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ORAL HISTORY PROGRAM

James Williams: Advancing Aerospace Through Material Design

2024

PREFACE

The following oral history is the result of recorded interviews with James Williams conducted by Adam Pilchak on December 21st, 2022. This interview is part of the AIME Oral History Program.

ABSTRACT

Since the Boy Scouts, James Williams knew he wanted to be a metallurgical engineer. The complexity of materials problems amazed Williams and drew him towards his first job as an engineer at Boeing. Williams went on to earn his PhD at the University of Washington and work in research and development of titanium alloys for aerospace, aviation, and nuclear applications. Beyond his roles as a researcher, consultant, and leader in Boeing, the Science Center, and General Electric, Williams has undertaken many faculty positions at Carnegie Mellon, Ohio State, and North Texas University. Williams has served twice as a dean of engineering and has been awarded many honors for achievements in his career. He was initiated into the National Academy of Engineering and recognized by special lectures organized by AIME and ASM. Williams' words of wisdom to young engineers is to take different opportunities to grow your career, but remember to value your support system.

Readers are asked to bear in mind that they are reading a transcript of the spoken word, rather than written prose. The following transcript has been reviewed, edited, and approved by the narrator.

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00:00:14 Introduction

Pilchak:

Today is December 21st, 2022, and I'm interviewing via video conference today, Professor James Williams. I had the distinct honor of being one of Jim's last graduate students at the Ohio State University. So, it's my absolute pleasure to be conducting this interview today. Jim is a distinguished research professor with the Department of Materials Science and Engineering at the University of North Texas and also professor and Honda chair emeritus with the Department of Materials Science and Engineering at The Ohio State University. He was formerly general manager of the Materials Engineering Department at GE Aircraft Engines in Cincinnati, Ohio, and held a number of other great positions that we'll talk about a little more today. So, thanks for joining us today, Jim. This is Dr. Adam Pilchak. I'm a senior technical fellow for alloys with Pratt and Whitney's Materials and Processes Engineering Division.

00:01:07 Growing Up in a Cow Town Surrounded by Scientists and Engineers

Pilchak:

How about we start by you telling us a little bit about where you grew up?

Williams:

Well, I always tell people when they ask me that question. I really never have grown up because it's a waste of my time. I've gotten older; there's no doubt about that. But I haven't really grown up, so that's okay. My hometown was Richland, Washington, down in the southeastern corner of Washington State. It was an interesting town. It was the residential community for people that worked, people and their families that worked at the Hanford Works, which was built at the same time they built a town when my father worked for DuPont during the Second World War in the construction business. And we moved around the country a couple of times. He was helping build gunpowder plants to support the Second World War, and when we were finished with his last gunpowder plant assignment, we were back home in Kansas with my mom's mom, who was a widow. And back then, you didn't get long-distance phone calls; you got telegrams, and you got a telegram from DuPont saying, we have an assignment for you out in Washington State if you're willing to take it. Well, of course, he needed a job, and it seemed okay to him. It turns out there was no residential housing there. So, he went out about a year, a year and a half early; they had dormitories and started on the project. And it turns out to be a huge project. And the whole idea was it was part of the Manhattan Project, and they had reactors and chemical separation facilities to make plutonium for nuclear weapons. So that ended up being called the Hanford Works, but it was part of the Manhattan Project during the Second World War.

Pilchak:

What did your mom do?

Williams:

Well, my mom was a schoolteacher until I came along, and she became a mom and a housewife. I was born in 1938, and it was a pretty common occurrence back then. My mom was 33 years old when I was born, and so there weren't going to be any brothers or sisters. So I ended up being an only child, which my wife reminds me left its vestiges of that behavior along those lines.

Pilchak:

So, tell me a little bit about your early school years and maybe what influenced you to become an engineer.

Williams:

Okay. So, I ended up as an only child. As I had said previously, I was age five when we moved to Richland, which was a town that the government built at the same time they were building this plutonium plant. I mean, it was quite an undertaking, but it turned out okay. They cited the Hanford Works on the Columbia River because they needed a lot of water to cool the reactors at the time. Richland was a little tiny cow town with maybe 150 people or something. So they obviously built houses. An interesting town because almost everybody that lived there either worked in the stores that sold things to people who were employed by the Hanford Works or they worked at the Hanford Works. So there's a consequence. There are lots of scientists and engineers in town, certainly on a per capita basis, much larger than maybe a couple of other towns in the country, Los Alamos and Oak Ridge, which were also part of the Manhattan Project.

00:05:15 How a Camping Trip and a Brittle Hatchet Influenced Me to Pursue Metallurgical Engineering

Williams:

So, with regard to schooling, Adam, you ask about schooling. I went through public school grades K through 12 in Richland, and I graduated from Columbia High School in 1957. I was about an average-sized guy then. I played football. I played at five feet, ten inches, 210 pounds. Today that wouldn't even be big enough to be a respectable water boy. So, I played football in junior high and high school as a lineman. And again, you would hardly be able to see the belly button of a lineman that plays football these days at my height. So, it worked out all right. And my senior year, I was selected as an all-state player in the state of Washington. As a consequence, several universities in our general area attempted to recruit me to come there to play football for them. And in the end, I elected to attend the University of Washington in Seattle. I chose to major in metallurgical engineering. It's unusual for a young person to enter college these days knowing what they want to do. And I'll tell you a little more about that in a few minutes. So, it soon became clear to me as I started playing football in college that football was definitely not part of my long-term future. It also became clear to me that if I didn't do something different, it was going to take me a lot more than four years to get an engineering degree because the University of Washington had quarters, which helped because that meant winter term. There was no football practice. But the rest of the time, engineering labs are in the afternoon, and football practices are in the afternoon, so that was a definite conflict. And so I gave up trying to play football at the end of my second year.

Pilchak:

Tell me a little bit more about your choice to go into metallurgical engineering.

Williams:

Well, when I was in high school, I was active in the local Boy Scout troop. The Blue Mountains were about a two-hour drive from my hometown. Richland was right on the Columbia River, and it was essentially low desert, so we didn't get very much snow. If we got a couple of inches a year, it was a lot. But the Blue Mountain was high enough, and we did a snow camping trip up in the Blue Mountains. And, you know, it was long before good synthetic fabrics. We were camped on the snow, and it was pretty darn cold, but we built campfires to keep us warm. The deal was that each of the scouts, in turn, would go out into the woods and maybe cut down a small pine tree for firewood. So when it came my time, I had a brand new war surplus hatchet, an olive green hatchet, and I went out into the woods and found a tree that looked like a likely candidate. I reared back with all my might to hit the tree with my hatchet and the tree hardly moved, but the hatchet broke into pieces. Of course, I was not happy about that because I bought it with my money that I'd earned delivering papers and mowing lawns and so on. So, I found enough scraps of wood to fulfill my obligation as a firewood gatherer.

