The American Meteorological Society in collaboration with
the University of Wisconsin-Madison Space Science and Engineering Center

An interview with

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PHILLIPS: Good morning. My name is Jean Phillips. I'm from the Space Science and Engineering Center at the University of Wisconsin-Madison. I'm here with Jinny Nathans, librarian with the American Meteorological Society, and Steve Goodman. It is Thursday, October 3rd, and we are in Boston at the 2019 Joint Satellite Conference. Good morning, Steve.

GOODMAN: Good morning, Jean.

PHILLIPS: So let's start at the beginning and talk a little bit about your early academic training; how you, you know, developed an interest in meteorology.

GOODMAN: Okay. Well, I did find a paper when I was in second grade. I grew up in Wisconsin, and I wanted to be an oceanographer from an early age. I grew up nearby Lake Michigan, and so for a kid, you know, that's an ocean. And I always wanted to be by water. I had friends who had lake homes, and so the lake is, you know, like an ocean. So that was always an interest of mine.

When I applied to go to college, I wanted to go to Northeastern University in Boston because they had a co-op program where you could get to Woods Hole Oceanographic Institution, and also I needed the money. It was a co-op where you went to school for five years but then you'd spend time doing work and you got paid for it in the summers. But even with a scholarship, it was still a private school. It was very expensive (compared to in-state Wisconsin). I hadn't planned to go to the University of Wisconsin; that was sort of a backup plan. I ended up going in-state, which cost $286.50 per semester, virtually nothing [laughs], hardly, back then.

I started out in oceanography. I went over to the geoscience building and the freshman advisor said, "Well, you know, they have courses over in the Space Science and Engineering Center building." "Oh, I didn't know that." I didn't know anything about atmospheric science, really. It wasn't where I was going. I went over there, and I started taking the oceanography classes, you know, in the Department of Meteorology, which became the Department of Atmospheric and Oceanic Science. As an undergrad [in the honors program] I took some graduate courses in air-sea interaction [with Prof. Ted Green] and physical oceanography [with Prof. Bob Ragotsky], and by my junior year I'd almost exhausted what I could take.

Next Charlie Anderson, who was a professor of meteorology, put up a flyer in the hallway looking for any students who wanted to go chase tornadoes. He and one of the former PhD students, Jeff Kimpel— Jeff had gone down to Oklahoma and he was the chairman of the School of Meteorology at the time, and he had this NSF [National Science Foundation] grant. This was just when the Doppler weather radar was, I won't say invented, but, you know, for our field became available, and they had this program called the Joint Doppler Operational Experiment, JDOP. They wanted people to go chase storms in order to document, back then, with 16-millimeter film and camera photography, what the radar was seeing in signatures back at the National Severe Storms Lab. I went out chasing. One of the people I chased with was on my committee—Howie Bluestein, who's very well known in the field—and I was with him when he saw his first tornado, believe it or not.

So anyway, Charlie Anderson said, "Yeah, go on down there at Thanksgiving time and you can

go talk to them." I drove down with a couple other Wisconsin students. I was the only one who decided to go spend the summer there. I wrote a letter to Ed Kessler, who was the director of the Severe Storms Lab, and they accepted me as an intern in May 1977. The day I arrived, I went storm chasing. I saw a tornado my first day, which, like, never happens to anybody. It was near dusk, and we did find out later a woman was killed by the tornado, so it really, you know, sets you off. Anyway, I morphed into atmospheric science and meteorology because of that experience. And then I came back to Wisconsin, finished up, and I started graduate school with Charlie Anderson as my advisor.

Now I was interested in the Doppler radar. And I didn't know if I wanted to do satellite meteorology or radar meteorology, but I wanted to do one of them. [Prof. Anderson wanted me to look at DMSP satellite images of lightning. I did an undergrad student thesis on lightning and storm electrification for Prof. Barchet (Cloud Phyics) so that got me a start in this career direction.] I had a good time down in Oklahoma, so I decided to transfer. I transferred to OU [University of Oklahoma], and I had an assistantship at the National Severe Storms Lab with Dr. Dick Doviak (D-cubed as he liked to be called), who was the head of the radar group at that time. And they gave me a couple of choices of projects to work on. One was looking at clear air with Doppler radar, and that didn't seem too exciting [laughs]. The other one was they had a very— a brand new project that began there where they brought in some new people who were trying to map lightning discharges in clouds. That's ultimately the direction I went. And they had a project with NASA Langley [Research Center]. They were going to fly an F-106 airplane and test its instruments. And I was always into instruments. I should have mentioned when I was at Wisconsin, I was a double major in mechanical engineering because I like to work with my hands, and then in atmospheric science.

So when I went down for that summer, Ron Alberty—another name maybe you know, he was head of the meteorology division at the Severe Storms Lab—I was getting ready to finish a double major at UW—he says, "So what are you going to do?" And I said, "Well, I want to go back and finish my second major." And he says, "Well, you know you might be better off with a master's degree than two bachelor's degrees." So I said, "Okay, what do I know, right? I'm an undergrad [laughs], just starting grad school." So, actually I went back to Madison, and that's when I decided I would transfer to OU. I didn't finish my mechanical engineering degree until much later in life—I got my PhD in engineering.

I went back and got the meteorology degree at Oklahoma, went and chased storms, made measurements of lightning in storms and how that related to the intensity of the storms. And that's become a big thing now. Jumping way forward 40 years, I got involved with the new geostationary lightning mapper (GLM) on the GOES-R [Geostationary Operational Environmental Satellite-R] series, so my history in that goes way back. They had their first kickoff meeting in Tullahoma, Tennessee in 1978, and one of my committee members, Dave Rust, down there, said, "Yeah, we're going to have this meeting, and we're looking at whether you can detect lightning from space." And I thought, that's pretty cool. And [laughs] so I think I even made a viewgraph for him on some of the work we were doing. And that's sort of how I got into it. I ended up going to NASA [National Aeronautics and Space Administration]. I ended up working on the prototyping for the instrument. I've been with it, you know, on and off the whole time, but it really started with Charlie Anderson giving me an interest in severe storms.

