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

An interview with

Hank Revercomb
Former Director
Space Science and Engineering Center
University of Wisconsin-Madison

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Conducted by

Jinny Nathans
American Meteorological Society

Jean M. Phillips
Space Science and Engineering Center
University of Wisconsin-Madison

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Transcript by

Aaron Gregg, University of Wisconsin-Madison
Sophie Mankins, American Meteorological Society
Katherine Johnson, Space Science and Engineering Center

NATHANS: This is Jinny Nathans on Friday, October 4, 2019 in Boston at the Joint Satellite Conference. I'm here with Jean Phillips from University of Wisconsin-Madison, SSEC [Space Science and Engineering Center], and we are interviewing Hank Revercomb for the AMS [American Meteorological Society] Oral History Project. So, first question, what was it that triggered your interest in meteorology or in weather?

REVERCOMB: In my case, I think it was kind of a late serendipity. I had always been interested in science, but I was— I ended up getting into physics, and I went to graduate school in physics. But in about 1970, Verner Suomi gave a physics colloquium. And that physics colloquium led a good friend of mine, Larry Sromovsky, to go straight from getting his theoretical physics PhD to the Space Science and Engineering Center to work with Vern. He'd always been interested in space science, and it was an immediate click, I think. I got my degree and went to Brown University on a postdoc. And I came back to see Larry socially over Christmas, and I could see myself bouncing around the country from postdoc to postdoc. At the time, it was hard to find positions. And he said, "Why don't you come back and work with me? We're doing all kinds of neat things, exciting things." So by March, three months later, I had moved my family—young son, wife—back to Madison, sold the house in Rhode Island, and I've been there ever since.

NATHANS: That's right, that was the era when jobs were very hard to come by, and it was the era of the gypsy scholar because you had to go where they would take you.

REVERCOMB: That's right. So I started out with something that you might say had something to do with meteorology—it was solutions to the Boltzmann equation for transport properties of helium three and four—but not very related to what I ended up doing.

NATHANS: Which was? [Or] Is?

REVERCOMB: Well, which is observational meteorology. Vern Suomi is known for starting us off in the satellite era, and he had the first instrument to look at the Earth from space in 1959. We're celebrating that 60th year. We're talking about TIROS [Television InfraRed Observation Satellite], that was one of the real big events that's almost 60 years ago. But Explorer 7 was almost exactly 60 years ago. [On the] 13th of October we'll celebrate that.

PHILLIPS: So once you started working with Suomi's small team at the Space Science and Engineering Center, what was the first program that he had for you? And so there's that, but also talk about Suomi, why Suomi wanted physicists on his team rather than atmospheric scientists.

REVERCOMB: [laughs] I'm not a hundred percent sure, but I think he felt that it fit well with his own talents in meteorology. And he was always interested in building things, so that made it fit pretty well. And he was the type of guy who would hand off responsibility. He would get things started and get you running and then give you the independence to go do some things. So at that time, Larry Sromovsky was really leading an effort to build the first—to design the first—sounding instrument in geostationary orbit, the VISSR [Visible-Infrared Spin Scan Radiometer] Atmospheric Sounder. So Larry hired me, and then a year later Paul Menzel, to work on that project. And it became an incredible experience for many reasons, many reasons beyond that project because Vern Suomi had an idea a minute and over those first five or six years, I worked on a huge diversity of projects. It went from VAS [VISSR Atmospheric Sounder], to designing a new Earth radiation budget experiment in competition with NASA Langley and with Colorado State, Tom Vonder Haar, to helping build a new sensor to fly to Venus, a net flux radiometer, to studying Saturn and Jupiter with Voyager and actually beginning some new things that became the next forty years. But all of those things happened at once, and they happened in quite a bit of depth. You know, people do things in different ways, and Vern was a guy who was fantastic at both breadth and depth because he'd get out the soldering iron, but he'd be the guy who was getting a lot of these things to start up internationally. I think I was better at depth. So after these first few years, I really dug in on some other things.

PHILLIPS: Such as?

