Geointeresting Podcast Transcript

Episode 28: NGA and NASA Map the Moon

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President Kennedy's Rice University speech clip: We choose to go the moon in this decade and do the other things not because they are easy, but because they are hard. Because that goal will serve to organize and measure the best of our energies and skills; because that challenge is one that we're willing to accept, one we are unwilling to postpone, and one we intend to win — and the others, too.

NGA: As President Kennedy delivered this speech to a packed football stadium at Rice University in Houston, the United States was in the midst of an intense space race with the Soviet Union. Following the end of World War II, the United States and the Soviet Union became engaged in an ideological conflict that would last for much of the later 20th century. Kennedy wanted to inspire the American people to support the Apollo mission — to be the first to land a man on the moon. This goal to reach uncharted territory required Americans to push the boundaries of scientific knowledge and live up to their pioneering heritage. Many of those pushing the scientific envelope worked for the Air Force's Aeronautical Chart and Information Center and the Army Map Service, both NGA predecessor organizations. Dr. Gary Weir, NGA's historian, gave us a tour of the lunar exhibit at the NGA museum in Springfield, Virginia, and talked about the nation's excitement of going to the moon and the tradecraft involved in getting there.

Weir: Well, one of the reasons we put this exhibit together, one of the many reasons, not only because the agency supported the lunar and other space-related efforts, was because I grew up in this era. When I was in grade school, I used to get up early in the morning — getting a guy to get up early in the morning to go to school: not likely, right? I would go to the television set and watch the coverage of the old; the Mercury shots. You know, with Alan Shepard and Gus Grissom and John Glenn and the others. The entire country was wrapped up in it. It was like a sort of a low-grade mania. You know, people just were so absolutely enthralled by the possibility, and this sort of covered my entire youth, because that's why I started, and they landed on the moon the summer after I graduated from high school. So that's the span, and just like when you walk into the exhibit, the first thing we offer you is something relative to the lunar experience. The glass negative slides that we have — we have many of them. One of the most beautiful that we have is the slide that shows the moon itself. And these are from the Apollo program. We not only did things on glass, so they can be preserved over time, but because glass is much more stable than celluloid in terms of film. But if you look at the next case as we walk down the aisle here, there's an atlas here. An atlas is very conventional. You can go to the library and see any atlas you want. Well, here we have NGA legacy agencies like Army Map Service, AMS, and ACIC, the Aeronautical Chart and Information Center, producing these atlases. Now the difference between those two organizations was Army Map Service remained with the Army, of course, but ACIC didn't come into being until the early 1950s. And what happens in between? In 1947, the air power arm of the Army is broken off to create the Air Force, so ACIC becomes an Air Force entity working out of St. Louis. So they do become separate, but they have similar roots, and both organizations supported all of the space efforts, including the lunar landing.

NGA: And they were working on it before?

Weir: Yes, they were. They were working on it before, because it's our moon, and having data regarding the moon, its distance, its topography, and everybody sort of thought we wanted to go there at some point. But after 1957, things become remarkably different. The Soviet Union puts Sputnik up into orbit, and it becomes an "I can beat you, and I will not be defeated by you," mentality. So things really began to accelerate at that point.

NGA: Much more aggressive?

Weir: Aggressive isn't the word for it. It was a war. It was a low-grade war. It was part of the Cold War experience. You have to characterize it in that way, but for Americans, it was much more positive than that. Initially, Sputnik was a bit frightening, because they had the capability to put a satellite in orbit. They also had the capability to launch a rocket to reach the American homeland. Of course, we could do the exact same thing, but it didn't make life any easier or less filled with anxiety. But the positive byproduct of this are things like these slides, are things like these atlases that we created that were open to the public to understand. One of the things that came home to me dramatically — I didn't get to see when I was young the kinds of things that ACIC produced or AMS produced, but my mother got Life magazine. She was a subscriber for years, and I remember the Life magazine showing up the first time we actually saw not an artist rendition — a photograph of the entire Earth from the surface of the moon.

