Oral History of Lynn Conway
2014 Computer History Museum Fellow

Interviewed by:
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Dag Spicer: What were your most important life lessons, over your career and life?

Lynn Conway: Reflecting back, I think some of the most important lessons have come from observations, just curiosity-driven observations that revealed meaning to me; you know, things I've learned along the way. Kind of always being a bit shy and on the outside, I think I've tended to be a keen observer and trying to figure out kind of what's happening and how to do things. And so in a way it's like life to me has been a long series of trying to figure things out; how to make something, how to do something, how to learn something. And so that became a habit I think at a very early age.

Spicer: What was your proudest moment?

Conway: Actually thinking about proudest moments is interesting. It's an interesting question because how do we define that and so forth? But I think the most- sort of the most exciting moments, the things that I was proud of because I knew there were so many latent possibilities in something, is when a cool idea occurred, just having a cool idea occur. Also kind of flipping that, sometimes taking a bunch of cool ideas and imagining how to cause some kind of happening or cool hack that you could do, if you're able to actually make that happen and pull it off-- it's savoring the moment; it's sort of reflecting on how cool it was to have done that. And I think an example there is really I had this amazing road trip back from MIT in late January or early February in 1979; traveled back to [Xerox] PARC and went across the Southwest in winter. And sort of the whole trip, I knew something amazing had happened and I was just savoring the moment, that whole trip, kind of on a- on kind of a high, listening to rock-'n-roll music along the way; which I've always tuned in to music. And so sometimes right after an adventure, just the feeling about reflecting on it and savoring it.

Spicer: And in this case it was your MIT course, in 1978 that gave you that feeling of…

Conway: Yes.

Spicer: …pride and--

Conway: Yes that's right. That was after the full success of that course, that actually everything had kind of amazingly come together and worked, with the help of our team at PARC, people there who worked and collaborated; and then of course the amazing group of students and other folks at MIT that helped make that happen.

Spicer: What were turning points for you in making your life decisions? What inflection points happened in your life that led you down the path you took?

Conway: Well you know, thinking about decisions, I think-- I made many kinds of decisions that really were inflection points; and made them differently in different cases. So there's no one clear pattern. An example was when I was leaving Memorex; and Memorex was fading out of the computer business and I had job offers from Xerox PARC and from Fairchild Semiconductor. And in that one I made a-- I actually made a kind of matrix of the two opportunities and a whole bunch of factors to cross-compare and weighted some of those and kind of came up with a decision method to decide. And I decided to go to PARC. And so that was a very calculated- apparently calculated and rational decision. But I think also embedded in it was kind of a set of intuitions and attitudes about- feelings about the work environments at both places, from what I'd observed and so forth. So that was that type. Now others, sometimes it's decisions that are made because they have to be made, under pressure; time and circumstance. A contingency occurs; and it may actually be a critical turning point. And that's made differently; you know, experience-based, trying to use as good a judgment as you have and so forth. And then others appear to be decisions but they're not. You know, when I transitioned that might appear to be a decision; but that was a point in life where some-- you can now actually make something, make it happen. But that was fore-ordained in childhood because I'd always struggled with that. And so the entire life before that was figuring out how to do that. And then you finally-- you know? And I think that's the way a lot of engineering is done; you know, you can't figure out how to cross that river but you want to cross that river, and you're trying to figure out stepping stones, a bridge, how do you make this, how do you make that? Somewhere along the line all of a sudden things fall in place and you see the pieces you can put together to cross the river. So you do it. And was that a decision? Not really. So I think a lot of things are done that way; and we're driven by our drives and our upbringings, our genes to do- to do these things.

Spicer: Can you think of a turning point specifically with Mead-Conway where that went from an idea to a revolution?

Conway: I think that something magical happened in the spring of 1977 when there was kind of an epiphany of realization about how to build the stepping stones to cross that river; how to see the pieces that you needed to put together; how to distill out a set of ideas, primitives, composition rules that were adequate to build that bridge but that didn't carry the baggage of everything that was known up to then about how to do semiconductors and how to make computers. And so it was really a matter of understanding and codifying very basic primitives at different levels of abstraction; at the switch or transistor level, if you will, and at the switching-circuit level and at the 'what is a computer?' level; and then embed that in some kind of framework so you could actually go and actually show someone right from the bottom to the top and from the top back to the bottom what is a transistor and what is a computer, and how do we go from one to the other? And in fact I still have a set of view graphs-- so I have to dig 'em out; I'm going to try to get them dug out-- where one of the ways I converged on all that was by playing with a set of view graphs on the old viewgraph-machines, you know, that projected those, where I could overlay some of them and where I could tell a story and unfold how to visualize what a chip was. And so I would just walk up on people all over the place at PARC and tell them about what a chip is-- okay?; namely how a microprocessor was built from- simply from where red wires cross green wires it made switches and how you hook 'em together- red wires cross green wires and you hook 'em together. And I learned a lot by watching what people could follow and couldn't follow; and tuned it to where I could walk up on a lot of smart people and just go through that story, and they'd just get it, sort of. And so there was that dimension. But then there was this dimension of the scalable design rules; and that came in one of these sort of-- you know, 'the muse speaks' sort of thing, where you're wrestling with problems and you wake up one morning and you've kind of got it. And that was tremendously exciting because all of a sudden there was a way to connect the simplification of abstraction levels with scaling and with the fabrication technology, so that you could actually imagine how people could learn to design, but not just for a current process but for a whole range of processes on into the future, creating this opportunity for 'open source libraries' of cells where you would be able to scale; except of course at the external interfaces and so forth and so on. And so it was a really exciting time; and it happened pretty quickly, in a matter of six weeks or so. But there'd been this period before that of learning and struggling and like: What on earth is all this stuff? And how to make some kind of sense of it, so that it was easier to do. But anyway, that period was really something. And then that set the stage for triggering events that followed where sort of unexpected turning points occurred that-- and it's hard to explain where the ideas even came from. But just one was I got the idea of doing a book, doing one now that looks like a book that would be published 10 years later, after all of this had already been codified and certified and proven; but creating it out of whole cloth and making it look that way but it would- but that would work. So there was that; and on and on and on. But anyway, I've written a lot about that. And I think, I think it's sort of fun to see it as kind of adventurous playing; just something kind of took hold-- it got a lot of us going-- and infected the other folks on the team at PARC and at Caltech.

Spicer: What was the problem that VLSI design and the program and materials you developed would kind of solve? I believe there was an issue with complexity and the number of wires and metal layers and--