REVERCOMB: Well, this one I attribute to Bill Smith. Bill came back to Wisconsin—he had been at NOAA [National Oceanic and Atmospheric Administration] and been the principal investigator on many projects—but he came back to Wisconsin to do the processing for VAS, VISSR Atmospheric Sounder. And he recognized even before that instrument was flown that we needed to do better. In geostationary orbit, where we were studying mesoscale events, we needed detail in the vertical as well as detail in the horizontal, which we couldn't get well enough from the first sounder. And he recognized that we needed high spectral resolution measurements in the infrared to be able to get high vertical resolution in the soundings. And that's been a major part of what, certainly, I've been involved with, and our groups in Wisconsin have been involved with since before 1980, before the VAS instrument flew.

PHILLIPS: So talk a little bit about this long lineage, instrument lineage, that really began with VAS. And we have CrIS [Cross-track Infrared Sounder] flying now, which has a direct connection to some of that early work on the polar side, and so let's start there.

REVERCOMB: [laughs] It was a little bit of a crazy path because the first thing we did in 1980 and '81 in conjunction with partners, Santa Barbara Research Center and ABB Bomem in Quebec—who we chose out of a large number of proposals to design the first geostationary sounder—we also designed an aircraft instrument. So in the mid-'80s, we built and flew the first instrument that could actually demonstrate that this idea of high vertical resolution coming out of high spectral resolution measurements would work, and that it was practical to build these kind[s] of instruments. So we built at Space Science and Engineering the HIS [High resolution Interferometer Sounder] aircraft instrument that flew on first the U-2—because NASA [National Aeronautics and Space Administration] was using them for environmental studies—and then its follow-on the ER-2 [Earth Resources-2]. And in 1986 it was able to successfully prove that this worked, and we started to realize that it was bigger than that because to do any kind of remote sensing, you also need to have models of radiation that are extremely accurate because you're looking for sub-one degree types of brightness-temperature differences.

And when we first showed the results from our aircraft instrument at a conference, Tony Clough, who had been doing radiative transfer for many years and was the innovator of fast code, got so excited that he finally had a way to verify how good his calculations were that was highly accurate. And of course you can't derive things about physical properties of the Earth from measurements if you don't have a model for the measurements that tells how they relate to the properties of the Earth because you're measuring radiation above the atmosphere, not the properties directly. So it's equally important to have that type of thing as it is to have the observations in order to get properties of the Earth. So after the aircraft instrument, there were periods of time where we had trouble getting it funded. We flew it many times and very successfully in a lot of research experiments, but at those times it was again Bill Smith's idea that we turn the aircraft instrument upside down and make ground-based measurements. And those ground-based measurements turned into a project of about 20-some years, the DOE [Department of Energy] ARM Program, Atmospheric Radiation Measurement Program, which was aimed at improving these radiative transfer calculations. So we designed an AERI—

PHILLIPS: Which is an atmospheric emitted—

REVERCOMB: —radiance interferometer.

PHILLIPS: —radiance interferometer.

REVERCOMB: Yes. So the same type of instrument we had on the aircraft generically, in a very different implementation, looking up from the ground. And it proved to— and its main objective was to improve radiative transfer for ARM—it was a climate program, ARM. And so we wanted climate observing systems at all types of domains around the Earth that would characterize different types of climate and allow you to understand how to do radiative transfer in different types of atmospheres. So in the process we also—Bill Smith again—did inversion routines so that we could sound the boundary layer and the lowest two or three kilometers of the atmosphere where things change the most rapidly, the area that you really want to know the most about in the atmosphere. It's the part we live in, it's where severe storms originate, and we proved that this instrument could look at it almost continuously and give us information about the boundary layer. And we still hope that these will end up, at some point, as part of our ground-based networks around the country to help do that type of thing.

PHILLIPS: Well they are being used extensively in field experiments—

REVERCOMB: That's right.

PHILLIPS: —all over. And I guess talk a little bit about—we'll come back to this other thread—but talk a little bit about the extensive field experiments that you've been involved in when you look back, with all of these instruments.