I wasn't what they call a weather weenie, you know. I was in the oceanography path, and I wanted to be a diver. I even took SCUBA diving at Wisconsin. I got certified to be a diver, and we dove in quarries, we did nighttime diving, I even went ice diving behind Lake Mendota in the wintertime. It was 6 degrees Fahrenheit, and we drove down there, me and my dive buddies. We cut a hole in the ice the night before. The ice was about a couple of feet thick. It was so thick that you couldn't stick a snorkel up through the hole in the ice that you make. That's for safety reasons. So me and a guy from the math department, we were teamed up as buddies on that dive,. We went under the ice, using a little jig we built that would roll out the rope that connected us and then connected us to the surface. We swam around in Lake Mendota. And people go, "Well, why would you do that?" And I said, "Well, it's the only time you can see anything, because all the algae is gone." We saw dinner plates from the student union down there [they laugh], a number of interesting things.

I kept my water interest—you know, did SCUBA diving and continued to do that—but the meteorology got me attracted with the severe storms in particular, and it just stayed with me as an interest. Oklahoma was the place to go study severe storms, but at Wisconsin of course they did the satellites. I was an unusual person when I got to Oklahoma, because having come from Wisconsin, I had been exposed to satellite meteorology and McIDAS [Man computer Interactive Data Access System] and all that. And I got to Oklahoma and they had a map room—back then they had DIFAX [black-and-white weather charts creating using specialized paper], they didn't have all the fancy stuff. And, you know, nights before storms we would go in, and me and this other guy John Weaver, who ended up in NOAA [National Oceanic and Atmospheric Administration] for quite a long time, we were the only two who ever looked at satellite imagery. Everybody else was all about radar. I was open-minded. In fact, to this day, I'm interested in integrated observing systems—radars and satellites and the lightning measurement all packaged together, or you cannot really understand convection and severe storms.

I remember we were [in the map room] for the very famous tornado event, Wichita Falls Tornado in April of 1979. And we looked at the map. They have this thing you can do called the Miller Analysis—[named after] Fawbush and Miller who made the first tornado forecast—and you draw a map and you put different— Can I be technical or no? So there are certain meteorological fields that you want to look at for the likelihood of severe storms: moisture convergence and where the high is and where fronts are. Anyway, you draw that on a map, and sort of where they come together in a big mess [laughs] is where you might find storms. Well, it turned out everything came together right over Wichita Falls, Texas. We had a good idea the night before, you know, that that could be pretty serious.

And it turns out during this Doppler radar experiment—so I've always been involved in this new instrumentation—NOAA was considering whether the NEXRAD [NEXt-generation RADar] network was going to be a five-centimeter or a ten-centimeter radar. And what happened was there was another line of storms near Lawton, Oklahoma. If you go to southwest Oklahoma from central Oklahoma, you hit Lawton and Fort Sills, then you get into North Texas and Wichita Falls. Well, it turns out that the radars only have a certain range, and this squall line near Lawton, Texas attenuated the signal from the Air Force—at that time it was Air Force Cambridge Labs or Geophysical Research Labs. And it attenuated their five-centimeter radar. Meanwhile the

Norman, Oklahoma NOAA Doppler radar was a ten-centimeter radar, and it saw through that line to the Wichita Falls storm. And that was the death knell for five-centimeter radar for the NEXRAD network. They said well, you know, we can't have that happen. So NEXRAD became ten centimeters, which, you know, on the one hand no one wanted that because it's expensive compared to smaller radar, but that's what it took to go see through storms, and that's how that came to be.

And, you know, back then, the satellite imagery was 15-30 minutes, and we learned, or I learned, I guess, from looking at radar, you know, storms develop very quickly. And in fact, in 1986 with Ted Fujita we had a microburst experiment in Huntsville, Alabama, and I was a PI, well co-PI I guess, for the NCAR [National Center for Atmospheric Research] CP-2 Dual-pole [polarization] research radar. And dual pole radar was kind of new to us at that time. So again, you know, I was lucky I got exposed to these new developments. And what we saw with that radar was rapid change of lightning activity. Like, over two minutes we would see a cloud go from just raindrops and precipitation into frozen precipitation and hail. That made us real[ize]—that made me realize, anyway— you needed the rapid refresh rate for the current generation of satellites, we have one-minute rapid scan with the GOES [Geostationary Operational Environmental Satellite-R] satellite. I later after joining NOAA became the chief scientist for the GOES-R program. The Europeans [with their new Meteosat Third Generation (MTG)] satellite, the Japanese with their new [Himawari] satellite, [and South Korea with Geokompsat 2-a satellite, are all] doing two and a half minute rapid-scan imagery. Well, I learned from watching what the radar can see, you really needed to get down to two, two and a half minutes, , no slower than that, no worse than that, in order to see these rapidly developing [updrafts in] severe storms. I'm not sure people until then really appreciated how fast these storms could develop. Of course now with the rapid-scan imagery that you get from the GOES satellite, [the depiction of storms] is just phenomenal, and everyone loves it [laughs].

PHILLIPS: Well, and it was demonstrated with GOES-14 [Geostationary Operational Environmental Satellite-14] when it was moved to various locations.

GOODMAN: Yeah, we had an idea. It was at a Norman conference. Ralph Peterson was there from Wisconsin, Tim Schmit, and me. And we were thinking, how do we show what the future capability is to the forecasters? We asked the operations at NOAA, "Hey, could we get GOES-14 when you pull it out of storage and take one-minute imagery, even at the lower spatial resolution than we have today?" And they said, "Yeah, we'll do it." And so the forecasters frankly had not had, [since long ago], maybe for decades, from an experimental test, what the rapid scan imagery could show them, and they ended up loving it. Yet they still didn't know if they wanted to run rapid-scan, what we call mesos [mesoscale domain] imagery, operationally. There was a part of the Weather Service that said, "Well, you know, we're moving to NWP [Numerical Weather Prediction], and we'd like the five-minute [continental US (CONUS)] mode of the satellite because then we can have continuous data that can go into the forecast models." We had been hearing that after we had already been demonstrating—this was, like, after five years of showing them the GOES-14 one-minute data. It was, like, this wasn't making sense to us why they weren't, you know, more excited.

