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Paul Emma by David Zierler
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DAVID ZIERLER: Okay, this is David Zierler, oral historian for the American Institute of Physics. It is September 7th, 2020. I'm so happy to be here with Paul Emma. Paul, thank you so much for joining me today.

PAUL EMMA: It's a pleasure. Thank you, David.

ZIERLER: Okay. So, to start, would you tell me your most recent title and institutional affiliation?

EMMA: I think it was Senior Staff Scientist at Stanford. At SLAC. I'm now retired. But, my last title was that. A Senior Staff Scientist.

ZIERLER: When did you retire?

EMMA: Two years ago.

ZIERLER: Oh, recent.

EMMA: But, I'm actually still connected with SLAC and I do some work on more of a consulting basis. But it's quite miniscule compared to what I used to do.

ZIERLER: [laugh] What kind of stuff have you done with SLAC since retiring?

EMMA: Helping to document and calculate tolerances for the LCLS-II, the next phase. Which is gonna be starting up. It actually is starting up right now, so…

ZIERLER: Okay, Paul. Well, let's take it all the way back to the beginning. Tell me a little bit about your parents and where they are from.

EMMA: My father is from…he was born in the U.S., but just barely. Most of his family was born in Sicily. And my mother was born in the same town as my father, in Illinois. Geneva, Illinois. And they're both gone now. But, they were both from Italian families. And, yeah, I miss them.

ZIERLER: How did your families get to Illinois?

EMMA: I don't know the details. I wasn't there at the time. [laugh] I think my grandfather came to New York first. He went back and forth for several years before he finally decided to become a citizen. And when he came back one time he decided he was going to stay. He sold fruit on a little stand somewhere in New York. And eventually he moved out. Thought that was a little bit too crowded of a place and he knew somebody in Chicago. So, he moved to the suburbs of Chicago, which the whole family stemmed from.

ZIERLER: What did you father do for a living?

EMMA: He was an architect. He had his own firm in Geneva, Illinois. And he worked at it constantly until he retired as…my mother pushed him to retire.

ZIERLER: Right.

EMMA: He retired when he was about 68, I think.

ZIERLER: Did he involve you at all in architecture? Did you get to learn at all about his work?

EMMA: A little bit. Now and then we'd go help him empty the wastebaskets in his office, which was always in need. He actually asked me to build him a 3D model out of cardboard of a house he was designing so he could see it better. And I had fun putting that together. He showed me how to read the drawings because I didn't know quite the…what all the terminology meant. And I had put this together and he was very happy with it. And he actually built that home for himself up in Green Bay, Wisconsin.

ZIERLER: Oh, wow. Did your mom work outside the house?

EMMA: She did off and on. When we were younger, she was always home. But as we started leaving the nest, she started making her own…she built her own company called Brochures R Us…I think something…something about brochures. And she would make resumes for people who were trying to clean up their act. Getting new jobs. She had a little business on the side and she was very pleased, I think, to have that rather than just sitting around the house with an empty nest.

ZIERLER: Paul, when did you start to get interested in science and engineering?

EMMA: It wasn't for quite a while, actually. I went to several universities trying to figure out what to do. And I went to Western Washington University, up in Bellingham, Washington. It's a beautiful place. I took a spattering of courses there and I took an astronomy course just because it sounded like very different than everything else I was taking. And I really liked astronomy. Just to hear…see simple equations come together and predict some motion. And of course, it was more a layman's class. But it got me excited about the possibility of chemistry or physics or science in some way. So, I joined a couple of chemistry and physics classes. I didn't know a thing. Got me interested in it to the point where I started doing very well in it. And then there was no stopping me.

ZIERLER: Now Bellingham is a long ways away from Illinois. How did you get up to Washington?

EMMA: By motorcycle. [laugh]

ZIERLER: [laugh] I meant, why not go somewhere closer to home?

EMMA: I just wanted to try something new. Get away from the Midwest. I had no problem with it, but I wanted to see the mountains in the West and see the ocean and maybe live there for a while. And I've stayed. I never went back to the Midwest. It led me to Stanford and everything else.