Audio clip of Frank Borman, Jim Lovell and William Anders:

Borman: Oh my god, look at that picture over there. There's the Earth coming up. Wow, is that pretty!

Anders: Hey, don't take that. It's not scheduled.

Borman: You got a color film, Jim? Hand me a roll of color, quick.

Lovell: Oh man, that's great.

Borman: Quick!

Lovell: 250 at f:11. Now vary — vary the exposure a little.

Anders: I did. I took two of them.

Lovell: You sure you got it now?

Anders: Yeah, we'll get, we'll — it'll come up again.

Weir: It was the first time anybody in this country or any other country had seen it all in one shot, and there it was on the front of Life magazine — that's what we look like. So the effect of that was quite dramatic, actually. It took us out of ourselves. So it's not only the atlases that we're talking about, but other things as well. If you walk into a library or a school classroom, no matter what the level, you may find atlases, of course, you may find maps like the mosaic maps that we created from individual lunar shots taken by telescope or by satellite, but you'll also have things like a globe. Every classroom has a globe, or in this case, our legacy agencies were producing a globe of the moon based on imagery, based on whatever data that we had up to that point in time. It, the lunar globe that we have here, we have three of them — the original generation. We have one out in St. Louis at our museum there, one in our museum at Springfield, and one that just come back from a long tour of museums down in the southwest. The Denoyer-Geppert Company actually built it. All data and all the artwork was AMS and ACIC, and that's —

NGA: Can you talk about the process?

Weir: Of course. Of course. We have to remember that this — well, for this era, a Commodore 64 would have been advanced; you know, a primitive computer. Personal computers didn't exist, really. Computers were giant mainframes owned by companies and federal government agencies. So everything was done by hand by and large. The photography was taken and developed by hand. The mosaics, of course, were done by people arranging them by hand. We did mosaics for terrestrial purposes, as well as for lunar purposes, so it was something we had done for a very long time. In terms of actually rendering things in a map, sometimes we forget maps are so ubiquitous, that, oh, it's a map, there's no big deal here, right? I could pick it up at the gas station or Barnes & Noble, but if you take a look at it, the color is important, the position is important, the clarity is important, because if it's not there, the map as useless as a tool, and it was intended to be a tool, right? So we have a situation here where we have to include not only the technology, satellite technology, not only people looking through telescopes, not only the people doing the mapping skills, but also the artists who have to render this stuff, so people can see it precisely and accurately. Imagine the moon. How many craters are there on the moon? You count — I don't know. But the point is every single one has got to be outlined properly. The shading's got to be right or else the map or the globe is utterly useless. So all those components come together, and they're all hand done. They're all manual. They're not digital at all. They're analog. So the three goals we have are very important.

NGA: And even airbrushing the photos here of the artists, actually hand airbrushing these.

Weir: Right. Now as you can see, as you walk down the line here, just beyond the globe, we have actually an airbrush in the case. Now people say, “What’s unusual about an airbrush?” An airbrush is a component here that’s absolutely vital, because look at the images above it. Here we have people who are artists, who can take the data and the imagery and render them in such a way that people can actually use them in terms of maps and finding their locations, whether they do it in 3D form or whether they do it flat on a piece of paper and require a 3D rendition as an artist can provide. Now we sort of looked into that in a way. We had images of it. We knew NASA built it from scratch. It was not an NGA product or an ACIC product, but we knew components of it did belong to us. So I called my colleague over at NASA, my fellow historian, Steve Garber, and asked them if they had in their archive the specs for this Simulator, which is long since gone. He said, “Yeah, we’ve got it.” And they found it for us. So I went to a 3D model shop over at Langley and said, “Can you render this for us?” And they did. That's why we have the model in the collection, but the importance of the model being there in the exhibit is the fact that NASA built the whole thing, except for the lunar surface simulations. That was all AMS and ACIC.

NGA: All of their data.