Well, it turned out we weren't really talking to the right people. We had a severe storms

conference in Madison, and Tim Schmit and myself and Jordan Gerth were sitting down with Russ Schneider, who was now the director of the Storm Prediction Center, and Steve Weiss, who let's call him the chief scientist there. And we said, "You know, we understand you're not really interested in this mesoscale mode from the satellite, that you want the five-minute mode." And they said, "What? Where'd you hear that?" And we said, "Well, that's kind of the message we've been getting from the Weather Service, you know, the world's going to be about NWP and so you don't really want this rapid-scan imaging." And they said, "No, when we get within 12 hours of a storm event, we go heavy into looking at the satellite imagery, [and] this one-minute stuff is fantastic." So they see outflow boundaries developing [and overshooting cloud tops] — It goes back to the early days of Jim Purdom where he was showing people what you could see, you know, with these satellites, and now it was on the verge of being an operational capability.

So when we got that message, we said, "Okay, we need to redouble our efforts in getting forecasters exposed to it." So we brought [the GOES-14 1-min imagery] into the Hazardous Weather Testbed, which is one of the NOAA testbeds in Norman, and got more exposure to forecasters, not just to Storm Prediction Center people. Now they are sold on it. and I don't know if you've heard, but since we launched GOES-16, the Weather Service has been asking for this mesoscale mode like almost every day. And it turns out it's useful for fires, and it's not just severe storms, but going to observe a hurricane they want one-minute data. In South America they had a field experiment last year, November-December, and said, "Hey can we get rapid-scan imaging?" It was an international experiment with NSF-NASA-NOAA called RELAMPAGO [Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations]. [Note: You can read about it in the *Bulletin of the American Meteorological Society*. We collected over 1000 hours of 1-min data for the Project (on a non-interference basis with NWS priority interests).]

PHILLIPS: Yes.

GOODMAN: And we said, "Okay, well, we have a priority list for collecting rapid-scanned imagery. Research is at the very bottom of the list. If it's a forecast for enhanced severe weather from SPC [Storm Prediction Center], that's number one. If it's a volcanic eruption, that's in the top couple. So you guys are at the bottom." But I said, "You know, make sure you tell NOAA that— two things. One, have it come from the director of the Weather Service in Argentina, Celeste Salio—she is now like the third vice president of WMO [World Meteorological Organization] I think." I said, "That could carry more weight than if you guys at the universities say you'd like to have it." And I said, "The other thing is, well, if we're going to do this and you have all that instrumentation, you can help us with further validation of the GOES-16 [Geostationary Operational Environmental Satellite-16] performance. And if you're doing validation, that moves way up the list instead of being at the bottom."

So it was serving two purposes. One was to get the experiment— the data in real-time, which they got ultimately redistributed from NCAR. We were also trying to penetrate the world of radar—so another benefit of me having gone to grad school at OU and being at the Severe Storms Lab is I knew how radar-centric everybody was—and penetrating that world with satellites. Again, my interest was the integrated observing system, so I think that [perspective was helpful]. I had a foot in two different camps. I had a foot in the meteorology camp, but my

PhD in engineering put a foot in the engineering camp and the meteorology camp. And then being in Oklahoma, I had a foot in the radar camp. And I had a foot in the satellite camp from Wisconsin. I was maybe one of the very few people who had my foot in all these camps. And so being the chief scientist for GOES-R, you know, I was able to communicate with the engineers at Goddard. I could communicate with the scientists in the Weather Service and forecasters. Maybe it was just fortuitous that I'd ended up in that position, but I was able to work very easily with everybody.

We created a thing we called the GOES-R Proving Ground, where we spent a number of years [enriching this activity since I joined GOES-R in 2008]. I started it with Greg Mandt, and he was the director at the time, and we were able to get the prototypes of what the GOES-16 and -17 products would be in front of forecasters. Not only at the Norman Hazardous Weather Testbed, but the Aviation Weather had a testbed in Kansas City for aviation, the Hurricane Center had their Joint Hurricane Testbed, so we were trying to touch a number of places across the country. Even Alaska and Hawaii, Pacific region, and Alaska Region with its Arctic testbed. We were just trying to get them all to see what the possibilities were because GOES-R 16 and 17 truly is a huge jump in capability. The lightning mapper we never had before. That was new. [We] went from five-channel imager to 16 spectral bands, which Wisconsin had a big role in. We had twice the spatial resolution, and we could see things like turbulence and wave clouds, which with the old GOES-15 and earlier, the spatial resolution was too coarse to pick that up. And now the Weather Service is very interested in what can you do in picking up, you know, convective turbulence?

All sorts of new applications were enabled by the big transformation of GOES-R. And, you know, I also got to be involved with JDOP [Joint Doppler Operational Project], as NEXRAD got rolled out. [I was able to participate in] dual-polarization, new parameters that the forecaster can see, and then the lightning mapping from the ground and also from space. And so now we're throwing so much information at the forecaster. "Okay, wait, how do we digest all this stuff?" You know? Now [Big Data in] the cloud is emerging, [AI] and machine learning. Can we do something with the cloud and machine learning to get just the information the forecaster needs to see? So we've got this great advance in observation capability, but I think it's overload for the forecasters. I would go to the forecast offices with Greg Mandt, and we'd sit with the forecaster— "Bring down your menu in AWIPS [Advanced Weather Interactive Processing System] and show us what satellite products you look at." We were just testing them. And so they would scroll down their menu. Every forecaster has their own little personal menu of what they like to look at. We wanted to see what are the things that you focus on? Again, trying to get an idea of, you know, how can we penetrate, you know, their standard way of doing business? Because change is hard.

And we even had a big effort for training. Wisconsin was very much involved in that as well from the get-go. We worked with the [National] Weather Service and developed a training plan. Louis Uccellini, the director of the Weather Service, was able to get the union to sign off on everybody in the Weather Service had to be trained on GOES-R. And they did, you know, thousands of hydrologists and meteorologists. And I think it's Mark DiMaria, who's at the National Hurricane Center, [who] had said because we started so early with all these demonstrations, they said that this is the most prepared they were for a new observing system

ever. So, like, going back to I think it was GOES-8, GOES-I, they had the data, but they didn't know what to do with it because we didn't have this strong outreach to the user to say, "Look, at what we're bringing, and here's what you can do with it." And we really did a good job, and there were a lot of us involved that made that happen. We have a transformational observing system, but we did transformational training to get the users ready. And I think people look at that and say, you know, this is a great success. And after we did that, the polar program, JPSS [Joint Polar Satellite System], started a proving ground as well. So, you know, it's sort of taken hold, I think, as something we want to continue as we go forward. [Note: Now integrated GEO and LEO is called the Enterprise Proving Ground.]