So I went back to camp, and I showed my scoutmaster this broken hatchet, and it turns out he was a metallurgical engineer that worked at the Hanford Works, and he was a really good guy. He sat me down and told me how steels could get brittle in cold weather if they weren't properly processed or to the right composition. And then he told me the story about the Liberty ships. It turns out in the wintertime during the Second World War, the US Navy lost a number of so-called Liberty ships due to brittle fracture of the hull steel in the cold water of the North Atlantic. It was tragic. It was a combination of a bad design and a bad material selection. So, the design— they went from riveted structures of plates to welded structures because they could make ships faster, and they were losing ships to the Germans at a pretty high rate out in the North Atlantic. So now, when you got a crack in the hull, the crack could run continuously from gunnel to gunnel because there were no plates that required riveting. And then, you could restart the crack in the next plate. But it was not, certainly in today's terminology, not a damage-tolerant design for sure.

00:10:45 Calculus, Marriage and No Sleep – My Time at the University of Washington

Pilchak:

Jim, can you tell me a little more about your time at the University of Washington?

Williams:

Yeah, you know, back then, and it's a bit different now. But I enrolled in metallurgical engineering, and back then, the first two years of engineering school was typically chemical chemistry, physics, mathematics, and some kind of humanities. I found the chemistry interesting. The physics was a bit baffling for me, but I managed to struggle through it. The math was taught by my faculty from the math department, and so it was taught with theorems and proofs and not any discussion of practical applications of this. Now, calculus wasn't easy for me anyway, so I found that pretty boring. Fortunately, I survived that part of the educational experience, and then we started getting real metallurgy courses in my junior year. At the end of my sophomore year, I got married, and that changed my lifestyle considerably. So when my new bride and I went back to Seattle for me to go to school, she took a job at the University of Washington, and that's the way we survived, essentially.

It was a different experience. So, I changed my schedule tremendously. I mean, the first little while, before I had any kind of a job myself, it was okay. But as we settled into the courses in the metallurgy department, one of the relatively young faculty from MIT, Bill Flanagan, sort of befriended me. So that was a huge help to me. He was an excellent teacher, and he was a good guy. He had twin girls; he was from Boston, and his wife was from New York. So, if you met the two of them, they had very different accents. Bill drove an old white Ford coupe back and forth to campus, and his wife had a Ford Blue Ford Station wagon. The twins had talked about Daddy's white car and Mommy's blue car. And so that was my introduction to Northeastern accents.

Pilchak

And so, during your time at the University of Washington, any classmates of particular note or any classmates that influenced you during your undergraduate studies in any way?

Williams:

Yes. There, in my hometown, Richland, there were three small towns close together, Richland, Pasco, and Kennewick, and they were called the Tri-Cities. One of my classmates was a guy named Gray Clark, who happened to be from Kennewick, and we got to be good friends. Since we had an apartment not far from campus, in the afternoons he was working at Boeing on the second shift, which is 4:30 to midnight. We would go over to our apartment and study together, and then he would go to work. It wasn't long before he said, “We're looking for another technician in the metals quality lab where I work. Are you interested in looking into that?” And I said, “Yeah, sure.” So, I interviewed for that job and got offered the job. I started working the second shift along with Gray, and we drove back and forth.

But that really changed my life schedule-wise. My typical day was I'd get up at six in the morning, have a bite to eat, study for a while, go to campus at about eight, go to class, and then the break study and then about 4:00 p.m. Gray and I would get in one of our cars and drive down to Boeing to work. And we'd work till after midnight. It was about a 45-minute drive back home. So, I got home just before one in the morning, and if I had an exam coming up, I'd study for a couple of hours. I had lots of weeks where I went with maybe 4 hours of sleep at night. I look back on that, and there's no possibility I could do that today. But my joke is that I really learned to manage my time because there wasn't a lot of time, and there certainly wasn't any spare time. So, I comment that that was probably a better time management class for me than anything you could get from any business school in the country.

00:15:59 First Job as an Engineer at Boeing – Tackling Material Design Problems

Pilchak:

How did you get your first job as an engineer, and what type of work did it involve?

Williams:

Boeing offered me a job as an engineer when I finished my bachelor's degree. So, I started working in the summer, then after I graduated as an engineer, and we were doing some—Boeing was doing some really interesting, interesting stuff then. One of the things they were doing was trying to build a space glider that didn't have an engine on it, but it would be lifted up into space and then it would glide back down to Earth. And the vehicle was named Dynasoar D-Y-N-A-S-O-A-R, and there's a picture of it in this write-up. It was a really big undertaking because the reentry during gliding back to earth, it would get so hot from aerodynamic heating that they had to build the Dynasoar of materials that had a quite high-temperature capability. In the end, they picked up a quite new nickel alloy called René 41, which was available in tubing for the frame. Then, they were going to cover the frame with sheet material; basically, molybdenum half percent titanium and called Moly half TI. And Moly, of course, is a refractory metal and has a serious oxidation problem if you heat it and expose it to air, so the plan was to coat the Dynasoar.

They were working on the coating system, and it was basically a fluidized bed that had silicone in it at very high temperatures. Then, you would put little coupons in when the silicone vapor would contact the Moly half TI material; it would react with it and form an oxidation-resistant coating called Moly disilicide, $MoSi_2$. My job was to look over the different lots of René 41 tubing as it came into Boeing for consistency, and it turns out the consistency was not very good. Now, what that meant was that in order to design to the worst of the material, you had to add weight to the Dynasoar, and it became very quickly a weight problem. The other thing I did in my job was to examine the integrity of this Moly disilicide coating on the Moly half TI, and it wasn't very good either. So, the project was obviously conceived by a theoretician and was trying to be executed by an engineer, and that's usually not a very healthy combination. Eventually, the Dynasoar program was scrapped.

00:19:25 Screening Titanium Alloys for Pre-crack Stress Corrosion Cracking Susceptibility

Pilchak:

So, what other sorts of projects did you work on while at Boeing?