ZIERLER: Now I understand that you did not complete the degree at Western Washington. Is that true?

EMMA: I did not…I had a physics degree going, but I did not…I took all the physics courses, but I did not take about four or five other courses that are more general rounding. I should have, but I got accepted to Caltech for a graduate program there and I just left Bellingham the way it was and I figured I'd take care of it later someday. I only lasted about six months at Caltech before I decided I didn't want to continue. Then I went to Fermilab from that.

ZIERLER: Now Caltech accepted you knowing that you were not going to complete the undergraduate degree?

EMMA: Yes. I called them and asked if that was doable. And they said, "Yes. We've got no problems. We just want you to come the way you are. Or either way."

ZIERLER: You must have done quite well in undergraduate for Caltech to accept you on those terms?

EMMA: Yeah. I had a good GPA at the time.

ZIERLER: And what were you looking to pursue? What kind of degree were you looking to pursue at Caltech?

EMMA: Uh, physics. I was pretty well focused on physics by that time.

ZIERLER: What kind of physics?

EMMA: Well, it was a graduate program in physics. I hadn't…I was working with one of the professors there. We just started. I was trying to help him as an assistant in this proton decay experiment in a big Ohiomineshaft. That was…what…1982 or something like that. So, I started working on photo] tubes and trying to understand how this whole experiment was gonna work and I didn't stick with it. But I probably would have gone into high energy physics, which I eventually did. Except for, it's not really high energy physics from my point. It's accelerator physics now.

ZIERLER: Now who was this professor that you were working with initially?

EMMA: His name was LoSecco. I don't remember his first name. He was new at Caltech and was one of the researchers for this proton decay experiment. And I didn't get to know him very well cause I wasn't there long enough. But, he was very helpful to me and got me started.

ZIERLER: Now six months at Caltech. Were you looking for a way out? Or did Fermilab sort of present an opportunity and you decided this was the better way to go than finishing up at Caltech?

EMMA: Well, when I left the Midwest for Caltech I was working already before I left. I was working at Fermilab in the summers as a…what they call a summer student. And I think that I did two or three years of that while I was in Bellingham. I came back during the summers to the Midwest. Worked at Fermilab for three years in a row. And then each time I went back to Bellingham to finish my degree, which didn't quite work.

ZIERLER: Now was Fermilab close enough to where you grew up that you were able to be at home for the summers?

EMMA: Yes. Fermilab is…where I grew up it's five to ten miles distance. Just down the road.

ZIERLER: Oh, wow. And what kind of work were you doing at Fermilab during the summers?

EMMA: We were drilling holes in the ceiling. And pressure testing the holes with anchor bolts in them. They actually gave this job to me and one of the other guys. And we ran around that ring with a golf cart inside there and drilled holes in the ceiling for…places they told us. And this was for an upgrade of the big machine. It's the Main Ring at Fermilab. And yeah. It was a simple job, but it was fun to get to see all the equipment and took underground tunnels and the accelerator itself while we were doing this very simple but fun work. Cruising around the ring.

ZIERLER: And now what was that initial job that you took at Fermilab when you left Caltech?

EMMA: It was for accelerator operations. There's a crew of four or five, typically young people that run the machines there in the control room. And they learn a lot about the procedures and how to inject into the Main Ring from the Booster Ring. And I was part of that crew for about three years. Maybe two years. And then they advanced me to crew chief which meant I was in charge of the four or five people that are on shift. It was fun. You learn a lot. You really learn the Fermilab layout. Especially the accelerators. But it was a lot of heavy weekend work and night work and owl shifts and twelve hour shifts. And it was hard to take. There's a lot of turnover in those spots.

ZIERLER: Were you interacting with physicists in this work?

EMMA: Yeah. Definitely. In fact, the operators had the in on everything because they're present all the time. You know how to turn on, turn off, calibrate. Whenever it takes components from the control room. And physicists…they know the physics and the machine very well. But they don't know the control system…how to do it. They're not there all the time like we were. Operators learn a lot.

ZIERLER: Can you describe a little of the day to day of what it looks like to operate these machines?