Our challenge today is the forecasters like looking at imagery, and they're looking at these things we call red-green-blue composites. You can combine [the different spectral bands] on your monitor into different products, subtract them, add them. It's like false-color information. It's a qualitative product, but they can quickly discern what's going on. But we haven't really made our stride yet with the quantitative products. So, we have quantitative algorithms for volcanic ash, sea surface temperature, atmospheric motion vectors or derived winds. And really their focus has been more on just looking at the imagery, looking at the spectral channels. Going forward our challenge is, not just U.S., but it's the whole western hemisphere of users, to understand what they might do with the quantitative products and not just looking at the channel and imagery stuff. So that's kind of where we're at right now.

PHILLIPS: Do you see a coordinated effort across national or international agencies?

GOODMAN: The coordination is primarily coming through WMO. WMO has this thing called Virtual Laboratory [VLab], and we have people at NOAA, with university partners and the Cooperative Institutes, who are very much involved with the training efforts. In fact, with NOAA NESDIS [National Environmental Satellite, Data, and Information Service], we have done a lot of training at conferences, short courses. And so tonight the satellite requirements user group is having a meeting headed up by WMO. Participants from all these different countries in the Americas, representatives are coming from their national meteorological and hydrological services. And the question we want to pose is—once we get through the Joint Satellite Conference, as it's been a busy summer for us—is to ask, "Okay so we would like to do one WMO region three, South America, one WMO region four, Central America and Caribbean, training event, big training event, next year. What are your needs and where might we do it? Who wants to be a host for it?" So that's what we're doing after tonight, getting ready for next year. And the plan is to just keep continuing this.

And maybe one other big change is when we started, users had the new polar system JPSS for, like, five years, starting with [the] NASA Suomi NPP [Suomi National Polar-orbiting Partnership] satellite. We didn't think they needed as much help for the new capabilities because they already had five years under their belt looking at that data. But here comes GOES-R—you know, truly transformational—and we put a lot of effort in, but now we procure the geostationary and the polar satellites separately. The user doesn't care, the user uses what they need. And so we're sort of morphing. The GOES-R program and the JPSS program, [with the WMO Coordinating Group for Meteorological Satellite (CGMS)], GEO [Group on Earth Observations] and polar constellations, to do something mutual.

We still find that there are training events where they just want the GOES-R part, the geostationary part. And JPSS does some of their own stuff because they're global, we're hemispheric. We have Himawari, so we kind of go back to Asia. The Europeans have not launched their new satellites yet. The EUMETSAT [European Organisation for the Exploitation of Meteorological Satellites]- MTG, Meteosat Third Generation—which also is an advancement, but not as big an advancement because they're already ahead of us with their 12-channel imager. Now they're going to 16 channels and they're also flying a lightning mapper. So, they're learning from what our experience has been, and of course WMO and all of us—the atmosphere is global, so we all want everybody to have the best information that is possible.

I guess the other big challenge will be to assimilate these new satellite data into the global models and regional models. And so that's another big step that I guess will happen over the next couple years. We know the models are already drowning trying to ingest the new polar data, so what are you going to do with the geostationary data? And I talked to someone at the Hurricane Center, or at EMC [Environmental Modeling Center], the modeling center for NCEP [National Centers for Environmental Prediction], and I said, "I hate it that you guys are throwing away a lot of our data." Because they do this thing called thinning, when they get high-resolution satellite data. But at the meeting last year, they said "No, we're starting to assimilate the data, but we've got to do a lot of test runs before we put it into an operational model. So, at the same time that we're trying to make the data quality high-quality, we've got the users, the modelers, you know, trying to figure out how to bring in that data to have the most impact. I think we're getting there. The fact that we got data out to the users as quickly as we did I think has accelerated that whole process.

Louis Uccellini made a comment, I know, a long time ago, he said, "You know, we get a new satellite capability in orbit, and we sit there for three years not knowing what to do with it." And so that's sort of the genesis of trying to do all this early stuff. You hit the ground running when you open up the door of the camera and start looking. We've done pretty well on that. I'm sure there are refinements one could make, but just getting it out there and a user willing to work with us. And the key was getting it into their operational environments. These testbeds are good because it's as if you're there and doing your workflow, [learning] how to use the satellite data.

We've had some products we've demonstrated in our proving ground and they said, "Well, I'm not sure that really adds anything to what I already know, either from radar or just from other information." And I should mention another big transformational change for the satellites was if you have radar data—again because I've lived that community—and you're getting updates every few minutes, no worse than six minutes, but the satellite data doesn't come in until a half hour later, for what we call nowcasting, sort of the extrapolation of near real-time data, the satellite's not helping you because it's too late. So now with GOES-R, you know, there's that one-minute imagery at the time they're getting the radar, and so it only makes sense that they're finding it useful. The timeliness was a big jump forward for the new satellite system. If we had the spectral bands and the resolution, all you're going to say is, "Well, I validated what I already knew." But now it's playing a role front and center in the nowcast.

And the [fire detection] was a bit hit. You know, we knew it was good but we didn't know it was

that good. You see examples of the current geostationary imager versus the GOES-16, you pick up these fires quicker than when you saw them in the old imagery. And you combine it with some of our new spectral bands, like the blue band, and we can see the diffusion of the smoke plume, and you couple that with the hot spot, we couldn't do that combination before. And then RGB, so the false-color imagery highlighting where these phenomena are. That was a huge jump forward.

PHILLIPS: So you took all of that information. And you have your book coming out—

GOODMAN: It came out October first!

PHILLIPS: And so talk a little bit about how you decided to frame that, the story of GOES-R.