Conway: Yes I think the-- there are kind of two levels of abstraction to the problem being solved. One is- one has to do with the roles of designers and who do designers work for and what do designers do; namely the designers of the content that gets printed in silicon? Okay? And having to do with-- if you think of it this way-- The making of a- the making of a chip is to some extent, or a large extent, it's a printing process. You have authors that do creative works that get printed-- using a set of masks, just like a set of printing plates. And then you print it; and you're actually printing little machinery. So you're printing this machinery. Now what's interesting about this is that, just like the authors of newspaper articles didn't really know the insides of the printing presses-- in the old days; and now they probably don't know exactly how the printers work that they laser print on-- in the same way, the people that make the laser printers, or in the old days made the printing presses, may not have understood some of the deep abstractions and political dimensions and human dimensions of the journalism that was getting printed on those printing presses-- you see?-- i.e., all the stuff encoded in text and in pictures. You would have companies back in this era in the '70s that were making commodity parts-- microprocessors and memory chips-- and in a highly competitive environment. And other people could then make a lot of things out of those. But what hadn't occurred to people was that there was a vast domain of potential creative works that could also be printed in silicon, that weren't just microprocessors or memory chips; but all kinds of other digital systems of specialized parts- that could then be composed with the microprocessors and the memories to open up an envelope of lots of other things you could do other than making just a computer. And the problem was that all the-- the only people who could design these kind of chips in the newly emerging MOS technologies, which had this dramatic scaling future, the only people who could do that were people who worked in the semiconductor companies! And so a lot of this had to do with how do you shift that to where anybody that knew how to frame designs and create them in a language, if you will, that could be printed, could do that; and then another place could simply print those. And the possibility of doing that was very analogous to what was emerging with the laser printers at PARC. So it's sort of like: Okay now we have all these people that are writing stuff and whatever; and then it's being printed. Why can't- why can't we do that same thing with creating machines to be printed in silicon? Okay so there's that. Then the other side to it was that the reason-- one of the reasons that the designers were working for the semiconductor companies was that - in order to design a chip at the time - you had to have a whole bunch of special, different pieces of design being done at different abstraction levels, including the basic architecture, the logic design, then circuit design, and then very importantly the layout design; all being done by different people. And the various people in the different layers passed the design down in kind of a paternalistic top-down system, they- the people at any one layer- may have no clue what the people at the other- levels in that system of people are doing or what they know. They only know if it's been sort of, quote, 'correctly transformed from a prior level to come down to them', how to decode that level of design and then re-encode it and pass it to another level further down. So there's this hierarchy of disciplines. So you had a lot of- you had a lot of people involved in the design of something like a microprocessor. But it turned out that you could look at the whole thing another way and you could realize that really from the designer's point of view about all you needed to know for kind of a first-order cut at designing was, to use our new kind of the terminology and coloring of the day, that when a red wire crosses a green wire, it makes a field-effect transistor; which is to first order an almost perfect switch. And when it's on, it has a certain resistance. And what's really important-- both on and off but especially when it's off-- it has quite a large capacitance just hanging there open. So that you can compose things out of switches, resistors and capacitors-- no inductors; everything is simple. And you have the ability to make all kinds of elaborated structures where you don't even have to do, in a sense, logic design as had been previously conceived; because really the primitive isn't the logic gate, the primitive is these FET switches. And so an architect -- knowing what a computer is, and knowing how it's composed of registers that are connected in data paths, with state machines to control the flow of information and processing through those data paths -- could see that all of that stuff could be composed out of these FET switches and interconnecting wires. It was kind of like designing a microprocessor wasn't a lot harder than like designing a pinball machine, back in the 1930s when you knew about relays and about symmetric functions and all that sort of thing. And what you see is what you get. You could look at it, and you could reverse-engineer in your mind exactly what's going on, by just looking at it. But the way the industry system was in the 1970's, a lot of the people working in logic design or working in circuit design or layout, including some of the architects, actually had no actual clue either what an FET switch was, or what a computer was; in a sense. They were very specialized in some arcane area of it, working with a bunch of other people to tune and evolve existing designs. By coming up with the simplest-- kind of like 'stepping stones across a creek'-- composition rules and primitives at each level of abstraction-- it seemed possible, as with using the viewgraphs and conveying what this was, to have people learn how to do all this by just learning at each stage what those primitives were and how you could put 'em together; and in a very short period of time they grasped how to playfully explore making digital systems in silicon. So that-- all of that kind of came along.

Along with all that, there was sort of a sudden realization that what appeared to be toy-like work—remember, this is going on at Xerox PARC, and it's not in one of the major semiconductor places – although we had a big laboratory there doing semiconductor processing research.--But this group of people at PARC, in playfully working with this, came up with essentially a really dramatic simplification of how you design chips and put them in a-- put the patterns in a form that could be really easily made. And that last step-- was kind of the key one-- was coming up with a digital specification that was scalable for how to create the geometric patterns, how to instantiate them, so that they could be printed in silicon. And I think-- I think that's had a lot of impact over time, even in a variety of areas as we've moved towards making more multi-physics kind of machinery in MEMS technology and beyond -- where the same process is going on of understanding what design rules to put in the EDA, the software --so that if whatever you specify at that level can be scaled down to a certain point- but no further- that thing can be made if you then convey it to a process that is consistent with those rules. So now what's really interesting about this is that-- we have to remember that in parallel with these conceptual notions of how you would make chips-- is this notion: 'Okay we need some tools to actually do the making; we need the equivalent of word processors to take our thoughts and put them into language that can be printed'. And so there was a kind of new form of electronic design automation that started to appear that was very simple, that just simply-- and it evolved in parallel-- that played with these methods and jointly evolved, so that you could- you could specify designs using these tools-- although they were very primitive tools at first, such as the work on Icarus that Doug Fairbairn and Jim Rowson did—these apparently very simple tools let you quickly capture your ideas, put them into a printable format and do things like make arrays of cells from a cell and so forth; and then we accessed fabrication so that we could make and see 'would these things work?' 'Would these rules work?' And they did! And so to kind of jump ahead on that, you can now see the possibility of creating a-- almost an ecology of methods and tools and software and printing-- where you have one set of machinery that you're using to put your tools into to create the next level of machinery. So you have tools that are helping you create what amounts to more powerful machinery, which you then print. And as you print that you now put your EDA software, further evolved with new dimensionality and more power, into those new machines that are more powerful. And you can now create an expanded class of machinery very quickly; and you have new ways of validating the designs as they get more complex. So a lot of the story of dealing with complexity has to do, not with something that's static, but has to do with the evolutionary process of the exponentiation of the dimensionality of the tools and the machinery where there's 'gain in this system'. So that was something that I found very interesting; as you can envision. And now you had not just microprocessors on which you could do various kinds of signal processing, various kinds of image processing, but you could create special digital structures to do that, you could- you could thus present an opportunity space for more people to play in the game. So along with this came- built around this was the idea of doing a book to propagate the methods-- well actually even to create the methods; you know, to kind of have an evolutionary process where you have the book-- you create a book that looked like a book that would be written 10 years later. But you're actually doing it now; and you're evolving it, but only with stuff that works and only using the very- the minimum sufficient stuff for any particular part of this. And so that would then be-- instead of it's like we're doing designs with new methods, little crude things to get started--now you have the methods, and you're taking pieces of this book and you're having people try pieces of it in some courses. And so that higher-level process started. And it reached a point in the spring of 1978 where a really amazing opportunity presented itself; and that was because - Bert Sutherland had been on the Visiting Committee of the EE/CS Department at MIT, and he-- I don't know all the details about how, I'm sorry--, but he ended up working out an arrangement where I could go back to MIT and be a visiting faculty member and try a 'dry run of the book', sort of offer the whole course in prototype form, to see how this would work and to explore it and to try it out. Now this wasn't to an 'integrated circuit Course' like some of the things happening at the time in the precursor trials of the methods. Instead the idea was to actually take senior and Master's level students in EE and CS and see if in a short period of time one could actually teach them everything they needed to know, to turn loose, and do creative writing of systems in silicon. Okay? But that was a difficult thing for me to anticipate at the time. I was very shy and for a whole lot of reasons I was extremely apprehensive of doing this. But I think I realized the adventurous opportunity that was presented; you know, this was like- really might be something- that if it worked it would be amazing. So to make a long story short, [I] went back to MIT and had this dramatic experience there of running this course. And in preparation for that, I worked with people in my group at PARC, to see if we could find a way to take a lot of student projects and implement them immediately at the end of the course; i.e., take the design files, things that students had done in the second half of the course after learning how to do it in the first half; and get them implemented and get them back to the students right away. So that was a stage in this succession of adventures where I tried that and that actually worked. And after that, I think I really felt that we really had something. And then I had that ride back to PARC. And of course whenever- whenever you do something that's sort of weirdly noticeable, even if it's ripe with possibilities that would be exciting or cool, all of a sudden people start to wonder: Oh my God, what is going on? You know? So you have different kinds of reactions starting to occur. And it sort of worked in two ways. There were a lot- there were people in the [Silicon] Valley-- I didn't know it at the time-- but there were people in the Valley who really picked up on this and got excited about it; and there were a lot of- kind of a network of people there that heard about what happened at MIT—although nobody ever asked me about it-- but kind of started off trying to understand that. At the same time, there was kind of a growing pushback like: Who is this Conway person anyway? What is this going on? And people who looked at the fragments of this book that were appearing --and I think especially in academia--a lot of people thought this stuff looked extremely toy-like and strange and unsound. You see? This seemed like *unsound methods*; even though some of the designs at MIT had really worked.

For example, Guy Steele's first design—he hadn't designed anything along these lines before-- his first project was an entire LISP microprocessor! And of course we didn't have any good design rule checking and so forth at the time-- it was all done manually under these early methods-- and so there were a couple of wiring errors. Now it turned out the next year he got it working with some other people helping on the design. But there were other projects that worked completely. Jim Cherry did a transformational memory array that can rotate and mirror the bit patterns in a memory. And that worked completely, and on and on.