GW: Exactly. All of that data, their artwork, the photography — everything that went into the atlases and the globes went into this as well, although now with 3D, and it's in different scales, because, of course, the simulator is designed to allow the astronauts to see the moon at distance, to see it closer, and then closer and then closer and then closer. So by the time they actually get there, what they're looking at they've already seen it, and many of them commented about the fact that they could, indeed, actually pick out pieces, parts that they were looking at [on the] lunar surface, because they had already discovered it back on earth in the simulator.

NGA: It was so accurate.

Weir: Precisely. It was very accurate, and that's why the skills that we have here — very often, we look at our imagery analysts as the only people who really work with imagery. That’s not so. Our cartographic people have been working with imagery for decades, and they also use photogrammetric techniques to look at size, shape, angle, shadow — all of these things that allow you to make more of a photograph than otherwise might be the case; to derive more from the photograph. So in order to surrender that properly, you have to have a good idea of the spatial aspect of it, the geospatial aspects of it. And so you've got a situation where while NASA built it, we made it effective. So in other words, they could run back and forth across the simulator and see it on a screen in their orbital simulator. But what they were actually seeing was the real moon: the way it actually looked. We found that they had little railway cars with the cameras on them moving at whatever speed they wanted to set them, and they were sending the TV transmission, essentially, to a central box, which would then send it to the simulator that the astronauts are actually sitting in, so they could actually see it. So these guys are probably in a mock-up of the LM, the lunar module, that was actually going to land, and they could see what Neil Armstrong eventually saw when they approached the moon in ‘69, in July of ‘69. But the thing is that we could do all that, because we were experienced cartographers, and we had been for a very long time, because we're working on the moon for very long time — also, because we are used to being lunar supporters of the federal government, because after all, we had supported both the Mercury and the Gemini program, because in the exhibit, you'll also find orbital tracks rendered as maps from both programs, as well as a lot of the satellite imagery that we have made available to the visitors who come into the museum. Well, let me tell a story. My very, very able curator we've just brought on board — she's of an age where she doesn't know this stuff: you know, the excitement that came along with the space program. I asked her to go look at the film “The Right Stuff,” and she laughed. “Are you prescribing films now?” I said, “Sometimes, the film is right. Sometimes, the film is wrong. There's too much drama and all the rest, but the one thing that it does capture is the way the entire idea captured the whole country and really mobilized people to want to get up [at] oh-dark-thirty in the morning to watch the rocket go up, alright? To think that we were actually going beyond our own world was fascinating for people, and it really grew up the entire country.”

NGA: So the country was united toward this common goal: to put a man on the moon. But what was it like to work with the team who did it? Al Anderson is an NGA alumnus who back in the day managed the Army Map Service team that provided mapping and charting support to the lunar mission. So what was your role in that project, and what was it like working on it?

Anderson: Well, let me back up and say that when President Kennedy announced it — the goal of landing a man on the moon before the end of the 1960s and safely returning him to earth — NASA loved the challenge, but it was a huge undertaking. Everything had to be invented. Everything had to be developed. Everything had to be tested and trained: hardware-software procedures, clothing and so forth, everything new. So it was a mad dash to do all that, and, of course, also the lunar surface had to be explored in advance with unmanned vehicles to make sure that the soil wasn't so deep that everything would just sink out of sight — in other words, that you could land there safely and move around, and that was a surveyor series that did that. As part of that overall effort, the Department of Army and Air Force both agreed to provide mapping and charting support for NASA for the lunar program. And in the case of the Army, I was working for the chief of engineers, who had Army staff responsibility for all mapping, charting, surveying activities of the Army worldwide, and the project was given to me to manage, and it was being executed at the Army Map Service, which fell under the chief of engineers. The Air Force turned to, of course, to the Aeronautical Charting Information Center out in St. Louis. The Army Map Service put together a little team of about 14 people — very energetic, bright, eager young men. Anyway, the requirement was to produce small-scale charts and atlases for the general planning purposes and then large-scale maps of the landing sites or the candidate landing sites, of which there were 20, and then also plastic relief maps of them and then relief models for use in their simulators.

