JSC, and I got digitized versions of all these movies that were taken in the LRL. Fifteen missions had quite a number of these videos. Sixteen had only four. Seventeen they only did one. I guess even the videographers were losing interest. Unless Dr. [Robert R.] Gilruth was coming over, or Chris [Christopher C.] Kraft was coming over to look at the samples, the video people weren't interested—or I guess they were movies at that time. They weren't videos. They were 16-millimeter movies. They weren't interested unless there was a big shot coming over, I guess. I don't say that in a derogatory way. That's just the way things are.

But yes, that's Jim [James W.] Head there in the picture with me. I guess you got the names her somewhere. That's Dave and Jim. I was recording their comments. I'm sure what I did is I gave that tape to Gordy Swann for the field geology team to work with. I never got it back. Now that I've got the movie, I would love to be able to tie the silent movie to that tape because that would have been possible. But I've never been able to locate [it]. The USGS doesn't know where the—if they have the tape, they don't know where it is.

ROSS-NAZZAL: Oh, what a shame.

LOFGREN: I went through all my tapes. I had a lot of tapes from these field exercises. We would actually tape the field exercises. We went back through them with the crew a little bit and would criticize their comments from the tape as well. We didn't go through every single tape. That was just too much. We didn't have that kind of time back here at the Space Center to do that. But we had a little bit of time, and we did a little bit of that. I've got a whole stack of those tapes. Most of them won't even play anymore, because what? They're 40 years old. Those cassette tapes don't last all that long, and they weren't high-quality tapes to start with. But most of them would actually still play. I'm surprised how well some of them do.

But unfortunately, I didn't find that tape amongst them. So I was very disappointed. But I am going to take these now videos and annotate them a little bit, because they're useful. They have historic value clearly. They have value—they look at processing a little bit. They're some of the few records we have of the actual processing of samples. That's valuable from the curation point of view.

I mentioned that I would say something about working with the surface video. Another thing that I decided to do, and I'm having a little fun going back. I didn't do much with Apollo for many several decades, and now these last couple years I've become the lunar curator. I've been curating lunar samples. But I've also decided to play around with some of this Apollo heritage. So I've gotten the Apollo 15 surface video, and I'm working with a group at the University of Texas at El Paso to take that video and break it up into the stations, put it on a DVD [Digital Video Disc] in such a way that if you want to go look at the collecting of a certain kind of sample at a certain station you can do that. Right now there are tapes available, but the only thing you get is just one continuous stream of video, and you just have to watch it from one end to the other. It's hard to go and find something you want to look at. So the idea is to break this up into stations as little chapters, and even the collections of certain kinds of samples, like a rake sample or a drive tube or collecting the Genesis Rock. That can be an identifiable activity that you can go look at and not have to hunt for hours to find it.

The other thing we're doing, when we brought the samples back to JSC, part of the curation activity was to take high-quality photographs of the rocks. We would take a set of pictures at orthogonal directions, east, west, north, south and then top and bottom, so you'd get like a set of 6 pictures from 90 degrees and top and bottom. Then they also took this complicated set of stereo pairs. If you take pictures at a small angle, depending on the distance, the angle would be defined by the distance you are from what you're taking the picture of, to get a stereo image. You can look at it in a stereo viewer and actually get a stereo view, a three-dimensional view, of the rock. So we would take these sets of pictures at the same different orthogonal directions, only stereo pairs. That was a set of like 40 pictures. Those would always be black-and-white.

Well, there's all these pictures that the photo lab has tucked away safely, not doing anybody any good, because nobody can look at them. So we're going through a project right now to digitize all those to make them readily available. But we're taking those images. When the crew collects a sample, we'll then insert a still that was taken with their Hasselblad camera, which is much higher-quality than the video, so you get a nice view of the rock on the surface, one of those documentation photos that I mentioned that they were taking. We would insert one or two of those. Then we would insert a picture that was taken back here in the lab, a real nice picture of the rock, so they can really see what the rock they just collected looks like. Then there would be a voiceover that describes a little bit about what they're doing. The crew talks in a lot of acronyms and letters, just I guess to abbreviate their conversations. Explain what those were where it was pertinent to collecting samples. So it just makes the video more watchable and more useful. That project will be finished up this summer for the 15 mission. Or by fall, anyway, we'll have a product.

ROSS-NAZZAL: That'll be on your website?

LOFGREN: Well, yes, we're going to insert some of that. We are developing an effort with Google Moon to insert a ton of information at the different landing sites. We're working on the 15 landing site right now. With Google Moon, you can go to that just like Google Earth.

ROSS-NAZZAL: Never heard of it.