Spicer: How did critics respond to silicon? I mean, they can't call it a toy app when it's producing--

Conway: Well, you know, it's interesting. A way to think about it from the point of view of critics, and actually to be fair, from the point of view of people who weren't familiar with what we were doing, this had to look really quite odd because let's-- let me give you an example: If you looked at the design rules used, and you would find that they were not-- they weren't a large set of rules. And so, they weren't 'optimal'. You could easily in the current process take a particular area on the chip and have people hack at the layout using a finer set of design rules and shrink it by some amount. Now, the counter to that is it turned out people in most of the industry at the time, were actually creating the layout patterns by carving and cutting up Rubylith. So, the layouts for the masks weren't computer-generated. It was being done by hand. These huge things were then essentially photographed, reduced, replicated, and so forth. But our designs looked very unoptimal, and a person who knew about handcrafting Rubylithst would say 'this can't be right'. And 'It's not'— for it could be made much smaller in that way. And other people look at some of the patterns. And the patterns just look too simple, too much like weaving or quilting, rather than complicated looking tangles of gates all connected together, okay? But I think what people didn't realize is that even then, if you took the area and time and energy that you would invest in doing a particular computational function created our new way, even though at every level of abstraction, it appeared to be 'unoptimal', the net result would be it would be way more powerful in those measures than something similarly implemented that had been optimized at each level of existing abstraction! So, this is potentially very unsettling, because now you don't need people that know how to minimize gates. You don't need people to carve layout patterns in Rubylith. All these people that are working these different specialties and optimizing them are now going to be displaced by essentially some simple EDA tools and creative writers that know how to write things that you can print in silicon. So, you could see how the pushback started -- and then there's other dimensions: At some point, the existing TTL industry noticed, and began I'm sure, becoming concerned about 'what would happen if [this stuff took off]?'.Okay, it's fine if somebody makes microprocessors and memories. But you made everything else out of TTL. What if people could actually just 'print stuff in silicon'? And now all these boards full of TTL could be replaced by a few extra chips? Well, so now we have that kind of pushback happening. And quite frankly, since it all appeared to be coming from kind of 'unknown, uncredentialed sources, if you will', and being done in a university course at MIT rather than in a high tech, hugely funded industry that was making lots of monies off the commodity parts they were selling, it seemed 'unsound'. So, I would say that that was—that was when that sense of unsoundness was starting to propagate. At the same time, the excitement propagated in some of the other academic community out here in the Bay Area and elsewhere about what had happened at MIT, how they'd done that. And of course, that's always interesting because I guess it's like: 'okay, MIT did that'. Meanwhile-- no one seemed to think to ask me what had happened! It was really kind of cool. I mean I think that's the other thing. There's this theme running through all of this: I think very often the people in charge don't have any idea of the dangerously innovative things that people down in the ranks, who are unknown to them, might be doing. You see? And even here, that might even be part of what cast a layer of apparent-unsoundness over it. However, all of that pushback kind of created an atmosphere where I increasingly felt it. Part of it was generated by internal pushback at PARC. PARC had an internal politics among different laboratories, the System Sciences Laboratory and the Computer Science Laboratory. A lot of pushback came from the Computer Science Laboratory. They had to think that whatever was going on with Conway was clearly unsound, because they knew me, and I'm just a regular PARC person there just doing my thing. How can this person have anything to do with upsetting an industry? Well, it had to appear to be unsound, really quite seriously. So, there was that. And I think all of this caused a lot of mental turmoil in my mind. And it was in the spring of '79 that I got an idea. And I ran around trying it out on people.

Like on the General Science Lab. They had a silicon fabrication line and -- I thought well, we can do this thing! And, what the thing was is I was trying to figure out how could you take what had happened in the MIT course and get it to happen a whole bunch of other places the following year! [I] came back from MIT in like February, so now this is in like March or April ‘79, kind of in that timeframe. And I remembered something I’d done at MIT: You know how sometimes when you’re hacking, you have a lot of stuff that is very elegantly going together, but there are parts of what you’re doing that there’s no prior art? So you have to cook up something, you know, with duct tape and string and wires. Well, in this case, what made that MIT project set work as we neared—began-- to enter the final phases of the designs, it’s like I have all these design projects going on—but how are we going to get them all packed onto a chip set. Well, it turned out to be two chips. And all the designs had to be packed on those. Well, how are you going to do that packing? So, the way that this was done was to start a process of bidding for area and giving area, with projects saying whether they thought they were going to meet the deadline, or not, and evolving the packing. And that was done kind of like-- it was done a blackboard kind of like a spreadsheet. It would look like spreadsheet, the project names and the area and dimensions. So, there’s a bunch of information there and status on a spreadsheet, i.e. a blackboard. And then on a white board sitting next to it, the whole white board ended up being the boundaries of the chip, the chip set. I started taping pieces of paper cut to proportional dimensions to the scale in there, thus doing the floor plan of how you arranged things. Okay? And the whole idea was to be able to pack everything into a reasonable chip set without having a lot of empty space in it so we could get the most project pieces back for the most students out of basically one boatload of wafers. So, you run the numbers. You can sort of visualize how that worked. Well, because the whole idea was these things are processed in essentially what would amount to a regular processing line. The only thing different was that when that boatload of wafers was run through, it was run through with a different mask set, the set for the student projects, rather than whatever’s being regularly run. And so, now you start to see there’s sort of an intrusion into what appears to be a normal production facility right at a reasonable level of technology, but something different’s being done. All of a sudden a whole bunch of different projects were all going onto the one boatload of wafers. Well, in thinking about that in the spring, I realized, okay, what if you created software to do those functions you’d just done using duct tape and wires and stuff -- in other words, if you’re going to scale up, you’re not going to have just twenty projects or so. You’re going to have a hundred or two hundred projects. How are you going orchestrate getting those all together at a deadline and arraying them on many multi project chips for several boatloads of wafers? So, you could see there’s a piece of the puzzle falls in. And there’s nothing complicated about that. The programming of that is not complicated. It’s the ‘knowing to do that’ that’s the innovation. Okay, that’s part of a new way of doing things. And so, this is really making and hacking but in an exploratory way -—like a door opened. And you’re doing it out here, out in a place nobody’s played in before! And so, there’s that part of it. And the other thing that fell into place happened by reflecting on kind of what was happening at PARC. A lot of this was informed by the gestalt at PARC relative to document production. And it’s really thinking about silicon as just another kind of document. You can make a magazine with a laser printer. Then the whole issue is not the printing. It’s how do you have everybody’s work-- the thing’s that are going to get printed -- how do you get everything organized and all the articles edited and formed, and then have them all get into a set of pages in like a little magazine, let’s say, or a little book. So, in the air at PARC, there was a lot of thinking and knowledge, and just automatically understanding the social processes involved and how you provided the community of people participating in that social event, how to use tools that collectively enable them to all in a coordinated way, get their stuff printed in the same magazine. Same thing, now with silicon chips, except all of these people were scattered somewhere else. They're all around the country because you want to have this roll out at different universities. So, there's a dimensionality of it that has to do with using the Arpanet, i.e. the Internet, to provide social connectivity and data connectivity to cohere and orchestrate all these things. So, as that spring went on, I got the idea of creating what amounts to a 'happening' that was a 'collection of, in a sense, hack-a-thons like the one at MIT', but now more than one would be going on at the same time. We'd have to run courses, have students do projects, which would be collected at the end of that time, and all merged together at PARC in a project-merge way, then convert them into mask format, then send them out for printing. And it turns out we were, again, going to do this in a collaborative arrangement with Pat Castro and her Integrated Circuit Processing Lab over at Hewlett-Packard. Not only was Hewlett-Packard providing the fabrication. They were also internalizing at the same time the new design methods and so forth, with Pat Castro and Merrill Brooksby, there working to get HP into it from their end, because they wanted to go off and do designs in the same way. You see? And so, it was a win-win for everybody to explore this space and see if this would work. I think the critical point came when I talked to Bert Sutherland and explained kind of what I thought we could do with this. And he thought it was a pretty cool 'wild idea'. And then basically, there had to be the social orchestration by basically using emails to announce to the university-- research community that if people ran a course like the one that I'd run at MIT, we at PARC would take any projects that they produced. And we would turn them into chips! All they had to do was follow the MIT script. The feeling that went along with that was a projection of the notion that 'this all just seemed like, this is just regular stuff'. This is 'what you did'. And we were just going to 'do this for them'. I.e., there wasn't any projection of the sense that this 'was a first'. The reason? You can't have that or else people will worry 'is this going to work?' So, again, like the book and like the MIT course, there was this dimension to it of people being attracted to participate in an adventure or hack-a-thon without really having a clue what they're getting into, but because they actually get a feeling 'if this works, this would be cool for me'. See, for the student it's 'if I want to design something, I'm going to learn how to that, etc.' The faculty member, the young faculty member, 'if I teach this course, and this worked, maybe I can get tenure' by doing x, y, and z and 'getting into this new research community, publishing a few papers, bladdy blah, getting some students, etc.' So, you can see-- so, a lot of this was aimed out at a community around the world of young faculty members who were willing to take a chance on a new area. And one of the things that helped here was that at the MIT course, when I taught that, I was so incredibly shy and fearful, just all the time, of people learning about my past history and so forth. And I had terrible difficulty speaking in front of groups and so forth. The way I worked it was that every time I had a lecture—although I had the whole course and lecture-sequence all planned out. But every time I had a lecture to do, I wrote it out in complete detail, handwritten notes, every sort of important point, every equation, every diagram. And in a manner that was accessible to sort of any student coming from EECS, revealing to a lot of students in CS who hadn't had really much background in circuit theory, the basics of electric circuit theory. You see? And to a lot of the electrical engineering students, who had not really delved into computer architecture and digital system design--maybe they had been mainly in the circuits area-- revealing to them what digital subsystem design was really about, how open ended it was, and also how, by putting your feedback loops between your block diagrams, what a stored program computer was, what a microprogrammed computer was, bladdy, bladdy, blah. So, I unfolded all that in these notes. So, I handwrote all these notes out. And it was the only way I could cope with teaching this in a way that I felt comfortable going in the class and just doing it each time. So, it was what happened. So, that spontaneously happened. And the interesting thing about that was when I rode back from MIT to PARC, I had what amounted to a complete detailed instructor's guidebook on how to teach this course! So, when instructors signed up to run such a course, one of the things they got sent was a copy of that instructor's Guidebook, along with some other work that was being done on more details for project lab coordinators on how to deal with the fabrication process and to do with things like test patterns and this and that. The other thing they all got were files for input output pads, PLA's, etc, in a library of cells that was a starter set for all the courses. Dick Lyon created them all at PARC, and Dick became really the first 'major maker and explorer' in making stuff in this new regime for sharing widely. And his stuff all worked elegantly and incredibly well.

