Arthur "Art" Erdman, PhD
Narrator

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The Bakken Museum
Interviewer

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Art Erdman -AE
Kristen Reynolds -KR

KR: 00:00:09 I'll need you to state your name for the record.

AE: 00:00:15 Arthur Guy Erdman.

KR: 00:00:17 Thank you. I'm going to jump in with our questions…First, to ease us in, I would love it if you could tell me a little bit about your early life, culture, and how you became interested in the work that you do now.

AE: 00:00:41 Thank you for the opportunity. I grew up in the early part of the Baby Boomers [generation], so in 1945. My dad was not in the armed services because he worked at a company called Bendix, and they made optics for aircrafts. One of the things that affected myself and my twin brother [John Erdman] was that [my father] was not a graduate of university. He earned the title of engineer. He was leading engineering groups but did not get the same type of pay. He had one objective for us, which was to get good grades and go to college to get a degree.

We grew up in a northern New Jersey community. My mom was an expert at getting stuff from thrift shops, hand-me-downs, and things like that. We weren't poor, but we didn't have a lot of extra money. It was conservative, as you might imagine, because they went through the Great Depression. It's still in my genes to be financially conservative.

I've been blessed with having a balance of right brain and left brain, but neither to a degree of one being superior to the other—I think that's a little bit unusual, particularly in

		the engineering community. That has helped me through the years.
	00:02:57	My brother and I both went to Rutgers University in New Jersey. I majored in mechanical engineering, only because I didn't know what I was going to be good at. There was no logical decision. I was a little bit good at math, and that was about it. I did okay as an undergraduate. When I was finishing up, I had gone through the ROTC [Reserve Officers' Training Corps] and the Vietnam War was starting to raise up its head. I didn't feel strongly enough about my coursework, that it would be something that I wanted to do for the rest of my life. Mechanical engineering is so broad that this was a good spot to start, but I didn't find something that I really enjoyed doing. At that juncture, I considered going to grad school.
KR:	00:04:14	You were at Rutgers in the sixties then?
AE:	00:04:20	I graduated in 1967. I grew up in the sixties and it was an interesting time. I had a very simple childhood. On weekends, parents didn't worry about you. You might show up for lunch or you may not. You're sometimes three blocks away, playing softball, baseball, or something like that. It was a very simple time. There were some nice things about growing up at that time.
KR:	00:05:03	And you said you have a twin brother?
AE:	00:05:05	I do. Identical.
KR:	00:05:08	And you both went to Rutgers together?
AE:	00:05:09	We did. To tell you what the state of medicine was at that point in time, my aunt was a nurse, and she said many times to my mother, "Betty, I think you're having twins." She went in for a checkup and the doctor said, "No, you're not." Then [during the birth], I said, "Oh hey. I'm in here too!" [Both laugh]. It wasn't until the day of the birth that they knew. The story goes that my bassinet was a dresser drawer. So, there you are.
KR:	00:05:56	Wow! Did your aunt have any impact on your work, with you going into mechanical engineering or moving into medical technology?

AE: 00:06:05 Not so much, but all my aunts and uncles are down earth people, and they prayed a lot for everybody. That helped me get through my college years. We were at the far end of all the kids in [the family]. I have a younger sister too, but we were the youngest.

KR: 00:06:37 Of how many?

AE: 00:06:38 Including all my cousins, there were seven others that were much older.

KR: 00:06:51 Wow, that's a big family! In the sixties, you graduated from college and Vietnam is doing its thing. Did you go to work? You said you did ROTC too.

AE: 00:07:04 Yes. I did ROTC, and then I was able to defer to go to graduate school. My brother enjoyed the fraternity a little bit more than I did, and he lost a year. He didn't get that opportunity [to defer]. The bottom line is that he finished Rutgers a year later, and then he went to Vietnam. I went to RPI [Rensselaer Polytechnic Institute] in Troy, New York. I got promoted to first lieutenant. He was in Vietnam as a company commander getting his folks shot up. He was still a second lieutenant, so there was something not right about that. He came back. He doesn't talk about the war, even today.

He's the famous Erdman twin [Both laugh]. He's part of the National Academy of Medicine at the University of Illinois. His area is very different than mine. [He studied] food science and nutrition. But we can talk about technology from dawn to dusk. And the issues that you face with students, how you lead, and funding and all that. It's uniform across so many disciplines.

KR: 00:08:34 You said you went up to New York to RPI? What is that?

AE: 00:08:39 That's Rensselaer Polytechnical. Actually, it's the oldest engineering school in the country.

KR: 00:08:48 Ah yes, okay. So, how did you wind up in Minnesota?

AE: 00:08:52 At RPI, I discovered a discipline I really liked when I took a class from George Sandor [György Sándor]. He became my father away from home and adopted me because he didn't have his own son. But his wife had a couple kids. He

was a Jewish man in Hungary that escaped during the war. He taught kinematics, which is the science of motion mechanisms. I thrived under his mentorship. Many people did. He was a fabulous, kind-hearted person and brilliant as well. For example, if he wanted to write a paragraph to somebody, he had the ability to write it one hundred different ways to set the perfect tone. English was not his first language, which also illustrates his talents. We wrote books together later.

