Oral History Center
The Bancroft Library

University of California
Berkeley, California

Global Mining and Materials Research Oral History Project

# Everything Connected to Everything: Diran Apelian, Metallurgy, and the Transformation of Modern Research Universities

Interviews conducted by
Paul Burnett
in 2015

Since 1954 the Oral History Center of the Bancroft Library, formerly the Regional Oral History Office, has been interviewing leading participants in or well-placed witnesses to major events in the development of Northern California, the West, and the nation. Oral History is a method of collecting historical information through tape-recorded interviews between a narrator with firsthand knowledge of historically significant events and a well-informed interviewer, with the goal of preserving substantive additions to the historical record. The tape recording is transcribed, lightly edited for continuity and clarity, and reviewed by the interviewee. The corrected manuscript is bound with photographs and illustrative materials and placed in The Bancroft Library at the University of California, Berkeley, and in other research collections for scholarly use. Because it is primary material, oral history is not intended to present the final, verified, or complete narrative of events. It is a spoken account, offered by the interviewee in response to questioning, and as such it is reflective, partisan, deeply involved, and irreplaceable.

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Diran Apelian

**Diran Apelian** is the Alcoa-Howmet Professor of Engineering and Founding Director of the Metal Processing Institute (MPI) at Worcester Polytechnic Institute (WPI). He received his B.S. degree in metallurgical engineering from Drexel University in 1968 and his doctorate in materials science and engineering from MIT in 1972. He worked at Bethlehem Steel's Homer Research Laboratories before joining Drexel University's faculty in 1976. At Drexel he held various positions, including professor, head of the Department of Materials Engineering, associate dean of the College of Engineering and vice-provost of the University. He joined WPI in July 1990 as WPI's Provost. In 1996 he returned to the faculty and leads the activities of the Metal Processing Institute.

He is credited with pioneering work in various areas of solidification processing and powder metallurgy – specifically in molten metal processing, aluminum alloy development, plasma deposition, spray casting/forming, and semi-solid processing of metals. During the last decade, he has worked on sustainable development issues, and particularly, resource recovery, reuse, and recycling. Apelian is the recipient of many distinguished honors and awards – national and international; he has over 600 publications to his credit; and serves on several technical, corporate and editorial boards. During 2008/2009, he served as President of TMS. Apelian is a Fellow of TMS, ASM, and APMI; he is a member of the National Academy of Engineering (NAE), and the Armenian Academy of Sciences

**Table of Contents—Diran Apelian**

**Global Mining and Materials Research Project**

For over twenty years, the Regional Oral History Office (ROHO) produced in-depth oral histories of members of the mining community, under a project called "Western Mining in the Twentieth Century," which was overseen by Eleanor and Langan Swent, Douglas Fuerstenau and others. http://bancroft.berkeley.edu/ROHO/projects/mining/index.html The 104 interviews in the project covered the history of mining in the American Southwest, Mexico, South America, and Australia from the 1940s until the 1990s.

ROHO has recently changed its name to the Oral History Center of the Bancroft Library, and with that change we proudly announce a new project entitled "Global Mining and Materials Research," which will focus on key transitions in technology, policy, and geopolitics that have brought mining to its current state worldwide.

Much has changed in mining industries in the years since the Western Mining project was in full production, including the increased globalization of mining operations, the decreasing concentration of mineable minerals in ore, increasingly complicated regulatory environments, new systems of environmental remediation, new technology for exploration, extraction, and processing, and new stories of political conflict and resolution. In addition to collecting interviews about mining engineering, metallurgy, and administration, we also hope to explore the history of information technology and data analysis with respect to mining, as well as the legal, regulatory, and policy history of the industries.

This interview was funded with support from the American Institute of Mining Engineers, Metallurgists, and Petroleum Engineers (AIME), the Society for Mining, Metallurgy, and Exploration (SME), the Association for Iron & Steel Technology (AIST), the Minerals, Metals, & Materials Society (TMS), and the Society of Petroleum Engineers (SPE). We are also collaborating with the IEEE to host these oral histories on the Engineering and Technology History Website, located here: http://ethw.org/Oral-History:List_of_all_Oral_Histories. Thanks also to former Western Mining Project Lead Eleanor Swent, Dr. Douglas Fuerstenau, and Noel Kirschenbaum for their advice and support while the Global Mining Project was being established. Finally, we are most grateful to Diran Apelian for taking time out of a busy schedule to speak to us about the evolution of the mining industry over the past forty years.

Paul Burnett, Berkeley, CA, 2015

Interview #1 March 17, 2015
[Audio File 1]

01-00:00:09
Burnett: This is Paul Burnett, interviewing Diran Apelian, and it's March 17, 2015, and we're here at Orlando, Florida, for the TMS [The Minerals, Metals, and Materials Society] conference. And this is audio file one. This is for the Global Mining and Materials research project. So let's start at the beginning. Can you tell us where you were born, and where you grew up?

01-00:00:39
Apelian: Okay. I was born in 1945, October. October 28, 1945, in Cairo, Egypt. My dad was working with the British Army at the time. Not as a soldier, but selling them typewriters and things of that sort. And my mother's family, who's from Milan, Italy—[Benito] Mussolini was in Libya, and he had some holdings in North Africa. So my parents met there, and I was born in Cairo. Grew up there, until I was about nine, nine and a half, ten. It was a wonderful time. It was a different era, obviously. There was a king at the time. King Farouk. And he was deposed, my dad's company was nationalized, so we migrated to Lebanon, to Beirut. Which was French influence from World War II, still a French colony, to some extent. Then we lived there for about four, five years, and then problems began there as well, where [Dwight] Eisenhower sent troops in.

I remember distinctly one day, I was about fourteen, my dad came home and said, "We're leaving the Middle East. We're going to go to America." And he found—at that time, you couldn't go to America. You had to have a sponsor. And he found William Saroyan's brother—I don't know how he met him—to be our sponsor. So we're actually heading to San Francisco, to Fresno. We stopped in Philadelphia, and then he met a third or fourth cousin of ours, and we end up in Philadelphia. So at the age of fifteen, I came to America, having lived in Egypt for nine, ten years, and then four, five years in Lebanon at a private school.

01-00:02:42
Burnett: How was that adjustment, coming to the US?

01-00:02:45
Apelian: Well, that's interesting. I had a lot of adjusting—much of who I am today, like anybody else, is a product of our experiences. So I had to learn how to adapt. I had to learn how to be agile, not to whine. Just figure out that—survival. Survival skills. So leaving Egypt, going to Lebanon, first year, I had to be in a boarding school in a completely new area. So you become independent, you figure out things, you learn how to deal with situations, language. Because my first fifteen years, it was mostly Italian, Armenian, French, a little bit of Arabic. And after fifteen, coming to America at the age of, you know, tenth grade, all of a sudden in a high school in Haverford, Pennsylvania,

everything's in English. I can't figure out what the words mean. You know, it was a transformation.

01-00:03:54
Burnett: Some of the students must have been interested in where you'd been, right?

01-00:04:00
Apelian: Well, that was the lucky or fortunate part, which is the essence of America to some extent, and the reason why I love this land of ours so much. And you'll find that most immigrants are more fervent Americans than people who were born here, because you don't—you take it for granted. It's natural. Natural, human to do so, unfortunately. But what I found coming to America at the age of fifteen was classmates who were just so intrigued, wanted to learn. I got—I was welcomed. I was worried about having a different name; it didn't matter. That pluralistic, democratic DNA of the nation, you know? I mean, my second year, I was selected to be the vice council for the student body. It was pretty cool. I got adapted and inculcated into the culture very quickly, very quickly. I think much of it was because of the welcoming, the hospitality, the sincere, genuine happiness of people having somebody from—with my background.

01-00:05:19
Burnett: From somewhere else. Right, right, right. And you went to high school in Haverford?

01-00:05:25
Apelian: I went to high school in Haverford for three years, and then after that I went to—we really didn't have the means, actually, because of we couldn't take things out of the Middle East. My dad was not able to bring much of his—when things get nationalized by the government, you can't take things out. So I had applied to Yale [University], Carnegie [Mellon University]—at the time, it was called Carnegie Institute of Technology—and Drexel [University]. I went to Drexel because of the cooperative experience. You know how that works: you go to school first year and fifth year, and then between six months in and out. So you're making some money to pay for the college. So, I didn't want to be a burden to my parents, so I paid, essentially, my way through college. I saved every penny from the work-study, and was able to fund my college education that way.

01-00:06:23
Burnett: In a lot of universities, that work-study is not just—perhaps it was, for the disadvantaged? But it's now seen as a positive boon. Do you think that helped you, in the sense that you got real work experience?

01-00:06:38
Apelian: Yeah, yeah. I know we're going to come back to this later, but today, I'm at WPI. I've been there almost twenty-five years, at Worchester Polytechnic Institute. And the school was founded during the Industrial Revolution by two industrialists who believed in theory and practice. There was no income tax at that time, as you well know. So it was mostly philanthropic, but it was more

self-serving. They needed people for their factories, and their workshops. So the application side of engineering was the hallmark of the school. So what I am at WPI today is all based on the German—the motto of the university is *Lehr und Kunst*, which means theory and practice.