Spicer: Dick Lyon?

Conway: Dick Lyon, yeah. And so, as things headed toward this point of announcing this, all this stuff was sort of potentially available. So, one could envision doing this. And yet, it was a, in some ways, a more dramatic decision to go forward and actually do that almost than going to MIT was the previous summer. MIT was more a personal issue of 'could I cope with actually going in front of the class and unrolling this?' And yet, that was like it was foreordained that I had to do that. And there were some role models I had in mind for doing that. I particularly was very aware and knowledgeable about Steinmetz and his paradigm shift in the AC revolution.

Spicer: He was the director of General Electric's [Research] Laboratory?

Conway: Yeah, he was at General Electric. And a lot of the propagation of his work was via a course that he began teaching. But anyway, the thing with MPC79, which was the name we put on this happening (Multi-Project Chip 1979), was that launching it was pretty scary. The reason? Even if hadn't done that, everything was now cooking along well. The book was going to come out that fall of '79. The book had been essentially pro-- a prototype [that] had been used at MIT. Now, the book was going to actually be published. The normal thing would be to let that just go out there. And then, over a period of years, it would gradually be used to build courses and so forth at some universities. But I think, because of the pushback that was starting -- especially the pushback I internally received at PARC due to the total unawareness in the Computer Science Lab of what we were doing over in SSL on this stuff-- all that got me fired up to want to push back. And my pushback against the pushback came in the form of launching this 'multi university hack-a-thon'. And so, anyway, there were two people in my group at PARC that built essentially the framework of what we called an "implementation system". And basically, it was kind of like a current-day 'e-commerce system'. What we had to do was create a way for people in the multiple universities to keep track of what was going in terms of deadlines, any change in design rules, or other things they needed to know about in order for their project labs to work, but especially scheduling events for major milestones along the way while running their courses. So, we created an essentially automated message handling system to handle that, while also using the Arpanet to run test runs on design rules checks and on merging, doing a lot of trials that were getting everything ready for the final merge of the projects. So, at the end of the fall in 1979, about a dozen universities were participating in running courses. And over a hundred projects were being done. I think it was a hundred and twenty-nine. And-- now see-- something on that order. I think maybe that's the number of designers participating. But the-- all these courses were kind of launched and kept on track and stoked by a series of messages we sent out in order to keep everything cohered as a social-- sort of a 'social happening'. And it was really very interesting, because if you can go back and talk to people who participated and ask them what did they think was going on. See, this is-- because it's not clear that they had any idea that this was anything but 'ordinary business'. You see, it all seemed so simple. And it all just kind of went along. And it turned out everything fell in place, just like it had at the MIT course. Virtually all of these courses ran that script, and could predict where they were because they were all using those handwritten notes. And it was easy to communicate with them about things, because they're all operating within a common culture. But the variances would now be that different schools started to make their own EDA tools. And so, all of a sudden, there's a startup of competition in that EDA dimension to make tools that would help with design rule checking, etc., that would do various things that they might be able to do better than the other universities could -- but everything was cohered by having all of the layout specifications transformed, in whatever tool they were using, into an open source intermediate format -- so that you were able to essentially shield yourself from the particular kind of code or methods being used by a particular EDA tool to create the layout patterns. And at that same time, that same interchange format was used to distribute to all the universities Dick Lyon's common set of input/output pads, a common set of programmable =logic arrays for making finite state machines, etc. And so, it all began to develop the sense of kind of an open source framework where you could share things that helped everybody do their designs. But whatever designs were produced could be shared with other people, if they worked, because they were all in this format. And so, all kinds of possibilities started to emerge. And the mind could reflect back on what was happening in just making group magazines where a lot of people participate in a happening to get a magazine out on a certain issue, where, let's say, the different authors are actually working in a coordinated task where there is some connection between all the articles. They're using pieces of one in the other, or cross-referencing and so forth. So, there's a whole set of sharing possibilities that can be done. And so, observing what was happening, the mind could race ahead and think about how to further stoke EDA development and how to stoke sharing so as to amplify the activity. And I think part of then what happened and was so interesting-- now, I think this is really very important-- is that at almost all these schools-- I visited a few of them, a couple during, and some later -- you would see the following thing: You would know, if you walked around EECS departments, you could almost spot it from the end of a corridor or from a lobby looking out, you could see where 'it was happening'. And that would be where these VLSI gangs had got some territory. And they put their totems on the walls, which would be these big checkplots, because the thing people did was amaze their peers, whether they're students or faculty, with their giant check-plots they could produce that showed every transistor, every wire, in their designs. And so, these things were all over walls everywhere! So, this now you see took on the atmosphere of 'being a movement' <laughs>. And it was really interesting how this all kind of cohered. Now, in parallel with all that, Doug Fairbairn and Jim Rowson were getting ready to go off and start a magazine called *Lambda*, later *VLSI Design*. And this turned out-- I thought this was absolutely too cool-- because what this was is: 'now there's this opportunity'. This was like the impressionists, you know. You don't take all your work and write papers and scatter them into journals, and they come out at different times and all. This is a body of work that only can be understood if you see it all by itself. So, when the impressionists got going, they didn't go and put their art as different pieces into the traditional big exhibitions which wouldn't have accepted them anyway because they looked too weird. They went and the showed them at their own showing. When you see them together, it's like 'now you catch on what this is'. So, this what was happening in these university hallways all around the country-- was this sort of thing that was happening out there. But who would know it was connected with anything else? Well, Lambda magazine cohered that. And reports were made on this. And so, that magazine evolved along with the development of EDA tools, along with the now surge of courses that started expanding. And so, by the '82-'83 school year, it went from one course at MIT in 1978. In 1979, it was twelve courses. By '82, it was over a hundred. And it was an explosion of activity. But it also-- now began getting out of hand--So, now we have lots and lots of people learning how to do creative writing in silicon. So the issue was always 'how are you going to print all these designs?' Bert Sutherland had begun talking about maneuvering this before this actually triggered and started. So he was thinking about this. We had run another event, MPC580, in the spring of 1980, I mean, actually, a little group was even started in order to cohere that. That was tremendously successful, too, but we couldn't do this anymore just at PARC. So, what we did was that Bert, having connections at DARPA and USC/ISI—(USC/ISI, the Information Sciences Institute did a lot of contracting for DARPA for software development) --and the idea occurred to Bert to see if we could institutionalize the ongoing operation of MPC79, MPC580, somewhere like ISI, and doing it via DARPA support. The folks at DARPA-- Bob Kahn and the folks there; Duane Adams and Paul Losleben--could see now, with the success of especially MPC79, that 'this was it'. It was really clear what the possibilities were. And so DARPA provided funding for the transition of that technology to ISI, where it became known as the MOSIS System. And, of course, what's sort of interesting about that, is MOSIS has been running all these decades, okay, and MOSIS has no idea where it came from! <laughs> See, that's the way-- it's a way-- <sighs> and, you see, Bert saw a way to transfer technology that was running, and to expand it, build it, feed it, and grow it there at ISI. Well, if you come forward in time from all that, you can see where the modern view of how we do fabless design, which is that all these people out there use EDA tools, and we have silicon foundries, which would accessed through a MOSIS-like system or subsystem to a backend