Williams:

Well, I went back to graduate school from '62 to '64, but then I took a leave of absence from the university and took a full-time job at Boeing. Boeing, at that point, had just won a major contract to do a design feasibility study for a large supersonic commercial airplane. There was another one being built in Europe called the Concorde, but the American SST was intended to be faster. So, the Concorde's cruising speed was 2.7 Mach number. Mach number is the speed of sound at sea level; that's one Mach number. The Boeing SST needed to have a cruising speed of Mach 2.7. The reason for that is so that the American SST could make two round trips to Europe in 24 hours because, for economic reasons, that was the only way that it was going to be economical for the airlines to operate that kind of airplane. There was a relatively new titanium alloy that had just come on the market, and it was interesting because it was available in sheet. It had a higher anneal strength than the older titanium alloys, but it also had a higher modulus. The composition was titanium, 8% Aluminum, 1% Molybdenum, and one weight percent Vanadium, so TI 8-1-1 it was called. It had about a 2 million PSI higher Young's modulus stiffness also. So, between the higher yield strength and higher stiffness, it was a very attractive alloy for the SST. The designers fairly quickly settled on that and began to design the airplane.

Well, it turns out that unbeknownst to anybody at the time, 8-1-1 had a major flaw. If you tested it under stress with a three-crack, fatigue pre-crack in it, and alternately dipped it in a three-and-a-half percent sodium chloride solution, it would crack in a matter of hours. This came as a total surprise because the way that we at Boeing had always tested the susceptibility of aluminum alloys and steels was not with pre-cracked specimens. Well, the 811 uncracked specimen ran for 30 days. The guy that was in charge of the so-called Ferris wheel, that was the older emergent device, was getting really grumpy that we were taking up space on his wheel and not getting any data. So, Floyd Brown and his team at the Naval Research Laboratory discovered that if you pre-cracked 8-1-1, it failed in a matter of hours, and that was a huge shock to a lot of people. It was clear, I mean. I don't know whether everybody understands, but an airplane that's been in service for a couple of years, it has lots of cracks in it. And the cracks are not fatal. They're just there. They grow over time.

The pre-crack stress corrosion cracking susceptibility of 8-1-1 made it a totally unacceptable alloy. So we set forth, on with a huge task force looking for alternate titanium alloys that didn't have this problem. At the same time, nationally, there was a huge new effort on stress corrosion cracking, a titanium alloys issue. The Naval Research Laboratory turned out to be a contender as one of the thought leaders in that area. So, we were screening initially about six or seven titanium alloys and a couple of them also had pre-crack stress corrosion cracking susceptibility problems. Others were very strong and that was going to be an issue for weight with the airplane and over time.

We went through a huge screening activity. And I, from the metallurgical side, I got appointed the group leader of a group of four or five guys, one of which turned out to be Rod Boyer. He ended up spending the rest of his career at Boeing and became their number-one titanium guy, ironically or interestingly. It also turned out that the microstructure of the higher strength titanium alloys, any of the alloys we were looking at that were acceptable from a strength standpoint, had a very, very fine length scale microstructure, and it required transmission electron microscopy to elucidate the critical variables, microstructural variables. So we were doing that, and we worked for over a year. We worked seven days a week, 12 hours a day, doing the screening to keep up.

00:25:08 Boeing Scientific Research Laboratory – Using TEM to Study a Metal's Microstructure

Williams:

During that period of time, Boeing had a relatively new scientific research laboratory called Boeing Scientific Lab, Scientific Laboratory, BSRL. One of the guys—on one of the PhDs on the staff at BSRL asked his boss to ask my boss if they would loan me to him. His name was Martin Blackburn; he's a Brit, well really, a Welshman. He went to Cambridge for his PhD and worked in Nottingham Group, which was one of the early pioneers of using TEM for looking at metals. He was an expert electron microscopist, and of course, when they said, would you like to go work with Dr. Blackburn, I absolutely immediately accepted the opportunity. Martin and I worked together for quite a long while, and he was a great guy; had a wonderful sense of humor. He had a relatively unvarnished vocabulary, which I won't say any more about here. So, on the first day or two, I went up to BSRL to be with Martin.

Here was this, this guy with a PhD from England. He had a very pronounced British accent. And I thought, Man, I'm going to have to really behave the way I say things because sometimes I've been known to use some not-very-nice words. And it turns out Martin used them also, so we got along. We got along famously from day one. So it turned out also, that the BSRL transmission electron microscope (TEM) was not a state-of-the-art machine. It was not easy to use, and over time, I became a bit more courageous. I began to work on my boss back at the regular Boeing and say, look, we really need to have a new transmission electron microscope here. Over time, he agreed and requisitioned the money to buy one. We ended up putting in a brand-new Philips EM 200, which is one of the best microscopes available at the time. So, Martin and I did some nice things together, and it was truly a joy to work with Martin.

When he thought we had enough in the way of results to write a publishable paper, he would say, "Okay, you write a draft, and then we'll work on it together." So, then I was working, you know, 8 to 5 at Boeing. I'd go home in the evening and have dinner. We had a daughter at the time, and she was just a baby and then spend two- or 3-hours writing drafts of what would end up being a publication. And then next morning, the drill was I would take what I'd written the night before. It was all handwritten because it was long before personal computers. And give it to Martin to read. And we'd go down to the cafeteria and get a cup of coffee each and then come back and sit at my little desk. And I could see Martin's eyes going back and forth, down the written page, and then go back and again and again. And then he leaned back, and Martin smoked cigars and puff on his cigar, and he said, Well, right, tell me about this sentence. And I'd tell him what I had in mind when I wrote that sentence down. And he said, Well, that's actually a really good point. Why didn't you write it down? So, you know, he helped me a lot with my technical writing by being a friendly but pretty severe critic. And so. Over time, we published several papers that are actually still referred to in the open literature. So.

00:29:38 Returning to the University of Washington for a PhD on Phase Transformations in Alloys

Pilchak:

So up-through this point, you'd completed your master's degree. Tell me a little bit about how you got your PhD.

Williams:

Well, I decided I wanted to do a PhD, and Professor Polonius in the metallurgy department at the University of Washington had an opening in his research group. He had a guy that was a couple of years ahead of me that had been making some really interesting electrical resistivity measurements on titanium copper alloys and finding changes that couldn't be explained with existing knowledge. So he told me about this. And the guy's name was Richard Allen. He was a nice guy. He was kind of closed mouth and kind of kept to himself. But when he thought I was going to maybe get involved in working on Titanium Copper, also, he got a little nervous and not so friendly because I think he thought I was going to mess up his PhD plan, which of course I wouldn't do, and Polonius wouldn't allow that to happen.