So to your question, absolutely yes, even though at the time, my motive was to make money so I can pay my way, but ultimately, the real advantage of that was the realization of the beauty of how the things I was learning in the classroom were being applied, and connecting the dots. There's a wonderful saying by a great English, T.S. Eliot, a great English poet, Renaissance man, whatever, T.S. Eliot, where he said, "Heaven—" No, not heaven. But, "Hell is a place where nothing connects with anything." So my experience working as a coop student at Drexel, every six months at Franklin Institute Research Labs, at US Steel, at a wire company in Rahns, Pennsylvania. Those were just great experiences. Formative. Formative. So I graduated from Drexel in 1969. Five years at Drexel Institute of Technology, which is now Drexel University. And then I went to MIT after that, for a good four years or so, and did my doctorate under a pioneer, and a wonderful man. Still a great friend and mentor. He's in his eighties—mid-eighties or late-eighties, now. Merton [C.] Flemings, who to this day is a great mentor and friend. So I did that for about four years, and graduated from MIT in, what, 1972 or so?

01-00:09:26
Burnett: Can we just pause a minute on that period in the 1960s, early seventies? What were the leading research questions in your field, or the fields that you were exploring as a student, and later as someone who's doing his doctoral research?

01-00:09:49
Apelian: Well, let's break it up into three areas. One is high school, last year in high school. And at Drexel, which is five years, between '63 and '68, that era. And then at MIT, between '68 and '72. So I'm going to break it up into that. The reason I ended up at Drexel, and into metallurgy, was actually a math teacher at Haverford, who I had a good relationship with, and he was somebody I looked up to, and I was pretty good in math. Still am, probably. And the Sputnik occurred that year while I was a senior. So the idea of sending a man to the moon, this is Kennedy, John F. Kennedy's period, was, as a young man, incredibly inviting. It was pretty interesting. So when I was asking Mr. Kent—his name was Mr. Kent. He's deceased now—"What field of engineering should I go into?" He says, "Absolutely, no question: go into metallurgy." So without knowing much about it and the applications, I just put down metallurgy. And I remember, I had a date for the prom, and you know how it works: you go and you pick up your date, the parents want to meet you, and the father asked me, "What are you going to be doing next year, son," or something of that sort. I said, "I'm going to go to college and study engineering." He said, "What kind of engineering?" And I said, "Metallurgical engineering." He said, "there's a great career being a weatherman. That's good for you." So I realized thereafter that I had to be

very, very specific when I said metallurgy. Not—so that was the first revelation I had that maybe the field that I'm getting into is not that well understood. But that's a true story. So Sputnik Age was one, certainly, milestone in my lifetime, which influenced me into going into materials and metals.

At Drexel, you know, as an undergraduate, you're very—not naïve, but, you know, you're moldable, and you can get influenced very quickly. I had some incredible teachers. Some of them are still alive, thankfully. George [E.] Dieter was our department head, who was one of the big names in the field. He was one of the pioneers of mechanical metallurgy. He was a department head. He took me under his wing to some extent, and watched over me, making sure I was on the right track. Dick [Richard] Heckel was another famous professor, who's deceased now, unfortunately. So I had some very important influences in my life. So the things that—metaphorically with the Sputnik Age before going to Drexel was advanced powder metallurgy. That was a field that was blossoming at the time in terms of making things not from a liquid metal, where you pour into a cavity and make the thing, but rather making it into small powders, and compacting it, and making it into a shape. One of the exciting things as an undergraduate at Drexel was having the fellows from Pratt Whitney, United Technology Corporation, Budd Schank coming in to talk about single crystals: how to make turbine blades completely out of a single crystal. I still remember it; it was fascinating. And I said to myself, I think, subconsciously, that's an area I want to work in. And as it turns out, I ended up going to MIT working for one of the pioneers in silification processing that enabled making these turbine blades and single-crystal components that enables us to fly today in jets. So Sputnik in high school era; at Drexel, would be powder metallurgy, a lot of advances there, and advances in manufacturing from liquid metals, you know, the casting composites. I remember we studied Wayne Kraft's work from Lehigh. So these are all coming back to me as you asked the question, but those are probably the important things that were occurring then.

01-00:14:40
Burnett: And these are essentially brand new—well, in powder metallurgy, this—

01-00:14:44
Apelian: Well, at the time, it was pretty revolutionary. So—

01-00:14:50
Burnett: And when you manufacture from a single crystal, this gives you incredible strength, and it's strong and lightweight?

01-00:15:00
Apelian: The way to think about it in a very simple way is that materials are crystals, by nature. And when you have the component that's manufactured, it has many crystals. Each crystal is identified, or characterized from another crystal, by the boundary that exists between the two crystals. And we call that a grain

boundary. It's just a boundary. It's a place—it's a fence between the two crystals. So whenever you use a material at higher temperatures, the first place where failure may begin, or a crack may initiate, or degradation will occur, will be at these boundaries, because they're the weakest points. That's where the atoms are not bonded as well. It's a place where you have a lot of imperfections. So the one way to strengthen the material is to get rid of all these boundaries, and to do that is to just have a single crystal. So maybe you haven't seen these blades, but these blades are about this big. The whole thing to be one crystal? It is not a—is a feat. It is a technological feat, to have the dendrites go in that direction, and that be the one crystal. So it is a curiosity that gets you into the door and once you find out how it's done, and you realize the complexities of fluid flow, mass flow, heat flow, and the beauty of being able to manipulate that, and to make things that couldn't be done before, is pretty intoxicating.

01-00:16:46
Burnett: It sounds like you were hooked pretty early on.

01-00:16:48
Apelian: Yeah. Yeah, I was, actually. I was.

01-00:16:51
Burnett: And also, going to MIT, which is one of the best places for this kind of work, to work with this great advisor that you had, Merton Flemings, perhaps you could talk about then your transition from being a student to being a professor, and how that came about.

01-00:17:18
Apelian: It really didn't come about. The last thing I thought I would be is an academic. As you can tell from the discussion so far, applications were always of interest to me. The Sputnik, the turbine blades, the aerospace. So as much as I loved the theory, I didn't really see myself doing theory for a career path in academia. So applications always interested me, perhaps more than the theory part, though I appreciated as much the fundamentals. So while I was at MIT, it was a period of four years of tremendous professional growth, also maturity as a young man. I had great—still to this day, I have these wonderful friends from those days at MIT, and all of them were going into career paths in industry. And no one, none of my peers really were thinking of going to academia. As I said, those are formative years, so you get influenced by your buddies and close friends. So I was recruited by Bethlehem Steel, which was at that time a very important company. It doesn't exist anymore. So I was recruited in 1968 by Bethlehem Steel to go and be a project engineer, senior engineer. I was fortunate to work on just the right project, a hot project, if I can use that term. It was high strength, low-alloy steels. These were steels, they were higher strength, so you could use thinner gauges of it, and lighten the car's weight, or whatever the infrastructure. So I worked on that for a good five years, and had a great run at it. It was a wonderful experience. Really applying all the things I've learned over the years in college. But I wasn't

married at the time and I had a girlfriend in Philadelphia. So, Bethlehem is about forty miles north of Philadelphia. I was going down there a couple times a week. Of course, the drive is not—it's a drive. It's not next door.

And then one day, I got a call from my old department head at Drexel. This is, remember, a vignette of maybe five, six years later. Told me that Professor Smirnoff is going on a sabbatical, and they need somebody to teach thermodynamics. Would I be interested? So I'm doing a confession here. The reason that I actually went to my boss at Bethlehem and said, "Could I take—could I do this thing?" was not because I really wanted to teach the course; I wanted to be in Philadelphia. So I took a leave of absence for three months, which they were able to do, and I'm glad they did. And I stayed at Drexel and taught two courses. My parents were living in Bryn Mawr, Pennsylvania, so I got to see them a bit. It was a good time. I was ready to go back to Bethlehem, and then the dean called me in, and said—Dean Woodring, Richard [E.] Woodring—and he said, "This hasn't happened previously, but you won the award that is the best teacher, selected by the students, and usually that doesn't go to a part-time adjunct faculty. Maybe you want to think about a career at Drexel here." In those days, you could do that, you know. The search processes were not—you know, you have to advertise, and whole process, so. He essentially made me an offer. And then Alan Lawley and Harry C. Rogers weighed in, and before I knew it, I got a job offer. You know, half my pay from Bethlehem Steel, and I took it. I took it. So I got sucked into it in a very circuitous way.