fabrication facility that prints the designs-- it's all an elaboration and expansion of that same MPC79 idea. And a lot of it is fueled by the fact that an opportunity space was created by a sort of 'cybernetic engine' that had 'gain in the system', that expanded as a combination 'machine and cultural enterprise', attracting people to participate in a variety of ways, whether they're tool builders or creative designers or fabricators, to participate; and the scaling kept dramatically expanding the opportunity space for the kind of things that you could print and actually get to work! So you can sort of see how that goes. So, actually, jumping forward to now, we're still in this incredible adventurous state, where, although Moore's Law, the scaling law, is kind-of finally coasting down towards some limits, all of a sudden we've broken out in a number of new directions, out of these engines just being digital systems. Now we have micro-mechanical-electrical systems. We have biological, chemical, and fluidic microsystems, and all sorts of sensors and transducors- we have all sorts of other kind of machinery that can be, in effect, printed, either in silicon or now in other digitally specified production systems. We know about 3D printing, but you can imagine how, over time, we're gradually going to be able to make both finer and finer and bigger and bigger things that are digitally specifiable so they can be designed using all sorts of new exploratory EDA tools to make stuff! So, instead of seeing Moore's Law and the scaling being kind of a 'constraining final limit', it's like right when that's happening, it's breaking out in all kinds of new directions where we don't even know the scaling limits! We don't know how far that can go. And so, in the end, =we get to the point where we're also seeing now a rate of change of our technology capability that's so dramatic that the sort of waves of almost generational waves of technology, instead of coming in 20-year cycles, or 10-year, or 7-year, are now coming in maybe 5-year or 4-year cycles. And we're also seeing now another kind of convergence come back. It almost reminds me of the 'microprocessor + memory' production in the early days of the semiconductor industry, to where now what we have is, we have as OEM systems like, right now, there're cell phones. That'd be kind of-- the smartphone is now the commodity thing that has incredible capability, and so many people find it central to their life that all over the world that's spreading like wildfire. But that is actually channeling thought that really-- everything is done with this "one-hand machine", as the Chinese call it. And what's so interesting is there could be so many more things that the microcontrollers, if interconnected, could be embedded into and animate, that aren't just a commodity part, but where there's incredible diversity of possibilities of new things that could be created and designed in all sorts of new ways. So, instead of having high rates of change of a common technology shared by everybody, so the whole world is going through these huge changes in what we're doing almost in lockstep, it's like it'd seem to be healthier to turn loose a much different 'kind of making' that's more participatory, more diverse, more locally situated, and so forth. So that's kind of a thing I've been thinking about a lot lately, and wish there were ways to encourage that to happen. And so it's almost like-- it's really strange and eerie--it's almost like I'm finding myself, and people I collaborate with are finding themselves thinking, "My goodness, we're right back in 1975, '76, where we're seeing the peaking of something and dramatic possibilities for it all being different". But how do we-- what stepping stones do we put in that creek to go from here to there? What bridge do we build to get from here to there? And I think the younger generation is all wondering that, too, because there's a lot of age structuring in our current situation that is becoming really difficult, because imagine: If you actually were an older professor now at a lot of universities, even our best universities, have you been able to stay up with all the technology waves that have come over the last 30, 40 years? <laughs> Are you in contact with the world the students you're teaching are now living in? And they're looking at you to give them the wisdom to know what to do? See, the changes are so fast that-- and they're all occurring in lockstep. That's why, in a sense, some spreading and diversification of that, back through the breaking out of the bubble of "you only make microprocessors and memory chips". Now "you only make cell phones". Well, no, wait a minute. <laughs> You can embed the silicon machinery and the MEMS machinery and all these wonderful new things that can be made in the microworld into all kinds of things, and it could be more participatory because we know how, now, to have learning be done in new ways, where it's experiential-based and team-based and more of a social process. So-- and then there's room for elders <laughs> who have the wisdom of having seen many prior changes so that they've seen each of these before, and they've seen the effects of a change. And so that's sort of like remembering back. I'm thinking about changes I had known about because I happened to be interested in them; things like the AC revolution-- the electrification of America-- things like the radio revolution, [Edwin Howard] Armstrong's work. One person had provided this series of steps-- did so much-- and a body of-- a community of people cohered around that knowledge and just went wild with it. And then there's this breakpoint in World War II at the Rad Lab [MIT Radiation Laboratory] — pulse and digital circuitry for exploiting radar, and so forth. And that opened the door along with the computing machinery that was also being exploratorily developed during World War II; the two converged, and, after the war, the explorations ramped-up towards computing machinery. And so, closing the loop on that, it's as though maybe we need for people to see the grand adventure that we're all on as we participate in the production of innovations that connect like pieces of jigsaw puzzles, and create a new kind of awareness of, "Oh, we can do this," and then that is another abstraction level that we can use to launch off in a new direction. And instead of everything being a pyramid leading to a few commodity parts that are sold to the world, a few people get rich, and everybody else is a consumer of a common commodity and their lives are run by it, you flip that, and maybe almost everybody gets a chance to participate as a “designer and maker” for at least some of the things in their local habitat. And so things can be innovated and made at finer scales, more locally situated, and more people can participate in the adventures of designing and making. So, anyway, I’ve gone on and on. <laughs>

Spicer: No, that’s a great answer.

<crew talk>

Spicer: Ready for the next question?

Conway: Sure.

Spicer: This one is kind of interesting. What might you have done besides what you did, if you had another career or another life?

Conway: Oh, I--

Spicer: It’s kind of a weird question.

Conway: Yeah. I’m thinking about other directions. When I was little, I was always really very interested in music. I was always fascinated by music, and so I learned to play instruments; played the piano, played the saxophone, and then later played the trombone, which was deemed more appropriate at the time. <laughs> And... but music really fascinated me, and during World War II-- I grew up during World War II, and so there’s a whole set of things around the aura of that era. But I listened to classical music especially, and I had a little vacuum-tube radio-- a little, small thing-- that was on a bed table by my bed, and so I would turn it on at night, and I’d go to sleep early, but I would listen to radio for a couple hours, and quietly so to not disturb anybody, listening to music. And there were really good stations out of New York City. I grew up in Westchester County, mostly, except for a period during the war when we lived in Bethesda, Maryland. So there was that resonance with the feelings and emotions stimulated by music that was kind of always there, and-- but, while it affected me a lot, I think I was too constrained and inhibited to be a good music performer at the time, and so, although I really enjoyed playing-- I actually ended up playing in the Westchester Symphony, playing my trombone, <laughs> and that was wonderful, but I never got, really, into any of the garage bands or stuff that was really creative, that I also resonated with highly. And so I could imagine, if things had been different, I could’ve been a musician of some kind. I don’t know what. And that would have been wonderful. I mean, the adventure of music that’s still unfolding is just incredibly dramatic, and I think people totally underestimate the power it has in our lives and the way it triggers memories. And if you're responsive to music-- I use the music of the different periods to actually evoke and cohere visual memories of what was happening at that time. And so, at peak times, a lot of my memory is based on the connection between music I'm listening to and what was happening. It was really kind of interesting. So that's one possibility, but there are probably others, and... maybe I could've been a teacher. But, see, I'm not sure I like the idea of teaching. I have a lot of questions about-- I think more about learning and how to put stuff out that you can play *with* and build *from* than showing *how to do*. It's just a different notion about it.

Spicer: Who were your role models?