LOFGREN: It's not really out there yet. It's still in a beta stage or a formative stage. We're really just getting busy putting information on that version. It's working together with Google. They're providing the base for it. The people out at Ames [Research Center, Moffett Field, California] are setting this up. There's special software that's been developed to make it easier to insert stuff into this. We're using that software now here. I've got a summer intern working on that project right now.

So anyway, you've got this good nice photograph. We would map out the traverses, and then you can blow that up in Google Moon just like you blow up things in Google Earth, and you can find the individual stations, and then there'll be little flags that talk about individual samples, and you can click on one of those flags and it'll show a surface picture of them collecting the sample. It'll show a picture of the rock in the lab. We're going to insert little video clips from this effort we're doing so they can play a little video clip of the guys collecting that rock.

So again, it's an outreach kind of thing, and can be used at many levels obviously. Junior high school kids can look at it and have fun with it. Scientists can look at it and learn a lot from looking at those kinds of things. It'll help them understand the mission. So the content is fairly intensive. It's not really dumbed down. For the scientists, it's useful. The kids will get out of it, they'll see the pictures and they'll see the guys doing stuff, and different kids will get a different amount of benefit from it. I think it's a valuable thing. So all these things are coming together to do many things. It gets what was done out there where people can see it. It documents what was done in a way that's accessible.

This does fall under the knowledge capture thing that we're doing here at the Center. We've gotten funds under that knowledge capture concept to do some of this. I'm very enthusiastic about trying to. We'd like to carry this on and do it for [Apollo] 16 and [Apollo] 17 too. We're going to need a little funding to do that, because it's a lot of time and effort to do this. Students have been doing it, so it's a little less expensive. But it's not a $1 million production. It may be a 100K production, but it's not a $1 million or $2 million production obviously. We'll make a set of DVDs, and beyond that I haven't really thought about how we're going to distribute them. I don't know. Haven't crossed that bridge. We're going to make it, and then it can be used to train astronauts, the current ones.

Just watching the guys, what they had to do to do things on the surface, to maneuver, how they moved around. Most of the astronauts today were kids when these guys were on the Moon and may never have seen this video. Some may have seen excerpts of it, a little bit, but I'm sure some of them have never seen it. I know some of the scientists that get samples have never seen it. I say, "Well, would you like to see this sample collected on the surface?" "What? You mean I can do that? You mean we know that?" It's kind of like amazement, because these scientists were in high school or less when this happened, so some of them don't even know the video exists, amazingly enough. Because there's not been a great effort to put this video out there.

There's this one outfit that has the video, and you can buy a set of DVDs from them on the Web, but again like I say it's just a straight video with no editing, with no cutting it up into chapters much. It's hard to view. I've looked at it. I've tried to look at it. It's hard to look at. The way we've enhanced that video with all the other documentation I think makes it much more valuable and much more watchable and much more of a learning experience. I'm pleased that we're getting somewhere with this. These are ideas I had a couple years ago, and it's nice to see them coming to fruition. So I've gotten renewed into the Apollo heritage in just the last couple three years.

ROSS-NAZZAL: It sounds like a great project.

LOFGREN: I think it is. This other thing that we're doing that I alluded to where we're going to digitize all this, you wouldn't even guess. We've probably got 50,000 pictures we've taken of lunar samples, and we're probably going to digitize about 40,000 of those, somewhere in that ballpark. That's a huge project. I have like 400K to do that over a period of four years from a proposal I submitted to NASA Headquarters [Washington, DC], and they funded it. The photo lab is doing it. We've probably digitized about 10,000 of those 40,000 images. So we reached our first year's objective, actually exceeded a little bit, which is good.

These are high-quality images. The original image is going to be collected at a resolution very comparable to the resolution of the film. So that is a further archive of that image. Obviously they're preserved in the photo lab with their high-quality preservation that they do. They actually freeze the negatives, and then you know their procedure probably. So they preserve them very well. But this is yet another way to preserve them, and also we're going to have compressed JPEGs, which are more easily viewable on our website, so that scientists then can go in and look at not just one picture of the rock they might find in a catalog, but they can look at a rock from every direction. They can look at pictures that document how that rock was subdivided and look close up at some of the subdivided pieces of that rock.

From a science point of view, that gives an incredible amount of information to help them study rocks, request samples in the future, once this becomes available. It'll be a good resource for people who value seeing the pictures. There are some people who analyze rocks who could care less what they look like. There are other guys care very much and want to study the rocks based on what they see. While we have a bunch of pictures over in our collection, you have to come to Houston to see them. They're stuck away in file folders. Trying to look at them would be a monumental effort. It would take weeks to look at a significant number. With them on the Web, you know how quickly you can scan pictures on the Web. So it just makes things so much more accessible.