NGA: How did you choose the landing sites?

Anderson: NASA did that. After examining the — let me put it here: the imagery was collected from unmanned satellites, which did not return to earth. There was a lunar orbiter series, and I think there was something like five — I think it was five missions, and since this was a pre-digital era in terms of imagery photography, the imagery was processed, developed from film on board the spacecraft and then scanned and radioed back to Earth, where it was reconstituted. So that gave us the first good look at the lunar surface, up fairly close, and that's what they used then in determining where the candidate landing sites would be, and then further analysis from things like the surveyor series resulted in the final selection. So that was the imagery on — I should add also that when we got involved, we found that the process had to be used. The scanning and radioing back to earth and reconstituting was subject to introducing lots of different systematic and nonsystematic errors. So almost at the 11th hour, our people persuaded NASA to put a Réseau plate in — a Réseau plate being little ticks at a specified intervals, which would then; they were tiny ticks, but they would show up on the film or the reconstituted film — and through that we could reconstitute much of the geometry, and that's how we got the accuracy that we did achieve. There was a tremendous sense of urgency. Nothing was routine. Everything was needed today or maybe yesterday and despite all that rush, the Houston people were unfailingly cordial and supportive and appreciative of our efforts, and we never felt like we were being overly pressed, because we all were so committed to this thing and even at the Army Map Services and, I'm sure, the same way at the Air Chart and Information Center out in St. Louis. Even if you weren't directly involved in that project, as these 14 young men were, everyone was excited and proud of having this role that anything those guys needed was — they had just a blank check for whatever they felt they needed, and support was immediate from anybody in those agencies

NGA: A lot of people have talked about not even within the agencies, but just in the country in general, that there was a sense of excitement.

Anderson: Yes, it was a tremendous boost for the country. Here we were. It looked like we were losing the space race. The Soviets were the first ones to get a satellite in orbit. They were the first ones to put a man up in orbit, and, in general, the country was depressed and concerned. So Kennedy's goal was a shot in the arm for the whole country and just rooted attention, which made it even more demanding and that we succeed with that undertaking. Beyond that, we made lots of trips down to Houston, and they were important. To give you a sense, also, of the urgency of the situation, several members of the Army master’s team needed to go down to Houston for a meeting [and] only got as far as Atlanta, and it was fogged in, and no planes were coming in anymore or departing. So they call down to Houston and say, “Sorry, we can't make it.”

NGA: Houston, we have a problem.

Anderson: They said, “Yes, you can,” and NASA arranged for a bus to bring them back to Washington and then take a different flight down there, and they got to their meeting. Nothing was going to get in the way, not even a fog, so that was a [inaudible]. Well, at any rate, we had a lot of interaction with them, including with astronauts. One of the astronauts happened to have a Ph.D. in geology, so he was designated as our main point of contact: Jack Schmidt. Jack was a very fine person to work with, and he did get into the last mission to go up there. He’d been scheduled on Apollo 18. It got scrubbed, and so NASA decided it was so important to get this man up there, a highly professional geologist, that they bumped someone else from 17, trained him how to fly that lunar lander, and he made that mission. So that was — I think I mentioned the lunar maps Army Maps Service. They were large-scale, and some of them were paper maps plasticized with plastic coating so that they would withstand any moisture, whatever — [they] were taken on board, and they helped it guide them when they would go out exploring on the moon, and on one of the last missions, the astronaut, Commander Cernan, just after they got up there, he accidently broke one of the offenders on the Lunar excursion vehicle, the LEV, and they started driving out, and they found out that dust was coming up and clinging to their masks, and they soon wouldn't be able to see. So they radioed down to Houston to explain their problem, and some bright engineer down there said, “Take one of those maps and duct tape, and make your own fender,” and it works so well that, although the landing vehicle, the excursion vehicle, was left up there, they took that fender off, brought it back to earth, and you can see it today in the Air and Space Museum, down in Washington, D.C. So it’s worth a look.