Conway: Whoa. <sighs> Role models. Who are my role models? There's many dimensions. I always had a picture of Steinmetz that I always had on my office walls all along, because he was symbolic of someone who somehow was able to surmount, really obvious in his case, physical challenges, but also political challenges. His-- he'd had to come here, with problems being-- this sort of thing about socialism at the time, and all of this. So, kind of an outsider kind of person who, nevertheless, was accepted, embraced, and appreciated because of the fun things he was doing, and how exciting it was to be doing that and spreading that and having that all take off. An amazing guy, and even-- and older in life, the love of the outdoors, the Adirondacks that-- never married or had children because of concern about passing on whatever that [his ailment] was, but beloved by people, surrounded by a lot of people. An amazing life. There's a-- he-- so you take someone like that, and you see there's a touchstone there, and it isn't on the work, it's the having the adventurous, fun-filled, engaged life, in spite of this or that or the other thing. But there are others. I know when I was growing up, I think I took my parents as role models, and in different ways. And my father was a chemical engineer-- research engineer; worked at the Texas Company, as it was called. He was in the Chrysler Building in New York City. That's where I was born-- in Mount Vernon. We lived in Hartsdale, and then Scarsdale. He's working down there. And he was tapped early in the war to be chief engineer of the U.S. Synthetic Rubber Program, and ended up running the program that did the shootout of-- I always get mixed up if it's seven and six or six and seven different kinds of rubber and numbers of plants, but there was this big, huge, monster shootout to select the best of the processes that people could pilot for production scale-out of the types of rubber that were needed that could be made from oil. And so he was involved in that. We went into Bethesda, Maryland. And so there's a lot of stories I could-- I actually recall a number of incidents and fragments from the war, and things that happened around that, including him coming home all hyper and excited, bringing these smelly blocks of different kinds of rubber that had just come off of some facility somewhere that were particularly interesting to him, and I don't know why they were, except they each smelled different. <laughs> And I got to see-- later in the war, I got to see some of those same things when he took us to a flight line where B-17s were heading off to the UK. I didn't know where they were going at the time, but I think the whole idea was they were going to go bomb Germany, and-- but taking the tour and seeing all the different kind of rubber that was in the airplane. The airplane wouldn't go without this rubber that was in it. So, you see, there's an infection there. There's a thing there. There's something happening there. My mother was a kindergarten teacher, and she was-- <laughs> became, actually, quite an expert in early childhood education, and passionately involved in it, and her whole thing was stimulating creativity among the children in a classroom. And so her classrooms were a never-ending saga of giant adventures going on-- of kids building things with blocks, and playing music and dancing, and doing art, and all that. So, somehow, out of all of that, I got infected with all sorts of strange memes, you see, just because there's this stuff going on. And so my father got me and my brother a really giant chemistry set when we were fairly young, and that led later to all kinds of adventures, doing all-- making all sorts of things that you probably weren't supposed to make, <laughs> and just exploring. So there were my parents and a lot of other people. I-- clearly, I was meant to be an engineer, be a maker, builder, but I got really infatuated with physics because of how physics helped cohere everything, and helped cohere making. And so, actually, when I went to MIT-- I was 17 when I went to MIT-- I really didn't know what the heck was going on, so I decided I'm going to be a physicist, because at the time this was the coolest thing to be. And I think a lot of other people have followed that path because of the war. The physicists 'had saved the universe and made bombs that blew everything up', and 'they were the ones that knew it all', right? And, of course, it wasn't till I was a bit into my studies at MIT that I realized that I'd actually missed my calling there, because I really ended up there getting infected with the emerging surge of paradigm-shifting knowledge that had come out of the Rad Lab at MIT, and it was being injected in the electrical engineering courses there, to where you didn't just learn traditional circuit theory, but you also got infected with the basics of pulse and digital circuitry right as it was sort of being rushed out of the lab and being codified in engineering courses. And that was a profound experience for me because you could look back and you could see, okay, Steinmetz, and then Armstrong, and then now this stuff! It was happening again! So it's sort of like... I've always been interested in these sort of shifts, and it even goes back into astronomy, because when I was little I got very, very excited about astronomy. We went to the Museum of Natural History in New York City, went to the planetarium, and actually saw a little telescope that you could actually we couldn't afford tit, but some could buy it. You could-- if you had this thing, you could actually see craters on the moon, and all this sort of thing. And I got really interested in astronomy at a pretty early age, and began reading stuff to the extent I could understand it, and looking and trying to understand how planets and things moved, and how to visualize all that. But what was interesting is I had this book-- I think it was called *Men, Mirror, and Stars*, and I think I must've been about... I don't know... nine or something. But what it was is it talked about telescopes, and it went through the history of telescope technology. And there, again-- there, that was maybe the first time I actually fully-grasped this idea of these revolutions that were occurred at points where you went from, for example, the long, small-lens, compound telescope of the very early days of optical telescopes, to circumventing chromatic aberration that way and its limitations, to how you could scale that by making speculum mirrors, and then silvered mirrors, and then the innovation of the achromatic objective, and suddenly you have a burst of movement and pushing of an envelope in refractor technology. And then the big mirrors and the big silvered mirrors came, and then, of course, later, photographic technology. But that book showed the dramatic shifts in technology. That was what was actually driving the science. You did the science, but you did it with things that were engineered, and the science could move in new directions when you engineered something that let you look there and see there. So there's that. And so I think there's something where my mind was prepared, in some ways, for seeing an opportunity. It's like... <sighs> you can wander around, and if you're not a prospector and you don't know what the stuff you should be looking for looks like, you won't see things that are right in front of you. But if you're aware of kind of a-- some kind of framing that lets you notice things at a meta-level, not just the instance but the generalization, you can see complex structured opportunities that might not appear to other people, and even have a clue what to do with it, because there may be role models back then that did something that actually has a parallel, you see? So it's really interesting. I kind of feel like a lot of what I've done is just playful adventuring, but having been stimulated with sort of an unusual collection of sort of basis points-- of points of view about what people can do, and so forth. And, in a way, it's never about the things; it's about the ideas that get in motion in groups of people-- ideas on how to make things and how to compose things, whether that be music or silicon chips or radios or just simply electrical technology. A lot of the same-- a lot of the-- and so here we are now, and it's like we're almost back in 1975 again, or '76, like when I first jumped in on this.

Spicer: The revolution is continuous, actually, and always has been, but textbooks oversimplify and take snapshots of things, and they also like to point out heroes, whereas the nature of invention now is more teams, probably, than individuals. Last question before we break, and I know this is dear to your heart: What advice do you have for current and future generations?