01-00:21:35
Burnett: Yeah. But the work at the Horner Research Lab was not uninteresting, it was—

01-00:21:41
Apelian: Oh, I loved the job. I didn't leave Bethlehem because I wasn't interested, but I so—when I was there for that three-month period, which was a blessing—you know, sometimes things happen. I went there for the wrong reasons, or reasons that were not virtuous, let's say. Girlfriend in Philadelphia, I wanted to be —it was romance that took me down there, you know. I never ended up marrying that girl, I just—we broke up thereafter. The nucleation event was romance. But when I was there for three months, the opportunities that I saw where I could—and it had nothing to do with metallurgy; it had to do with the soul. That I could actually carve out in my life the things I wanted to work on, the things that interest me. Perhaps selfish, you know? But I wanted to work on the things that I'm interested in working in, and I would—I could be my own boss. I would work harder, but I could at least have a destiny where I could manage and control myself, and I would not be influenced, controlled by corporate America, whatever. So I saw an opportunity where I could have a life of enjoyment. So it was more quality-of-life issues. I probably couldn't articulate it then at that time, but I can now. So maybe I was wise enough to figure that out at a young age. And when the offer came to go to academics at

Drexel, even though the compensation was less, and all the fringe benefits were less, it was really the quality of life that I was hoping to have someday, attracted me to that position.

01-00:23:36
Burnett: So even though there was more freedom and independence in this new life, you were also later at the time at Drexel, writing about the need for universities to have a better integration or concern for industrial questions.

01-00:23:59
Apelian: Yeah. Yeah.

01-00:24:00
Burnett: And so did you find when you were at Drexel that there was a lack? Was it kind of more ivory tower, and—?

01-00:24:06
Apelian: No, Drexel actually was a great fit. Was a wonderful fit for me, and probably still is, to that extent. Remember, I went there as an undergraduate. I had the coop experience. And then at Drexel, I saw even more opportunities from a pedagogical, academic point of view, how we can enhance the theory and practice, and how we can enhance learning. So I became more of a facilitator of the learning environment, but I also had the urge to tell colleagues and the world that what we were doing at Drexel was so right. You can't tell people what they're doing is wrong, but you can only go by being a role model. So what we were doing—so, I did write about things of that sort, in terms of integration of theory and practice, and enhanced learning. We got involved in a self study, a project, actually, with a colleague from WPI, Roy Bourgault when I was an assistant professor Drexel, a self study where students would learn even though while they're on coop, and they're away in industry, they could take a course, self learning, with modules. So we had, for example, introduction to material science in ten modules. So very much before internet, before web, before MOOCs [Massive Open Online Courses], all of this, the learning by yourself in a guided way. Just like in the old days of great universities—you know, Oxford, Cambridge, students learned on their own. But you had a tutor that you went to see. You know, in Christ College, you went to see your tutor once a week, and he or she essentially validated, confirmed, guided you, put you back on the right track. It was really that model, which we see today in online learning, to a large extent. So we were pioneers in that, back at Drexel in 1978, '79 era. Long time ago.

01-00:26:15
Burnett: Integrated into work study, so that they would be learning practical things. And presumably, students might have questions. If the tutorial material was at all related to what they were experiencing in the field, then they would have questions they could bring back. So it's kind of an enhanced tutorial, that's coming both from theoretical learning—but it brings the university right out into the work program.

01-00:26:45
Apelian: You captured it better than I could have said it. In fact, I remember, I recall, the word will not mean anything to you, but it doesn't matter: electroslag refining. It's a process for making special alloys, super alloys, very clean. And I was teaching a course on process metallurgy, talking about electroslag remelting. I've got pictures, and talking about the process, what happens. And I had one student who just raised his hand and says, "Professor Apelian, I did that last summer at Carpenter." I think it was Carpenter. I said, "Really?" "Yeah, yeah." I said, "Come on out here and tell us about it." This is a junior in college, and he came to the front of the class and talked about it with great proficiency. I still recall that moment, that saying to myself, this theory and practice thing really works. Imagine for a second cooking, if you're just reading cookbooks, versus seeing a great chef on YouTube, or whatever. It's a big difference.

01-00:28:05
Burnett: Oh, absolutely. Even if you spec out exactly the instructions, there is going to be stuff that is missed. Absolutely. So during this time, you mentioned that you were now free to explore the kinds of things that you were interested in.

01-00:28:25
Apelian: Well, don't take it to the nth degree. There's no such thing as absolute freedom.

01-00:28:30
Burnett: Freer?

01-00:28:31
Apelian: Freer, yeah. I had the opportunity to carve out and shape things. I actually don't think there is anything like absolute freedom, I really don't. I think it's bounded. And when it's bounded freedom, it's even more precious. But I had the opportunity to do things that I really wanted to do. I started a career at Drexel in 1968 as a young assistant professor, got married that year, in 1976, and it was a nice—it was a good period.

01-00:29:09
Burnett: So you got your degree in metallurgical engineering in '68 from Drexel, then MIT you got your doctorate.

01-00:29:15
Apelian: Yeah. '71, '72 got my SCD [Doctor of Science].

01-00:29:17
Burnett: '71, '72. And then you were assistant prof starting in 1976, at Drexel.

01-00:29:22
Apelian: Yes. I think '76.

01-00:29:26
Burnett: And so during the 1980s, there are a lot of changes in industry that are coming online that we could talk about. What were some of the processes that you were interested in exploring research-wise during the time that you were at Drexel?

01-00:29:49
Apelian: I want to answer your question, but I want to do a preface first, because it's going to come back again in later on, I'm sure, as we talk about the transformations in materials science and metallurgy over the last thirty years or forty years. As an academic, when you want to do research, you've got to get funding. Vision without resources is hallucination, right? So you've got to get the funding. So there is this tension of doing the things you want to do, and who's going to fund it. It also applies to architects, or artists. You know? So it's not just engineers or academicians. So if the funding is available by the government, the federal government—you know, nanotechnology, and there's lot of money in this, or biomaterials. You could get swayed into that, because there's funding available, and you write proposals. Versus, this is what I really would like to do, and let me write proposals. So there's a—you have to have a balance between those two. Sometimes it's not one. Actually, most of the time, it's not one versus the other. You're sort of in the middle line. So that's going to come back and forth, I think, all the time, so I want to make that preface first. So I was aware of that early on, and made sure that I was not taking any funds to do things that I had absolutely no interest in, but at the same time, I tried to influence agencies to see the opportunities that they would fund the things that I want to do. So you've got to play that role.

So to answer your question, in the late seventies—remember, I joined Drexel in '76, and I left Drexel in 1990—there were probably three areas that—or maybe four—that I got involved in as pathways for research, pathways for making innovations, pathways for having grad students work in these fields, and making an impact. It's all about impact, actually. All right? It's all about impact. You want to make a difference. So one area was molten metal processing. You remember now when you're making a casting or silification, you've got start with liquid metal. How you treat the liquid metal, and all the things that you do to make sure that the metal is clean, doesn't have any dirt in it, things of that sort. So that's one area. Molten metal processing. Second area would be casting: casting processes, how do you take the liquid metal, put in the cavity to make the component, how to manufacture things, so those are two. Then—I told you earlier that Drexel had a major initiative in powder metallurgy. And powders are not something you find at Home Depot, you know, you have to make it. And it starts with liquid metal that you atomize, so every powder is a small casting. So I looked at—my meta-view, meta-beliefs of how you view the world—I looked at a powder not as powder metallurgy, but as a small casting. So the third area would be droplet consolidation: how to take powders and consolidate them together, and that led to a whole bunch of initiatives. You know, the VADER process, we developed, the Vacuum

Arc Double-Electric Remelting, with specialty metals, special metals, up in Utica, New York. We developed the Osprey process with Osprey spray-casting plasma deposition, so droplet consolidation would be the third area. So molten metal, new processes for casting, droplet consolidation, which includes a whole bunch of technologies. And came out of that as intelligent processing: how do you control these processes?

01-00:34:26
Burnett: And so this is—because kinetics becomes more important in metallurgy, that the actual movement and pressure can affect how crystals are formed in the metal? And that's a really key area, and this is what Dr.Massalski was talking about yesterday, that there's this—metallurgy used to be understood mostly in terms of thermodynamics, and what they started to realize is that the rate at which you cool something under certain kinds of pressure gives you different kinds of crystals, and so this is an extension of that. At least that's my primitive understanding.

01-00:35:10
Apelian: Absolutely. Absolutely. In fact, everything you've said is absolutely correct. There's thermodynamics, which is the science of how the energy is distributed and what is allowed or not allowed, depending on the energy state. Thermodynamics is a beautiful science that tells us what can be or cannot be. Is it possible to even have this phase, thermodynamically, energetically? Depending on its chemical potential, free energy. However, the kinetics—meaning how fast you do it or how slow you do it, and at what point in time you do it—the kinetics of it can change things. So it's a balance between thermodynamics and kinetics, but at the same time, how you impose or execute those kinetics comes about by processing methodologies.

So let's take droplet consolidation: when you atomize a liquid metal into small droplets forty micron, thirty micron size, that droplet has seen cooling grades that are not similar at all to a sandcasting, which is this big. So that little droplet cooled much, much faster, has a much more refined microstructure. The spacing between, in the indices of the microstructure, we call that the dendrite arm, which have defined as an index—dendrite arm spacing, that tells you how refined a structure is, and a powder is really, really fine, versus in a sand casting, where it's much coarser—where the spacings are much larger.