Getting back to your question, there was this obscure quarterly publication from the from the American Society of Engineering Education or something like that. We wrote a two-and-a-half-page, little article.[1] Darrell Frohrib, who was the Head of Design Manufacturing at the University [of Minnesota], saw it. They happened to be looking for a person that was a combination of kinematics and dynamics, which my thesis was about. They invited me out for an interview.

00:11:08 When I started my PhD with George Sandor, he said, "Well, what would you like to do?... Come on in my office anytime and go through my papers."I spotted one that he had done at Yale on spine kinematics. The spine is a very, very complex joint in the body. I said, "Dr. Sandor, I'd love to work on this." We went to Albany Medical Center, and there was no interest. There was no research going on at that time, but that's changed since. We did more of a traditional NSF-sponsored [National Science Foundation] project.

I came out to Minnesota, and I knew I had this army obligation still. I said, "Oh, by the way, where's Minnesota anyway?" [Both laugh]. Seriously. I knew it was somewhere in the Dakotas or Wisconsin area. I had no idea that [the University of Minnesota] was first-class. It could have been any university, and of course, I was tickled and honored that I could be invited out.

The Lord's been looking out after me long before I came back to him in the mid-nineties. There was a recession in 1971. The department head was very astute and knew that they were going to cut off all hiring. I probably wasn't even

[1] A. G. Erdman and G. N. Sandor, "Kineto-Elastodynamics—A Frontier in Mechanism Design," *Mechanical Engineering News* 7 (November 1970): 27-28.

		the first one that they invited, but he offered me the position.
KR:	00:13:08	This was your first job out of your PhD program?
AE:		Yes.
KR:		And you're hired for faculty?
AE:	00:13:13	Yes, as assistant professor.
KR:	00:13:15	Nice! [Both laugh].
AE:	00:13:17	Who would've thought? In fact, my intention was to go into the industry because I had enough faculty who you could tell when they didn't have any industry experience. It was a very different experience whether they did or didn't. Then I was offered the job. But as dilemma, I had already gotten my orders to report for active duty. My advisor said, "Oh, you'll fix that." I said, "Oh yeah, I'll fix that." So, I called a woman who was a civilian working for the military, and she pulled some strings. She said, "Well, I think you can report for active duty within a year" [Laughs]. At the end of the year, the war had really gone down and I joined the reserves. I never had active duty.
KR:	00:14:46	Do you remember her name?
AE:	00:14:49	No, I wish I did.
KR:	00:14:50	Okay. Okay. But wow, lucky. That's really beautiful. That all worked out for you. And then you wind up here at the U.
AE:	00:15:00	Yeah. Even before that, when I switched from a master's to a PhD, someone similar helped me. It wasn't the same woman, but I said, "Well, am I able to do this? Am I able to defer?" She said, "I'm looking at your form here and it says you're in a PhD program. And I said, "No, I'm not." She said, "Listen carefully. I see a form here." I replied, "Oh yes!" [Both laugh].
KR:	00:15:38	That's lovely. That's wonderful, I'm glad!
AE:	00:15:41	I'm supposed to be here.

KR: 00:15:42 Yeah, exactly! So now we're in the seventies, right? Can you tell me a little bit about your first few years as Assistant Professor and the department you were in?

AE: 00:15:54 I was in mechanical engineering. I found out that all this biomedical engineering activity was going on here [in Minnesota], so I started meeting with individuals. I always have been interested in practical things—they call it translational work now. If there's an equation and I can hold it in my hand over here, then I've learned it [Snaps fingers]. If it's thermodynamics, where the equation is not [tangible], like if I can't see the heat going through, then I have a little bit harder time grabbing onto the meaning.

I was drawn to dentistry and orthopedics. In fact, within six months, I was contacted by a team at the University of Minnesota. Perry Blackshear headed up the team, and they were working with the dental school to monitor jaw motion and develop a system for modeling jaw motion. It was very cutting edge [technology], using a high-speed camera system with about 1,100 frames per second.

00:17:31 In the stereo views, they were designing this system so you could mount light emitting diodes on the upper and lower jaw. The patient would chew and then you could record, very accurately, the movement of the jaw, which had never been done before.

[Blackshear] came into my office and said, "Do you know what a screw axis is?" I said, "Yeah, why do you ask?" The screw axis is also called a helical axis. That's an axis in which you rotate from one position to another and slide along. He said, "Yeah! Maybe you can join our team." I replied, "Yes!"