But anyway, so Polonius showed me some of the some of the electrical resistivity results, and I said, you know, maybe things going on that you can't see with optical metal orthography, why don't you get me a couple of Richard's samples that have different conductivity characteristics and let me make some thin foils out of them and look at them in the TEM. And we did. And we found some very interesting reactions that were occurring that couldn't be observed with a light microscope. And so I ended up just basically doing a PhD on face transformations in titanium copper, copper alloys and, Polonius had a colleague in mechanical engineering named Ray Taggart. And he and Taggart said, Look, we'd like to let Richard Allen use some of your early results as attributable to you in his thesis. And that made Alan happy because he realized he wasn't going to end up playing second fiddle somehow. And so that worked out, worked out pretty well. And then based on that, then I just went ahead and did a pretty thorough study on four different composition, two, four, six and weight percent copper in titanium.

Pilchak:

So, Jim, we need a good lead into the interaction between the University of Washington and then observing the foils at Boeing using their TEM, right?

Williams:

Yeah, the new TEM that my old lab down in Boeing, not BSRL, turned out to be really useful. So Martin and I continued to collaborate and did some nice stuff with that new TEM. Then, when I took a leave from Boeing to go back to finish my PhD, it turned out that the University of Washington TEM was really not in good shape at all. And so I felt at first kind of stuck and then I had a had an idea. The screening of SST alloys was still, going on. The guys that were in my group at Boeing, were struggling because they didn't do TEM. So I proposed to my old boss at Boeing that I would come in after lunch and coach these guys on doing TEM of titanium alloys. Then, if I was allowed to stay in the evening and use the TEM for my PhD thesis—and we did that on a trial basis. It worked out. Then, the guys in my own group were thrilled to have an opportunity to really learn a lot more about TEM of titanium alloys. And the TEM was so much better than the one they had at the university.

It really worked out—it worked out well. So, I would go to the campus in the morning at about eight. And if I was taking a class, obviously go to class, and study, and then go to Boeing after lunch and spend two or three or four hours with the guys in my old group and then looking at their alloys of the SST alloys. And then, when they went home for the day because it was the end of their workday, I stayed and looked at my thesis alloys, sometimes as late as midnight or one in the morning. So again, it was a period of my life where I spent pretty long days, but it was really interesting and exciting, that stuff that we were seeing. So it wasn't work; it was fun for me. My wife, bless her heart, was raising our kids. And we had had a son by then, too. That's a long, different story. And so she was basically the homekeeper, but she was also working at the university. And so it was not easy. It worked out all right in the end.

00:35:11 Working at the Science Center – R&D for Aviation, Space, and Defense Applications

Pilchak:

So, as you're finishing up your PhD, tell me a little bit about how you got your first job following that.

Williams:

Well, Boeing had been pretty good to me, so I felt obligated to look at them. But because some of the stuff that Martin and I had done that had appeared by then in the open literature, I got called from Pratt & Whitney, from Lockheed Martin. It was actually Martin Marietta at the time. And, of course, Boeing was trying to recruit me. So, I got, in the end, interviewed all those places and was offered jobs by all of them. Pratt & Whitney was in Connecticut at the time, and Martin Marietta was in Florida. My parents and my wife's parents both lived in Washington state. So one of the considerations was taking our kids, their grandkids, that far away from them. Air travel was coming along, but it still wasn't what it is today. Oh, and sorry, North American Rockwell and also in California. And so they all offered me a job. North American Rockwell had an aircraft division, and then they had a very nice research laboratory also. So, both the research laboratory and the aircraft division offered me a job, and I ended up going to the research laboratory called the Science Center.

Science Center was an interesting place. It was established when the aerospace companies had access to a kind of government funding called IRND for independent research and development. And what happened if you were doing something for the government, either DOD or NASA, you could actually charge him as a tax a certain amount of the billable effort and use that as your independent R&D, R&D effort. So the Science Center, when I joined in 1968, was 100% funded with North American nuclear R&D money. They were doing a lot. They were doing the B-70 there, which was a one-time thing. The space division was doing the Apollo program, and the Rocketdyne, the rocket engine division, was doing the boosters for the Apollo program. But then, the B-1 bomber program was won by the North American Aviation Division or the Aircraft Division, and the shuttle orbiter program was won by the Space Craft division. The main engine for the space shuttle was won by Rocketdyne. So, there was a lot a lot of government work going on.

But later on, there was a competition for a new fighter, which exists today as the F-15. But that competition was won by McDonnell Douglas in St Louis. So, the amount of IRND money that Rockwell was entitled to shrunk dramatically. I still remember that the guy who was the vice president for technology for the whole company came out and called the staff of the Science Center together and said we have decided that we will give you the opportunity to pursue external funding. That changed our life at the Science Center quite, quite dramatically. The Science Center was modeled after Bell Labs. In fact, the first director of the Science Center came from Bell Labs, and unbeknownst to me, when I took a job at the Science Center, there was a whole lot more science than engineering going on there. Because it was basically free money from IRND, and they could do—they had lots of physicists, lots of chemists, a few mathematicians. The metallurgy people that were there were basically not PhDs; they were basically technicians, high powered technicians to make samples for the physics and chemistry guys to study.

Well, it became clear that this model wasn't going to hold up, so they established a new metals and ceramics group and hired this really interesting Australian guy, Brian Hickman, to be the group leader. So I was a second PhD or staff member in his group, and then we had some really good technicians. Bob Sperling and Cecil Rhodes were outstanding at what they did. Cecil Rhodes became a really good colleague as well as a good friend of mine. Over time, we added about another five or six PhDs, and we had some really good guys. People like Tony Evans, which people would know if they followed the ceramics business, and Greg Germann, which ended up going back to law school. I teased him he was a loss. I used to tell him that engineers create wealth and lawyers redistribute it. [laughs] So anyway, we were friends. And Greg was a bachelor, so, you know, he was an interesting—we did some things together.

00:40:49 Metallurgy Group Leader – Consulting Research Divisions on Materials & Fracture Mechanics

Williams:

Then, Brian Hickman was offered the lab director job for Australian Consolidated Industries back in Australia and elected to go back to Australia to do that. I, luckily or otherwise, was appointed to replace him as a group leader. So in that capacity, the operating divisions, the space division, the rocket engine division, and the aircraft division, when they had a problem, they often called. It was for any materials-related dimensions; they would call and ask if the metallurgy group leader could come in and serve, essentially, as a consultant. So, I was spending quite a bit of my time down in the division. The Apollo program had a couple of very significant problems that we did help solve. And the B-1 bomber, which still exists, was the first military aircraft built under a construction called ASIP, Aircraft Structural Integrity Program. What that meant was that you needed to use fracture mechanics to determine the safety of the critical structure on an aircraft like that.