REVERCOMB: Yes, I mean that was the very exciting thing about approaching satellite instrumentation from really building aircraft and ground-based instruments. Because I think as everyone knows, you're fairly lucky in our field if you are directly connected to one spacecraft instrument—it takes a long time—and having these ground-based and aircraft instruments allowed us to do science continuously and approach new things all the time.

So we had numerous, numerous field experiments with aircraft instruments, including the first HIS then its follow-on which we're still using [inaudible]. And we studied cirrus clouds in projects called FIRE [First International satellite land surface climatology project Regional Experiment]. We've studied fires in projects called FIRE. We studied the ozone hole out of New Zealand in 1994. We studied emission and fires from—natural fires—in South Africa in 2000. And it's just been one experiment after another. We flew over Greenland for validation of spacecraft high spectral resolution instruments—which we'll get back to in a minute—that were outgrowths of this program.

PHILLIPS: And even most recently this past summer, the FIREX-AQ [Fire Influence on Regional to Global Environments and Air Quality] mission?

REVERCOMB: That's right. So the exciting thing there is you have a team with an incredible range of talents. I mean, you have to do all kinds of things to get something to work on an aircraft instrument. There are engineering challenges. There are communication challenges. Actually one of the more exciting ones that we did—not too long ago, not sure what the years were, but—was the Hurricane and Severe Storm Sentinel Experiment where we flew on Global Hawk over the Atlantic. And Global Hawk had 24 up to 30 hours range, and so you'd really like to know what's going on during that flight and get that information to the pilots so it can be used to help decide exactly where to go next.

This was trying to understand what causes hurricanes to intensify or diminish and get detailed information about where the water vapor comes into the hurricane and what you see in the eye. And we did both of those types of things, and it was just amazing what our team was able to do. [It] turned out—and that means a wide range of people—but it turned out that we are able to get the data sent back by satellite to Wallops Island. Then it went to the West Coast and got transferred to Wisconsin where we did all the analysis to get calibrated spectra out of it—detailed, thousands of point spectra. Those get inverted to get temperature and water vapor, plot them up, and have all that come back to the command center and get to the pilots in less than a minute. It was unbelievable. I don't think any of us thought that that could be done when we started this, but you get a bunch of people inspired, and things happen. That was a wonderful experience.

PHILLIPS: So I want to return briefly to your comment about a global network of AERIs—

REVERCOMB: Well, you know, money determines a lot of things. I think a lot of people have recognized—and there are people like Dave Turner still working very hard through NOAA, in NOAA, to get it recognized—what kind of value we would get out of a network like that and try to get it implemented. Not just AERIs, but AERIs with LiDARs [Light Detection and Ranging], put them either in a row so that you see what comes in out of the Gulf of Mexico or put them at all the airports around the country to augment what you get from sondes.

PHILLIPS: Yes.

REVERCOMB: The sonde data comes in—

PHILLIPS: —twice a day.

REVERCOMB: —twice a day. And here you can get measurements every five or ten minutes of what's going on in the most important part of the atmosphere. But at the same time, actually a little before we started these ground-based measurements, we started going from a geostationary spaceborne sounder to a polar sounder. And we competed for what became the AIRS [Atmospheric Infrared Sounder] program. So we had a design that was a Fourier transform spectrometer that competed with the JPL [Jet Propulsion Laboratory] grading spectrometer, and ended up not winning that one, but we designed an instrument very similar to what became IASI [Infrared Atmospheric Sounding Interferometer] in Europe, and is now part—a very important part—of the Joint Polar Satellite System—

PHILLIPS: Yes.

REVERCOMB: —that covers the 9:30 orbit in the morning, where the U.S. CrIS now— AIRS and CrIS are in the 13:30 orbit. So it ended up— It was a very exciting competition. We learned a lot, both from the aircraft instrument, the details of how to do it, our confidence in being able to do it, and it also led to, in 1990, doing a design effort again with Santa Barbara Research Center and ABB Bomem. Wisconsin led the effort, working with EUMETSAT [European Organisation for the Exploitation of Meteorological Satellites] to design the next polar sounder. At that time it was called ITS. We'd had HIRS [High resolution Infrared Radiation Sounder] and HIS, and we had to have ITS [they laugh]. And that's what became CrIS, through a competition. And of course, there was a detailed redesign done at ITT in Fort Wayne, now L3Harris, [which] did a fantastic job on designing and building that instrument around the ABB Bomem interferometer, the same direction we had followed.