So imagine if you have heterogeneities within the structure, segregation. If the distance between the segregates are small, like in a powder, they're going to diffuse with each other much closer. Imagine if we're at such a distance versus we're further apart, the diffusion distances are small. So it's the diffusion distance that dictates how fast things are going to happen. If they're farther apart from each other, it's going to take longer; if they're closer to each other it's going to take a shorter time. But how do you control, manipulate, the diffusion distance? It's really through processing. So the droplet consolidation technologies, whether it's vacuum arc, double electrode remelting or plasma splaying, droplet consolidation, all these technologies make a big difference in terms of the control of the kinetics.

01-00:38:20
Burnett: Yeah. And as you were saying, these research programs were with an eye to applications, how they could affect industry. And there are new casting techniques coming online in industry. Are these for special materials only, like in biomedical applications, or do these have implications for mass production?

01-00:39:00
Apelian: Two questions in your question. I'll segment them. All of the processes that I've been involved in—when I say I, I really should talk about the team. It's colleagues, grad students. I want to say that upfront. So whatever we developed, at Drexel or at WPI, in my institute now at MPI [Metallurgy Processing Institute], it's a team effort. But all the things we've done are applicable to a variety of alloys. So even though we work in aluminum systems, it's applicable to magnesium, titanium. You know, it's mechanistically driven. The mechanisms, the principles that you can apply to different alloys. And all of it for us, for me, has been driven by applications. I don't like to work on something that is not going to be applicable, applied, and cannot have an impact. That's been a universal driver, in probably all of my work.

01-00:40:06
Burnett: And these presumably make things cheaper? I mean, they have different aspects to them. Metal can have different properties, so aluminum alloys, you developed improvements in the aluminum, or you developed—?

01-00:40:22
Apelian: Yeah. The way I would characterize is that you make things that you could not make any other way previously, so it's a way of making something that you couldn't do previously, so you're not reinventing the wheel. So if you have that capability, let's say—now I'm going to go all the way to the other side. Let's say a knee implant. Today if you need a knee implant, it's made in a certain way, but it's not made specifically for the size of your knee. There's a small, medium, large, extra large, and they put in whatever makes the most sense. But let's say if we could take an MRI, magnetic resonance image, of your knee and make one exactly the size of your knee, that's not necessarily cheaper, but believe me, if you don't have to do a lot of PT [physical therapy] and it's going to be exactly your size, you'll be willing to pay a little bit more. So the way to think about this is you develop processes that you're able to make things that you couldn't make otherwise. When it comes to commodity products, there, cost is really a driver. You want to develop things that are going to reduce the cost, you know?

01-00:41:48
Burnett: One interview I did last year was with Dick Teets, and he talked about the development thin slab casting, that was in a sense revolutionary, and that it made steel production a lot cheaper, and a lot more efficient. And so there are these old industries. You were at Bethlehem—

01-00:42:15
Apelian: Absolutely.

01-00:42:16
Burnett: —and Bethlehem is no more, and in part that's because of the rise of these new processes that are just far more cost effective. That that's—

01-00:42:25
Apelian: Yeah. Yeah. Well, actually, when I was at Bethlehem, you had open hearth and basic oxygen furnace was the way steel was made, but now we're recycling steel. There's quite a bit of supply of steel that we just remelt and reuse. Actually, we're doing that with aluminum now. But to your point also, another example would be—remember I said there were four or five bins or categories of my work? One is a molten metal processing. Aluminum foil, that's an application. Right? Imagine the world without aluminum foil, eh? Think about it for a second. All the burritos would not be [laughter] wrapped up in aluminum foil. But to make aluminum foil, you've got to roll the aluminum really thin. All right? Really thin. The gauge is incredibly thin. So if you have inclusions, which is really particles that comes into the molten metal—if you've ever done any pastry work in the kitchen, you know when you're rolling dough, you get holes if you have impurities, or defects, or inhomogeneities, or inclusions. So to be able to roll aluminum foil to the gauges that we do? That metal, that liquid metal before it freezes cannot afford to have too many inclusions. Or beverage cans, for that matter. And we developed technologies, actually, out of my PhD: filtration. How to remove solid inclusions, how to remove liquid inclusions—these are liquid phases—out of the molten metal before you cast. Major impact. Major impact.

01-00:44:15
Burnett: We've all noticed that the aluminum cans have gotten lighter and lighter over the years.

01-00:44:18
Apelian: Yeah. That's because of molten-metal processing. Getting the gas out of aluminum. Aluminum loves hydrogen. So in the molten state, there's a lot of hydrogen that goes in solution. When it freezes, however, has a very limited solubility for hydrogen. So the hydrogen has to come out. As a solid, the hydrogen cannot be in the solid state. It comes out and forms gas bubbles, so you get holes, which is not what you want. I'm probably boring you with all this.

01-00:44:51
Burnett: No, not at all. Not at all. We've talked a bit about spray casting and molten processing. Plasma processing was something that you were involved with.

01-00:45:04
Apelian: Yeah. This is under the droplet consolidation umbrella.

01-00:45:06
Burnett: Okay, that's part of that.

01-00:45:07
Apelian: On the droplet consolidation—remember now—let's go back and make sure we have the context here right. To make a component, you've got to—whatever it is, you've got to make it. So one way is to start with liquid metal. You take the liquid metal and put it into a cavity, the mold, and you make that part. Chinese have done it in the Zhou Dynasty, if you look at their, you know, bronze vessels, etc. So you have a mold in which you pour the liquid metal. The other way is to make a small droplet that freezes—that's the powder—consolidate that into the shape that you want to make, and that's being held physically by compaction forces, and then you treat that thermally. You give it heat for the fusion to occur, so that the component has integrity. That's powder metallurgy. The droplet-consolidation technology is, you know, spray casting, Osprey, plasma definition, all of these, is taking the powder and consolidate it *in situ* in the chamber itself. Don't make the powder and then collect the powder, and then take the powder, put it all together. But do it as it's being atomized and it's coming down. So plasma deposition is applied today to turbine blades, where every turbine blade is coated—it's essentially coating. It's just like spraying. But the spray is not a droplet. It's a droplet at the beginning, but then it becomes solidified or partially solidified, and gets deposited.

01-00:46:47
Burnett: So you're essentially, in coating, your—normally, coating *something*, but you're saying that you're actually kind of coating a mold, effectively?

01-00:46:59
Apelian: Yeah.

01-00:47:00
Burnett: And then that becomes—

01-00:47:01
Apelian: The soft shape becomes a mold. So you could have a platform, or a substrate that's rotating, so you could make a roll.

01-00:47:14
Burnett: And shape casting, is that a separate family of innovations or research?

01-00:47:23
Apelian: Well, not really, but neonate shape means that you're not making the shape and then processing it later, machining, and all that. You're trying to get to the final shape as close as you possibly can in one step.

01-00:47:39
Burnett: Right. Oh, this is what Dick Teets was talking about the with dog bone I-beams that they were making: they used to have to roll those in a number of processes, but if you could cast it in a way that's close to what becomes the I-beam, you need to roll fewer times to get that.

01-00:47:59
Apelian: Right. Or from a very simplistic way, look at systematically, from a systems engineering point of view, look at what are the things you have to do to go from liquid metal to the final product. What are the various steps? Can I alleviate some of these? Do I really need all of these steps? Can I go directly from here to here? If you can, then it's a much better way of doing it. And then you figure out what are the various ways of doing that.

01-00:48:28
Burnett: So you spent from 1976 to all through the eighties at Drexel, and then you make a transition. Can you talk a little bit about the next phase in your career?

01-00:48:48
Apelian: Well, from a not scientific or technical point of view, I did my graduate work at MIT, and after we got married, you know, family, two daughters between '76 and 1989, that period of fifteen years—wonderful period. Lot of growth, professional advancements. Was a professor, became department head, then I became vice provost of the university, the whole university, of Drexel. So it was a great period. A lot of professional development and growth, and learning. And with a bunch of great colleagues, you know? Al Lowly, Roger Doherty, Michel Barsoum, Mike Koczak who's deceased now. So it was just a great period. And many others. Raj Mutharsan. But all of our vacations were done in Massachusetts or New England. We'd go to Monhegan Island, we'd go to Nantucket. All our vacations: hiking in the White Mountains. So I wasn't looking for a position, but I got a call from a recruiter, about a school called WPI, which I didn't know much about, except that I had done these self-study learning modules with this professor, Roy Bourgeaux, years ago. So we looked into it. And I think it was just a time where we needed a change. We just needed a change. And Drexel was going through a lot of changes too. As vice provost, I think I had served under four different presidents in a five-year period, so it was a turbulent time at Drexel at the time.

01-00:50:37
Burnett: Right, right. And you were learning more about university administration.

[Audio file 2]

01-00:50:58
Burnett: And this is audio file two. So we were discussing the shift from Drexel to WPI, and it was a time for a change. Did you become a professor there? Did you change over?

01-00:51:19
Apelian: At WPI?