EMMA: Yeah. It depends on what's going on. If it's routine running, it can be quite quiet. But if it's maybe bringing up a new machine…and when I arrived they were just starting up the Tevatron. So, it was fun because there was a lot of people coming in and out of the control room constantly…real hard push to get the first beam around the Tevatron. And I was standing around wondering what they're doing. Of course, I learned a lot. I was just there. Just arrived. And I didn't know what was going on. But I eventually learned what was going on and had a fun time. And I became very efficient with the Tevatron tuning. Which was fun because I was the new guy and yet I could be good at something that others weren't yet.

ZIERLER: What were some of the challenges in operating the Tevatron? Given that it was the first of its kind?

EMMA: Getting enough protons in from the old Main Ring and from the old Booster and the old LINAC that's been at Fermilab since the '60s. This was a brand new ring on top of [actually below] the Main Ring. I think a six mile circumference, if I remember right. 2π miles circumference. The challenge was getting the protons to fill the Tevatron at a high enough energy to be…satisfy the users. And that meant snaking the beam around obstructions and steering it properly and diagnosing the beam loss and trying to maximize the throughput. It was always different. Every day it seemed to be a little different. So, it was challenging to try to figure out what to do. Sometimes you got frustrated and spent days not correcting a problem. Other times you'd get lucky and hit the right switch and you're a hero overnight. [laugh]

ZIERLER: [laugh] Paul, was it your sense that the Tevatron was really going to determine the future of Fermilab?

EMMA: At the time we didn't think too hard beyond Tevatron. I'm sure management at the Fermilab was. But from an operations point of view, we were just struggling to run that one machine. There was lots of talk about what would come after. And in fact, antiproton acceleration was phasing in at that time too. So, they were going to collide protons and antiprotons. So, accelerator systems and proton production systems had to be built and tested. So, there were a lot of challenges. Fermilab had a bright future at that point. There was no talk about Higgs bosons at least at my level. It was all about getting the machine to run right and bringing in the new systems for Pbars, they called them. Proton-antiprotons.

ZIERLER: And who were some of the physicists that you remember who were most involved with the Tevatron? Both at Fermilab and visitors who would come in?

EMMA: Oh boy. Peter McIntyre was one name. I think he's at Texas A&M these days. But he gave me some nice work to do one of those summer…I think it was when I was there during summer. He wanted me to help him with a storage ring. What is it? Electron cooling. Which was the hot item at CERN and Fermilab at that time. And it was an electron ring with…I forgot. Electrons and protons put together in order to cool the proton beam. It was a new scheme and I remember he had me bolting up a flange. I had to crawl into a giant pipe and reach my hands around the corner of the pipe and put in 24 stainless steel flange bolts. It was very hard to reach and I spent the entire night on my back in that tube in the darkness feeling the bolts onto the flange. Got it done, but boy that was a real…

ZIERLER: [laugh] It's a day that sticks out in your memory.

EMMA: Yeah. Sticks out in my memory.

ZIERLER: What were some of the safety considerations that you had to think about when dealing with the Tevatron?

EMMA: Well, people always wanted to go in the tunnel to fix something, to add something, to bring somebody down there for a tour. So, we had to make the ring safe for people entering it. We had to go and do…what was it called? I am forgetting a lot of this stuff. We would make a controlled access situation in the Tevatron. Where people would come down if they had the right key with them. And that key was supposed to go normally into a key bank. And they were given the key as our way of keeping themselves safe. Because as long as they held that key the machine would not turn on again. So, after they were done coming out of the tunnel…But when we were all done putting the keys back into the key banks. We made them all up. We had to make sure that there was no one in the tunnel because somebody can find a way in once you open that door. So, the keys weren't quite enough. We also had to go down into the tunnel and do a search. Search the entire tunnel to make sure there's nobody there at all. And that was one of the safety aspects of the job. Sorry for that long description.

ZIERLER: No, that's great. That's great. Paul, when did you know it was time to move on from Fermilab?