And the North American Rockwell guys had almost no experience with fracture mechanics. So what they did at the corporate staff down at the headquarters, down near the Los Angeles airport, they stood up an inter-divisional technology program. The whole idea was to take company money and pick a problem or an area of emerging technology that would be of interest and value to more than one of the operating divisions and then manage it as it matured out of the corporate office. I got offered the program manager [position] to do that, so I did that for about 18 months, in the end. What I learned; I learned the hard way, was fracture mechanics was one of the subjects that I immediately chose. I'd go to the rocket engine guys and just talk to the chief engineer and explain to him what fracture mechanics did, what they could do. I needed to have one of his key guys be part of my interdivisional team. Invariably, the chief engineer would say, look, I think you've made a good case for this, and I agree with you that fracture mechanics, for example, would be helpful to us. Probably essential to us in the long run, but the guy you're asking me to release to work on this full-time also figures in my plans to meet my annual financial targets. So I'm not willing to release him to do that.

After that repeated itself a number of times, I began to wonder if I was spending my time profitably as the manager of this interdivisional technology program. Then, when the space shuttle came along, NASA told Pratt & Whitney, which was one of the other contests—Aerojet and Rockwell, that they had to bid the space shuttle engine to be reusable for 100 relights without any maintenance. Well, you know these engines use liquid hydrogen as the fuel, and liquid oxygen is the oxidizer because it's a very high-energy reaction product. Obviously, spacecraft are very weight-sensitive, so they needed all the thrust they could get out of their engines. But it turns out the hydrogen vapor left over from the liquid hydrogen just ate the materials in the shuttle engine alive. So they were struggling to get even to ten relights, not 100 relights. NASA came and said to the chairman of Rockwell, Al Rockwell was his name; look, if you can't get this shuttle engine problem fixed, we're going to take the program somewhere else.

So, Al Rockwell was, I don't know what, he must have been a financial guy. He definitely was not an engineer. He went down to Rocketdyne and basically laid off the chief engineer of the shuttle engine program and the chief financial guy; didn't set them aside. I mean, these guys had been with Rocketdyne for years. He put them out on the streets. That evening, I went home; I was already feeling a bit discouraged about my inter-divisional technology successes, or lack thereof, more accurately. I said to my wife, you know, that could be me in 20 years when our kids are in college, and she said, I know. And, you know, the stuff that Blackburn and I had done and I continued to do research with Cecil and other people at the Science Center was pretty visible in the literature.

00:46:10 Moving on from R&D in California to Academia in Pittsburgh

Williams:

I'd had several universities that asked me if I had any interest in becoming a faculty member, and I had consistently told them, no, I have a pretty good situation here at Rockwell. But after that, I thought maybe we ought to. So I asked my wife what do you think if we at least do a little exploration with these folks? And she said, sure if that's the right thing for you to do. Bless her heart. And we did, and we ended up with a short list of Michigan Technological University up in the Upper Peninsula of Michigan and Carnegie Mellon in Pittsburgh. So we were invited to visit each of those places. Dale Stein, who I'd known professionally, was the materials guy; he was the dean of the engineering school at Michigan Tech at the time.

I guess he was the department chairman, and when we went to Houghton, he was smart enough to have us visit in the spring because it can get pretty darn cold in the Upper Peninsula. He assigned one of his PhD students to take us around. Us being my wife and I around Houghton just to see what kind of a town it was. It was a typically, you know, relatively small college town. It used to be a home for copper mining, but the copper mines had essentially all shut down because of environmental problems. Good ores were largely depleted also. So, as we were going around town, I looked at some of the houses, and I said, you know, why do these houses have doors on the second floor? And the kid, bless his heart, was honest; he said, “Oh, when we have a really big snow, you can get out of the house without having to shovel your way out.” And I sort of said, Oh. So when my wife and I got back to the hotel that night, she said, Look, I really don't care what they offer you here at Michigan Tech, but if you elect to take it, then you're going to miss me. So that meant we—by almost default, we ended up at Carnegie Mellon for 13 years?

Pilchak:

Jim, tell me a little bit about your move to CMU and the kind of work you did while you were there.

Williams:

Sure. Sure. Well, as we've already discussed, I became pretty disillusioned with Rockwell after they fired the two chief guys in the shuttle and engine business. And we looked around and we talked about that. So, in 1968, we moved from Thousand Oaks, California, to Pittsburgh, Pennsylvania. And interestingly, and in no connected way, Rockwell was moving its headquarters from California to Pittsburgh because Rockwell had now basically consumed North American Aviation. Although it started out as North American Aviation, when Rockwell got involved after the Apollo fire, they became North American Rockwell. And then more recently after that, it became Rockwell. The joke was that amongst the people that were working in the aerospace part of the company, that North American aviation is gone, but hopefully not forgotten. So, we voluntarily moved from Thousand Oaks to Pittsburgh, and the top management of Rockwell was now going to have to move to Pittsburgh. Some of them were native Californians, and they left. I jokingly said they left transcontinental heel marks. I mean, well, they're moving to Pittsburgh. So it was kind of a funny situation. But Carnegie Mellon was very attractive—they had a very good metal program. I mean, it's where Robert Mill was. He was no longer there, but he was still alive when it was Carnegie Tech.

00:50:41 The Carnegie Tech & Mellon Institute Merger - Six Years as Dean of Engineering

Williams:

And we'll talk about it later. It merged with Mellon Institute and became Carnegie Mellon. It's a relatively small, very focused private school. Very different than where I was educated at the University of Washington, which is a very big, sprawling public institution [with] 55-60,000 students. But they offered me a faculty job and they offered me a faculty job as associate professor with tenure, which is very unusual. So it was a good move for us. And unbeknownst to the Rockwell senior executives that were fussing about having to move to Pittsburgh, Pittsburgh's a really good town. It's, in my opinion, one of the most misunderstood cities of its size and in America. We had a good time in Pittsburgh. I started as an associate professor teaching and doing research and had some really good students because it was a very selective admission school. Then, I had been there and got promoted in two years to be a full professor. The Mellon Institute, which was a part of Carnegie Mellon, that's how Carnegie Tech became Carnegie Mellon, was a freestanding industrial research institute, kind of like a mini Battelle. They did contract research for companies for all and that it was really struggling financially.

The vision on the Carnegie Tech side of the world was when they merged that the Mellon Institute would generate enough in the way of indirect costs that they could help with the budget of Carnegie.