PHILLIPS: Mm-hmm [agreement].

REVERCOMB: We actually got involved with ABB Bomem early on when we chose people to work with for the very first GEO [Geostationary Earth Orbit] sounder.

PHILLIPS: They're a Canadian company.

REVERCOMB: They're a Canadian company out of Quebec. And they had already solved and implemented in the instrument many of the issues with Fourier transform spectroscopy that people were laying down theoretical definitions on. And so it was practical to go to an aircraft instrument with the type of instruments they were already building and avoid a lot of the pitfalls that can happen. You know, if you ever saw an interferometer in a physics lab, if you touch the table, or if you breathe on it, you see the fringes—the interference fringes between two paths of light—move around. Well you can't have that happen when you're trying to make detailed measurements.

And they had done a clever thing where they auto-aligned the plane mirrors which brought in the two beams for the interferometer, with servo control, so that even if the environment was vibrating, as long as you controlled the frequency band's vibration, you could stay in alignment. So when we flew on the ER-2 and the U-2, we were almost bolted to the jet engines. We were in an old fuel tank under the centerline, and it worked beautifully thanks to this mechanism. So it really led us on a long course of getting involved with the future operational high spectral resolution instruments, and how to better calibrate them, how to better intercompare them, and use the data.

PHILLIPS: Mm-hmm [agreement]. So you've brought up the idea of, you know, cooperation. That seems to be a huge theme this week, cooperation and collaboration. Talk a little bit about the European version of the high spectral resolution sounder and our, your collaboration with them along that path.

REVERCOMB: Well, of course, we've been very supportive of getting this type of observation in orbit. We were convinced that it was going to make a huge difference in forecasting. It's proven to be true. And it's the European Center that has demonstrated that with the best success so far.

PHILLIPS: Mm-hmm [agreement].

REVERCOMB: Right now at the European Center, the microwave sounder has the most impact, but the next most impact is the hyperspectral IR [InfraRed]. And many people believe the difference between those two is the numbers of instruments. There are many more microwave instruments than there are infrared. But it's clear that we benefit from having both. You know, that's part of the cooperation. It's not just cooperation, it's the fact that you don't— you can't really rely on one technology doing everything. And you're usually best off when you endorse the virtues of each and try to fly more than one type. And it's certainly true of infrared and microwave. Microwave sees through the clouds. Part of the virtue of the infrared is it does see the clouds, and we need to get the clouds right in the models too. And the infrared has higher vertical resolution, it generally can be done with higher spatial resolutions. So when you're looking at mesoscale events, it's nice to have the infrared before the clouds come in. And then you can see what's likely to happen in the way of severe storms. And the microwave is great for peering into storms, into the hurricane.

But working with Europe has been very rewarding. You don't get— When you work internationally, you don't get your hands on the instruments, but you can have an impact on where things go, and work as a team, and it requires pretty big teams. And of course the European industry has designed their own instruments and didn't use our design.

PHILLIPS: Right.

REVERCOMB: I think what was useful in what we had done was to show that this could be done, and the virtues of what you could accomplish if you went that way. And so it has become a worldwide effort to provide these types of instruments to the whole international fleet, which gets defined through international agreements with WMO, the World Meteorological Organization, and CEOS [Committee on Earth Observing Satellites], the definition of the Earth Observing Systems.

And we've worked with the Chinese who are very active now in putting out new instrumentation. They actually have the first hyperspectral sounder in geostationary orbit—it was launched in late 2016—and are moving to improve it every couple of years so that in the mid-2020s, it will be an extremely accomplished instrument, very similar to one that we designed in the early 2000s called GIFTS [Geostationary Imaging Fourier Transform Spectrometer].