EMMA: It was about three years into. Maybe four. It was a personal matter, really. I wanted to get back to the West and get out of the Midwest. I was stuck at that point without…remember I said I didn't finish my Ph.D.? Or my degree at all. And I decided I would go visit my brother. Spend a year with him and fix that degree problem before I went back to work. So, I really left Fermilab with no other job. Just went back to school and took courses again. Not physics courses, but the ones that were missing from my original bad choice of leaving for Caltech without finishing.

ZIERLER: What school did you go to for this?

EMMA: My brother was living in Hartford, Connecticut. He had started his own architectural firm there. So, I went out to Hartford, Connecticut and to the University of Hartford for just over one year to finish up. I think four quarters of work did it. Maybe five. I've forgotten.

ZIERLER: And what was your degree in when you finished up?

EMMA: Then I had a Bachelor of Science in Electrical Engineering. Seems like that was the best way to get a job in the future.

ZIERLER: I wonder with all of your experience if a lot of those courses were sort of…you had already learned a lot of that already on the job?

EMMA: Yeah, but they were formal engineering courses. They weren't much into physics. I remember we talked about a current and a conductor. I've forgotten the setup, but I asked the instructor if that's the derivative of a charge. Sorry.

ZIERLER: That's okay. The question was if you felt that you had already learned a lot of these things on the job? And you were saying, you know, these were formal engineering classes.

EMMA: Yes, they were formal engineering classes. And they were not quite the same as what I was doing before that. But I did have a physics understanding going into that. But I could see things more clearly I thought, than some of the students....

ZIERLER: That's fine. So, you graduated with your degree in electrical engineering and then did you want to…I mean were you looking specifically to go work at SLAC? Was that the goal after you finished up your degree?

EMMA: Oh yes. Yes, definitely. After I got my electrical engineering degree, I sent a blind resume to Stanford. To SLAC. And I got a phone call back and they said, "We've got an operation staff that could use your help." And I said, "Sorry, I did operations for three years at Fermilab. I want something else." And they called me back. A new guy, a different guy called me back the next week and said, "Yeah, we've got something else for you." So, I jumped in my car and drove across the country. Which was fun also. And went to work and it was wonderful. Just starting up the Collider there. The SLC. The Stanford Linear Collider. And…but it was a real tough machine to deal with…but it was a lot of fun though. Frustrating as hell, but…

ZIERLER: What was so tough about it?

EMMA: It was the first linear collider of anything[?]…no one had built anything like it before. It was electrons colliding on positrons at 45 GeV each. And was very difficult to make the beam stable, to preserve the beam size. The emittance of the beam. To diagnose the beam at any one time and change the parameters. They cheaped out when they built it. In fact, Burt Richter, who was the laboratory director at the time says he wished he would've put more money into the facilities, because that's what kept us off. Water pumps, electronics without enough cooling. [sigh] You name it. It was very difficult to run that machine and long enough to tune it up properly. And it took ten years to get to get to the design luminosity. But we learned a lot in that process.

ZIERLER: Like what? What are some of the things you learned over the course of that 10 years?

EMMA: To build electron diagnostics into the machine design, rather than putting them in after the fact. With the SLC we tried to get away cheaply with everything. From facilities to beam diagnostics. And they weren't there when we needed them. So, for the LCLS, we put them every place we could imagine using them and then we…it was a very well diagnosed machine as compared to the one before.

ZIERLER: And who were some of the key people that you worked with on the SLC?

EMMA: Key people…I don't know how to answer that. There's just too many people involved.

ZIERLER: Right. Who was your boss?

EMMA: Well, I evolved all the time too. So, at first it was Andrew Hutton who I think is at Jefferson Lab now. And then it was a young British physicist named Nick Walker, who really helped me get going. A guy named Bill Spence. Unfortunately, he was a little mentally unstable. I think he's gone now, but he was brilliant. He was an amazingly smart guy. He taught me a lot of things. He had the patience to show me through them. Unfortunately, he became violent at times too and you had to stand away from that. But Bill Spence must have been a genius. He really knew accelerators, but he couldn't work with anybody. Except for me at times. I was his translator.