NGA: So the maps were useful in many ways.

Anderson: Yes. So that’s right. We served in anticipated and unanticipated ways.

NGA: I mean, clearly, we’ve continued a lot of this work, and, obviously, with developments in technology and things, they may be doing it different ways now, but we’ve continued this study.

Anderson: Well, of course, it's our only satellite, the natural satellite, and something big we can all we see, and so just the challenge of getting there, the interest in the challenge of it, never goes away, I suppose.

Bruce McCandless: Roger. We copy.

Neil Armstrong: It takes a pretty good little jump.

McCandless: Okay. Neil, we can see you coming down the ladder now.

Armstrong: That's one small step for man, one giant leap for mankind.

NGA: You've probably heard that clip before, but if not, spoiler alert: the United States reached its goal of landing on the moon in 1969, and Neil Armstrong got to say those famous words. But what now? Is there more to explore? How much do we really know about the moon? To get the answers to these and many other questions, we went straight to NASA. Here's Dr. Noah Petro.

Petro: I'm a lunar geologist here at NASA Goddard. I've been here now just over 10 years, the last seven of which have been [as] a civil servant working on studying lunar and planetary processes. But one of the cool things I get to do is I'm the deputy project scientist for the Lunar Reconnaissance Orbiter, which has been orbiting the moon now, continuously, since 2009. It’s the longest-lived lunar orbiting mission of all time in terms of conducting science continuously. It's an incredible experience. It’s been an amazing opportunity and really allows me to continue my passion for studying the moon, which has gone on now my entire professional career and even into my childhood. My father was an engineer who helped build parts for the Apollo program, and so this is sort of in my blood — is studying and working on the moon.

NGA: So why do you think it's so important for us to learn about it; to learn about our moon?

Petro: So that's a great question. I personally — and this is not something I've ever vetted and is not accepted by the community — but if I were to have to explain [to] someone why the moon is so important, I’d say the moon is the eighth continent of the Earth. Geologists study the rocks in the Earth to understand how the Earth works, and we learn a lot about the fundamental processes of geology: mountain-building, erosion, tectonism, all of the wonderful geology that occurs on the Earth. But the moon offers us an opportunity to study processes that are more ubiquitous throughout the solar system: impact cratering, interactions of the space environment at the surfaces of planets, volcanism on planets that don’t have water, or abundant water, volcanism on planets that don’t have plate tectonics, how do planets respond to being gravitationally pulled and tweaked? Which the moon gets pulled and tweaked by the Earth. So the moon is this — I mean it's an extension of the Earth. One of the theories about how the moon formed is that it was debris from an impact into the Earth so that it really is an extension of the Earth quite literally, but, also, I think, metaphorically, it's an extension of the Earth, because it is, and, again, it’s three days away for humans to get to. It's our nearest neighbor in space. It occupies the same, as I call it, corner of the solar system. It is an extension of the Earth, and so by studying it, hopefully, we learn not just about the moon, but also about the Earth as well — in particular, what happened very early in the Earth’s history, which is not recorded well on the Earth’s surface because of erosion and plate tectonics. This great recycling of the crust of the Earth has pretty much erased the record of that earliest history of the solar system, which is so beautifully preserved, although difficult [to] interpret, but preserved on the lunar surface. The Earth’s moon is unique as moons go in the solar system. Compared to the size of the

Earth, it's very large. Think of the moons of Jupiter and Saturn. Those are tiny relative to those enormous planets. Moons of Mars are very small, asteroid-like moons. Our moon is very unique, and I think it's not a too bad coincidence that we have this wonderful object in the night sky but also so close to us that it allows us to really better understand the rules of how planets work.

NGA: Well, we've been studying it for a long time — I mean, even back way before the space race but maybe ramped up a little during the space race. How much has technology evolved, and how much more have we learned, and what more is there to learn?