GOODMAN: Okay, sure. Elsevier the publisher, Academic Press, came to me maybe it's five years ago—I think it was 2014—and said, "We want to do a book on satellite imagery." And they came to me because I was the chief scientist for the program. I was the person they called. They could have called anybody. And I said "Well, you know we haven't even launched yet. And if we haven't even validated our data, we can't even publish the imagery in a public document until [is the data are] validated." First I said, "What do you want to focus on?" "Well, [they said] we're thinking of imagery." And I said, "Were you thinking [Kidder] and Vonder Haar, [Academic Press], 1995? Because I have that book, and it's a very nice book, but it's before the Internet." And they said, "Well, that's kind of what we're thinking. We could give you 350 pages." They had a page limit, so I guess they know what they're going to charge and that determines how many pages. Next me and my co-editors, we started to hammer out an outline—well, it would be nice to show every product we're making, the main products. We have 13 product teams, and wanted to have, like, a fire example, lightning example, shortwave radiation. But then we also wanted to add [an] instrument chapter, which our program director Pam Sullivan was kind enough to write up. And then I said, "You know what we've never done, and it's not in the earlier book? No one talks about space weather." And we do space weather products. In fact, we have four space weather instruments on the GOES-R series and only two Earth-viewing instruments: the imager ABI [Advanced Baseline Imager] and the GLM lightning mapper. So I asked, "Can I include those?" And they said, "Yes, sure."

I brought on Rob Redman from NOAA's NCEI, National Center for Environmental Information, in Boulder. My strategy with co-editors was to add Jamie Daniels, who was our algorithm lead, [and] he would nag all the people in College Park. And I brought in Tim Schmit from Wisconsin so he could nag all of my Cooperative Institute scientists at Wisconsin who were also heavily involved in writing the algorithms. And then Rob took care of the space weather because, you know, I wasn't physically where they were. It's a lot easier to walk to someone's office and say, "I need your chapter finished!"

Before we got even to writing, we had issues with the contract language terms. The DOC NOAA— I guess in the ethics office, found somebody and said, "Oh, well, this Elsevier contract is eight pages long, and we now have a new book contract form we use. It's one page." And I said, "Well fine, you guys, can you work it out?" Because they want their editors to sign, a book contract [the government lawyers are here to protect us]. After a year and a half [laughs] they

ended up using the original Elsevier contract [laughs]. It's like, well okay, we lost some time. But it didn't really matter because the launch was delayed. We got delayed six months because of Hurricane Michael, so that took some time. That just set us back, and when we'd have what we call provisional validation, meaning it's not fully validated, but we understand what the problems are, or we think we do, and they're documented so you can use it operationally, you know, caveat emptor, or however you say that. Caveat emptor, yeah. Buyer beware [laughs]. So we think it's pretty good. And we would document: here's the issues that we still have. The reason there's no GOES-17 imagery in the book is for that reason. We only got as far as the provisional, and in some cases full, validation, but some of them not even at that stage. For some of the space weather products and some of the official algorithm products that we had, we only used GOES-16. But Tim Schmit from Wisconsin and the imagery team got the initial validation for GOES-17 done. In the end what we did is we have a stitched -16 and -17 image of the western hemisphere. That's our one GOES-17 piece of imagery in the book.

It took a long time to get the writing done. The editing was bizarre because our editor was in India, and I think they farmed out the chapters to different people, and [there was] a lot of back and forth on the editing. That was my first big book. I've written book chapters, but not done an entire book before. I may not do another one; it's a lot of work. I had no idea, and, you know, people were really worn out from it. But we hope it's useful. We were worried it would be outdated the day it was published, and so we have lots of URLs for the internet, for example, from Colorado [State] for their VISIT [Virtual Institute for Satellite Integration Training] and SHyMet [Satellite Hydrology and Meteorology] where users can go for training, Wisconsin too of course. The book is chock-full of web links, including the GOES-R .gov weblink, where you can get more information. The earlier book couldn't do that in 1995. Our hope with the new book was one-stop shopping. If you want to get an overview and introduction to the program, the satellite and its capabilities, and that's how the book was intended, you can find what you need there. There are references, so you can go and deep dive on your favorite product.

The last thing I'm working on is access. I don't want the University students—books are expensive, so I found out from a colleague of mine if your library subscribes to ScienceDirect that you may be able to download the chapters at no cost. I contacted the NOAA Library and I said, "Hey, here's this book we're doing—so this was a couple of months ago—and we'd like to make it widely available, and do you guys subscribe to ScienceDirect?" "Well, yeah, everybody subscribes to ScienceDirect." "But can you get the book?" And I guess there's an extra price you're going to pay because if you have the book— Like, this is an e-book and a printed book, and the ebook has all animations. I made sure every chapter had animations so that's the one that the students would really want to go look at. And they said, "Yeah, we can look at that." And they came back to me and they said, "Well, we can't afford the subscription, but would you give us a copy of the book so we can put it in the library?" And I guess they can advertise it. I said, "Sure, I'll give you a copy of the book so you can do that." Then I called the Goddard Library, you know, because it has a lot of involvement by NASA, and GOES-R is a joint NOAA-NASA mission. And I haven't heard back from the library, so— They may have deeper pockets and maybe they can get the subscription so anybody who has a NASA.gov email address can download the chapters for free because of what the library repository has done. [In the end the Goddard library purchased its own copy that can be loaned out]. Tim Schmit gave the SSEC library a copy.

PHILLIPS: Yeah. It isn't necessarily part of our license with Elsevier, but I've placed a request to have it as an add-on to it.

GOODMAN: I'd like to know what that's going to run. Maybe NOAA will ultimately do it because then every forecaster can download [the book contents] and there's no cost, and also the university students. That's my hope. We're not getting paid for the book. I started the book while still a NOAA employee, so we got copies of the book in lieu of royalties. That's fine. We just wanted to document [the GOES-R mission]. I told the EUMETSAT people, at the EUMETSAT conference too, that when we first were conceiving of the book, we wanted to include international satellites. I have a chapter in there—I did a couple chapters of the book—and I said we wanted to include the next generation GEO-Ring, but of course you're not up yet. So Elsevier told me that the ebook could be updated, it's sort of a living book. [Maybe] within five years and they're [operating in orbit] and satellite imagery is available, then that can be included.

But the focus [of the book] was on the new GEOs, it wasn't on the LEO [Low Earth Orbit]satellite constellation. Next there's going to be MetOp [Meteorological Operational] and [the next generation EUMETSAT Polar System [EPS]] and they'll be amazing. The growth of all the observation systems is pretty amazing. I should mention in the book not only did we do space weather, but I said [to the editors] that earlier book didn't talk about how the data is disseminated, and that's had great changes. We have the CSPP Geo [Community Satellite Processing Package for Geostationary Data] from Wisconsin, which is widely used by the folks who have the GOES rebroadcast receiving stations, what we call the GRB. There's at least 70 of them in the western hemisphere including Leon, France, where they've always gotten our satellite data direct broadcast across the Atlantic. And then from there, they distribute it to all the EUMETSAT member countries.