ZIERLER: [laugh] You were involved in a lot of accelerator design development. Let's talk about each of those. Let's start first with the LCLS. What was it like to be on that design development team for LCLS?

EMMA: It was a very small team. We started in…Claudio Pellegrini suggested this in 1992. And we started the…what do they call it? Brainstorming. About how to do it in about '96 or '97. So, I was given the responsibility of designing the bunch compressor systems and where they would go in the existing LINAC. And also, the beam transport systems and the vacuum chambers, magnets, focusing diagnostics. Where to put them, what their needs were, and how to fit them into the existing enclosure because it's all existing. There's the LINAC…is already in place. And so, you have to figure out where to put any new devices. And I was asked to write a couple of the chapters for the conceptual design report to the DOE and started the proposal. So, I was heavily involved in the design. But it was quite a small group. There was other people there for the undulators or X-ray optics or injector for the gun and the injector for the electron beam. But LINAC and its transport lines and bunch compressors was my responsibility. It was a lot of fun.

ZIERLER: What about the SPPS?

EMMA: SPPS was a quick little idea to get us started in X-rays before the LCLS was built. SPPS was simply a bunch compressor that I designed to put into sector 10…sorry, the 1 kilometer point in the SLAC LINAC. We decided if we…we had calculated if we placed a new bunch compressor, which is just four guide pole bending magnets…if we placed it right here and made it this particular strength, the electron bunch could be compressed in length down to around 100 femtoseconds. That's 10^{-15} seconds. And it's quite a short pulse. And it would be good to generate that kind of a short pulse in a spontaneous radiation undulator downstream of that.

ZIERLER: What about the NLC, Paul? Can you talk a little bit about the NLC?

EMMA: Oh, the NLC. Yes. It was the Next Linear Collider. It was supposed to take up the gauntlet for high energy physics. And after the SLC was over and we started writing conceptual design reviews and working on the design for that in the early '90s...unfortunately, it was one of those machines that, after you work on it for several years and seem to be doing the same thing over and over again, it was clear that it wasn't going anywhere very fast. So, I jumped ship in '96.

ZIERLER: Why? Why was it not promising, Paul?

EMMA: Nobody was in yet.

ZIERLER: Why was it not promising? How did you see that this was a reason to jump ship?

EMMA: Because it was extremely expensive. The Linear Collider design. It was very difficult. And we were making little progress with funding, real estate plans for design. And it looked to me like it was never going to be built and I think I was close to right. It's still not built. It may be built in Japan, but the rumors continue.

ZIERLER: And then when you became commissioning leader for LCLS-I, in what ways did that change your day-to-day?

EMMA: Um. It actually, for the SLC, I was in the control room a lot of the time working on the machine in a practical sense. When I went to the LCLS-I design group, which was me, and maybe two others that were part-time…Yeah, so I went from SLC which was continuous practical control room work to LCLS-I, which is a lot of rating and computer work, design work, simulations, all in my office. And so, I was really…I mean, never had done anything like that before where I worked in my office for several years in a row. When it came time for it to…commissioning itself…then I had to come out of the office and go back to more of a practical approach to doing my job. And that was…it was fun to do both for a while. Theory and design, followed by practical commissioning and operation.

ZIERLER: And in this capacity you were probably working more closely with leadership at SLAC?

EMMA: Uh, yes. Because there was a small team that…John Galayda was the leader of the LCLS project at SLAC. Before him there were several other people too that were pushing this proposal along. Like Max Cornacchia. I worked with him for quite a while. He was the one who set up the brainstorming meetings. And Herman Winick who did the first cost estimate for the machine, which was way low. But of course, that's the way they always start. I worked with a bunch of people from DESY in Hamburg, Germany who were building a similar machine and they were extremely helpful to our design. Yeah. There are names I'm forgetting but…

ZIERLER: You were also, Paul, you were team leader for this superconducting undulator, the research and design for the ANL and the LBNL. Was this afterwards?

EMMA: Yes, that was after the…that was from 2011-2013, I think. I was asked to come to Berkeley. They had a job opening and they wanted me to come and be the technical lead for the…I've forgotten the name of it. NGLS. Next Generation Light Source.