One of the projects that I have done over recent years is to take all of our catalogs that were paper copies that we distributed to everybody in the world, and with the digital age we want to put those catalogs on our website. But the minute you PDF these things, and if you OCR them at the same time, pictures just become black blobs. You're probably familiar with what happens if you try to do that.

So what we do is take the OCR'ed part, so it's a searchable document, and we substitute high-quality electronic images for the original photographs in the catalog. So we now on our website have electronic versions of these catalogs where all the text is there, but now we have high-quality electronic images there. These are better-quality images than were in the original catalogs, which were just screened black-and-white. Now they can see the color images. They can see them in much higher resolution on our website.

When I was doing that, I'd ask the photo lab for 300 or 400 pictures to go in this catalog, and I'd sit there and I could just scan through the 300 or 400 pictures just to see how they all looked. I just realized how valuable that was to do as a geologist, to sit there and look at these pictures and look at them quickly and easily on your computer screen. I just said, "This is really great to be able to do this." But then I would get frustrated. I'd only have a picture of a rock from one direction. I said, "What's the rest of that rock look like?" I didn't have those pictures. So that's what gave me the idea that we really needed to have all those pictures in electronic versions and make them available. Fortunately enough, other people believed me that they gave me money to do it.

ROSS-NAZZAL: I did want to ask you before we moved on to some other topics, what did you think about the series *From the Earth to the Moon*, especially the episode about Apollo 15?

LOFGREN: As it stood, it was very good. I thought they did an excellent job of capturing the spirit of what we tried to do. I don't think they captured [all of it]. They captured only a fraction of it. They were limited by space and time obviously. For the amount of time they spent on it, they did a good job I thought, but it doesn't tell the full story by any stretch. For a lot of people, the full story would be boring.

But I think the full story is a significant issue as well. Bill [William C.] Phinney, who I think actually has done an oral history, wrote an extensive scholarly book—which they'll never get published as a regular book, it'll be some kind of internal NASA thing, because it's pretty dull—but it documents the astronaut training in great detail, and it's an excellent documentation of the training, but far too dry to become a popular book. But a valuable resource for future ideas about training. I don't even know how that's available. It's at some stage now where they're trying to make it some kind of NASA publication, which it hasn't gotten quite there yet. I've got a text of it because I worked with Bill very closely. He was my boss when we were doing all this training. He retired a decade ago, I guess, or something or even a little more now. So he was writing this in retirement.

ROSS-NAZZAL: Is there anything that you wanted to talk about in terms of Apollo 16 and 17? Did things change very much?

LOFGREN: The training didn't change much. It got a little bit better, more sophisticated, but it was fundamentally the same. I was involved in three or four trips on [Apollo] 16 and three or four on 17. I was not one of the main guys, but I did help out on a few of the field trips that I helped organize. Again, Jack was involved again in 17 obviously. Gene [Eugene A.] Cernan wound up working with him rather than Dick Gordon. But no, it didn't change.

The mission objectives changed. Sixteen went to a very different kind of site. It's an interesting story there. It's probably somewhere in this oral history already. But I'm sure Bill Muehlberger talked about it. But I'll talk about it.

ROSS-NAZZAL: Please do.

LOFGREN: The intelligence about the 16 site was that this was fundamentally a volcanic site. Looking at the site, from the photographs we had, they figured it was some kind of lava flows or lava ash flows that we see here on Earth. They figured that's what it was. This was back when we still thought most everything on the Moon was volcanic, and we didn't really appreciate how much the impact process shaped the surface of the Moon.

So they were taught a lot of volcanic geology. But fortunately, they did see the breccias. This good friend of mine was my equivalent on 16, Fred [Friedrich] Horz. Then he took it over. But he and I did a little bit of showing them the rocks, and then Fred went on and did that. It's a good thing we did that.

When they got up there, there wasn't a volcanic rock to be found. Not one. It was all impact-generated breccias. The crew recognized that immediately. They weren't on the surface for an hour and they said, "Hey Houston, no volcanic rocks up here." Well, they hadn't gone everywhere yet. "Where we are right now it's all breccias. No volcanic rocks." Guys back at Houston were going, "Wait a minute, no, no, no, they can't be right, that can't be right."

The back room didn't believe them, actually, until the rocks came back, for sure. Some guys believed them, some guys didn't. "No, no, no, that can't be right, we can't be that wrong." But the interesting thing was that their training was good enough that they recognized right away what they were seeing and weren't afraid to say so. They were right. John and Charlie, not a geologist among them, but they learned very well.