GIFTS started something really new in this area. The concept is simple: you take an array of detectors and put it behind the Fourier transform spectrometer. So instead of measuring a few pixels on the ground at a time, you measure, in the GIFTS's case, 16,000 pixels on the ground. And this allows you to do things in parallel and get much more rapid coverage of the whole globe, and much more rapid and detailed coverage of mesoscale events, also. So it allowed us to go from spatial resolutions on the order of 15 kilometers to 4 kilometers. And that's going to happen in Europe, it's going to happen in China, and we're hoping in the same timeframe we're going to have a Pathfinder in the U.S. And that would provide what the WMO has called for, a global ring of this type of capability.

So people talk about imagers and sounders, well, our sounder is an imager in geostationary orbit. It can be from polar orbit as well. So we shouldn't think of one as providing images and the other as providing only isolated soundings. These imaging interferometers are true imagers, and what we need for studying the details of mesoscale weather—severe weather that kills people, tornadoes and hurricanes—is much more rapid and more detailed measurement. And so while the imaging from the imager has one or two kilometers resolution in the infrared, the sounder can have two to four kilometers resolution in the infrared and provide all of this information in the vertical that tells you about the stability of the atmosphere. And so— And at the same time, when you measure it as a sequence in time, you're fundamentally tracking the movement of water vapor, and you're getting independent wind information. And right now Tony McNally at ECMWF [European Centre for Medium-range Weather Forecasts] has evidence that shows that we're actually getting more wind information out of the current hyperspectral sounders than you get out of the atmospheric motion vectors that are measured by the imager.

PHILLIPS: Oh, really?

REVERCOMB: Yeah. So you're getting temperature, water vapor, and winds as a function of altitude from the hyperspectral sounder.

PHILLIPS: So you mentioned that this— your hope is that this becomes part of a Pathfinder mission?

REVERCOMB: Yes.

PHILLIPS: What is the timeframe for that?

REVERCOMB: We submitted a proposal to NASA a few years ago for a project we called WARN.

PHILLIPS: Yes.

REVERCOMB: And the idea of— There are going to be many proposals from different people as to what should be done from GEO next. So I'm just talking about the concept that we have and the ones that show that this can be done quickly. I believe that before we go into the full-blown operational GEO system, we want to put up something that we know how to do now, quickly, so we start saving lives and get the benefits of it before we can get a full-up operational system in place. And we submitted a proposal that showed that you could make use of things that the government has already bought, either a GOES-Q [Geostationary Operational Environmental Satellite-Q Series] satellite that's never going to be launched, sounder, or a prototype for ABI, the current imager from GOES-R [Geostationary Operational Environmental Satellite-R Series], and put an interferometer package that was developed for the HES (Hyperspectral Environmental Suite) development in the early 2000s inside of it, and that that's the type of program we could move very quickly on and have in orbit by 2025. So it would have great benefits quite a few years before you can actually practically think you're going to have a full-blown operational system.

PHILLIPS: Sort of like Suomi-NPP [Suomi National Polar-orbiting Partnership] did for the polar test.

REVERCOMB: Yes. And in a sense, what VAS did for sounding from geostationary orbit to begin with. What it did was take out a filter wheel, and put in some— Well, it didn't take out a filter wheel, but it put in types of spectral measurements that you needed to do sounding, rather than just imaging, as an experiment in the back end of what was an imager.

PHILLIPS: Okay.

REVERCOMB: It was very similar.

PHILLIPS: So the future looks optimistic.

REVERCOMB: I think it does.

PHILLIPS: As you kind of look back over your career, talk a little bit about people who were your mentors or models over time.

REVERCOMB: Well, there were a few important people in grade school, I guess, that were inspiring teachers, and that got me interested in science early on. But I would say probably one of the first major ones was in graduate school where there was a person in physics, Professor Blanchard, who was known as the father of the graduate students. And he pretty much made it his job to have everyone succeed. So if you started a project with someone and it didn't work out, he would look around and try to find somebody that you could work with where it would work out. And that happened to me. I started out working for one person in theoretical chemistry, actually, where the work was similar to what you do in physics as well, and then ended up working with Ludwig Bruch, who was a perfect person to work with, who gave me a lot of rope to go either succeed or hang myself with [they laugh]. You know, the opportunity to work with someone who was very good. He gave me a project which wasn't clear it could be done at the time, but we ended up doing it.