01-00:51:20
Burnett: Yeah.

01-00:51:20
Apelian: Yeah. Well, yeah. I was at Drexel, active in my research, but I was vice provost of the university. It was a period when I was getting quite interested in the administration of a university, how it should be run. I think you probably have seen a thread now, from everything I've said so far that I always had the interest in the business side of things, the applications. How are things run? How are things made, in addition to how are things run? So before vice provost, I was department head. That was also a wonderful period, where we recruited a lot of people. I think I mentioned Roger Doherty and Michel Barsoum, Frank Ko. It was a growth area, growth time. So I learned a lot about the administration, organizing universities, and the finances, and so. It was natural. it was a natural progression. It was not something I sat down one day and said, "I want to do this," you know? It was just natural evolution. When the recruiter called for the position of provost, which is the chief academic officer, it was attractive, enticing. So we thought about it: is it a big move? Changing from Pennsylvania to Massachusetts. But Massachusetts has always been an attractive state for us. You know, always loved New England. Maybe it was graduate school days influence, but I liked the—my wife and I, and my family liked the culture of New England.

So I moved to WPI as provost, but of course with tenure, as a professor in mechanical engineering. And in fact realized after seven years as provost that I wasn't having much interface with students, nor I was having much interface with people who are doing a lot of good work, but I spent most of my time with people who were having issues. [laughter] So, you know.

01-00:53:33
Burnett: That can be a little demoralizing, over time.

01-00:53:35
Apelian: Well, on reflection, it was an interesting period of our lives that I don't want to relive again, but it was an interesting and learning experience. So I'm thankful for that.

01-00:53:49
Burnett: And was your term seven years, or was it a five-year term, and it was—?

01-00:53:53
Apelian: No, it was—there's no real term for a provost. You serve at the pleasure of the president. So I went there under one president, Jon Strauss. He left, so I stayed on as the interim—not the interim, I was still provost, but the interim president, Jack Brown, who's deceased now, and he was more of a figure head, in the sense of keeping things—just keep the ship afloat until they recruit the next person. And he essentially told me, "You run the place." So after Strauss, the provostship was a bit more pleasurable in the sense that I had more authority, and some of the issues that were there with the previous administration were gone. It was a great period of building at WPI, but there were a lot of stigmas and issues with the leadership. Tension between the university—the president and the trustees. And a huge recession. This is after [Michael] Dukakis's run for presidency.

You know, going from Drexel, where I was building things all my life for fifteen years, going to WPI where we were cutting budgets by 8 percent, 7 percent, you know, $4 million this year, $5 million this year. It was a period of four years of just, you know, almost going bankrupt. So I actually asked myself what the hell did I do at one point. But that's what I'm saying, I'm thankful for the experience, it was a great learning experience. So we had to come up with a plan, how do you save the place? And I chaired a blue ribbon panel where it was a very important milestone in the university's history: it was about 75 percent, 80 percent engineering, mostly male. The place was—it was like going to a restaurant, all you have is meat and potatoes, you know? So we're not attracting students who are technically savvy or technically centric who may have interest in bio, or life sciences, or premed, or prelaw for patent attorneys. So we're very narrow, monolithic, in a way. So we expanded it. So the blue ribbon commission that I chaired, after a year and a half, we said, we've got to make dramatic changes for us to survive. We've got to go from 75, 80 percent engineering to 45, 50 percent. Life sciences have to increase. So it was a major turning point, and nothing happens real quick in universities, so it took about seven, eight years for that to happen. And today, what you see is WPI is very prosperous, "hot" school, if I may call it that.

01-00:56:53
Burnett: Prestigious, yes.

01-00:56:54
Apelian: Very prestigious. Inquiries are up like crazy. We send these beautiful letters to incredibly talented young men and women saying you're not good enough to come to our, essentially…we don't say it that way, but, you know, rejection rates are high. We're a private school, so we're not mandated to, like at the UC [University of California] system or someplace else, to take a certain number of—so, we can do essentially what we want to do, but you've got to pay for it yourself. So I got really interested in the administration of the university, and I actually liked it. It was just a difficult time.

01-00:57:32
Burnett: Yeah. But a period of building. It was a crisis, but an opportunity to make something new.

01-00:57:35
Apelian: Yeah. A turnaround artist, or whatever you want to call it. I never think of myself that way, but that period between 1990 and 1997 at WPI—let history decide, but I think we made a major impact in changing the culture and changing the direction of the university for it to be prosperous in the future. But it was not easy to do.

01-00:58:05
Burnett: Yeah. Yeah. And it sounds like you can have more opportunities for interdisciplinary collaboration when you get other forms of—

01-00:58:15
Apelian: Yes.

01-00:58:16
Burnett: I mean, you could sort of choose the things that were related to the engineering that was already there, and you could build on those strengths and include other things.

01-00:58:24
Apelian: Yeah. Yes, exactly right.

01-00:58:27
Burnett: But as you said, you didn't have as much time—initially, at least—to do the research, to be involved in research communities, and to teach. So I am looking at papers you were publishing in the nineties, so there's things going on. But you are starting to write more about the nature of teaching—

01-00:58:54
Apelian: Yeah. Yep.

01-00:58:55
Burnett: —so you're kind of more of a—I don't know if public intellectual is the right word, but thinking about the nature of the project of education, and the nature of higher education, in particular, as it relates to engineering.

01-00:59:14
Apelian: Well, you're right, Paul, because between 1990 and '97 I spent a lot of my time thinking about the academe, and how to—how do you execute it? How do you provide a forum for young people to really learn? How do you enhance that learning? And how do you do it in a cost-effective way, where tuitions—you know what they are. Going up every year. How does a family who has four children can fund, you know, $250,000 per child. How do they fund a million dollars' worth of tuition costs for four kids? It's just not—So actually, I wrote a paper which hasn't been published, but I sent it to a bunch of people

on globalization of education, where I thought of having the faculty's role be not a lecturer in the classroom, but a facilitator of the learning environment.

It was chemistry 101 which was the model. You have chemistry 101 is taught at—I'm going to take a guess—at least 3,000 universities or colleges in America. We have 3,400 colleges and universities. So chemistry's probably taught at least at 2,500 places. And you've got a bunch of faculty in every one of these 2,500 places who are putting together a syllabus for chemistry 101. So why don't we take the 100 best performances in chemistry 101, faculty who have incredible skills—oratory skills, and getting the message across, and YouTube videos. The best of the best. Take these 100, put them in a room someplace for five weeks, pay them a lot of money, and tell them, "Come up with ten modules, or fourteen modules of chemistry 101." So that's the content. The knowledge, content. And then the distribution can be done the way we do today. The students can have access to that. The faculty's role is being that tutor back in 1450 in Oxford, where they're no longer lecturing on a blackboard and students are taking notes and taking the exam. Students can learn on their own. They're smart. But have some great content that's put together by scholars, and have the faculty's role be the facilitator of the learning environment. They can do their scholarship, of course, but, you know.

But that's very threatening. That's very threatening. I've actually written about this, and the other thing that was not a very popular move on my part, or maybe insane or crazy, was the proposition—proposal I made that tenure should be reviewed every five or six years. So once you get tenure after six years, the next six years thereafter, twelve years after you join the university, you should be reviewed again. Not to be kicked out if you're not doing well, but really reviewed, a real critical review. And if you're not doing well, you know, get some feedback. You know, what are the things you need to do? But this idea of having a contract for life, to me, is insane. And I know it's not a popular thing to say, and a lot of my colleagues will not like it, but I really down deep in my bones believe so. Accountability is a very important thing. High standards and at the same time, have accountability. And that's how you make progress. And I think in the sciences and engineering, tenure just doesn't make any sense anyway. I can see why in religion, or philosophy, or—

01-01:03:14
Burnett: Or something more political.

01-01:03:16
Apelian: Political, maybe. But we're living in a day and age where freedom of speech is protected. You know. But in the sciences, you know, is tenure really even relevant?

01-01:03:33
Burnett: Especially, it also seems that there's more circulation, it seems—or maybe I'm not right about that—and engineers can move between the private industry and the academy.

01-01:03:48
Apelian: Yeah. So I'm not being critical of the academe. I mean, that's where I am, I love it. It's my place, if you will. I feel comfortable there. It's my home. But I'm always looking at how we can improve things.

01-01:04:03
Burnett: The knowledge—a lot of people talk about a kind of service model for universities. Certainly a public university, officially, you are supposed to be of service to the state, to the people. But that seems to be part of what makes you tick as well: you want to be of use to multiple communities.

01-01:04:25
Apelian: Exactly, exactly.

01-01:04:26
Burnett: And that's part of it, you know?

01-01:04:28
Apelian: I mean, if you look at higher education in general, what America has that is so unique is the community colleges. If you go back into history in terms of how community colleges are formed, it's a beautiful history. We haven't really leveraged that. It could make a big impact. I think the Obama Administration is doing some good things on that, but—

01-01:04:55
Burnett: The plan to make—or the desire to make community college free.

01-01:04:58
Apelian: Yeah, yeah, yeah. If Congress can become functional, maybe.