Anderson: Well, boy, that's a difficult question, but, I mean, it's a good question. So I think, and some folks that have done this: if you were to plot sort of our interpretation of the moon, it's increased as a function of the resolving power of how we can look at the surface of it. Whether you're looking at — whether it was the early telescopes looking at the surface. Oh! Flat areas that might be water! They might be oceans. Let's called them mare. And as our ability to study the surface, the nearside surface, with earth-based telescopes, and then, eventually, you start putting objects flying past them or orbiting them. Then again, the resolving power of being able to study the surface, see the surface up close, has not only increased our understanding of what the surface is like, but also what's going on there. What's happening to the surface? So the moon is a great place for studying, like I said before, all of these processes, but because we have samples from the surface, and we have now such a wealth of remote data, we can really tell really robust stories that no other planet really allows us to do yet.

NGA: Can you talk about some of the legacy data? I mean, do you still use that historic data from way back when?

Anderson: Absolutely. I mean, every picture of the moon is unique. One of the things about looking at pictures of [the] moon, just standard pictures of the moon, whether it's telescopic earth-based images, which the very early lunar maps were generated from, or images from our spacecraft coming down today from the camera, is that depending on the illumination conditions, whether you're looking at a full moon or a crescent moon, and depending on what part of the moon [it] is, different features pop out. And so, I mean, in my mind, you almost always have to go back, especially if you're looking at broad areas, larger areas, and look at the full spectrum of images that we have, whether it's earth-based telescopic or not. Now the data we have from orbit of the moon has obviously got incredible resolution, 50 centimeters per pixel. We can see the boot prints of astronauts. We can see the rover tracks. But you need a broader view as well to really get context, and so we have data that allows us to do that as well, but, I mean, I'm writing, getting ready to give a presentation now, and I went back and found Apollo-era images to use, because those were taken at very specific illumination conditions, and maybe we don't have that illumination geometry from our spacecraft right now. So all of this data comes together to tell a story. Now not everybody goes back and uses that data. Some of it's not easily accessible, but, certainly, it's a great place to start going back to, just the broad regional view of the moon or of an area that we got from the ‘50s and ‘60s.

NGA: And even like you said, just to provide some additional context.

Anderson: Exactly. It’s very valuable to do that.

NGA: Can you talk a little bit about some of the tools or technology that you use? We were talking about the simulator that they built back during the space race and how back then everything had to be done by hand, and it almost looked like something out of a George Lucas film, right? It was huge, and it was built on a track. And so how has the technology evolved, and what kind of visualization tool can you use now?

Anderson: So there's a couple of tools that we use now to really interact with the data that we have — and to start, where those early landing site simulation tools used an image, and OK, we know that the sun was this far above the horizon, so we can estimate how high that mountain might be or how deep that crater might be, so we'll make our simulation that looks like that. There's a certain artistry to that. Well, now we’ve got this topography for the moon, this incredible topographic data set, courtesy of the Lunar Orbiting Laser Altimeter, LOLA, on our space craft, for instance. It gives us the most accurate, topographic map of any planet in our solar system. So from that and higher-resolution topography from our camera, we can sort of take the artistry out of that. We know what shape those craters are. We know what it's going to look like when we get there.

NGA: And you don't have to airbrush it.

Anderson: No airbrushing, right. I mean, the artistry is different. I guess it's the artistry and the interpretation, rather than generation of the product, but when we want to visualize what it will be like to land in someplace or what it will look like to sit on, stand on, the surface, we can do that with the data that we have in hand. And so we've got folks here at Goddard in the Scientific Visualization Studio who can take all that data and make a 3D rendering of what it will be like to be on the surface or flying into the surface. Certainly, the other tools that are really widely used are the geospatial information systems, the GIS systems. [Inaudible] interact with multiple data sets. Early on, when it was just telescopic data, it was just images, basically, but now we've got images, topography, composition, rock abundance. There's a laundry list of layers that we can add just raw data, and then, on top of that, we can place in interpretations of geology, ages and things like that. So, it's a data-rich environment in studying the moon, which is good, because I think when we want to study any place on the moon, you want to have as much information about the properties of the surfaces as you can have.