So I think Professor Blanchard probably had as much impact as anyone before I started working with Larry Sromovsky and Vern Suomi, who were very different people, but both of whom had a big impact on me. Larry taught me how to do research. Vern taught me about people and projects [laughs]—

PHILLIPS: I guess one other question: you've spent your career really aiming to improve observations.

REVERCOMB: That's right.

PHILLIPS: Just talk a little about that. I mean as you look back you must say, "Wow, look at the improvements!"

REVERCOMB: Well, in many ways, yeah, the improvement's been spectacular. The shift from theoretical physics to observing isn't as big as it sounds. I mean, to do either one, you need both theory and observations. To just do theory and not compare it with anything doesn't make much sense, and to do observations and not have any way to interpret it doesn't make much sense. So they're really a continuum. They're not all that different, although we usually think of them as totally different fields. So working on developing models of radiation is part of getting the observations to improve.

And then certainly when you're in the middle of it, it seems slow and almost frustrating because you think you could move a lot faster than you're able to move. But then when you stand and look back, like you say, the changes are enormous. When we started this, actually for the first probably almost two decades of making measurements from geostationary orbit—first with VAS, and then with the three-axis stabilized sounders in 1994—it was very difficult to make any positive impact on the models. And part of that is the nature of the observations, and a major part of it is just the learning curve of how to use this new data. And we've made huge progress in both. We've had new observations, but these things where you're doing what's called 4-DVar, where you bring in an observation at the time it's taken, and put it in the model, and you keep updating the model continuously, seems almost mind-boggling that that can be done. And there's been a huge group of people working on that and making it happen. A lot of this started— The early successes started with Jon Eyre, who we worked with at Wisconsin, and was very instrumental in Europe. But the whole concept that you could do some of these things where you're optimizing a whole globe at once seems almost impossible. But the evolution of computers, the evolution of people's way of thinking about it, and the evolution of the observations have all added up to something that's now having a major impact on weather forecasting.

PHILLIPS: Yes. Did you want to move into—?

NATHANS: Yes. I'd like to switch gears a little bit and ask you a few questions about AMS. When did you first become a member?

REVERCOMB: [Laughs] I don't know if I know the answer to that. I must admit when I started in this field, I always felt a little bit like an outsider because we worked in many different projects, and we crossed a lot of different lines. Some of it was SPIE [Society of Photo-Optical

Instrumentation Engineers], some of it was AMS, and I evolved into AMS probably in the '90s.

NATHANS: What do you think has—

REVERCOMB: Part of it was planetary science. Sorry—

NATHANS: That's okay.

REVERCOMB: Yeah, that's an exciting part. We had to give five-minute talks. It was almost impossible [laughs].

NATHANS: What do you think now is the most important part of AMS for you? The conferences? The publications?

REVERCOMB: The conferences are the most important for me, meeting new people. And I really like these trends of having joint conferences with Europe because a lot of our work is mixed between the U.S. and Europe and China, you know. International meetings are very important.

NATHANS: And the publications, do they— Do you wait for your *BAMS* [*Bulletin of the American Meteorological Society*] every month?

REVERCOMB: I do get excited looking at *BAMS* and what's on the cover and some of the new things that I haven't been aware of. So that is beneficial. But I must say that I'm not as much of a reader as I'd like to be. I spend a lot of time trying to solve various problems, both hands on things and theoretical things.

NATHANS: It's really interesting to me, having listened to all these interviews over the last few days because I remember when people were saying that America was a nation of people who tinker with things. And when cars became much more sophisticated, people couldn't go into their garage and take their car apart. But being at this conference, there are a lot of you who are the tinkerers who've ended up here, in satellites.

REVERCOMB: I think that's a fair characterization, yep.

PHILLIPS: You come from an environment where you've had scientists working alongside engineers and—

REVERCOMB: —Machinists.

PHILLIPS: Machinists, and all—

REVERCOMB: And some of those guys are like jewelers, you know. The precision they can build things and the beauty of some of these instruments is really quite amazing.