01-01:05:06
Burnett: So, I would like to talk about—we have some time to talk about more work in the science—

01-01:05:16
Apelian: Well, look. I'm only sixty-nine. Come back and talk to me twenty years from now. [laughter]

01-01:05:21
Burnett: Yeah, we have some long-lived engineers. There are some very long careers to evaluate. [laughter]

01-01:05:25
Apelian: I hope I make it that far.

01-01:05:28
Burnett: In the early nineties, you were writing about the rise of intelligent processing. I think the paper title was "From Foundry Art to Intelligent Processing." So can you talk a little bit about that transition, and what's at play there?

01-01:05:54
Apelian: Well, I forget that paper, but that's a good title. I came up with that, huh?

01-01:05:59
Burnett: Yeah, you did. [laughs]

01-01:06:00
Apelian: The motivation was really the droplet consolidation. Remember the three buckets so far? And there are a couple more coming as time goes by. And the droplet consolidation technologies—spray casting, plasma deposition—it became quite evident that there were so many complexities that how to control the process was not going to be a simple thing. So I began to look at neural networks, fuzzy logic, how does a brain function, how do we know what to do and how does that work? Because sometimes you don't really know why you're doing things, but you're doing it for the right reasons, you know? So how does machine learning come into being. So intelligent processing really was that. How can we take complex processes and make it controllable, without necessarily understanding the mechanisms?

Actually, plasma deposition would be a good example to use to illustrate this. You have a technician who operates the plasma machine, the deposition. Plasma is nothing but an ionized gas, so it's a source of ionized gas. Lots of enthalpy, lots of energy, lots of heat. Putting the powders through it, begins to, not necessarily completely melt, but become warmer. You have all this momentum transfer, because it's pushing out towards the substrate. So you have powders that are being deposited on the substrate. And a lot of variables. The powder size, the powder distribution, the temperature, the plasma speed. Hundreds of variables. But a plasma operator who's been doing it for a while can tell you what knobs to change just by the sound, the decibel level, of the plasma.

01-01:08:19
Burnett: Oh, my God. That's fascinating.

01-01:08:20
Apelian: They know where their things are not going right. Yeah. So now, we're trying to find out from them what it is that they understood, so we can use that and put it into a controller. We're engineers, we've got to do this thing. You start questioning the guy—and questioning is the wrong word to use, actually. You start asking questions, they have no idea. They don't know why. But they know that if you do this, this happens. You do this, this happens. Just like the American Indians knew years ago, without understanding anything about heat transfer or radiation that if the sky at night is really clear and you can see all the stars, it's going to be a cold night. Versus a sky that's clouded. Without

understanding any of the scientific mechanisms. Similarly, the plasma operator knows exactly what to do. How do you take that and put it into a machine learning approach? You know, how do you do it? So it's almost causal relationships with intelligent processing. It's what works, what doesn't work. And creating a neural network, if you will, to control processes, just like the brain does.

01-01:09:39
Burnett: So it's—in that example, there's a detective work. So what changes when the sound changes, and trying to figure that out, and then figuring a way to sort of automate that with some kind of, as you said, a controller.

01-01:09:52
Apelian: Yeah, yeah. And also quality assurance versus quality control fits under that. You know, quality control is when you're making something, you check on the quality and if it's not good, you reject it. That's what quality control is. Quality assurance is that at the end of the process, you don't have to do any quality control because at every step you've done it. You've assured it as it's going through the process. And you do that through intelligent processing, you do it through controls. But the key thing is to know what is important. What is important for me to measure? I know I'm being philosophical here, but you can't control anything unless you can measure it. That's why they have these scales in the bathroom, which I hate. [laughter] So.

01-01:10:47
Burnett: Yeah, that's the frightening example.

01-01:10:50
Apelian: If you can measure it, you can control it. But then the question becomes what do I measure? And often, unfortunately, we measure the wrong things because there is a device that allows us to measure it irrespective of it. Oh, I can measure this! Okay, I'll use it. Do I really need that?

01-01:11:08
Burnett: Yeah. And we can make assumptions that because we're measuring one parameter that we have it in the bag, that there's nothing else going on. I think that can be a real problem. So we talked about the sort of five buckets of areas. We're coming into a period now, mid-nineties, there's a couple of things, I guess, that the Materials Processing Institute—can you talk a little bit about that, and—?

01-01:11:43
Apelian: Of course, yeah. It's an important one, in fact, and I need to segue to Drexel years, WPI, and the Metals Processing Institute. The Metals Processing Institute, let me just tell you what it is. It's an institute that, as the name implies, deals with metals, and deals with processes that relate to metals, okay? Metals. And in fact 95 percent of the time, it's on metals processing. Maybe 5 percent of the time, it's on mental processing. [laughter] But it has a very clear

mission. We don't confuse ourselves that we are all things to all people. It's very metals related.

01-01:12:25
Burnett: Okay. It's not polymers, or—

01-01:12:27
Apelian: We don't do pol—I mean, of course you can't exclude polymers, but our main interest is not polymers, or ceramics. It's metals. And within that, we have three centers. This is today now, but I need to go back and explain how that happened. We have three centers. One is the Advanced Casting Research Center, which is a center dedicated to the casting industry. The members of the casting center are about thirty-four companies who've been with us for thirty years, almost. And they represent casters, they represent people who use the castings, like the automotive industry, and they represent the companies that make the metal that you use to make the castings. So it's a confluence of various segments of the industry. And we're the educational home for that industry. Companies pay a certain fee on a yearly basis, about $20-30,000 a year. Those monies go into the kitty, and they allow us to have projects that serve the needs of the members. So it's fundamental research with a utility or application in mind. So the same model applies for the casting center, to the heat treating center: thermal processes, including plasma, cold spray. And the last center, the third center, is the Recycling and Recovery Center. So it's a big institute that I started, and I'm the head of it now. Close to ninety corporations are involved in the center. It's big.

The way this started was way back at Drexel, I had a casting center, which was made up of about twelve or fifteen companies, not thirty-four. And when I was leaving Drexel to come to WPI, the chairman of the board of the twelve companies, they went to the dean. They said, "Well, Apelian is leaving to go to WPI. What are we going to do? Are you going to hire somebody else to be in this area of metal casting and silification processing, metal processing? Because, you know, we like it here. We want to stay here." Unfortunately, the dean didn't say the right thing. He said, "Well, you know, we probably are not going to replace him with another person of this kind, because the interest was in probably somewhere else, nano, bio, whatever." I was not in the room, but I can only surmise what took place. So the chairman came to me and said, afterwards—I remember—"Most of us don't live in Pennsylvania. We come here. Instead of flying to Philly, we can fly to Boston." So we're going to come with you. Take us with you. So that was a lucky thing, because if I didn't have that casting center with me at WPI, I probably would have completely been sucked into, if you will, into administrative side of the house, and seven years later, I probably would have had a very difficult transition to make to go back to the faculty. So the casting center went with me from Drexel. The plasma center didn't. I left that behind with Ron Smith, but the casting center went with me. I had a post-doc, Satya Shivkumar, who came along, and he became an assistant professor at WPI. So between 1990 and '97 while I was provost, the casting center was there, and on Saturdays, Sundays, at nights, I would be involved. So I had, thankfully, that connection with the research world.

01-01:16:14
Burnett: Yeah. Because I was wondering how you were able to do that.

01-01:16:19
Apelian: That's the only reason, I think. It would have been incredibly difficult for me after a seven-year hiatus to go back. So even though it was a lot more work—I was trying to keep up with it and at times was becoming almost not manageable. But with my family's support—they didn't see much of me between '90 and '97—I was able to come back to it. So in '97, when I left the provostship—I didn't finish the story. So I had one presidency, then I had an interim president, I had Ed Parrish, who came in as president. Wonderful man, but our styles were very different. It was quite apparent that he and I were not going to be able to work together, so we agreed that I was going to leave. And with his support and blessing—and he's been very supportive over the years. So I actually served under three presidents at WPI in a period of seven years. You know, one president, Jon Strauss, for four, five years; Jack [Lott] Brown; and then Ed [Edward] Parrish. I actually was going to Bucknell [University] for a presidency. I thought that would be next tier for me. And I recall one night in Santorini on a vacation, first vacation I've had in a long time, my wife asks, "Why do you want to do this?" Because, you know, we're urban, we love opera, and Bucknell is a wonderful place, but it's not, you know, mainstream America. It's near Pittsburgh, Harrisburg. And in a complete—you know, you're on vacation, you've had a couple of glasses of wine, you're much more natural, and you're—

01-01:18:01
Burnett: And clearer, in a sense.

01-01:18:02
Apelian: Clear, and the beach. We were sitting on it. I said, "I think it's because—it's probably ego. I want to show my colleagues I can do this." And she said to me, "That's a hell of a good reason to do it, right?" And so the next day, I decided what I was going to do. It was a transformative moment for me.

01-01:18:21
Burnett: That's wonderful. It's also family. Family can represent—they know you. And sometimes they can really help you make choices.