Carnegie Tech, which was now going to be Carnegie Mellon. Well, it turns out [that] when the merger happened, they had about 250 technical staff and about 100 non-technical support staff. Machinists, glassblowers, chemistry lab accounting people, and so on. Over time, the original operating model was interesting that a company like US Steel or Alcoa or Coppers or any of the big industrial corporations that were headquartered in Pittsburgh would send maybe a couple of technicians and a couple of senior staff out, and they would sit at Mellon Institute and do research. They'd use the so-called research services on a shared basis. And so, it was a very economical way to have a small, focused research group for these companies. But over time, each of the companies, or most of the companies at least, set up their own in-house research operations. When that happened, then they withdrew their people from Mellon Institute. So when I went to be the president of Mellon Institute, we had, instead of 250 technical staff, we had about 100 technical staff, and we still had the 100 support staff.

So, it was no wonder we were not living up to our bargain about supply and surplus indirect costs to the university. So, as unpleasant as it was—there was a woman that was a very crusty maiden lady that ran the finances of Mellon Institute, and I began to get her to explain to me what was going on. She and I became really good colleagues. So, after about nine months of taking data on, we had a Black Friday at Mellon Institute, where the support staff was reduced by about 50%. Very difficult, very painful to do, but it was essential. An example was that they had a mail room [where] mail came in, and they had two women that operated the mail room, and faxes were just becoming—right. So the deal was that in the morning, the mail came twice a day, and in the morning—everybody had a mailbox. So they would put the mail in the people's mailboxes, and then there wasn't really much more for them to do. Why did we need two people to do that? I mean, they could do it. And so, one of them got laid off. It turns out that one of the ladies was an African American, and one of the ladies was a white lady. And the African American lady had a much, much better work ethic than the other lady. So the white lady got laid off, and she ended up suing, suing me and the Institute for reverse discrimination, and so that was it. That was a learning experience for me, I can tell you that.

Anyway, so basically, the Mellon Institute was stabilized. About that time there was the dean of engineering on the main campus, had been promoted to provost, and they were looking for a new dean. They asked me if I was interested in interviewing for that, so we did, and I did get selected for the job. So my last, about six years at Carnegie Mellon, I was the dean of the engineering school. It was an interesting job with some really good people in the faculty. It was an interesting job. You know, part of your job as a dean is to raise money, so I met some very interesting alums that were well-to-do. I still had a small, smaller, but real research group, and I was still supervising three or four PhD students while I was also the dean, and it worked out just fine.

00:57:26 Moving Back to Industry – General Manager of GE's Materials Engineering Department

Williams:

I also had some time, as all faculty do if they elect, to do some consulting. One of my clients was General Electric and in the aircraft engine business. The guy that was the general manager of the materials engineering department was a guy named Bob Sprague. I knew him from my Science Center days because he was at Pratt & Whitney at the time. Pratt & Whitney was just starting to do the F100 engine for the F-16 [Fighting Falcon]. They were using a brand-new titanium alloy. Titanium - six aluminum, two tin, four zirconium, six molybdenum. [Or in shorthand; Ti-6Al, 2Sn, 4Zr, 6Mo or <u>Ti-6-2-4-6</u>.] So I had known Bob a long time, and he got me to come once a month as a technical consultant. So one time when I was at GE consulting, Bob said, let's go have lunch. He said, if GE was interested in having you to be my replacement, what would you say? And I said, Well, there's no way GE is going to hire an academic to take a job, the level of yours. He said, well if they want to talk to you, are you willing to talk to them? And I said, of course. I didn't think much more about it because I had dismissed that as a possibility.

And sure enough, after I got back home a few days later, the vice president of engineering, human resource person, called and said, “Would you like to come visit and talk about a potential employment opportunity?” And I said, “You know, why not?” I knew enough about the aircraft engine business from my consulting that I was fascinated by it because an aircraft engine is a very, very complicated material. But there are places in an aircraft engine where the performance is limited by materials and there's no possibility that even a very good mechanical designer can design around a materials limitation. For example, in the turbine or up in front of the engine. So, you know, it would really be interesting to go back to working on a product. So over time, with quite a lot of backing and forthing and negotiation, GE offered me Sprague's job. Sprague wanted out of the job because he had recently lost his wife, and he was, you know, just didn't need the extra pressure and activity associated with the general manager's job. But he stayed. He stayed at GE for another five or six years after I came. So, as I said, being a materials person in a jet engine business is a really interesting and formative experience because there are places where you basically control the game in the airplane business. A good designer can literally always design around a materials limitation. Jet engines and nuclear reactors are probably two machines that demand more from the materials they are made out of than anything else that I can immediately think of. So, it was it was a great opportunity.

Welch was a chairman of GE. When I went there, Welch was called Neutron Jack because he didn't fool around with people that didn't perform, but he was a spectacular leader. He's a smart guy. When I was a general manager, I used to go to the annual senior management meeting in Florida in January. There would be about, oh, 250-300 people from all over the world because GE was a global company for a long time. And Welch could call every one of those people there by name and knew something, some high visibility thing they were working on. He didn't have some guy walking along behind him whispering in his ear; I mean, he knew this stuff. And I thought for a $2 billion company, I thought that was pretty remarkable.

01:02:21 Exploring Alternative Materials for Engine Components at GE

Pilchak:

So what sorts of things did you and your team work on at GE?

Williams:

Well, all the materials, including polymers and polymer composites, and ceramic composites. We had 20 engineers, that were working on materials to absorb radar because one of the toughest jobs to conceal an aircraft is to conceal the contrail. You know, sometimes if you look up on a clear day and you see the white trails behind an airplane, well, obviously, if you don't want the enemy to know you're coming, you've got to do something about that contrail. That's just like a searchlight. So the people that did that low observable technology, you had nickel-based guys, titanium guys, polymer composite guys, ceramic composite people, and coatings people. It was a big operation, about 650 engineers and technicians. So, the engines that were in production when I went there were the CF6, which is a 747 L1011 [Tristar] DC-10 engine. Then, we did a brand-new engine for Boeing's 777. It was a big engine [with a] 128-inch diameter fan that started when Boeing did the 777 Rolls-Royce. Pratt & Whitney also made engines for that airplane, but they basically did derivatives of their biggest engine, which was cost-wise very a good decision. GE elected to do a brand new clean sheet of paper engine, and so it had lots of challenges with it.