ZIERLER: Now, did you resign from SLAC? Or was this a leave of absence?

EMMA: It was a leave of absence. Yes.

ZIERLER: So, you knew you'd be returning to SLAC after a set amount of time?

EMMA: After two years I was gonna make up my mind which way to go. Because it wasn't clear that this new machine was gonna take. So, I kept the door open at SLAC. And I used it.

ZIERLER: I'm curious after all of your time at SLAC what your impressions were at Berkeley?

EMMA: I was back in the office again. Which was appropriate for the next job. But we had a very small crew working on a future design and you could see after about a year that it wasn't gonna take off. I did the two years. I tried my best to put together a good design with a small team there. But it was clear it was not gonna happen. And in fact, that was a superconducting machine that was gonna have very high megahertz rate…beam rate.

ZIERLER: What were some of the goals of the NGLS?

EMMA: The main goal was to get…I mean FEL…it was like LCLS. Except that it had 1 megahertz possibility for beam rate. And we would have future branches. I think up to 10 future FELs tapped off that one main LINAC. Well, yeah, so it was a high rate and the occupancy…the many light source taps that would be available to users. So, the users could…we were overbooked at LCLS quite a bit by a factor of 3-4 if I'm in the right. So, to build one FEL was great, but the users are clamoring to get in there. So, the Berkeley machine was going to have 10 taps. So, the users could be accommodated at the skill they were being…hoping to have at LCLS-I.

ZIERLER: Now, was your sense…could you have stayed on at Berkeley for other projects? Or…you could have.

EMMA: Yes, yes. It was a full-time position. But I had this option after two years and I'm glad I left it open because the LCLS-II was right down my alley. And that was what I needed to continue on anyway. I sort of followed the project back.

ZIERLER: That's what you took up when you returned to SLAC? LCLS-II?

EMMA: Yes. That's right.

ZIERLER: And how did LCLS-II differ from LCLS-I?

EMMA: Just like the NGLS at Berkeley. It was to have a 1 megahertz beam rate. Not 10, but several undulators and FELs. And it was gonna use the existing SLAC LINAC tunnel again. And that is a real tight squeeze when you've got an existing copper machine and you've got [??] giant superconducting RF cavities in the…adjacent to these and still have safe access in and out of the tunnel. So, that's all being done now. They've actually started installing these superconducting cavities in their cryo-modules. But it's a big job. Tight squeeze.

ZIERLER: And this is what we were saying at the beginning of our talk where you remain on in a consulting capacity for LCLS-II?

EMMA: Yes. For LCLS-II now.

ZIERLER: What are some of the goals that you see for LCLS-II?

EMMA: Well, that high rate is the main goal, I think. One megahertz is really something compared to…we were on the LCLS-I at 120 hertz. Quite low rate. And users wanted a lot. And they wanted more like a megahertz. And that's a huge jump for us. So, the goal was to attain that 1 megahertz and to distribute it among two different brand new undulators. One hard X-ray focused undulator and one soft X-ray. And then we would have quick magnetic kickers to deflect the beam off into switchyards. Putting it where it needed to be for the users. It was a very fast, very high average power machine. The electron average power was 1.2 megawatts. And that can, if you're not careful, can destroy things. So, we all had big jobs to work on there. It was machine containment systems. And machine protection systems. So, we don't burn the machine down or puncture a hole in the pipe. Or potentially a safety issue too. Making sure people cannot get anywhere near that beam when it's on.

ZIERLER: Right. Well, Paul, now that we've sort of worked up to the present day…what you're doing. I'd like to ask for the last part of our interview…I want to ask you a little to reflect on your overall career. Specifically, at SLAC, where you were there for over 30 years. So, my first question there is generally, how had SLAC changed over the years when you were there?

EMMA: Unfortunately, it became a lot more bureaucratic than I remember the first years. Lots of training to do. And the training gets longer and longer each year.

ZIERLER: Was your sense that this was because of the DOE?