Both John and Charlie, I worked with them on 13, and I worked with them a little bit on 16. They were equally enthusiastic bright guys, and they really dug geology. They thought it was fun. They actually found these trips to be relaxing. Even though we worked very very hard, it was a change of pace, a different kind of thing, a different kind of training from the intensive mission-oriented training, spacecraft-oriented training that they were doing. They really enjoyed the trips. I think they learned well partly because they enjoyed them.

But quite frankly there were no quantum leaps in the training from 15 to 17. I think we established a pattern and we used it throughout. Having Jack on the surface on 17 was a benefit, clearly. He certainly made excellent contributions. But if you look at what was collected and what we learned, there were not quantum jumps between the missions, and there wasn't a quantum jump on 17 because Jack was there. Jack may not appreciate my saying that. I only say that because—and I think Jack would agree with this—the timeline was so restrictive that it didn't allow Jack to use his geologic knowledge effectively. His activities were so scripted and the time was so tight that—the orange soil, he recognized right away its significance, and having a geologist there was certainly an advantage. Jack made lots of observations that were really good, but what we accomplished, it wasn't a quantum leap.

Dave and Jim and Charlie and John did very very well. I don't think we lost because we didn't have a geologist at 15 and 16. I don't think we lost anything. The Moon is kind of a funny place. You've got this ubiquitous cover of pulverized lunar material on the surface. We didn't fully appreciate what the surface of the Moon would be like. It's primarily the result of being on an airless body. The significance of that is that whenever a particle impacts the surface of the Moon and there's no atmosphere to slow it down, it impacts the Moon at the full velocity that things go in space. You know how fast the Station goes around? Seventeen thousand miles an hour. These particles are hitting the Moon at 20-30 kilometers per second velocities, many many times the speed of a bullet. That's an incredible impact velocity. So that the surface of the Moon has been pulverized over billions of years.

So that you have this soil or regolith—it's not really a soil, certainly in the classic sense. It has no biota, it has no plant life. Soils have a very strict definition of a soil, has actually an organic component to a soil. Technically it's a regolith, which is just a broken up debris of rock is all that means, and that's what the surface of the Moon is, but it's very very fine-grained. There's nothing on Earth, with the exception of very fine volcanic ash, that's anywhere close to the same grain size, as finely pulverized as the material on the Moon, which presents a problem for mechanical operations.

The lunar dust is a problem for going back to the Moon. It's a problem for moving parts. It's a problem for getting into a habitat and for breathing. So the dust is going to present engineering problems that we have to overcome when we go back. But the surface is so covered with this ubiquitous cover that there are no outcrops. There are no rocks in place in the way they formed geologically. The whole surface is like covered with snow. It's like going out in the mountains, but the mountains are all covered with a layer of snow, and maybe a few rocks are sitting on the surface of that snow, but you can't really see the layers of rock underneath. No place on the Moon did we ever see the original layers, except looking across that rille we saw layers of basalt in the vertical slope of that rille at Apollo 15.

This ubiquitous cover is so complete that it really hinders what a geologist can do. A trained field geologist like Jack was only really able to exercise his powers when there was a couple of huge boulders at Apollo 17. You could see where they had rolled down the mountainside from somewhere high up. There was one particular one where you could just follow the track all the way down to where it was sitting on the surface. We knew that before we went. You could see that on orbital photography. So that became a target to go to. We clearly wanted to see that boulder and sample it.

So Jack got there, and he could see the complex relations in that rock. He could see the different melted parts and pieces of the melted parts penetrating other parts, and he knew how to sample that. He intuitively as a geologist knew exactly how to sample that, what kinds of samples he needed to get to properly document that big boulder.

The other guys probably would have done a reasonable job of that. John and Charlie saw a couple of big boulders on 16 and did a good job of sampling them. But Jack was clearly—that's what he does for a living. So he did an excellent job of doing that. But those were the only times—when you see these big boulders—that you actually could see the relationship between two different kinds of rocks on the Moon in contact with one another, because of this surface being so thoroughly pulverized.

So it's a place where it's difficult to use your geologic talents even if you're a geologist. That's one of the reasons I think that the nongeologic crews, basically you went to places, craters that looked interesting, and all you had were rocks out on the surface that had come out of those craters or were there for some reason, and you went out there and you looked around and you saw what was typical, you collected a few of those, if there were some unusual rocks you collected one or two of those, that's all any geologist could do.