And you know, for example, an example of Welch and his knowledge and his leadership is at one of these meetings in Florida, annual meetings, he came up to me, and he said, I understand you're going to put a powder nickel alloy in the disc in the turbine disk and the GE 90, that was our 777 engine. And I said, Yeah. He said, "You know, there have been a lot of problems without nickel alloys." I said, "Yeah, we're well aware of that and we think we've got our hands around that. I said, if we didn't do that, Jack, we couldn't meet the fuel consumption promises we made to Boeing." And he said, "Well, if you mess that up, you'll be history around here." So I said, "Well, let's hope it doesn't turn out that way, Jack, because I wouldn't like that, and maybe you wouldn't like that either. I don't know." But my joke about the receptions—they always had a reception before dinner at these or the three- or four-day meetings. And because he'd go around and quiz people about things they were doing, my joke was it kept the liquor bill down because nobody would dare have more than they should have to drink and still be able to answer Jack's questions in a satisfactory way.

01:05:56 Switching from the Aviation to the Automotive Industry – Starting a New Job at Ohio State

Pilchak:

So, how long did you do that job as general manager?

Williams:

Eleven years, and it was a great job. It's probably the best job I had in my whole career. I mean, you can't compare a job like that to a faculty job because there are lots of satisfactions with being a faculty. I've been very fortunate over the years and had some spectacularly good PhD students, of which you're one, Adam.

Pilchak:

Well, thank you, John.

Williams:

But after a while, when somebody's $250 million airplane is sitting on the ground because they have a problem with your engine. Friday night, Saturday, Sunday all move. [They] lose their meaning because you have to fix it quickly. Not long after I went to GE the United Airlines flight that crashed in Sioux City, Iowa, which had GE engines in it, and it was a tragic accident. About 90 people were killed in that accident, including a guy I'd gotten to know very well, who was a polymer chemist from Colorado State named John Steely. He was sitting up front, and he lost his life, and that gets it pretty close to home. But after a while, that pressure, you know, it's not constant. If you add field problems all the time, you wouldn't have a very good business, probably. But when you do have a flaw, the pressure is really on. I thought, well, I don't want to retire, but I'm not sure I want to do this general manager's job that much longer.

And about then, Professor Frazier from Ohio State said, “Hey, are you interested in looking at a faculty job at Ohio State?’ And I said, “I always go home and talk to my wife about these things.” And she said, “Is that something you want to look at? You should look at it.” And bless her heart, she's always been very supportive of job changes. So, we did, and it was a brand-new chair endowed by Honda. Honda has a huge presence in Ohio. Since I'd never had any real association with the automotive industry, I thought, wow, it'd be a chance for me to learn something about that and bring my industrial background to the campus, and so on. So, we ended up in the end taking that job. We did that for about 13 more years.

Pilchak:

So let's see, that was around 1999.

Williams:

Yeah, that's right.

01:08:53 Short-term Move to Germany - Becoming the Dean of Engineering at Ohio State

Pilchak:

So, what happened between your time at GE and when you started at Ohio State?

Williams:

Oh, I delayed my starting time at Ohio State by six months because a professor lecturing from Germany and I were in the middle of writing a book about titanium alloys. So, I basically moved to Germany for six months, and, of course, naively, I thought that would be enough to finish the book. Of course, it wasn't, but that's okay. We got it finished, and then we did a second. Unfortunately, my friend and colleague Professor Newton is gone now, and I miss him. He was a wonderful guy. Remarkable guy. So then we started at Ohio State, and I had just a regular faculty appointment. I taught classes and supervised some Ph.D. students, and did research, and some consulting on the side. But one day, I was sitting in my faculty office and President Kerwin, who was the president of Ohio State University— My phone rang, and it was him on the phone. I thought, “Oh, boy. What have I done that the presidents calling me?” But he said, “Do you have a few minutes?” And I said, “Sure, I always have a few minutes for you.” And he said, “Well, I'll come over.” I said, “I'll come see you. You're a lot busier than I am.” “No,” he said, “I want to come see you.” So, in 10 minutes, he came over. He was in my office. It turns out that David Ashley, who was a dean of the engineering college when I was recruited and played a role in the recruitment of me, had decided to leave Ohio State and become the provost at the University of California’s new campus at Merced. He gave the university almost no lead time with this.

So Kerwin said, you know, I've come over to ask you if you're willing to be the dean. I said, Oh, I did that once before. He said, I know. That's why I'm here. So I said, Well, again, same thing; I go home and talk to my wife, and I'll give you a firm answer in the morning. He said that's fair enough. Again, my wife Joanne said, you know, if that's something you want to do, I think you ought to do it. I said, well, it really isn't what I came here to do, but I feel obligated to Kerwin because I have so much respect for him. So, I called him and told him I'd take the job, and he said, okay, well, we'll put together a five-year appointment package for you. His nickname was Britt. And I said, “Britt, if you appoint an old white guy for a full five-year term without a search, you're going to get a lot of feedback that you’d just as soon not have. I said, I think—what about a three-year appointment?” He said, “Okay, that's fair enough.” I said, “But I don't want to be called the interim dean or the acting dean; I want to be the dean. I don't want people not—feeling like they don't have to listen to me because I'm only going to be there for a while.” So he says, “Fair enough.” And that turned out to be good. It did. I mean, without having done that, you and I wouldn't be friends and colleagues, Adam.

01:12:39 Fundraising as Dean – Attracting Donors with Football Tickets

Pilchak:

That's right. That's right. So you did that for three or so years and then went back—

Williams:

Three years, yeah, and then went back to the faculty. Kerwin had left the university and gone back to be the overall chancellor of the Maryland system, and they hired Gordon Gee to be the president. Let's see, Karen Holbrook may have been in between, I'm sure. I think Karen Holbrooke came, and then she didn't get reappointed. She was a very smart lady, an interesting lady, a nice person. But she really didn't have much in the way of leadership experience. At a big place like OSU, she just had a hard time making decisions. So anyway, she was there, and she and I didn't get along all that well. But I mean, we didn't have any open—phrase. But in my role as Dean, for fundraising, you go out and talk to people that—you've done your homework. You know they can afford to give to the university if you can propose something that they're interested in and would feel was a good investment on their part. Several times, we would do that—with my development guy, Dave McCarthy, and the alum would say, Oh, we already give a lot of money to Ohio State. And neither McCarthy or I knew about that. It was very embarrassing. We’d say, “Who do you give it to?” We give it to the athletic department because we get better football tickets. So after this happened a couple of times, I went to see Karen Holbrook and said, look, you know, people that give to any part of the university in a very generous way should get special consideration about football tickets; I don't have any problem with that. But making it only the province of the athletic department—that they can basically keep these donors to themselves, it just doesn't make any sense. It's not consistent with where we're trying to go as a university. And she said I'm not going to get involved in that. That was her standard answer for tough problems. By then, I was a little bit irritated, and I said to her, “Well, maybe we should change all of our email addresses to OSU.FTB for football.” She said I don't find that very funny. I said, “That's good because I wasn't joking.” [Laughs] So anyway.