01-01:18:29
Apelian: Yeah. Yeah. Well, they anchor you. I mean, I said it. My wife, you haven't met, she's my anchor. She's very noble, and can see things through. It was a transformative moment. I said, yeah. This is silly. Why do I want to do academe? What do I love to do? I love working with students, I love to teach, I love to do research. So, I've done my thing. Should I really go for presidencies anymore? Even though I'm good. I'm good with people. I love

people. I'd like to raise money. I'd like to build things. I said, you know, I'm going to go back to my first love. And that was a major decision. Huge. I remember it's almost like a transformation, where all the sudden, you become really happy? You know? You've relieved some burdens? Because the provostship was a tough era. When you're cutting budgets all the time, and rebuilding things, reconfiguring things, it's tense. Tense.

01-01:19:34
Burnett: So you were able to—

01-01:19:37
Apelian: I was able to jump right back in. Yeah.

01-01:19:42
Burnett: And so that Metals Processing Institute is, then, fully established at—? It was—

01-01:19:52
Apelian: Well, in '97, when I came back to the faculty—remember, I was going to leave, and then decided to stay after that conversation with my wife, and also the chairman of the board, Howard [G.] Freeman, came over one night and says, "What the hell you doing? We heard you might be leaving. We want you to stay here." So I stayed at WPI, and thank God I did. I love the place, and my colleagues there. The casting center was there. I recruited—we hired Professor [Makhlouf M.] Makhlouf, who became a partner with me in building the casting center, and then we established a heat treating center, about a few years later. And five, six years ago, we established the recycling center. So it didn't happen overnight, but between '97, 1997, and today, 2015, over a period of time, we have, now, three centers. As I say, it's the largest industry-university collaborative in America. Over ninety corporations.

01-01:21:04
Burnett: Largest by number of corporations, or largest by total investment?

01-01:21:10
Apelian: By number of companies. Investments, I don't know. I haven't really done a calculation, but on a yearly basis, we bring in about $3 million a year just from the fees of the companies, but then we supplement that with federal government support. Our portfolio comes from three places: one is the fees that each company puts in to have the pre-competitive research projects that we have, very much fueled by their needs. But fundamental, not job shop. Then, we go after large governmental contracts, leveraging the relationships we have with corporations, because the government likes to see dissemination and transfer of technology. This year, last couple years, we had a $14 million contract with the Army Research Lab in magnesium alloys and rare earth elements. Rick [Richard D.] Sisson [Jr.] and I, and others, on cold spray technology with the Army Research Lab, about $8 million. Department of Energy mini-mills for aluminum, $3 million with Arika Corporation. So we supplement our base, $3 million, with lots of funding from the federal

government. And then we do get involved in proprietary, more—not pre-competitive, but where the IP [intellectual property] is either owned by the university or jointly owned by industry, or wholly owned by industry, depending on who's bringing the IP to the table. Projects with industry that are not published yet on this. They're more proprietary. So, three ways that we do it. So the institute is a very vibrant, and a very important institute that I've spent the last ten, fifteen years of my life building it.

01-01:23:10
Burnett: It sounds like it just evolved over time, and I was going to ask you if you looked at models at other universities, or for industry-university collaboration, or if you got some advice from different domains, but it sounds like it evolved over a very long period of time.

01-01:23:33
Apelian: Yeah. At the expense of sounding presumptuous, which hopefully by now you've assessed that I'm not a presumptuous ass, but at the expense of sounding presumptuous, I was—I think we were pioneers. When I say we, the companies that were involved with me were pioneers with me to build a model that I think will be here for a long time. In fact, the casting center at Drexel was even before the NSF [National Science Foundation] I/UCRCs, which is the Industry-University Cooperative Research Centers. That was before that time. And again, I think much of it is influenced by the theory and practice, coop at Drexel, bringing the T.S. Eliot model: bringing things together and making some sense out of it.

01-01:24:32
Burnett: When you say pre-competitive, that's an important distinction, right? So that this is requests from industry, or rather, investment from industry that trusts that you are going to work on fundamental questions—

01-01:24:56
Apelian: That's right.

01-01:24:57
Burnett: —that will benefit all of those industries.

01-01:24:56
Apelian: Yes. I mean, you said it beautifully, but that's not the way most industries would articulate it. I mean, you know about Henry Chesbrough, the open innovation book, open innovation concept, at [University of California] Berkeley? Well, that model, essentially what we've done twenty, thirty years ago. But most industry doesn't think that way. In fact, most industries think—in general, I hate to generalize, but in general—that they have a certain IP, that this is their baby. This is their crown jewel, if you will. And hell, they're not going to share that with anybody. They're going to protect that. As they should. But then they take that to such an extent that it becomes diffuse as to what is the crown jewels that must be kept secret, and what are the things that they can collaborate and learn from each other.

So, when we first formed the casting center, I recall, because it was a small number—you know, ten to twelve people—and when you're putting together a group like that, of course you have conversations with each one of them, as I had. And each one of them had shared with me an issue that they have. You know, a problem in their factories, in their field. The first meeting that we had, nobody was saying anything. Everybody was silent. So knowing the personalities, and to the extent that I could pull it off, I said, "Hey, guys, you all have a secret. You've shared that with me privately. But I've got to tell you: you all have the same secret." And thankfully, one of the people said, "What is that secret?" [laughter] Thankfully! Otherwise, it would not have worked. And I said, "You don't know what the hell you're doing. You all have the same problem." And that sort of broke the ice, that they realized that—you know, the realization that winners don't compete. True winners don't compete. True winners collaborate so that to bring everything—you know, the tide comes up and all the sailboats rise, and everybody benefits. So that's what we do.

We try to identify issues that are critically pivotal, important to the industry. Making a stake that if we really understand these things, we're going to be able to do all kinds of things. And Mercury Marine will do it for outboard engines, Audi will do it for cars. Harley-Davidson, a member, will do it for motorcycles. You know, everybody benefits. Having data on crack initiation, crack propagation and fatigue, and aluminum, that's a basic knowledge that everybody needs. They can use it any way they want to. But that realization, I think, is one of our contributions. That open innovation. By collaborating, we can all win, and we can all advance.

01-01:28:07
Burnett: So it sounds to me that the industry has gotten—they've kind of figured out what can happen as a result of this collaboration. Has there also been a learning curve for the NSF, and the other—the federal agencies?

01-01:28:26
Apelian: I really can't speak for them. I think we've been a good model for others to emulate. I know so, because others are actually wanting copies of our bylaws, and how do we do it? We've had colleagues from other universities come to visit us and be guests at our meetings. We're very open about that. They have to sign NDAs [non-disclosure agreement], because some of the stuff that we discuss, you know, we don't want them to get out. But we're open about it, let people come and see it. And I've actually talked and presented at various forums as to how this model works, because we truly believe this is not something unique to us, it's a really good way of doing research and development. But the beneficiary is not really—the beneficiary, of course, is the industry. Of course there are professors involved. But the true beneficiaries are the students. Imagine: when I was doing my PhD, I know it was funded by DARPA [Defense Advanced Research Projects Agency]. I didn't know exactly what the applications were. I didn't know who was going

to read the papers I was writing. I didn't interface during my PhD with the end user of what I was working on. All the students, the projects that I supervise, or my colleagues at the Metals Processing Institute supervise with their students, every one of the students meets twice a year with the industrial members, twice a year. If not more, because every two months there's a telecon with a group of industry members who are interested in that project. Feedback. Input. Why are you doing this? Why are you not doing this? Have you looked at this? You're doing the wrong thing. Come to the plant. Come to see us. Spend some time with us. That integration of real learning—students that come out are—you know, they're ready. They're ready to run.

01-01:30:25
Burnett: And have contacts now.

01-01:30:27
Apelian: Have contacts. And confidence. And confidence. And a holistic understanding of what they're working on and how it fits. They have no idea, because they don't know what it's like not to do it that way, right? But it's just a fantastic model. We're very proud of it.

01-01:30:47
Burnett: Can I ask you about how some of that research has become important for resource recovery and recycling?

01-01:30:56
Apelian: Well, I mean, the resource recovery recycling is a fairly recent center, right? So it's about five years old. In fact, this June, we will be celebrating—June 2 and 3, now 2015—celebrating thirty years of the Casting Research Center. Thirty continuously run years with the industrial base. Fifteen years of the heat treating center, CHTE [Center for Heat Treating Excellence]; and five years of the recycling center, $CR^3$ [Center for Resource Recovery and Recycling]. So fifty years. I sound old when I say that, but fifty years of—fifty times—a lot of meetings. We talked about molten metal processing and casting. We talked about droplet consolidation, intelligent processing. But the last few years, I would say—well, those all have continued, especially with the casting center and the heat treating center within the Institute, the Metals Processing Institute. But more recent activities would be in the Center for Resource Recovery Recycling. Which is a baby of ours now, and we have a lot of passion for it. And also more recently, the additive manufacturing activities that we're doing. The recycling center—and me call it the recycling center, though the emphasis really is not recycling. It's resource recovery and reuse. People call that recycling, but it's a lot more than just recycling.