The other crews were trained to do that too, and they could do that very well. Fifteen, that's basically all we could do. There were no huge boulders at 15. There was a couple that were this big [up to one meter] that we sampled, but nothing like at 16 and 17. So you're just reduced to picking out the important rocks that are lying on the surface. That's totally random. The ones that are there are basically random pieces that happen to be on the surface then, happened to be thrown up by the nearest little crater. So you do the best you can with what's there and just try to get a good representation of what's there. I'm sure that those guys, John and Charlie and Dave and Jim, did very well, as well as Jack and Gene did.

So I didn't see quantum leaps in what we learned. But it's partly the way the geology on the Moon is that prevented that from happening. It's frustrating, because we know now that we're going to have a tough time finding true geologic relationships, true pieces of the crust where you can really see it in place like you can on Earth. When mountain-building exposes rocks that are really as they were when they were formed deep in the Earth, and they've just been moved up, and you can see them as layers or as big masses of granite plutons and stuff. You just don't see that on the Moon because of the way its surface is so pulverized.

The one place we probably can see that, if we could ever go there, in some of the bigger craters you do get a central uplift. You get kind of a rebound effect when you get a huge impact, and sometimes you get some of the rocks that are under ground zero will kind of—you get this big impact and a lot of things happen, and then the last thing that you lose is the rocks in the center kind of come up and you get these central peaks in a lot of the craters. Tycho has a central peak. Some of the images that have come out of the Kaguya mission, the Japanese mission, this HD [High Definition]—I don't know if you've seen some of that.

ROSS-NAZZAL: No, I haven't.

LOFGREN: You ought to. It's just incredible. They've got HD cameras up there taking pictures of the Moon. It is just an order of magnitude over anything we have. It's just really spectacular. They're getting lower and lower now and getting even closer and closer to the surface. Jack made the comment after watching some of that. He says, "That's the closest I've ever seen to what I actually saw when I was there." It's just really sharp, really good. When we go back we'll have HD cameras too. It's just that's what's available now. It wasn't available then obviously. But it is spectacular.

So in these central uplift peaks, you can see what looks like layers, and that would be probably the only place where we can go where we can actually see probably outcrops. But again, they're probably going to be displaced from where they formed due to this impact process. But that impact process has just totally modified the surface so that it's very difficult to decipher the geology.

ROSS-NAZZAL: I did want to ask you—talking about Jack. There has been some debate over whether or not MSC was obstructive to science during the Apollo Program. That it was mainly an engineering site. Do you think that that was the case, working out there at that point?

LOFGREN: That's an interesting story, and I'll talk about that a little bit from my own perspective. I have a little bit more limited perspective than Jack, because he was around here longer during that period. I came in '68. Things had begun to move along a little better. Back in the '65-68 timeframe things were changing a lot.

What I discerned, there was a strong disinclination to worry much about geology among a bunch of people. But by the same token there were guys—and I'm not going to name any names, and I don't even remember the names of all the people that I talked to—but there were other guys who clearly understood that if we're going to up there and we're going to spend some time up there, we've got to do something. We proved we can do it. By the time we did [Apollo] 11 and [Apollo] 12, we did a precision landing on 12. We got up there and got back safely. The engineering objectives were largely fulfilled. We went there in a decade. We came back safely that was the original objective.

A lot of the engineers were ready to move on. It was a fight to keep even 17 in the queue, almost canceled that one. Some very prominent scientists fought very hard with Congress and Headquarters to save the 17 mission. It all happened behind the scenes. Some very prominent National Academy world-class scientists went up and banged on the table and said, "You can't do this." They did save the 17 mission. "You can't not send a geologist to the Moon."

ROSS-NAZZAL: Who were those scientists?

LOFGREN: I don't want to say. I can remember a couple of them. I can't remember a couple of the others. Well, I don't know, I can say them I guess. Gerry [Gerald J.] Wasserburg, Bob [Robert M.] Walker, Jim [James R.] Arnold, those are three of the high-stature people in the early program that really got science going on the Moon. These were the guys that had the connections to push NASA to do science. There were people within NASA who were very willing to be pushed. There were people within NASA who were reluctant to be pushed, just as you might expect in any kind of situation. But by the time I came, science was pretty well established. I'm sure Jack experienced, in the earlier '60s, frustration. I think he came in '65 or

'64 when his astronaut crew came on board. I think he very quickly realized, even though he was one of the first assigned to a crew, that science wasn't very prominent.

Jack played a big role in bringing Lee Silver into the program. He realized that there was going to be this quantum jump in surface time, that the crews were going to need training, and that we needed to get it done. The training had not been very extensive up to that point. The missions were so short that it probably wasn't a big deal. But by the time we were going to the J missions with three EVAs on the surface, 20 hours on the surface, this was a quantum jump. The guys really needed to be trained. Jack knew that, and Jack worked very hard in that '66-68 timeframe into '69 and '70 to make sure that training happened.