Conway: <laughs> Well, <sighs> a lot of-- I've been thinking a lot lately about the time-phasing of things. I mean, there's the issue of what is time and how to think about time. But... when you think about the future-- let's put it this way. Let's suppose you see something that you would like to change. There's something going on. Let's say there's some systemic issue in the way—in an organization or a company or something-- that's operating, and you see a way to do it differently. Now, the issue is that currently-functioning systems have a certain stasis or trajectory that's predictable because they work, okay? And so why would you change something that's working? Even if you know that it has problems, if it's still working, you're worried-- you can't just criticize it away and start it over again. You have all the founder's effects-- the memes that keep it running that you can't displace. So a lot of the thinking is how do you-- how-- for example, how to be an entrepreneur. Okay, how do you start something new? How to entrepreneur and innovate in organizations and technology and music and art-- whatever. And a lot of it has to do with when people are wrapped up in a current, highly optimized body of work, whether its own or a company or whatever, naturally people will have rank-ordered themselves. They'll be experts in one thing or another. It's then very difficult for them to step out and playfully explore some new area. The more expert, almost the more prestige you have, the less able you are to be a vanguard artist, and play, and see what you can do 'over here', because now you're back to being a beginner again in something new. You're going to have to ask questions: "How do I do this, what's that," and so forth, even give names to things that you're trying to figure out with your friends as to, "What are we seeing over here, as we begin to do this?" And so some of it-- <sighs> some of this has to do with if you want to participate as an explorer, as an adventurer, at least some of the time-- and I highly recommend it]-- do be able to find times in your life when you can do that, because it's a lot of fun--you have to be able to stay partly a child and be able to play in a new game. So a lot of this has to do with becoming a good learner of new games. Now, what games do you learn? Not games that have to do with gaming the system, which our society has kind of turned into, but going for things that excite you-- something so different and cool that just you cannot help it, but you want to be interested in that-- so, let's say you might want to become a birdwatcher. You want to know what a bird really is-- and think about it. There's a lot to be said for observing and watching animals, and there's an endless amount you can explore and learn, and so you have things like that. Now, in my case, I tend to be attracted to adventure sports, and you never know when the itch is going to hit you to jump into something like that-- fresh, new-- at any age. <laughs> And the only thing is, you can't learn to do something like that if you're unwilling to be a complete, total beginner, and crawl before you walk, before you run, before you run fast, before you enter races. See? So, but if you-- it's really interesting. If you're attracted in some direction like that, you'll find in different periods of life that you'll surge off into some new direction like that, and you'll just be compelled: "I got to get into this." And not that you're going to even go far in it, but you want to 'experience what this is like'. What is it like to do that? And so I think this idea of adventuring is something I really find interesting to think about, because I think that same drive is how adventurous leaders and guides recruit people to get into their realm of adventuring, because they frame it in such a way that people notice it, and they just know, "I've got to do that." You see? And so a lot of these things that are kind of revolutions where there's some door is opened, where a new landscape appears, and you can make stuff out there that's never been made before. Some people go out there and they stake claims, and they try to become-- own it all, and this and that. But a lot of the people that rush in there are just playing and making stuff, and they just do it. And suddenly, weird things start happening where other people back on the other side of the door are noticing, "Holy mackerel, this is really cool!" And a lot of adventure sports have that thing. The nice thing about adventure sports is you learn a lot about technology. I've participated in a number where, if you jump-in early, or mid, rather than late in the evolution of an adventure sport, you get to participate as an early adopter, an exploratory user, of he new tools and methods that are being developed. And it's not only those things, but it's also in exploring the moves you make and even the ethic of the new sport. You're thinking, What is it we're all doing? What looks cool? What is cool? What lets you reach goals? And so I've participated in a number of those things at those kind of periods in their evolution, and that would include rock climbing when I was younger, solo whitewater canoeing and slalom racing later in life, and then motocross racing. I actually did an awful lot of motocross racing actually fairly late in life, and that's a whole other story. My husband and I are both kind of... over stimulate each other to get into new adventures, and then after a while you can't do one anymore, or there's a break in your life and you're off in these career dimensions or whatever, but then you take up something else. So we're off now in some other areas, adventuring. And... <laughs> and the thing about that is, gosh, all of that is so incredibly meaningful. I mean, probably in some ways I've had more dramatic, actual adventures with other people that are memorable doing adventure sports than I've had in my career work! And then I started thinking, "I can't understand why career work couldn't be more like an adventure sport." laughs> That's another story. But there are moments when, for people that are beginners and attracted by and infatuated and eager and see dramatic possibilities, where learning about VLSI design was an adventure sport. Okay? And I'm sure that was happening at MIT, and I'm sure that was happening at the universities in MPC79. And--

Spicer: As an engineer myself, I can't think of anything more exciting than designing your own chip, even though it's many decades now since that was first done. There is something really attractive about that.

Conway: Yeah, well, you can see where it's headed, you see? Where we're headed is, it's designing your own system of microsystems that animate something. That's where that-- that's what's now coming, and that's going to catch on like a fever everywhere. Okay? So that's sort of-- that's why you kind of-- that's one of the reasons I kind of jumped back in the game, because I now see that coming and I just want to know about it; not necessarily do anything big in it, except maybe fan the flames <laughs> and sense a way of breaking out of the current box we're in with commodity OEM things. Instead of just having a few automobile manufacturers, and they all make automobiles that look almost the same, and you have your cell phone, and you go to your office and you live in your house, and they all look the same and they're getting more same everywhere. Why isn't there more wildness? Why isn't there more diversity? Why do we always stamp out wildness? I mean, I think... I sort of feel like I was always like a weed growing in a very, very tailored garden, and people would come and get rid of that because that doesn't look right; this doesn't belong here. And so why don't we accommodate wildness, and why don't we even have an area of the garden where you just let it go wild and see what happens? Not going to hurt anything.

Spicer: Well, English gardens are like that, I think.

Conway: Yeah, to some extent.

Spicer: <laughs>

Conway: Yeah, to some extent. And, in fact, there's a whole story there. My webpage links to that. There's a really incredible video about *What is Wild* that talks about English gardens and the alternatives, and I think there are many lessons in that about culture and about conforming things to a rigid pattern versus allowing some wildness and diversity, because in the end, more people, I think, would rather be in control of designing their own lives in a variety of ways and creating their own habitats in a variety of ways. But if everybody's going to make and create and design, then we need to provide means for doing it sustainably, and I think this whole microworld is a way of exploring that, that actually we'll shed many of these big, massive constructs, because it'll be possible to build structures, lives, mobility methods, and so forth, out of less and less material, and yet have it all be dramatically more adventurous and interesting and exciting. So there's all this to discover. It's ju-- so, in a sense, it's all just starting. It's all just starting. The printing of machines in silicon helped start something that is now going to just really run wild. But it won't run wild by all being run by just a few manufacturers. It will run wilder and be better at exploring all the niches of what you can do if it's done diversely by more and more participants. And--

Spicer: The Internet, to some extent, is more egalitarian in that sense?

Conway: It can be.

Spicer: It can have small groups of people who make a big impact.

Conway: It can be, and-- but even more now, you can recognize that if more people weren't just having their lives run by their career and their cell phones, were participating in making and exploring in some local niche that they're interested in, but then potentially sharing, open source, whatever they discover is interesting to make, and getting pennies in their social account, based on whoever might adopt or propagate that, there's some different way of that all running-- so that people collectively and individually can better notice an exciting innovation that's been made way around the world somewhere—an innovation they might be able to use that's kind of really cool for what they're just trying to do. So that is-- so a lot of this has to do with how do we even know what's going on, how do we notice, how do we share? So viewing the world as this giant bee colony where people have just been soldiering along and going out and doing things, coming back, doing the waggle-dance and all that, this whole colony is somehow now being connected in a way that we 'are coming alive' in a new 'group conscious' way, sharing and seeing and noticing and adventuring, so that we don't just end up being soldiers here and this there and that there, but a whole new set of possibilities emerges, even though we're still in this same sphere. So...

Spicer: Very good. Shall we take a break?

Conway: Yeah, let's take a break. <laughs> Yeah.

<crew talk>

Spicer: Can you tell us a bit about your childhood and your parents growing up, and early influences? Did you like school, for example? Those kind of things.