I started with dentistry, and then orthopedics and sports biomechanics. In the early years, if I had one MD [medical doctor] or dentist, or some person that I could work directly with, I felt like I was in heaven. I really did. That's the only way you really understand how to take what engineers know about and apply it in a very practical and meaningful way. And that would have an endpoint that could help eventually patients. It was, again, a pathway I didn't expect. But boy, I just jumped on it and was able to get some funding along with these folks. It was unusual then to get a good relationship with an MD.

00:19:17 There was a class system. In most places, engineers were viewed more as technicians. As in, "Oh, my engineer will do this." This dentistry project was different. The Head of Dentistry was in orthodontics but was interested in understanding how we describe relative motion in mathematical and graphical terms. I was trying to understand all the nomenclature in dentistry as well, including the role of the TMJ [temporomandibular joints], the role of the muscles, and jaw growth. Those were wonderful relationships, but unusual. Because if you went to conferences back then, it would be clear that the MDs were the kings.

00:20:23 In Minnesota, we were always ahead of the times. We really were. We really had a high-tech community. It grew out of the supercomputer industry, which had started here. It all got lost. [Seymour] Cray, who we worked with on another project, founded Cray Computers and Control Data Corporation. With others, they created a high-tech computer culture. When Earl Bakken started Medtronic, there was a group of trained folks that could move from the supercomputer side of things into the medical side.

My impression is that Minnesota was also ahead of most other universities in teaming. It's all about relationships and putting together cross-functional teams that are focused and have the same values. Over the years, those barriers fell away more and more. Today it's encouraged by National Institute of Health [NIH] and NSF [National Science Foundation]—they finally figured those things out, and everyone else now says "Jeez, we need everybody on board sitting at the table, on the same side of the table, to make hay, so to speak."

KR: 00:22:15 It's interesting to hear you talk about the interdisciplinarity that's necessary for the work you did and that you do. On that front, we can shift to thinking about some things that didn't work so well. Can you talk about any failures you might've experienced in product development? Or anything that kind of comes to mind for you. What did you learn from those mistakes?

AE: 00:22:46 Yeah, great question. On the relationship side, one thing that comes to mind is that I was part of some startup companies along the way. Some were reasonably

successful. There were some that had great technologies, but personalities got in the way. Human nature got in the way. Things like pride and greed, I suppose. It was disappointing to solve some important medical needs, with all the momentum and effort that went in. In one specific case, it looked like it would take off. We already had a huge investment. Some of the principals disagreed on who owned what. A lesson I've learned-that I preach a lot to students-is that, at least in the beginning, you must be on the same page if you're doing a startup.

00:24:24 You have to have common values. I've been fortunate to be around town a lot, for a long time. Some of the most successful companies are ones that are led by servient leaders. I mean, certainly you have to make money. You have to pay your employees and so forth. But if that's your first objective, you must reconsider. Because sometimes the biggest breakthroughs are made by a person in the shop, who is doing the most menial activity saying, "Well, have you thought about this?" It's really the team effort that is so important. Some of those things happen, and they really hit your heart [Pats chest] … And then the technology gets lost. Maybe there's some patents and papers out of it. But that's one of the lessons.

I decided along the way to steer away from startup companies. I think it was a good experience because I got to do things that I wouldn't have done before—talk to investors, write summaries, and do the business side of things, which you don't get taught in engineering school. I learned all that in enough depth to be a better teacher and a better mentor for teams as well.

KR: 00:26:27 It sounds like you developed some technologies that solved important medical needs, but then they disappeared.

AE: 00:26:39 Yeah, because the idea is just part of it. It could be a phenomenal idea—rocket science—but to get all the way to here [Raises hand], there's so many other things that have to do. You have regulatory approvals but also need the financing at the right time. You have to apply for intellectual property protection... There are so many things. Or some company may beat you to it. The idea is required, but all the rest is hard work. If you're on the same page and if people are equally passionate about a project, [it's possible].

Hopefully that passion is the patient or a disease state. Even basic devices, like arm or knee braces. A lot of people have them and they aren't super high-tech. But if you're going to put a product on the market, you ought to be passionate about that need. When I'm interviewing students for projects, for example, that's almost the first thing I ask them, "Why are you interested in biomedical engineering?" For example, I just co-advised a PhD student. Her father has Parkinson's disease, and she did a fabulous project on it. If I would've assigned [another] student to do Parkinson's, and they didn't have that passion, I think it would have taken twice as long and had maybe not as good of results.

KR: 00:29:03 Along that same line of thought, can you talk about some of the startups that you worked on? Maybe one startup that you worked on. What were the products you developed for that startup and how did that process go?

AE: 00:29:23 The one that went really far is now called digital dentistry. This is 1980 and I was working in something called CAD/CAM, computer aided design and computer aided manufacturing. I had also been working, since the early seventies, in dentistry. I saw when you go in for a cap or crown, even today, that the measurements are made and you get a temporary filling, right? If it warrants, they take stereo views and make enough measurements, where the patient bites into soft material in a dental tray to make an impression of the upper and lower jaw. In those days, the generation of a crown or cap was an eleven-step investment casting technique. That was an all-manual technique. They took the tooth surface geometry from your impressions, and because everybody's different, they would put the cast teeth on a dental articulator. Some of them have twenty-seven degrees of freedom. You make all these adjustments based on how you chew. Now we're going to put our crown in your mouth and see how it works.