He brought Lee Silver in. Lee Silver truly an inspirational teacher. The kind of teacher you just did not encounter in college very often. When you're lucky enough to have someone like that, you know it. I never had him as a teacher, but I saw him work with astronauts. I talked to people who were students of his. They say the same thing. So it was a big battle, but it was won by these guys that I mentioned, and a few others. They weren't the only ones. They were three of the more prominent ones. Since they were National Academy people, they had more stature.

So they managed to push enough to get science into the queue. Fortunately, there were enough people within NASA that agreed and were willing to commit to doing it. When I came here in '68, that battle had been pretty much won. I benefited from that. We were going to do these things. We were going to the Moon. We were going to have these J missions. They were going to happen. We were going to do science, and we were going to do a lot of science. So that battle had been won.

But yes, in the early days it was tough. There was this feeling on the part of some people that the engineering objectives were all that needed to happen. I understand that. I can criticize it. I can see their point of view, and I can see why they felt that way. They were engineers. I can understand that we were successful two times and they didn't want to take a chance on not being successful another time. You don't want to push your luck too. There was that attitude. We pushed our luck and were incredibly lucky, I guess.

I think we were incredibly good, but probably with a little bit of luck thrown in too. But you kind of make your own luck to some degree, because they had really good guys. But you look back on things, and we probably were a little lucky, on top of everything else. But they were originally scheduled to go through Apollo 22. It's five missions that were canceled. That's why there's so many spacecraft out there on display. We had the spacecraft. We had the LMs. We had all the hardware. We could have gone. We didn't.

That was disappointing for sure. We had lots more objectives. The scientists had lots more objectives to do. Lots more places on the Moon to go. A lot of those sites are being revisited now as potential places to go. Definitely want to go to the western part of the front side of the Moon. Oceanus Procellarum, where the apparently much younger basalts, probably the youngest basalts on the Moon, are found. We would definitely like to go there. There are other places we definitely want to go. There's lots of science objectives to still accomplish on the Moon.

I give lots of tours to people over in the Lunar Lab. People always ask me, "What did we learn on the Moon?" I get a lot of people who really aren't very knowledgeable. They're here on directors' tours or whatever, and this is one of the places on this tour they're going to do this day, and "Oh, I'm going to see the—oh, okay, I'm going to the Lunar Lab, okay. Well, what happened here?" Some people of course, this is the thing they want to do. Other people, it's just one of the places on the tours. So you get people with varying degrees of interest and knowledge about it. But you invariably get asked the obvious questions. Well, what did we learn? What did we do? What was spectacular?

You try to answer these questions. As a scientist, it was all spectacular. It's hard to pin one thing down and all these kinds of things. But probably one of the most important things we learned from the Moon, and one of the things that's really important today, is what we learned from the Moon is not just about the Moon. The Moon was a very small body. It formed much like the Earth, basically the same process. It had a hot core at one time. It drove the volcanism that we see on the Moon. But being a much smaller body, that internal heat engine dissipated early on so that the Moon never developed the kinds of surface geologic processes like we have on the Earth that totally change and renew the surface of the Earth on a regular basis. Such that the oldest rocks of any physical extent on the Earth are a little over 3 billion years old. All the rocks from prior to that, for the most part, have been destroyed in the natural geologic cycles that occur on Earth. The plate tectonics, the subduction, and welling back up of things. You can find a few minerals, a few isolated rocks, that are older than that. You might hear about them in the news once in a while. They're finding this one little mineral called zircon that are 4.4-billion-year-old zircons. But we don't even know what kind of rocks they formed in exactly.

The point here is that the surface of the Moon is mostly older than 3 billion years. The surface of the Earth is mostly younger than 3 billion years. So the Moon records our early solar system history. We're learning a lot about our solar system history and not just the Moon. That's one of the things that we didn't fully appreciate before we went there. We appreciate it very well now that the early formation of the planets is much better revealed on the Moon than it is on the Earth. It's helped give us greater insight into how the Earth formed, and Mars, and the other terrestrial planets.

So the Moon is very valuable. It's not just going to the Moon, not just learning about the Moon. The Moon also, because it has no atmosphere, because the particles that come from the Sun impinge on the surface and are trapped, the solar wind, the cosmic rays, we learn a lot about the Sun that we can't really do on Earth because the atmosphere gets in the way. Those particles—fortunately they protect us from them. They could be lethal for us if we didn't have the ozone layer, if we didn't have the atmosphere, the cosmic rays could be lethal. We know that. So we're thankful for our atmosphere for lots of reasons. But the Moon doesn't have that. So all those particles, the history of the Sun is recorded on the surface of the Moon. We learn a lot about the Sun by samples we get from the Moon. The Moon has been a resource that goes way beyond just trying to get a few samples from the Moon and learn about the formation about the Moon, which we've done.