NGA: What about collaboration? So one thing that NGA has faced over the last few years is that we're not the only game in town when it comes to satellite imagery. So we've been partnering with a lot of different organizations. So who does NASA partner with? Do you work on problems with anyone else? Do you get data from anyone else?

Anderson: Sure. And there's different types of data from the moon. In the last 10 years, there's been orbiters from a number of different countries. Some countries and some missions have their data published and available online very readily, [you can] go and interact with it the same way that all of our data is publicly available, and some data sets are harder to work with.

NGA: So what's been your biggest OMG moment or your biggest discovery that got you really excited?

Anderson: Well, every day there's a different OMG moment.

NGA: Yep, I said it.

Anderson: Yes! Well, it's true, but we have those still, and that's an important thing is we still have those moments where we say, “Whoa, this is really interesting” on the moon. There is this misconception that there are no mysteries left. Oh, we've been to the moon, and so we must know everything. No! No! No! No! We are still learning things about the moon that either contradict 40 years of experience. So we've learned in the last 10 years that there’s water on the moon; that there's water in the moon. For decades, there was this belief that the moon was figuratively bone dry. There was no water on the moon. Turns out that there is water on the moon. There's water in the moon. There's water on the lunar surface. The moon is now literally bone dry, because there’s water in bones. So that was a moment, where was said so — that was hard, because we had drilled in our minds there’s no water on the moon, no water on the moon, and we had this data and now multiple data sets that say, no, there is water on the moon and not just in a few locations — at the polls that are really cold. And so maybe they just store water from passing comets or something like that but that actually water gets implanted on the moon is found deep in the interior of the moon and say that challenges all of our preconceived notions. All the conventional wisdom gets not necessarily thrown out the door, but revisited, and has to be scrubbed. So that was definitely an OMG moment. More recently for me, I've been working with Harrison Schmidt, Jack Schmitt, who walked on the moon on Apollo 17 — he’s the only [one to] just go to the moon — and using the data from LRO [to] re-evaluate his landing site. And so we take a lot of time at looking at the new data, and now they’re finding new things or re-interpreting, again, 45 years’ worth of beliefs about what they did there in December of 1972. And so that's been kind of an OMG moment for me, because not only am I working with someone who walked on the moon and helped train all the previous moonwalkers and was a fundamental part of Apollo, but also realizing that even for a place that we’ve been, we're still making new discoveries. So those two for me have been — one has been kind of a community-wide OMG moment and the other a much more personal moment of reevaluating a place that we've been. And, again, if we're learning new things about a place we’ve been, you can only imagine what we're learning about places we have yet to go.

NGA: What's the atmosphere — sorry, excuse the pun — what’s the atmosphere like? We talked about during the space race, especially, that everybody in the whole country was just so excited and even at NASA, everyone knew: yes, we're going to put a man on the moon, and that’s what we're gonna do. So, I mean, it's good to hear, obviously, you said you're still excited about new. So what's the future? What's the next big thing that we're looking to do?

Anderson: Well, we don’t know yet. The next big thing for me is to make sure that LRO stays active. And now NASA’s not and the international partners, the international space agencies are not the only organizations that want to get to the moon. You’ve got private commercial enterprises that want to get to the moon. My hope is our — when I say “our,” I mean the community’s hope — is that when whichever organization gets to the surface, that science comes along. It's not just: well, we’ve landed. We’ve landed, and we’ve brought this very small instrument to the surface. Again, any time we get to the lunar surface, there's an opportunity to make some really fundamental observations, measurements, that can just enhance our understanding of the moon. The last time the U.S. landed anything on the lunar surface was with Apollo 17 in December of 1972. Again, a lot to learn from getting to the surface, and so that's probably the next big thing: is getting to the surface. There's still a lot left to learn from the lunar orbit as well. It's not to say that there's plenty of that we can learn about just, again, fundamentals of how planets work and interact with the sun from lunar orbit as well. But, yes, the moon is this great template for understanding everything, at least in our solar system and other solar systems in the universe.