00:31:15 Like I said, then they take that crown and put it in your mouth. You bite down on this film that has little ink spheres in it. "Oh no, we didn't do it right." Then you file down the crown. "Oh, it's not right…" For years and years people did that. And then it dawned on me, literally in the shower. Wow, we can improve on this. There are too many errors in this system. I even had a student that did a PhD on all the errors that accumulate in the dental articulator. We

started a project looking at how to scan the tooth anatomy and the opposing teeth. Take the same information, but into a digital form with computer aided manufacturing to create the crown and then put it into the person's mouth virtually. You ought to be able to take ninety to ninety-five percent of the error out of it.

00:32:35 Like I said, we began the project in the early eighties. It wasn't until 1985 that we found out that there were other people that had seen that need too—Siemens, a big, huge company. There was a researcher in France, [Dr. François] Duret, who started publishing a lot on the same kind of thing. Potentially we were the first to recognize this need and pursue this new digital approach, our team at [the University of Minnesota]. It became a big team. And then from that team, there was a startup company—Digital Dental Systems. We also teamed up with another company that came out of MIT [Massachusetts Institute of Technology] because they had a clever mechanical digitizer to digitize the tooth profiles. So that's the second layer of companies. We got a bunch of patents on it. It was delivered late eighties, maybe early nineties, at a dental articulator conference in Germany. This team, a German company (a third layer company), had put in one million dollars and developed this whole system that worked.

00:34:08 Unfortunately, they pulled the plug at that company's board meeting about three weeks later. The reason they pulled the plug is they didn't ever do anything in medical—it was all manufacturing machines. They said, "What are you doing? Why are you spending our money on this?" The whole thing imploded all the way down because [that company] owned the technology.

But nonetheless, I'm proud of that. We had a superior team here with Dianne Rekow, who unfortunately just passed recently. She did [digital dentistry] for her PhD here [at the University of Minnesota]. We had a lot of students working on the system. It was ahead of its time. This fellow Duret was at a meeting, and he showed his data. This data showed spikes over here and spikes over there, and someone in the audience said, "What are those spikes for?" "Oh, oh, they're just blah, blah…" We knew it was because he didn't have the accuracy. We had better accuracy. Sustaining a company out of the university is still difficult,

but it was certainly back then… That's one example. I'm very, very proud of that activity.

KR: 00:35:40 You should be! That sounds amazing. Just hearing the amount of time to get a crown placed… I had a rough time having a crown placed. It took three weeks, but it certainly wasn't this hundred step process.

AE: 00:35:55 Well, today it's routine. You go in, they do a scan, and it goes out. They use ceramic, but it doesn't have to be. Anyway, Dianne went off to NYU [New York University] as a chair and got lots of grants. And then she went to King's College in Great Britain as Dean. It was the biggest dental school in the EU [European Union]. She did very well.

KR: 00:36:32 Wow. So that really speaks to the broad reach of the project and the people you worked with. That's beautiful. Even though the product didn't pan out, there's still ways that it created these ripple effects for the folks who worked on it.

AE: 00:36:48 Yes, absolutely. Our product as professors should start with the students. Even small projects are important for students to do. You take a course, and you do a problem, and it's the right answer or the wrong answer. Then you go onto the next course, and so forth. But to get something that has no one answer, that's an experience that you really need to have.

KR: 00:37:25 For sure. I'm trying to determine where we should go next. You've talked a little bit about this in the question about failures that you've experienced and what you learned from that. But can you share a little bit more about how those experiences translate into the team that you worked with for the Coventor?

AE: 00:38:04 Sure. That's a great question. One of the things that I was motivated to do was to connect to the community. We have an association here, Medical Alley. It has had a couple of different names, and I think Earl Bakken was one of the founders of Medical Alley. At the end of the day, I would force myself to go to Medical Alley meetings in the evening because I remembered that every time, I came home I said, "I'm really glad I went because I have now all of these business cards." I talked to people at [Boston] Scientific, Minnetronix, or some other company I hadn't

encountered before. This allowed me to sort of develop relationships that lasted years and years.

And oh, by the way, people move around from all these companies. So, in some cases there's a trail of four or five different companies that they've been at.

00:39:19 But if you made a good impression, then sometime later, when a student is looking for an internship or a partner in funding, you know who to go to. It's all about relationships. And it's all about trust, developing trust. Some individuals or faculty think that you can walk into a company like Medtronic and say, "We have all these student needs, give us money for doing this." That doesn't often work, unless there's some relationship that has been developed. That's one important aspect.