Having this ability to look at the imagery was a great thing. [CSPP GEO] began because I was at an AGU [American Geophysical Union] conference and someone from SeaSpace came up to me at the time and said, "You know, we want to build hardware, but we don't want to mess around with how to display the imagery and the algorithms." And so I went back to Graeme Martin and Liam Gumley at Wisconsin. They had been doing [Direct Broadcast] for NASA for decades, like, the MODIS real-time direct broadcast, and that evolved into JPSS direct broadcast. And they said, "Yeah, we could do that." We are actually sustaining that now from [the] GOES-R program and OSPO [Office of Satellite and Product Operations] so that Wisconsin will continue to make the data available through the CSPP Geo, which sort of hangs on anybody's GOES rebroadcast hardware that they develop and sell. We know there are other users out there who plan to buy GOES rebroadcast stations, and if you want to get the one-minute mesoscale data, that's the only way that you're going to be able to deal with it, is to have the satellite receiving station. So that was another thing added. [Eventually the NWS liked CSPP GEO so much they decided to make it their backup.]

[In the book we also cover GeoNetcast] Americas, which is a low-cost way to get a lot of the satellite data out to users in the Americas. We talk about the GOES [Rebroadcast]. We talk about CLASS [Comprehensive Large Array-data Stewardship System], which is the [NOAA data and information] archive system. [That is] not described anywhere, so [I asked] Jim McNitt [to write]

a chapter with other colleagues of his on how we disseminate the data. I think that's pretty cool. I guess I'm proud that we were able to have this wide sweep of what the new constellation capabilities are able to do, again worried that we'd be outdated. In fact, we are already kind of outdated because some of the [official operational] algorithms [at launch are planned] to sunset because there are new, more advanced [algorithms or recipes] than we had ten years ago to make some of the products. I guess that's always going to be the situation. But hopefully we've taken care of [being dated allowing users to] still go find [the data] or the person they need. So anyway, that's sort of how it all came about. It was a [four- or five-year] effort to finally get it done. [Actually completed] this week, and I guess we'll see how well it's received. I was very worried, too, with the editing. We went back and forth, people find, like, typos and grammar errors in the index of terms at the front, or it looks like 25 people wrote these chapters instead of having continuity. We tried to do what we could to take care of that because I knew the reviewers would be brutal and say, "How could you let this out there?" So for anyone who hears this, we tried [laughs]!

PHILLIPS: So you're here at the Joint Satellite Conference, sponsored by the AMS [American Meteorological Society]. Talk a little bit about the role of the professional society in your professional life.

GOODMAN: I think I've been a member since I was a grad student. I don't think I ever dropped it. If I did for a year, it was by accident because I didn't get the notice to pay my dues [laughs]. So I've stayed with it, and I don't just go to AMS conferences, but that's the mainstay. At this point in my career and life, you know, I pretty much just go to the annual meeting. I don't go to the technical conferences like I did when I was doing more active research, but I still run into a lot of the same people. [Networking] is a big one for me now. I come here and network [with] all sorts of people, "Oh, I haven't seen you" and "Steve, I thought you retired, what are you doing here?" [laughs] And I say, "Well, I'm still working part time with the GOES-R program."

AMS made me a Fellow—I forget what year it was, it might have been 2011 at some point—so that's a longevity thing. And I was kind of surprised the next year when I got the same old bill I always got. I said, "So I'm a Fellow, no financial benefit there [laughs]." But that's good. It's nice recognition from your peers and the Society.

I think the Society [is to be congratulated]—on a hundred years [Anniversary]. I still get some hard cop[ies of the Bulletin]. I still go back to look things up in the literature. I gave a talk here at the conference yesterday and it was about long horizontal lightning discharges. I knew one of the first works was done in the 1950s [using radar]. Well, there's a *BAMS* [*Bulletin of the American Meteorological Society*] paper talking about some of that earlier work, so, AMS journals are still a go-to place to find the historical work that's still relevant to what we're doing now.

So yeah, the AMS conferences are good. You see your buddies, and then everyone's traveling. It's easier to get to them here than to get them on the phone or even to find them in the office. People told me, "You know, I never see anybody." Mary Kicza, who was one of the former AAs at NESDIS, when I was living out of town said, "Hey, so how's that working?" I said, "Well, you know, it's kind of interesting. Here I am back at Goddard, and I'm looking for so-and-so and so-and-so and so-and-so, [but] nobody's here, because the world is more connected—if I have a

laptop and a cell phone, you don't really need to be where you are, [in a fixed office]." I think we're still struggling to figure out how to do this teleworking thing most effectively, but the GOES-R program had two thousand people scattered around the country, and unless there was a review, there really wasn't a need to physically be in a certain place. So everyone's kind of operating separately. The time zones can be an issue. You know, someone is on the West Coast or in Colorado and it's an East Coast meeting, they want to start at 8:30 [Eastern Time]. And, then university people historically kind of stay up late and get up late. Well, engineers like to start the day nice and early [laughs]. So if you need to be on those telecons and you're out in Colorado or worse, you know, you've got to switch your sleep cycle [laughs] to get on those.

AMS is great. Good luck in the next hundred. The switch to electronic publishing has been a big help for us all. I can go online and if I have a NOAA.gov or NASA.gov [email with] the library [subscriptions and interlibrary loans] are connected, we can just get the journals electronically and we don't have to find a place to store stuff. And just going to the digital world is real good. I'm thinking— I've been to a couple of conferences where they had big—I mean big, really big screens for electronic posters because now you can routinely show animations of your work, [which works well for satellite loops]. I've seen that mostly at a tradeshow [or exhibit hall] because they can afford to do it. I think posters need to evolve to that next step, where most of us do that. I haven't done a presentation in the last probably 10 years that's less than 250 megabytes because we've got animations from the satellite as part of our talks. And so maybe that's a direction AMS is able to go, but I guess you've got to rent these things and I'm sure they're not cheap, though it's a more powerful way to have the exchange [with colleagues]. You bring your little laptop and maybe you can find one of those little round tables to stick it on next to your poster, and that's kind of hard. I heard there were like 700 papers for this conference. [There has long been] mixed feelings out there about conferences and doing orals versus posters. [Depending] what you're doing, I think there's a place for both, and I think posters are no longer viewed as like second banana. You know, it can be a better format, but maybe we need to go to more of this electronic capability to make it as impressive as people can. I'm sure you guys have talked about it, but you'll figure it out [laughs].