NGA: And again, that's why that legacy data is so important.

Anderson: Yes, exactly. Going back to our first global maps of the moon and even just images of the near side and saying “OK, what is the moon like? What's the state of the moon?” is not as easy a question as you’d like it to be, but it's there.

NGA: Do we want to talk about how you still have paper maps?

Anderson: Sure we can talk about — so, I mean, one of the — we can talk about just the working with the —

NGA: Yes.

Anderson: So one of the big changes in going from the early map products is that they were made available broadly in paper form, either printed images or paper maps, large-format paper maps. But if you didn't have it, you had to request that [it be sent] to you, or you had to go and work with it yourself. It was this resource, and so paper maps for decades were the — or books, actual paper books, atlases — were the one way to interact with the data. And, as we've entered this digital world, some of those atlases — I mean, honestly, I have some of those old atlases, still rectified lunar atlas and things like that; they're digital versions of it, but I love to have a paper copy and look at it up close. And there are high-quality scans of some of these, and some of these objects have never been digitized in a satisfactory manner, and that's really important, but now in the digital stage, all our data's digital, it's all recorded, but we do still produce paper maps. The U.S. Geological Survey in particular is the sort of the official map production agency for NASA's maps, for planetary maps, and so we've produced at least two official USGS global maps of the moon, both images and topographic information, and now several scientists are creating geologic maps of smaller areas of the moon using modern data sets, and for us, the ultimate goal is to be able to produce a paper map. Now all of that product is generated digitally. I mean, everything used to be done by hand using tracing paper and the like, but now, in this era of GIS, everything is produced digitally, is available digitally, but there's still this wonderful thing about being able to produce a paper geologic map. I don't know if it's just a historic thing that we all enjoy or if there's something more to it than just the thrill of having something you've made turned into a physical object, and it actually exists in paper form.

NGA: You know, we have a couple of those legacy lunar atlases in our museum as well.

Anderson: Yes, they're really cool. And I think it's important for people of a certain generation to remember that things used to be printed. Those atlases, those early lunar atlases, are — I mean, they're not just collector's items, but they're really important, because it's the archives. It's the record of that work in as best possible form as it exists.

NGA: Is there anything else you want to add?

AA: Something that has astonished me in the last 10 years, really, and, again, this is in the era when LRO's gotten to the moon — we had the LCROSS impact experiment that came to the moon with us — is how, and maybe I'm paying attention more, maybe, as I've gotten older. I've just been more attuned to it, but the moon seems to have established its place in the — gosh, this is going to sound really lofty — in the consciousness of the country. And what I mean by that and not to sound too hoity-toity, but what I mean by that is we just had a full moon on January 1. There's going to be a full moon on January 31 with an eclipse. We had the solar eclipse last year. There's been these wonderful astronomical events that people have gone out and, I think, enjoyed. I see much more about when we have these "super moons," these perigee full moons. That that really generates some interest and excitement; that people pay attention to the moon now. I'm thrilled that it's in the news when there's a beautiful close full moon that I hear about. And, again, maybe I'm listening to it more, but it seems like there's an awareness that the moon is —

NGA: — is there.

Anderson: I mean, everyone knows the moon is there and important. And so I'm really glad to see that, that's happening. And I don't know what that's attributed to, but I just think whatever it is, is good, and we as lunar scientists have to grab onto those moments when the moon becomes relevant and say, “Yes! The moon is relevant, and it’s important, and guess what? It’s also important for all these other reasons!” I think anytime we can get people looking at the moon is a wonderful thing. Whether you’re looking at it naked eye out of your backyard, through a telescope or binoculars or through the lens of our spacecraft orbiting the moon, now is a great thing.

NGA: A great thing indeed. At NGA, we are over the moon about our continual partnership with NASA. Special thanks to Gary, Al and Noah for letting us experience a special time in history and giving us the excitement to look forward to our lunar future.