A second aspect, which is another thing that the Lord was doing, and I didn't even know anything about, was that I avoided faculty committees as long as I could. Just because. Then I started being a member of faculty governance and on committees. It was a very different way to spend your time, but I got to know people. Then I was asked to run for the top committee on the pyramid for University of Minnesota faculty and staff—the Faculty Consultative Committee (FCC). And I said, "Why are you asking me?" "Well, we need another candidate." "Oh, you can throw my name in" [Laughs].

00:41:14 I got elected. The beauty of that committee is that it meets with all the senior people at the university. You go through a three-year term. Going into my third year, they asked if I would run for vice chair. That didn't make sense because the Vice Chair traditionally moves into the Chair position the following year. But I would be off the committee then. He asked, "Well, will you do it?" And I said, "Okay."

Bob Bruininks was the wonderful university president at that time, and I got to know him. I got to know Frank Cerra, who was the Senior Vice President of Health Sciences. I got to know the [University of Minnesota Foundation] folks. I got to know the Board of Regents. I sat on as a visitor to the Board of Regents committees. For the first time, I really understood how the university worked. From down in the depths of faculty, you don't really see that. A few of us had been pressing the university for a long

time to invest in the translational side of biomedical engineering. That was not something that would be finished in five or ten years. But it's something that could be completed in the foreseeable future. We all see, through our labs, that a student does some fabulous work. They get a publication and the student leaves, and it gets put on the shelf.

00:42:59 There are other ways of using that technology and development for helping humans. There was this moment when I had been telling people, "You should write to the President about this translational stuff. You should write to the Dean…" It was clear that, no, I was the person who was supposed to write something. So, I wrote up about a fifteen-pager, which envisioned having a center. It would be different because we had seen every three, four, or five years that some multimillion dollars came in for biomedical engineering. If it came from industry, they wanted the funding to be focused on translational R&D. But it always went somewhere else. It either went into basic scientific biomedical research, or it went into basic clinical [research]. It always got diverted off, every single time. So, persistence pays off. I was not a dummy and I started planting seeds along with others when I met with the University of Minnesota leadership through these committees. I was also a Chair of one of the athletic committees and got to go to the bowl games for free.

KR: Baseball?

AE: Football.

KR: Oh, football. For Vikings? Or for the team at the U?

AE: 00:45:05 For the Gophers. I had already been to one [bowl game] and I had just finished a fifteen-page white paper. I knew that President Bruininks would be there, and that every moment of the bowl game is programmed. You see this donor now, and then go to another next, and so forth. I said a little prayer, "Lord, if you can set up a time I can talk to [President Bruininks], it would be really handy." So, I'm visiting Nashville for the bowl game and there's a battle of the bands. This is the night before the game, in downtown Nashville. We got on the bus and then it screeched to a halt. A couple of people got on and it was full. My wife says,

"You better stand up." I said, "Yeah, I was going to stand up" [Laughs].

00:46:10 Then we leave again, and we screech to another halt. Who gets on the bus, but the President and the President's wife. Before them was the athletic orthopedic surgeon and somebody else. I'm standing in the aisle with the orthopedic doctor and Bob [President Bruininks]. I said to myself and the Lord, "Okay. This is my prayer was being answered." We were talking about whether Laurence Maroney and whether he's going to play or not. Then I leaned over and said, "Hey Bob, can I share something with you?"

And boom! It's a longer story, but the implementation of the vision took off from there. A couple years later, there was a special funding allotment from the legislature, which was entitled the Medical Device Initiative. And I was blessed to be invited to be the founding director of the [Earl E. Bakken Medical Devices Center], even though Earl's name wasn't on it at the time. In my mind, the envisioned center was a place that was custom designed so you could take an unmet need that might walk in the front door.

00:47:26 It might be a nurse or a doctor, who says "I have a need for this." And within days, we could have an initial prototype. We had prototyping facilities, electrical prototyping, and labs. We were able to put that together in one facility. We didn't start there, but now we're in an old garage where the surgeons used to park [the Mayo Building and Additions]. People hear about startups in a garage, well, we were kind of in the garage—it was a little piece that was left over from when they put in an NMR [Nuclear Magnetic Resonance] center. That's a long story too, how we got there—miracles upon miracles—but it's about 8,500 square feet and the facility cost over $2 million to put together. Our friends in the industry donated, especially Boston Scientific Corporation. Randy Schiestl, who you'll talk to as well, was absolutely wonderful. [Boston Scientific] was shrinking at the time—actually, the whole industry was shrinking—so, we got our choice of desks, microscopes, fume hoods, and all sorts of things.

KR: 00:48:46 All donated?

AE: All donated. I think Boston Scientific donated well over $1

million worth of equipment. Plus, they also financially supported the Center. The Center is so special. Even today, I wouldn't make any decisions about layout differently. It was just an open area where we could do anything we wanted with. I wouldn't change anything. It was good a good team: [The architecture firm] BWBR out of St. Paul did design work on it and Mortenson built it for us. We're told by visitors from overseas—from Japan, China, or Singapore—they say, "we have never seen a facility like this. Can we take pictures?" I always say, "Sure. Take pictures." It has really worked out well. This all preceded the need for the Coventor. Would you like me to go there?