NATHANS: Well, and this is the first conference where I've heard anyone use the word "solder." [They laugh.]

PHILLIPS: So Hank, is there anything else that you would like to touch on that we did not ask you about or that you haven't shared?

REVERCOMB: Climate.

PHILLIPS: Please.

REVERCOMB: [Laughs.] Because it's the same technology, but in order to apply it to really help improve our knowledge of the climate and have better observations to help weed out the various climate models as to which has the sensitivity right, we need better observations, observations that can detect very subtle trends over decades. And this technology is very well suited to that, but we had to develop some new things. And Fred Best had a major impact on that. We won an instrument incubator program to develop a new concept of a climate-sensing instrument as part of the CLARREO program—Climate, Absolute Radiance and Refractivity Observatory—which we got started in the decadal survey of 2007, working with Jim Anderson, and which ended up being organized through NASA Langley [Research Center]. And it hasn't fully proceeded, but we did develop a prototype for the infrared part of it, and LASP [Laboratory for Atmospheric and Space Physics], from Colorado, developed a reflective solar instrument. So we now have prototypes for the instruments that can do this.

And what it would do would [be to] make highly accurate measurements, even more accurate than we're able to do with the current sounders. And the concept in the infrared is then to be able to inter-calibrate the whole international fleet of infrared instruments so that you can use all of them to tie down the current climate state far more accurately. And if you do this every decade or decade and a half, then you'll be able to see the trends in a lot of detail—not just trends in radiation but trends in temperature, water vapor, and clouds—that are occurring over these timeframes. And you can see them probably at least twice as fast as we can now with the accuracy that we have in the current measurements. So we're very much hoping that there'll be an opportunity, as there's more emphasis put on climate, to move ahead with this type of a climate mission, which funding was removed from in 2010—

PHILLIPS: It was in the president's budget, yes?

REVERCOMB: Well, there was funding— up until 2010 there was funding to start moving toward a full Phase A at NASA Langley. On Valentine's Day, the plug was pulled in 2010. After that, we proceeded with the science team [and] put out a major publication by Bruce Wielicki as the prime author in 2013 to lay out the science and the approaches to doing this. At the same time, we were building these instruments that are now up to what NASA calls TRL-6 [Technology Readiness Level-6], so they're ready for a flight mission. And then in 2016, the Pathfinder mission to fly both the reflective solar and infrared were put in the president's budget at a very low funding level, and NASA decided they couldn't really do both. And they're now proceeding with the reflective solar as a Pathfinder, so we need to find a way to get the infrared up there as well. They don't even have to be up there at the same time, they just need to each be up there for an extended period of time.

And at any rate, I think that's a totally different science from similar technology, but what Fred Best developed was a technique for us to take what you normally do in the laboratory—with establishing a temperature scale—into orbit with us so that you don't have this break in what's called SI-traceability. When you characterize an instrument on the ground, you fly it, and you hope it stays stable for many many years. And what we're doing with this one is taking what we would normally do on the ground and will do on the ground, but also do it in orbit, so there's no gap. And so it will be irrefutable evidence that we have measurements that are accurate. And that's what we need, to convince people that we know what's really happening with the climate.

PHILLIPS: Globally.

REVERCOMB: Globally. I mean, we know— I shouldn't even put it that way because we clearly know what's happening in the sense that the greenhouse is caused by human beings burning hydrocarbons. But what you don't know is how all the various feedbacks work and exactly how strong the effect will be and how quickly. So we need to get those trends known better so society can be willing to act in very specific ways. We need to act now. But as we go along, it will be nice to have a little more guidance on what more needs to be done.

PHILLIPS: This has been another recurring theme over all of these conversations this week, the climate change issue and the need to act. Anything more?

REVERCOMB: Well, thanks.

PHILLIPS: Thank you so much for coming in to talk with us today.

NATHANS: This is great, thank you.

PHILLIPS: Thank you.

REVERCOMB: Thank you for doing this with the whole crew, it'll be a very interesting record. I'll be very anxious to read this one, or hear this one. [They laugh.]

[END OF INTERVIEW.]

[. . .]

[END OF TRACK.]