EMMA: Yes. There was a major electrical accident that happened at SLAC. I think it was about '93 or so. Maybe '95. I've forgotten the year. But, someone was really hurt badly when he tried to service a [480-volt??] panel in the LINAC gallery. And this went to DOE. We had to shut the lab down for…I think it was six months. And address all our safety issues. And there was quite a few of them. It had been very lax for a long time. And of course, that comes with bureaucracy and it continues today. But it was an important change to make there. There were people being hurt…that's not happening anymore. It was just a sloppiness. And lack of procedures and that's come a long way. But sometimes it feels like a little too long way.

ZIERLER: I wonder if in some ways, while the bureaucracy might be good for safety standards, it might stand in the way of good research and design?

EMMA: I'm sorry. Can you repeat the question?

ZIERLER: I was just observing that it seems that as you were saying, the added bureaucracy might be good from a safety perspective, but I wonder what its impact is on the process of researching and designing for accelerator physics?

EMMA: I think you could take it in stride and budget your time properly and take the proper training and understand what you're doing. I think it doesn't have much impact on the design. Maybe things go a little more slowly at times. Or procedures have to be referenced before doing any work that was imagined to be done on a shorter time scale. But, I think good design can be made consistent with very careful safety procedures. But at the time when you're dealing with it yourself, personally, it can be a little frustrating. But I think we still did good design and it's a much safer place to work these days.

ZIERLER: Paul, if you can reflect over your long career, are there any projects or particular moments that you're most proud of that stick out in your mind as you saying you really made a fundamental contribution to move physics and accelerator physics forward? Is there anything that really jumps out in your mind as you reflect back on your career?

EMMA: Well, I think the commissioning itself of the machine…it was very satisfying because all those things we learned from SLC about diagnostics being embedded into the design…that's stuck in the machine with a shoehorn. All that stuff went a long way and made the commissioning a pleasure. We turned on the way we expected. We diagnosed the beam all along the way and knew what we had. And it worked. Right away. Almost immediately. And that's very satisfying because I remember how tough the SLC was.

ZIERLER: Right.

EMMA: It took 10 years to get to the design luminosity at SLC. Here it took…it's hard to quantify it, but it's a much shorter scale.

ZIERLER: I wonder as you were saying before with Burt Richter that with the SLC, where he expressed regret in not investing more in the facilities…I wonder if that was part of the difference that you're referring to here? That there was better investment in the facilities?

EMMA: Yes. Definitely. I think we had to modify facilities in the area that the LCLS was being constructed. So, just by necessity we had to upgrade a lot of that equipment. And some of it was brand new. It wasn't all stuff. Some of it was brand new and got attention because it was a brand new item and installed properly. Diagnosed properly. Yes, that was also a…I mean, we were only using the last one-third of the existing LINAC. So that also helped clear out the…dealing with a one mile accelerator anymore or a two mile accelerator…you're dealing with only a one kilometer piece. I'm mixing units. [laugh]

ZIERLER: That's okay. Paul, for my last question, I want to ask you, you know, you're still involved even in retirement. What do you see as some of the major future trends in accelerator physics? Where does SLAC go from here?

EMMA: Well, the LCLS-II will certainly keep them busy for the next 10 years or so. That's being constructed right now. So, in about…well lately, the new hard X-ray…half of that new machine is already operating. Although it's just in commissioning mode. And the new soft X-ray system and the new superconducting LINAC are going to be commissioned probably in about two years. And that's a huge job and it has to be done very carefully. Cause as I said, it was a 1.2 megawatt beam coming and so you have to be very careful bringing it through different systems. And making sure you don't cause any damage to the machine or threaten any persons. And so…I'm not sure I answered your question.

ZIERLER: That did. Absolutely. Well, Paul, I want to thank you so much for spending this time with me today. It's really important that we've gotten your perspective for our oral history project. And to get an understanding of how things work. Not just on the physics side but on the operational side. Because that's…obviously that's a key part of these stories as well. So, I want to thank you so much for spending this time with me.

EMMA: Well, thank you for coming.

ZIERLER: Absolutely.

[End]