PHILLIPS: So, well, talking about electronic capabilities, I'd like to maybe conclude with your work in community outreach now in this new program that you're working on with NASA. Is it with NASA and NOAA?

GOODMAN: Oh yeah, this is exciting. Bob Baron, Baron Services, he's at the AMS conferences, he's in Huntsville where I am, and he created a nonprofit to work with the U.S. Space and Rocket Center [(USSRC), which includes Space Camp]. They get a million visitors a year. He was focusing on— Well, he's got a weather radar in one corner because they make weather radars, and he's interested in transportation weather. [He is promoting] a mesoscale network for the state of Alabama like Oklahoma has in each county and Texas, and maybe there are some others that have gone with the mesoscale because we all know now that high spatial resolution, high temporal resolution, is where we need to get to. How do we do it? [He has] worked with emergency managers to try and get mesonet sites out across the state. So it's growing.

[Bob] said, "Steve, you know, I'd like to include observing systems. Can you help me with the

satellite part?" So I said, "Well, let me see what we could do." So it turns out NASA Marshall Space Center has 70 3-D printers, and so I said, "Hey, can you guys make a scale model of GOES-R?" because initially Bob wanted GOES-R. And so I said, "Well okay, I know everybody, so I'll see what I can do." I contacted Lockheed, who built the satellite, and said, "Can you get me a high-resolution [CAD-CAM drawing] file of the satellite?" "Yeah, we can do that." So I gave that to NASA Marshall and they gave it to the 3-D printer people and said, "You know, what would it cost, and can you build a model?" And they said, "Yeah, we can do it." So we'll have our 3-D one-third scale model. It's going to be about 8 feet [tall by 2 feet wide]—like the size of a dining table—and then the solar wing will hang off the side of that. [The USSRC] actually moved us from where they first thought they'd put the weather gallery to a bigger room [with a 20 foot ceiling]. And so GOES-R is going to hang from the ceiling above everybody.

Originally Bob wanted to do a projection of the satellite imagery on the floor so a student could walk by and then they could say, "I'm from wherever"—some country or some city or whatever—and then it would zoom in and pull up a near-real-time image of the weather in their hometown. Well, then the Space and Rocket Center exhibit experts—and they're also education experts—said, "You know, the students will be walking on top of the image. So if you want them to see the image, you don't want to project it under their feet." We said, "Oh, there's a wall there, maybe we could use that wall." Well, that was before they gave us a new room. I said, "You know what I'd like to see is a video wall." You go to the airport and they have, you know, football games, and you see these video walls. I'd like to see— So imagine the room, a floor-to-ceiling kind of thing, and it would be segmented maybe so you could put up different displays. We have lots and lots and lots of media: launches of the satellites, spacecraft instruments, that you can rotate the view of and read about the instrument, and each of the products. There's tons of information there. We've got blogs, real-time blogs. We've got real-time imagery you can get from Wisconsin or CIRA [Cooperative Institute for Research in the Atmosphere] at Colorado State. And NASA Sport is another group with real-time dissemination, not to mention NOAA now has a real-time webpage. So I said, "You know, we could make all that available, and the student could pick."

So here we were— We had a visit with [the USSRC] during the National Weather Association [...] [meeting] [held in Huntsville. We also] had a GLM [Geostationary Lightning Mapper] lightning mapper science meeting the same week. And so people were talking, "Hey, can you come out with me to the Space Center." And I brought Liz Page and Amy Stevermer from th [UCAR] COMET [Education team]. I said, "You know, I see a role for COMET. We have hundreds and hundreds of training modules there, maybe we could repurpose or redo something that we could put up on one of these 65-inch interactive monitors." And I also talked to Margaret Mooney at Wisconsin. We've worked with her in what we call the Education [Proving Ground], where she was reaching out to high school teachers. We get everybody to the Space Center. I mean, mostly you think of space campers, but they get adults, and a lot of teachers. I know Lockheed, Raytheon, and others actually sponsor groups of people. I saw this tour group, in fact, it was all Japanese. Apparently, someone funded all these Japanese kids to come and go to the Space Center for a week. And they get a space suit, [they can go in a water tank to to simulate weightlessness] go in simulators, and all that kind of thing.

[There are] a lot of touch points for the public with this outreach, so we wanted to see if we

could make that work well. [Speaking of the] two 65-inch touchscreens— Well, it turns out that I was talking to Greg Mandt of the Joint Polar Satellite Program. I said, "Here's this thing we're doing with the Space Center, with the museum." And I started thinking, why— You know, Bob asked me about GOES-R, and I said, "Well, why am I only talking [about] GOES-R? I mean, we should talk [about] all of NOAA's capabilities." So I said, "Hey, would you guys like to get on board?" And he said, "Let me give you my outreach person, Ashley Hume." I said, "Hey, here's what's going on. Here's a PDF of the space [layout]. Do you guys want to get involved?" I said, "I think it makes sense. We only acquire satellites in sort of a stovepipe fashion, but the user uses everything, so you've got to get beyond [that the stovepipes]." I said, "You know, we're having a scale model built hanging from the ceiling, and, you know, you guys have lots of web content to go to." So they talked and they said, "Yeah, we'd like to do a scale model." So now we're going to have a scale model of GOES-R and JPSS from the ceiling, two 65-inch touch screens, and we went out to the CIRA [SLIDER] web page where you can see near real-time imagery from both geo and polar. [The woman educator] who's heading up the exhibit game plan, told us she's worked at many museums, big museums, and she says that's what's going to get the attention of the public: hurricanes, tornadoes, fires, volcanic eruptions. [The visitors] would learn stuff because we have text that goes with the imagery, which is more complete [story]. If you wanted to do deeper dive, you can do it. [We are] trying to pull all that together.