Interestingly enough, none of the ideas we had about the formation of the Moon withstood the test of going there. They all were left on the wayside. The current hypothesis is very different. So it's been a real educational experience. There's still more to learn about the solar system history and more about the Moon when we go back. The National Academy recently put out a report laying out all those things that we still need to learn and could learn by going back to the Moon. It's a very nice report. It came out about two years ago. You can get it from the National Academy website. It's about a 100-page paper or something like that. It was a committee that got together, one of the kinds of things that the Academy does all the time with their studies. They get a group of people together and they study the problem, and they come out with a report. They wanted to know was it worth going back to the Moon, what could we learn, and those kinds of questions were answered in that report. It's a very good one. I think it does a good job.

So there are good reasons scientifically for going back. I think that people give that short shrift. We've been there. Why go again? That's easy to say, but there's lots of good reasons for going back if you're willing to listen. There's lots of profitable things we can do there, in addition to the engineering objectives. If we're meant to explore at all the environment we're in, and we want to go beyond the Moon or go further, that's a logical stepping stone. There's all sorts of reasons to talk about it that way too. But just from pure science points of view, there's lots we can learn by going back.

ROSS-NAZZAL: That's great to put on the record. I did want to go back in time. We talked about the training. But one of the questions that I had for you was about Apollo 8. You were here at JSC at the time. What are your recollections of that mission and what you learned from that flight?

LOFGREN: Well, that was the mission that really captured me into the space program, because I had come in like August of '68. I was kind of overwhelmed by this whole operation. It was just kind of whoa, I'm here, what have I come to. I was busy trying to do what I came to do, to build the laboratory that I was supposed to do. But the Apollo 8 mission just really turned me on. It almost caught me off guard. I just wasn't prepared for it. I know there had been missions. So far, they'd all been orbital missions getting ready for Apollo, with taking the LM up there and uncoupling it and getting back and then transferring back and forth and doing the kinds of things they needed to learn how to do to go to the Moon. There had been what, Apollos 9 and 10—I guess one of them was while I was here, one was before, but those missions, they weren't on TV that much. They just didn't capture you like going around the Moon. That was just really—really caught your attention, really just captured me in to where I was and what I could do while I was here, and the opportunities to be here that I could do while I was here. I was starting to get to know the people.

About that time I was starting to—they were talking about getting me involved in training. So I was starting to see things. But seeing it happen on that mission just really solidified everything. This is what it's all about.

ROSS-NAZZAL: Then you started doing some work on Apollo 11. I read that you were training on the saw. Is that correct?

LOFGREN: Yes. I can tell my little story. I don't know how much I said in the *Ask Magazine* or not. But like I said, I came in August of '68. Then it was coming around to '69, and we were getting ready for the mission. It was going to be in July. It was looking like it was really going to happen. Apollo 10 was successful. I guess 9 and 10 actually came after 8. Wonder what I was thinking. So the group that did the training had taken the astronauts to this place in Alaska where they had this volcanic eruption in 1912. It's called Katmai National Monument. It's a very unusual kind of volcanic terrain. They took a crew of astronauts up there. The geologist, while he was there, he worked with the guy from the University of Alaska [Fairbanks]. He wanted to set up a project to study this valley. So they funded the University of Alaska to set up a project to study this. There was supposed to be a NASA person to go up there. Well, he set it up so that he could go back.

ROSS-NAZZAL: Nice place to visit in the summer.

LOFGREN: Yes, don't write that down. But that was obligated to have a NASA person go there. But with Apollo 11 landing during the summer, he didn't want to go. So he says, "Gary, you're going." So I said, "Okay, I'll go to Alaska. That sounds like fun." It was. So I listened to the landing on shortwave radio sitting out in the middle of Katmai National Monument. I was up there for six or eight weeks, camped out in tents on this volcanic deposit. So I got back. I guess I was gone most of July and middle of August. I got back toward the end of August, and I started getting to see some of the samples that went in the LRL and helped describe some of the samples.

Then everybody started getting ready for 12. I wasn't part of the formal LRL crew of people yet. I started doing that later. But I was like unattached or unassigned kind of. So they needed to cut up a bunch of the Apollo 11 samples to go out to scientists who needed samples of a particular size (e.g. a cubic centimeter). I did several of these things that were like three centimeters long and a centimeter square. I cut them on a saw. This guy Wasserburg I mentioned, he had a very high-powered technical guy that he worked with who could build almost anything. He was a master machinist and capable of virtually building anything.