KR: 00:50:06 Let me ask a few follow-up questions before we go there. You shared the story of how this Center comes to be, and this all starts about when?

AE: 00:50:20 The Center was in another building [Shepard Labs], about three or four rooms, in 2008. The funding was in 2007.

KR: 00:50:32 Okay. And then you talk to the President, and you get this huge expansion?

AE: 00:50:40 The expansion came later. We were okay there. Each year we got another room, but they were down the hall or downstairs. Nothing was connected. Still, we were feeling as if this was a real gift to us. Then the Dean came to me and said, "Would you consider moving?" When the Dean asks you if you would consider moving, you say, "Well, I hadn't thought about it, but sure." It turned out that the lower floors were flooded in the Civil Engineering Building next door. Our building Shephard Labs, which used to be called the Space Science Center, was next door to the Civil Engineering Building. So, Shepard Labs would be connected better to the Civil Engineering Building. We were able to eventually, after miracles, get into this new space.

KR: 00:51:44 Wow! How much time passes from when you envisioned the Center to when it comes into being?

AE: 00:51:57 I think I always envisioned a center. During my first year at the university, you have to go back many years, the emerging technology was called a hybrid computer. It was digital and analog, which meant a screen—one of these

things [Holds up cellular phone]. But it had a large, black and white CRT screen. It was the biggest new way of displaying data. You were able to put some of the math into the analog form and some into digital form. I was amazed because anytime a VIP came into our college, they came to this small room where we had this digital analog computer system. So that was the first time I noticed you have to have something to show people—that people show up and see new things. So that's one reason.

I did get pushback on my vision. People said, "You're going to build a shop? We have shops all over the place." Which we did at that time. No, I want it all there and I want to take every barrier down for innovation to occur. In one instance, we had a cardiovascular surgeon who called me up on a Friday and said, "Gee, I walked by your center. Can we come sometime?" I said, "Sure." Then he said, "How about now?" It was Friday at 4pm. "Okay, sure, come down." A couple of our innovation fellows were there. He got up, drew on the white board, and said, "I'm coming up here, and I have to turn the corner here [to explain his surgical need]. But I have no instruments to do it, and therefore I can't do my surgery." All the walls were white boards, you could write on them for envisioning prototyping.

00:54:17 And by the next Wednesday, he came back, and we had some prototypes. We weren't ready to go, but we had some prototypes on how he might turn the corner. That's what you want to do! Surgeons are busy, right? If I wait four weeks, they've forgotten what they asked me by then. You to be ready, with help from industry.

For example, Loctite, the glue people, give us free orders because they have their name on the wall. We have two or three other vendors. For 3D printing, one of the vendors provides free materials for that. Zeus, out of Germany, provides tubing. These folks, they want their names there on the wall. Without industry support, the center would not be as up-to date. And industry does support us because they want to hire our students. And they do. They understand they want to hire students that have access to all the latest materials and equipment. We have a really, I think, well planned out facility.

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KR: 00:55:41 And then it was originally called…?

AE: 00:55:43 It's always been the Medical Devices Center, but we were able to add Earl's name to it. We got a chance to go to Hawaii and make that official. He's always been a strong supporter of the University of Minnesota, of course.

KR: 00:56:04 Wow, that's awesome! I wanted to just clarify that history a little bit. You helped develop this big Center but tell me how that translates into the Coventor. Also, if you wouldn't mind, could you add a bit to the conversation about how COVID-19 impacted research in the labs. Because I know everything's shut down when the Coventor comes out in 2020, I'm curious about that too.

AE: 00:56:38 Sunday night, I think it was March 16, 2020, I got an email. I didn't see it until the morning. But Dr. Stephen Richardson, who is a fellow in anesthesiology had gotten together over the weekend with one of his friends [Jim McGurran] who works for MGC Diagnostics.

No one knew at that time how bad it was going to get, but it looked really, really bad. People were put on ventilators, and once you're on a ventilator, it's not good news from there. Projections, both in the country and worldwide, were that there weren't going to be enough ventilators. I know Medtronic, in Ireland, had doubled production of the high-end ventilators, but this would never be able to satisfy the need. We heard later that there was some type of pandemic years ago where they filled the Armory with very sick people whose breathing was being facilitated with manually squeezed AMBU bags.

00:58:15 An AMBU bag is what a loved one would be squeezing it to breathe for you, twenty-four seven. The worst-case scenario is that this emergency would, in fact, happen again. Because there were not enough mechanical or electromechanical systems to do that. Steve said, "We ought to be able to make a mechanical device to do this." In a toolbox, they put together a slider crank mechanism that would compress the AMBU bag. It was incredible that it worked that nicely in a short period of time.