They're doing a [follow-on] iteration of the layout for the weather gallery, and because the Space and Rocket Center is interconnected to all the NASA visitor centers, they're part of the Smithsonian. And the Smithsonian weather piece, I guess I'll call it, if you've seen it, is like archeological digging. I mean it's way old, static, and so on. So there is an interest in updating what they do. [The visitor centers and museums] tend to share things, so my hope is that if the Space and Rocket Center thing really comes off well, then maybe some of the other visitors' centers [will join up], and that expands our outreach tremendously once we get to that point. You know, the KSC [Kennedy Space Center] visitors' center, they already have a video wall I have seen. I think there's many possibilities, say, in the next 10 years to expand that. And we keep collecting [examples] from the blogs to share. That’s what we're doing, you know, in the museum universe, so we'll start there and then we'll see how it goes.

PHILLIPS: Well, we'll look forward to when it opens. It sounds like great community outreach.

GOODMAN: [The USSRC has] an IMAX that's been decommissioned. I guess IMAX doesn't make those 70-millimeter film movies anymore. So they have, I forget the name of it, but it's still the stadium seating in an IMAX format. But they had super [high-definition] imagery. They tell me you can't even see the pixels in an image unless you walk up to the screen. And so what we're planning is to get the GOES-R and JPSS program scientists, or maybe the program directors, whoever's available when we have the grand opening, to give a public lecture. And then maybe we'll have different people come in during the year, and they can give lectures on some topical thing. You know, the hurricane season seems to be a good one and in Alabama, of course, tornadoes are quite prevalent, so maybe someone will do a severe storm [presentation].

I guess I could say the possibilities are endless of where it goes. And I spoke to Jean Phillips at the Space Science and Engineering Center, a very famous library of the history of satellites, whether there's anything there we might be able to make available. Regarding the educators, I

leave it to them. I said, "Look, that's your expertise. You're an educator. You know how to do exhibits. I can get you the content, but you guys got to tell us how you're going to [tell the story]." So that's where we're at right now with that. We hope to open at the end of the year, maybe it'll be January or something. We were actually hoping to be ready for the conference in September, but just things drag on. But it's a definite go. It's funded, and it's going to happen. [The Weather Gallery was later delayed by COVID but is now back on track].

PHILLIPS: Fantastic. So with that, I think we'd like to just thank you for sitting for this interview today, and I appreciate your time.

GOODMAN: Yeah, well thank you. I'm always happy to talk about, not so much me, but, you know, the stuff that we've been doing because it's been a very exciting ride to do all those things. And now we're getting ready for the next generation, right? So 20 years from now we're going to have something new to put out there. Thanks.

PHILLIPS: Thank you, Steve.

[END OF INTERVIEW.]

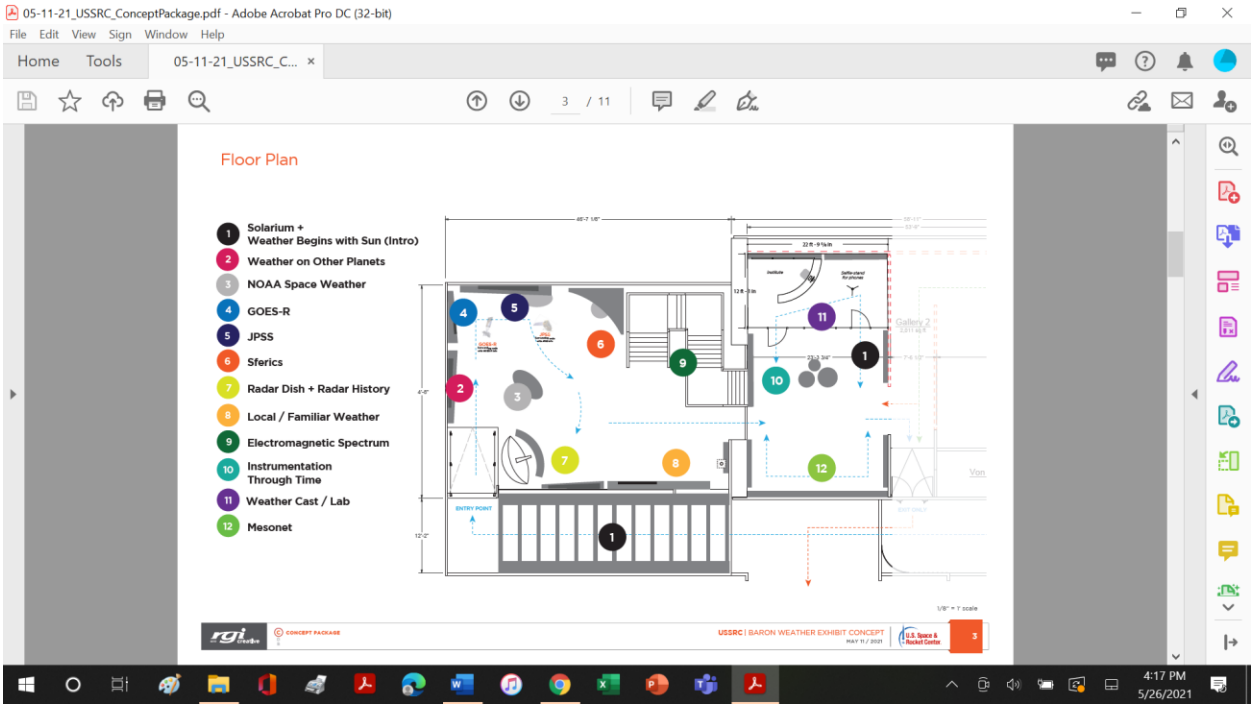
[END OF TRACK.]

Overview

The US Space and Rocket Center and the Baron Critical Weather Institute are forming a new outreach partnership.
Together, they will provide USSRC visitors with an exhibit of revolutionary technology and experiences, through which people will learn **"How We Know the Weather"** and find more information on Earth and Space Weather. Weather technology is complex, increasingly accurate science that makes an enormous impact on people - from what th ey decide to wear in the rmoning to how they get to school and work. Even space weather - weather we don't see as apparently - affects our lives every day, month and year.
Through the exhibit, people will learn how weather forecasting technology works and how it is improving lives and business. People will experience wonder and awe interacting with weather technology in the exhibit, expand their view of weather science and become inspired to stay engaged with the scientific innovations of the exhibit sponsors and partners.

The required components of the exhibit include:

- Dish and pedestal featuring radar, with large adjacent monitor(s)
- GOES-R satellite model with green screen floor projection
- JPSS - NSSTC data feed and Lockheed satellite exhibit
- Mesonet wall featuring car-to-car technologies and Alabama DOT sensors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