They designed a saw. We didn't want to contaminate the rocks with any kind of liquid. The way you cut rocks is you use water or some kind of liquid as a coolant for the blade, or the blade gets too hot, and it gets the rocks hot, and all these problems. You really don't cut rocks dry. There was no good way to do it. So he and his technician tried to develop a saw where we could cut rocks dry reasonably efficiently. Any time you use any kind of device to saw rocks, you contaminate them a little bit, but we had to saw them up. We had to do some sawing, period. We had to make that compromise.

So they developed a saw which fundamentally had a long wire, a 100-foot-long piece of wire, that would wind up on this big spool. It would unwind from the spool, go across the thing and then wind up on the spool again, and it would stop and go back the other way, 100 feet of wire going each way. The wire was impregnated with diamonds. So basically that's how you cut big slabs of granite. The slabs of granite that we use for our countertops are cut in a similar way. Only the wire is this big around [demonstrates], and it's 100 feet long, and it's as huge thing. This was a miniature version of that concept. The concept was there. Only that's run with water. This was dry. It goes very slow. So the idea was you cut slower so you could do it dry.

Well, they had to have somebody to do this who wasn't involved in getting ready for the 12 mission. So it was "Gary, we need you to do a job." So Gerry and his tech came to MSC and showed me how to use the saw. For a week I sat there and worked on the saw and practiced and learned how. It was tricky. It wasn't just turn a switch on and do it. You had to learn how to put the wire on the saw. You had to make sure you kept all the tension. It was like running a movie projector, the old movie projectors, you had to keep your loops just the right size or bad things happened. Everything had to be just right for this to work well. So it was a little tricky.

So I had to learn how to do all that. I did. Then they gave me this list of directives. A little list of what I needed to do. For this rock I needed to cut this kind of piece. For this rock I needed to cut that kind of piece. So I sat in this little room for three weeks or four weeks and did nothing but cut Apollo 11 samples on this wire saw to produce the kinds of samples that they needed to allocate to these scientists.

It was boring in a way after a while, watching this thing go back and forth, back and forth. I couldn't leave, because these were valuable samples. I had to stay there with them all the time. I was in a locked room. If I left to go to lunch, somebody else had to be there. I couldn't leave them. So one of the things I did was "Okay, well, I got to sit here and do all this, and while this saw is doing this," I got my tape recorder, which we were using in the training, and I started describing rocks. I sat there with a microscope, and I would sit there, and I recorded several tapes' worth of descriptions of rocks in great detail. I was getting to see them better probably than anybody had seen them yet, because they were looking at them in cabinets and through big thick glass. They all were covered with dust. The dust hadn't been swept off of them yet. I probably got a better look at the whole collection of rocks in four weeks or three weeks, whatever it was. I basically saw every rock and was able to sit there and describe it very carefully, which I wound up putting that in a publication that came out in the first proceedings. Those observations were incorporated into an introduction to the first proceedings, along with a couple other—[Harrison] Jack Schmitt was an author on that.

I tried to get something out of it. I did. So that made it interesting. But I got a really close look at the samples, like I say, like nobody else up to that point had been able to sit there and look at every sample and compare one to another. They were all right there in front of me, not at one time, but very close together. So it was an interesting experience. Really something I didn't expect to do. I kind of groaned when they first wanted me to do it. Once I realized what it really was, I said, "No, this is valuable. This is worth doing. Because I'll get to see the rocks like I never got to see them because I was in Alaska when they first came back."

ROSS-NAZZAL: What a treat for a geologist.

LOFGREN: Yes. That's the way I looked at it. After I realized the opportunity I had, that's the way. Yes, it was a real treat. I treasured that experience. Then I wound up being the test director for Apollo 12 in what we called our—in the first couple of missions we processed some of the samples in a vacuum chamber, but we didn't process them all that way. We had this other line where we processed. We called it the SNAP [Sterile Nitrogen Atmosphere Processing] line. I don't even know what the SNAP stood for. It was an acronym like everything else. But anyway, it was this long cabinet, probably 20 feet long, with like 8 or 10 ports where you could study samples with microscopes and gloves. So the scientists were doing descriptions of samples there systematically. Missions after that, I was involved in that operation in the LRL, after—I wasn't in 11 because I was in Alaska, but after that I was involved in that process of describing the initial samples that came back, of which there were more and more samples with each mission.

ROSS-NAZZAL: I think this might be a good time for us to stop. Then next time we can pick up with that. Do you think that would be good?

LOFGREN: Yes. We can do that. Yes, I'm getting pretty talked out.

[End of interview]