That came into being when I was asked by—actually, by TMS and ASM [ASM International] to give the Distinguished Lecture on Materials and Society. So this is a lecture—you remember I told you earlier, before we did the interview, that I have an interest in the history of science and technology as well. So I took that opportunity to really delve into it from that perspective of history of science and technology: where have we been, where are we going? What is the world going to look like in twenty, thirty, forty? You know, nine billion people versus 1.6 billion at the beginning of the century. The consumption of materials, and the consumption of goods and products, and how they're not being reused. So that was a revelation. I gave that lecture in 2000—I think '7 or '8 or '9, something like that. Sorry, I can't remember the time. And then from there on, it became quite apparent that we need to do something. So we started a center. And that's an NSF center, actually. It's an NSF I/UCRC. The I/UCRC is Industry University Cooperative Research Center. You have to have three universities. Or, more than one. So Brajendra Mishra at the Colorado School of Mines is my associate director, colleague, partner. And Bart Blanpain at the Catholic University—KU, actually, they've changed their name. KU Leuven. Three universities coming together. And we formed a center five years ago.

What we do is look at—sustainability is the driving force. And what we did is looked at what is the most sustainable organism that we have, that we know of. And it's nature. Nature's been around a long time. And nature has certain attributes and characteristics that are dramatically different from the industrial world in which we live. Nature doesn't have waste. The cherry tree, everything gets recycled, you know. Nature is a closed-loop system. In nature, there are a lot of subsystems, if you look at water sheds and all that. Lot of subsystems feeding each other. Holistic. And nature doesn't use that many elements. Very few elements in nature. And the state of wellbeing in nature is equilibrium. So I'm a capitalist, believe me, but we can learn from nature, because in the industrial system, it's open loop, lots of waste, and the state of wellbeing is growth, you know? Can you imagine reading an annual report from a major corporation saying—

01-01:35:33
Burnett: Equilibrium. [laughter]

01-01:35:33
Apelian: "We're at equilibrium." Yeah. "We haven't grown a damn—" Oh, God.

01-01:35:37
Burnett: We're exactly where we were last year.

01-01:35:40
Apelian: Yeah, we've been the same the last eight years. We're sustainable. Yeah, sure. That's what shareholders really love. But, we can learn a lot from nature. So production wastes, all the things that we make. Aluminum: every ton of aluminum that's made, they have three tons of red mud. What do you do with all this stuff? Production waste. Consumer waste. My iPhone is a good example of it. What happens to it after—the iPhone has fifty-nine different elements in it. We've never had that kind of a product before. You know, in the last twenty years, if you look at transformations, our products have become much more functional. We made things before because it was strong!

High integrity, structural. Structural integrity: bridges, cars. You know, it lasted a long time. Today, the products we have have a lot of functionalities. You know? The iPad, the iPhone. Electronics. Your television, which is a computer, in a way. Laptops, computers. We didn't have those thirty years ago. Laser pointers. You name it. Well, these functionalities come about because of the electronic nature of the elements. You know, the rare earth elements, they have very special characteristics. Magnetic properties, and many others. Phosphorus, luminescence. You know, LEDs. So we're using a lot more of these. So a lot of waste from production. Post-consumer waste, which is not being reused, recovered and reused, as well. And then we have needs for sensors and controls to be able to do these things.

And also the concept of manufacturing things—things meaning components—that society needs and has a need for, or wants, that can be, at the end of life, be disassembled easily. We don't make anything—we don't make that many things today—I was going to say nothing. We do make some. We don't make that many things that can be disassembled easily after life. Again, the iPhone—I hate to pick on Apple, because I love Apple. But—

01-01:38:05
Burnett: No, but to treat that—you have to have really advanced metallurgy to take apart an iPhone to separate out all of those processes.

01-01:38:14
Apelian: Well, to actually recover and reuse, you got to take the battery out. That's the first thing you've got to do, because it's—you know, it can explode. It's a fire hazard. So you've got to take the battery out before you can shred it, and cut it, and recover, and reuse. Well, try and take the battery out out of your iPhone. You know? It's a closed system. Purposefully. You can buy a special screwdriver on eBay. But should it be that way? Should we have things made in such a way that it can't be easily repaired and not the need to repurchase a new one? Could the things that we have, are modular, where you don't have to rebuy a new one because it's good for the economy, but rather you just buy a module and, you know—?

01-01:39:07
Burnett: So is that institute doing that kind of research, in terms of how you can—?

01-01:39:14
Apelian: Actually, our institute is doing three things. Some of them are more prominent than others, but we actually have our foundations on three things. Again, this is just philosophically, maybe vision, whatever. One is education. The other one—the three legs of the stool: education, the other one is policy. The third one is technology innovation. So most centers work on the technology side. But in this space of recovery of resources and recycling, it is—you need all three of those. And I'm not going to be abstract. I'm going to be specific.

Educating people, this is very fundamental. That taking a battery, you know, when it's used, and you need to change a battery in your laptop, or your mouse, or your keyboard. You take the old battery, and you throw it in the garbage can. I've seen people do it. That's a bad thing. Where does it go? Batteries have a lot of chemicals in them. If they end up in a landfill and it rains, all that chemical toxicity—landfills always leak—it's going to end up in the earth. It's going to come back and bite you. Nail polish. Paint removers. You don't put those things in the trash. Education.

Second one is policy: where the government puts a rule, there's a law, as to how to abide by it. One company is not going to do anything on this. There is a level playing field. So policy is really important. And the technology, of course, is the innovations and the technology that you need to be able to recover the materials. Lithium ion batteries: how do you recover the cathode materials? How do you reuse it? You know, things of that sort. A lot of science, a lot of extraction metallurgy that goes into it. So we're based on three, anchored in three ways, in our mindset.

01-01:41:25
Burnett: Well, since we're here at TMS, at this conference, and there's an awful lot of young people out here attending talks and giving talks, can you talk a little bit about the changing role of TMS over the years, and what you think the society and all the members of the society need to be thinking about in the future?

01-01:41:55
Apelian: Wow. That's a tall order.

01-01:41:57
Burnett: That is a tall order. Sorry to spring it on you.

01-01:41:58
Apelian: Yeah. How the society's changing, how it has changed, that's one thing. And—wow. Well, TMS is a global organization: 42 percent of the members are non-US. So it's a global organization. And it's a professional community where people come together to share with each other—there's an efficacy, almost like in the Web, where people want to share with each other what they're working on. Nothing mandates them. But there is that incredibly wonderful efficacy in scientists, and professionals, and engineers, where they want to share with each other what they're doing and learn from each other. So that, I think, will always be there, and that's one of the most wonderful things about TMS. It's a community of learners coming together and learning from each other. At the same time, making advances and having a voice. You know, we have a voice on the Hill, we have a voice through our publications, and it's a place where professionals and pre-professionals—grad students, before they become, in their career, have a home where they can learn from each other and be mentored by others who are in the profession.

So I think that has not changed. It just has gotten better. It has gotten a lot better. The recognition of our membership is 42 percent non-US. In fact, we had a conversation last night that maybe every five years this meeting should be overseas. Why not? Florida is very foreign to me right now from Boston. I don't see any snow. So I think TMS hasn't changed in terms of its mission. It just has gotten better and better, and more global. I mean, there is a whole initiative with Latin America, South America. North America, South America, our Canadian partners in the north, our Mexican and Latin American partners in the south, as well as Europe. It's global. In terms of the changes, we're living in an age where—we're talking about the young generation now, not people who are my age or mid-career. The very young generation feels—again, generalizing—that they don't need to belong to anything, because everything's available to them. I can blog, I can tweet, I can—you know, all this stuff. So that's where the challenge for TMS is, and I think that's where we we're making a difference in a successful way that the things that TMS offers, the community that you see here, you can't blog this; you can't tweet this; you can't do Facebook. It's a completely different personal—

01-01:45:13
Burnett: Face to face—

01-01:45:13
Apelian: Face to face. And it's all about relationships. You didn't ask me, but I mean, the reason the Metals Processing Institute is what it is today, and why we have ninety corporate members? It's all because of relationships. They're not doing it because of my looks, or—It's all about relationships. Doing what you say you're going to do. Being genuine and sincere about your motives and your mission. And delivering on the promise.

01-01:45:48
Burnett: Right. Trust.

01-01:45:51
Apelian: Trust. Relationships that are long term. We're not looking for new relationships every day. I'm not looking for a new customer every day. So if you do things the right way—let's use the word customer—you'll have a customer for life. You don't have to look for a new customer every day. You have a long-term relationship that is based on trust. You know, do what you say you're going to do. Deliver on the promise. And be genuine, and give feedback. But also hold people accountable, and excel. Those have been, probably—I don't think I had these like a compass when I was a younger person, but I think in reflection, those were the compasses that I had.

01-01:46:40
Burnett: I want to thank you for taking the time to sit with us and talk.

01-01:46:45
Apelian: Sure. Sure. It's been fun.

[End of Interview]