Like I said, I got an email from Steve [Richardson] asking if we could meet first thing Monday morning. He needed some 3D printed components. We got together that morning and he also brought down some other MDs that

were on the ECMO [extracorporeal membrane oxygenation] side of things.

KR: ECMO?

AE: 00:59:26 ECMO is when you put someone who is having heart troubles on an external system that circulates blood, particularly in the upper portion of the body. The oxygenated blood comes through that system.

The Conventor started that day. I gathered graduate students and one of our fellows, Dr. Enio Perez, to meet with Dr. Stephen Richardson. You'll talk to one of our grad students, Aaron Tucker, as well. Like I said, we put a team together and it was the most amazing experience that I ever could have imagined we would have. But it couldn't have started that day if we didn't have the Center to be able to very quickly make prototypes. Also, the people. We needed people who were already trained—Aaron [Tucker], Cara Piazza [now Cara Herbers], and Dr. Enio Perez, who was a MD that worked on the team. We eventually had a bunch of undergraduate students who weren't taking classes due to COVID-19, but they were still on campus and were willing to come in and build units. We also needed industry. We needed our relationship with Boston Scientific particularly. But not only them, Medtronic was ready to go too. All these potential vendors, if we didn't have that trust or that capability, none of this would've ever happened.

01:01:16 We were fortunate that everything was in place, and we had some good people… It wasn't twenty-four seven, but it was, whatever it took that day, to get things done.

01:01:35 Within days, we were conducting animal trials—with not the unit they built in the toolbox, but a new one. Then we had a new version, and then we had an even newer version. We were just rolling out these versions very quickly. We got some publicity locally in the [Star] Tribune, KARE 11, and some other local television stations. As soon as that happened, of course everyone said, "What can I do?" I think we had almost 200 individuals or companies that contacted us. I gave Cara the job of just keeping track of all those wonderful folks who wanted to help us out. At one point in time, we decided and realized that we could spend all our time just talking to people. They would say, "Oh, I've got a sheet metal shop here and I can do this. I've got

this capability. I've got that capability. We can do this. We can make that." It showed a part of humanity that we lose sight of.

01:03:06 We go about our days… We have our jobs, or we're at school and wherever else. But an emergency comes up, and suddenly you focus, and you understand what's important. We're so grateful for all those people and donations that came in. Toyota donated $50,000. A lot of other people donated. It was like GoFundMe. It gave us funding which we desperately needed as we went through iterations of prototype/testing cycles.

We rolled up our sleeves and said, "Okay, what do we have to do to do our next animal test?" Because without the animal test, we're told the FDA [Food and Drug Administration] won't listen to us or this [approval] won't happen. We are nowhere without Dr. Richardson's knowledge of title volumes and all those critical details, which I don't know much about. I can guess what the breathing rate would be, but for the rest, we need his expertise. I was amazed at how the university leadership came through.

01:04:33 Can you imagine the issues with intellectual property and the concern about liability? If I oversaw those critical concerns, I would worry about that too. But there was a certain individual at the university that just cut through that and said, "Well, first, we gave away the IP [intellectual property]. It's the only thing to do." That helped a lot. Then working with a company, like Boston Scientific, we got the supply chain of things taken care of.

We were in the first animal trial, and they had a film crew and Steve [Richardson] says, "Oh, we have to call it something. We should figure that out." I said, "It's an invention. We're in COVID. It's a collaboration. COVENTOR!!" [Both laugh]. There we are.

01:06:00 You get the call on March 16th, and then you FDA emergency authorization when?

AE: 01:06:11 Thirty days.

KR: 01:06:12 Thirty day later, wow!

AE: 01:06:18 It was a record. I don't expect that ever to be broken. The companies that we were working with, Teknic and a couple others… Medtronic was there ready to help, DigiKey, and others. They had their connections up through to the FDA and the government and UGH, United Healthcare Group. We were not privy to all those discussions. In fact, we were not privy to where all the Coventors went. We have a pretty good idea, but we were told that the White House was involved in some way. Somewhere in the White House and in all the other [governmental] organizations. We had helped to put the paperwork together to go to the FDA.

And we understand there were maybe four or five other versions [of ventilation devices]—MIT [Massachusetts Institute of Technology] had one version. But we were the first ones through, although I think Boston Scientific was already committed. It was totally amazing there too. They took a production facility up in Maple Grove and pulled everything to the ends of the room. It was put together in a very short amount of time, this assembly line. I think I have the number right, in eighty-two days from the toolbox, they had 3,000 units. Eighty-two days.

01:08:22 I think it was about sixty days that it took them [to manufacture the Coventor.] I understand that most of their employees were just volunteering. As I was saying, in the assembly line, they had to do all their regulatory processes the same way that they normally would.

KR: 01:08:51 Folks were putting these things together by hand? Wow.