01:15:40 “Lecturing is an Activity, Teaching is an Outcome”

Pilchak:

So, I see you have a University of North Texas shirt on today. Can you tell me a little bit about that?

Williams:

Yeah. After I retired from Ohio State, a couple of the guys that did PhDs at Ohio State with Professor Fraser were on the faculty down there. They put the department chairmen up to seeing if I was interested—they invited me down to give a seminar. Then, after a while, they came back and said, are you interested in a part-time faculty appointment? I said, Yeah, but you know, it's not right for me. I can't move to Texas. They said, it's okay; you can come and spend little blocks of time, and it'll work out just fine. So, we ended up with a quarter-time appointment, and I'd like to believe I was helpful to some of the younger faculty. The dean, when I got appointed was named Costas Tsatsoulis. He came from one of the Kansas schools. I never remember whether it's University of Kansas or Kansas State, but neither have a big engineering research reputation, and Costas struggled to understand engineering research. And that's so important these days.

Eventually, he left, and they hired a Chinese-born American guy named Hanchen Huang. I was visiting the campus in the fall, and I got a call and he said, can I come over and meet you? So we met, and he and I got along famously, and I think I was able to help him. I was a pretty experienced neutral ear, and he'd come and tell me about things he was either thinking about or struggling with, and then I'd give him some feedback. He's—unfortunately, now he just left in the fall [2022] to be the provost at UMass Amherst campus. So sorry, UMass Dartmouth campus, correction. So I miss him because he was a good guy, and I felt like I was earning my keep there. In the spring, I teach a course called Mechanical Behavior Materials, or at least I lecture it. Adam, do you know the difference between teaching and lecturing?

Pilchak:

You'll have to remind me.

Williams:

Lecturing is an activity description. Teaching is an outcome description. Last spring, when I was grading midterms, I said to my wife, you know, I'm afraid I'm just lecturing. [Laughs] But it's okay. You know, it's a subject that can be very theoretical, or it could be fairly practical. My students have told me that I do a pretty good job of finding the middle ground between theory and practice because of my extensive aerospace background. So.

Pilchak:

Yeah, I know your course at Ohio State was always really well-received. I think you loosely called it "Everything that You Should Have Learned While You Were in College" course.

Williams:

Right. One of the courses I taught when I was full-time at Ohio State was the so-called senior capstone course. That's while they still were doing quarters. And yeah, the capstone course had some fancy academic title, but my name for it was "All the Stuff You Should Have Heard About but Haven't." So we talked about all kinds of practical things that real engineers in a real engineering business have to have to contend with.

01:19:53 Professional Societies - Awards and Recognitions

Pilchak:

Well, Jim, thank you so much for recalling all that background and talking us through your life here as we wind down. Any thoughts or comments on participation in technical and professional societies?

Williams:

Oh, professional—you know, I got involved in AIME when I was an undergraduate, and then ASM shortly thereafter. These days, the industrial folks are constrained about what they can talk about because of this sometimes, in my opinion, overreaction to proprietary information. But the societies, both ASM and AIME provide a forum where you can meet with people that do similar things to what you do and have thoughtful conversations without giving away any proprietary information. But if it weren't for the societies, I don't know where that would happen. So yeah, both AIME, really TMS, and ASM have been good to me. I've been a trustee of ASM and been a big participant in TMS committees. I was the chairman of the Titanium Committee for quite a long time.

Pilchak:

Having reviewed your CV, I'm aware of the extensive list of awards and honors, and I was just wondering if there was any that you were particularly proud of that you'd share with us today.

Williams:

Well, while I was still at Carnegie Mellon, I got elected to the National Academy of Engineering, in 1987. They only elect about a hundred people a year from all of engineering, and so I was very pleased and surprised, quite honestly. It's a nice form of recognition. The Diamond Awards at the University of Washington, my alma mater, gave me. They only give three a year: one for academics, one for industrial person, and one for private innovation. So that's a nice form of recognition. And then the special lectures that both the societies have that I've been one or the other at times. Then, when I was at GE, GE has a propulsion Hall of Fame, and I got elected to the Propulsion Hall of Fame, which made me happy. They always come as a surprise because I've never campaigned for any of those.

01:22:49 Last-minute Words of Wisdom – Seek Support from Your Significant Other in Your Career

Pilchak:

Anything else that you have to say or any last-minute words of wisdom for us?

Williams:

Well, I feel very fortunate to have had the career I've had. I've had lots of different opportunities to do different things they've been interesting and instructive. One of the most interesting things, to me, about engineering I'm talking about industrial engineering now. Some of the most important things you learn are not engineering intensive, but they're about people and leadership and things like that. So the things I learned about why the interdivisional technology job I had at Rockwell didn't play out was a reflection of people that find themselves in senior leadership jobs that have limited understanding of how to lead engineers and provide them the opportunity to grow. So that was interesting. The Mellon Institute job, I guess I could summarize and say out of three or four jobs I've had that I learned a lot that I would not have guessed I was going to learn. So, the Mellon Institute job prepared me for the tough times that we went through at GE. Watching a new product evolution that is done for the design engineering crowd elect to bet out a lot of their chips on unproven, new, unproven materials is very instructive. Everybody who is involved in helping with material selection should go through that at least once in their life.

Pilchak:

Thank you. What a truly diverse and fascinating career that you've had, Jim. I want to thank you for sharing your time and your stories with AIME, TMS, all the listeners, and also for all the time we spent together, and for being my thesis advisor. I wish you and your whole family Happy Holidays and look forward to catching up with you in the New Year.

Williams:

Thanks, Adam. Same to you. Best to Jenna and the kids. And I've valued your long-term relationship.

Pilchak:

Absolutely.

Williams:

So thank you. Oh, one last comment. If you begin to change—as a young engineer, if you have the opportunity to change jobs. If you're married or have a significant other, my advice is to be sure you discuss it thoroughly with them because it can be a pleasure for you and a hardship for your partner. So, it's important that you get your partner invested before you make the decision.

Pilchak:

Yeah. For instance, moving from Dayton to East Hartford.

Williams:

Right. Right. Right

Pilchak:

Luckily, I'd taken a page out of your playbook.

Williams:

Well, I think it's a great opportunity for you, and I know Jen well enough to know she's very supportive, and your kids are not at a bad age to move. When your kids are in high school, you know, that's a tough time to move.

Pilchak:

Definitely.

Williams:

Okay. Thank you.