AE: 01:08:57 Yeah, it was all by hand. But before that, if I can step back, was version 3.1. That was where we decided it was tough to stop because we kept wanting to add more features. But we made conscious [decisions] on version 3.1—it's going to have these features and these features only—so we can draw a line in sand and get the units done. And then in our Center, and we have some great pictures of this, all these students came in from their dorms to sign forms. The university had to quickly make that available. They assembled twenty-five units in our Center, and that was within two weeks. Those were distributed. Then we also got a call from North Dakota, and the governor in North Dakota wanted units made too. Appareo is a company in North Dakota. They built 3,000 units for use in that state, or in South Dakota. But I would've never imagined that things

could move that fast. But when you have this very important goal in mind, then your mindset changes.

KR: 01:11:08 Wow, that's amazing! I didn't realize that things moved quite so quickly. Thank you so much for sharing that. I think since we're about at the hour mark, give or take, we can probably move on to some closing questions. You've been talking for a while. When I ask you about your music, you light up. I don't know if you know that [Laughs]. You also mentioned a few times the role that God has played in your life. I was wondering if you wouldn't mind sharing a little bit about your religion, and potentially coming back to it. You said you came back to the Lord in the nineties at one point. How has that impacted you and your work?

AE: 01:11:51 Thank you for asking. As a child, we went to a Methodist church and did all the activities there. Looking back, I don't think I was listening well enough. I always believed in God, and I always prayed. But when you go off to college, you get distracted, and you don't go to church anymore. Then you go to grad school, and it's the same thing. You get further and further away. When you get to a university, there's a lot of pressure to publish and bring in money. I think this gets you even more self-centered, forgetting who is important and who is really in charge.

Because you go to the University of Minnesota, you can go anywhere from there. I've had lots of job offers, but this is a wonderful community and I've never left. I've never really had any serious interest in leaving as well.

01:13:31 In the eighties, my wife and I lost a set of twins early. They were born prematurely and did not make it. That changes your attitude. And today, [premature babies] do just fine. But back then, they didn't have the wherewithal to do that. So, I began questioning. By then, I'd gotten lots of awards and there was still something not fulfilled within me. That would be a very long story, but I decided to give Jesus a chance and there he was. It just totally refocused me. You wind up making your own rules about what's good and bad. But being founded in the Bible is so very, very important to me. My wife and I started going back to church and got very involved.

01:15:12 When I was a kid, I had an interest in music. My cousin

taught us piano, and she was a Julliard graduate out of New York City. My father was a fabulous piano player, but I never had any lessons. So, I have about this much of his talent [Pinches forefinger and thumb]. In fact, I play by ear mostly and I don't do well staying on beat. At one point in time, I thought, "Do I go into music, or do I go into engineering?" If I was able to sing, I might've gone the music route. I'm kind of glad I didn't, but I always tinkered in and kind of glad I didn't. I've always tinkered [with music]. In grad school, I had an electric piano. After that, the Lord started giving me some songs over time. In 2006, I put out a CD with mostly people at our church that are good musicians. And it was great fun. It was a better than amateur…

01:16:22 Several people say they were blessed by the songs. I either gave them away or they were sold at church, and the church kept the money. One of the things about COVID-19 is it gave me some time to sit down and play some more. I've had ten songs that I was working with. I decided this time to try to do it nicely. I have a local producer that I'm working with, and he's fabulous. He is a very accomplished guy, Jeff Victor. It gives me a chance if people want to listen to the music, then they'll hear what my value system is and who I owe my life to. And if they don't want to listen, then that's okay.

KR: 01:17:27 That's beautiful. Thank you for sharing that.

AE: 01:17:29 Thanks for asking.

KR: 01:17:31 I think that's a lovely way to close this out. So, thank you so much, art. This is just such a beautiful, I'm kind of teary. This is such a beautiful way to learn about you and learn about your work. I'm really grateful to, thank you, have met you and have this chance to talk with you today. Yeah, thank you.

AE: 01:17:50 Thank you. Creativity comes in many forms. I mentioned when I started, I have this a little bit of both sides. That has helped me, in my job, because I think differently than many engineers. Not that everybody doesn't have some part, but a lot of engineering and science is just deep understanding. The creative part is a little bit less. The natural ability to team up, and exhibit leadership is not there. I think this has really benefited me in my thirteen years as director of the

		Center. But music and collaborating creative genius. I mean, this producer I worked with was so good.
KR:	01:19:05	Thank you. I think that's an excellent point, the balance that you bring to your work and the impact that it's had on your long time in the game. You've been doing this for a long time. You've had some beautiful, innovative ideas. It sounds like you really take the work that you do with your students so, so seriously, which I, as a graduate student, very much appreciate. I think we can wrap up here.
AE:	01:19:38	Just one other thing. I mentioned George Sandor, who was this fabulous mentor to me. I couldn't imagine a better advisor, as I said. He's in many ways was more of a dad to me than my dad was. I feel an obligation, and a happy obligation, to try to be that kind of person-when I can-to my students. You can't always do that. But I try my best to instill the kindness and motivation in my students that he did for me.