Conway: Yeah. I... I-- as I'd mentioned, I grew up in Westchester County, living in Hartsdale, and then Scarsdale before the war, and when we moved to-- let's see. I was probably just entering school when we moved down to Bethesda, Maryland. I really started school there. And it was during the war years, and so that that's a backdrop for a lot of experiences, and framed a lot of experiences that I had. But just within school, which is the main preoccupation there-- and I remember a lot about the school-- had a kind of uneventful but really exciting period in kindergarten, and then went into first grade, and actually did very well in school, and as a part of that, ended up skipping a grade, and that's how I got ahead of the thing. And school was always just really a lot of fun for me. I really liked it, but I had a lot of issues developing within the family and in myself, related to gender variance and issues along those lines, and so that kind of channeled me in certain ways. And after the war, my mother and father got divorced. We moved back with my mother, my brother and I, to White Plains, New York-- ended up there-- and she began teaching in the school system there as a kindergarten teacher. And so during my childhood there, she was very busy at school and so forth, so the childhood provided-- actually, at the time, there was quite a bit of freedom: freedom to wander around, ride your bicycles all over the place, and go places and do things. So kids back then grew up much more as free spirits than they do now, and I spent a lot of time just wandering around in the woods, and so forth, in the outskirts of town-- secret places I knew to go and wander and figure things out and stuff. And so it was-- there was this-- there was sort of that dimension to life. And also, my brother and I-- he's three years younger-- got into doing a lot of making and stimulating each other into doing stuff with chemistry sets, with all kinds of stuff that my mother brought home, partly in preparing to take it to her school. She would go to lumber yards and get all the little pieces of wood that were left over after they chopped things up, and so we had this huge pile of junk down in our basement that was stuff in transit to being slightly sanitized or checked did it have any nails in it or something before it ended up at the kindergarten classes. And so that provided always a backdrop of this-- we could always take whatever we wanted out of that pile, then we could go take it out in the woods somewhere and mix it with other things and do stuff and make stuff. There was all this making going on all the time-- making with the chemistry set, which led to various adventures that we'll not talk about, <laughs> and then getting interested in astronomy and telescopes, and so forth. I think the pivotal event in my childhood-- what was otherwise a kind of a channeled and pushed-towards-conformity childhood, but that was breaking out with wildness in a lot of other ways-- the thing that really was a central experience was when I was ten years old and went to summer camp in Maine. And this was just totally amazing-- totally amazing-- because I learned-- I didn't know how to swim. I learned how to swim. I learned how to swim really well, and learned how to go fishing. We'd go out in rowboats and fish and catch things. And learned how to ride a horse. Learned how to start fires. Learned how to go camping-- how to put on a pack and wander around with other people and go off somewhere and make a camp. Learned how to do various kind of crafts and making things, and I learned how to shoot rifles, and I learned how to use a bow and arrow. <laughs> I mean, it's all this stuff in like, I don't know, eight weeks or something, or whatever it was that it lasted in this beautiful place up in Maine. And that, I think, was really central in triggering me to always wanting to follow opportunities to go off on weird adventures in the woods or in the mountains or in the rivers or the seashore-- to go places and just do stuff. And so that kind of-- you can see how that led into things like rock climbing, and even, later in life, whitewater canoeing and even motocross racing: being out there, in action, in the wild, with other people. And so, in a kind of interesting sense, what it was is there was gender variance, but the way I would perceive it is that I was a tomboy. I know that doesn't make any sense, but that fits the pattern of kind of how I was programmed from the inside, okay? And this is not like high maintenance. This is more like someone that wants to go off in the wild with the boys and just go off on crazy adventures. And so that's-- you see, so that's a little different than people might think about. And in a wolf pack, I'd be the alpha female. So, and there's a lot of things about that. And, of course, people learn a lot about how to be people by watching animals, and that's a whole other story. But I think that was a kind of pivotal thing that helped trigger a kind of a living where you don't see the career as the main thing in life, where the main thing that centers you in life is simply do what you do to get money, do this, stay alive, have a place to live, and have food to eat, but always thinking about how are you going to have the next adventure. <laughs> It's always about how to have the next adventure, and those are always things you do with people to jointly experience something that you have witnesses to, you have shared memories with. And it almost doesn't matter what it is. It's more whatever opportunities sort of you stumble into that you have that attraction to. Then, by being like that, you end up sort of seeing a common thread through all this, where it's like, "How did I get so interested in doing *that*?" <laughs> "God, how did I"-- and what-- and so you-- from that, you kind of go-meta on that and think about 'what that's an instance of?', and then you think, "Ah, I think I see how to get <u>them</u> interested in doing this, <laughs> with artifacts, with behaviors, with the framing and with cultural rituals." And so a lot of that actually got amplified, as I began to grow up, with an infatuation I got with anthropology, and especially with the writings of Ruth Benedict, but especially Margaret Mead, because my mother was studying at Teachers College at Columbia to get her master's and then her professional degree in early childhood education, but among other things, she got really infatuated with anthropology. So she's flaming about this anthropology she's studying, and she brings the books home, of course, and so I was reading these books, and it's like, "Oh, my God! <laughs> This speaks to me." You see? *Coming of Age in Samoa*. Seeing outside our culture, seeing other experiences with growing up and becoming a living, animated, mating, behaving human being, but differently; and, in fact, some differences there that you could decode as, "Wait a minute, there's people out there that are acting-out kind of like I feel," wherever "there" is, and I forgot in that particular instance. But-- and so that was very illuminating, so I became very interested in anthropology. Jump ahead to years later when I was at Columbia, really at the perfect timing to get into computing. It was just as well I kind of abandoned my studies at MIT and left kind of in desperation, just completely almost shattered by being unable to transition, but going back at Columbia entered just with enough delay that computing was just coming in strong, so I could jump into that-- got attracted to that-- and launched that career. But while I was there, I studied anthropology. I minored in anthropology, and in the process tuned-into a scattering of then-stovepiped work surrounding that field being done by a number of individuals doing separately very interesting work, where their work spoke to me and empowered me to think about how to use their points of view in understanding and, in effect, <u>doing</u> paradigm-shifting in engineering. So the sixties was an interesting time. There was just a lot of work then that became later reified along the lines of 'what a paradigm shift is' and how these breakpoints happen, and so the idea of spotting things like that and knowing when to jump in-- like when you see the tsunami on the horizon and you run get your surfboard and you're going down there, and you're going to get out there, and you're going to be out on that wave as it comes in, so you're going to experience that ride. They only come once in a while, and in between such things, you go adventuring, doing other things. But in engineering, these times of opportunity and change come where, gosh, you just <u>have to</u> go jump on that thing and ride that one for a while. Even as now a beginner, let's say, as some giant new wave comes in; you're thinking, "I never saw these kind of surfboards before", and "I don't know if I can get on that one," but you have to be out there and participate and experience it. And sometimes you get lucky, and you get up high on the wave, and you actually maybe can make some cool new moves and go with it. So there's a thread that runs through all this that has to do with adventuring and with the anthropological, or, better yet, the ethnographic viewpoint -- of trying to decode what's going on, and then synthesize from that, trying to decode what's going on, and how do you reverse engineer and take components of it apart, and put them together in a new way – so that when you put them back out there, everybody goes, "Oh, boy, this looks like fun; let's go do that" And I think these are all things that we all do. This is not just me doing it. This is-- I'm simply evoking and projecting what I observe myself doing, and what I see other people doing too. And all of us are doing that, but it's just that we're programmed to look outward for social support, prestige, acknowledgement, ranking, and we often become obsessed in gaining that, so that we actually don't notice what we-- or, in fact, other people-- are actually doing-- and instead observe only the ranking process and the measuring according to measures that have been handed down by people that, in other dimensions, are, in a sense, wanting to control, wanting to order, wanting to make money through others. And no, that's fine. That's what we do. But when you look at it, there's so much more latent possibility for exploration, for adventure, for fulfillment in all people -- but they don't tune into it and almost don't dare try, because they don't want to look like a beginner at something. How do you start doing something that you really want to do? It's scary. But if you just kind of 'don't allow yourself ever to fully grow up', if you always 'stay partly childlike', you can take that part of you and pull it out when doing something new, and just behave that way again, because you can 'get it to where you'd never lose that'. You then never let yourself fully grow up. And I now see that in a lot of people, and I just wish there were ways for more people to share in such adventures, and especially in the adventures of making things as an engineer. I mean, I think just the making of things-- the fun of designing, combining, making, where you have a need and you just figure out how to fill it, the process of innovating— even where you may be re-innovating something that's been innovated before, but if you innovate it and you didn't know anything about it, then you innovated it! And that process is accessible to everybody, rather than this myth that, "Well, we all know that almost everything has been done so far, and we're operating now only at a frontier where only the most elite geniuses can even understand what's going on." That's ridiculous. Quite far from it, the world is now becoming ever more knowable, diverse, full of cool stuff, and there's all sorts of different ways to take it apart and put it back together—ways that no one's yet thought of, and all that is exponentiating. So it's sort of like hot-rodding. Go out and reverse engineer stuff, and see if you can take all the pieces apart. Now, think of different ways you can put them back together or add other things to it, that make a whole bunch of it 'go better'? And now it's all becoming open-sourceable. So you can spread your innovations around, if they're any good. Maybe there's even a way that we'll all get little credits in the IP(intellectual property) universe of the future, so that we get some pennies-in for every one of these things we projected-out that anybody found useful, and we sort of go off in some different direction, economically. Yeah. <laughs>

Spicer: I think we're done, unless you have any other things you'd like to say.

Conway: Let's see. I don't really think so. I have no idea what you've got, and in a way, it doesn't matter. I think what you see is what you get. I've just been here and I'm being myself, and--

Spicer: Yeah. No, it's great.

Conway: <laughs> You know--

Spicer: We've got lots of great material. Not to worry.

Conway: Really?

Spicer: Yeah.

Conway: Do you think you do?

Spicer: Definitely.

Conway: Yeah. I... and the thing that's interesting, I don't often have situations where I have to try to explain myself. See, that's the last thing I want to try to do, see? Mostly, I get involved in situations where people don't really have a clue, really, who I am or what I'm doing, or if they know who I am, it's, "Oh, okay, we have this computer scientist or this professor here," but you're there because you've insinuated yourself into a situation where you don't want people to know what you're doing because, if they do, you can't ask them just random questions and figure out what's going on. So it's kind of like I think of myself like I'm a detective trying to decode things so I can figure out their parts that I might be able to put together and do in a different way, and it's all just play. <laughs>

Spicer: That's great.

Conway: Does that make any sense?

Spicer: Yeah. Perfectly.

Conway: <laughs> Yeah, okay.

Spicer: Thank you.

END OF INTERVIEW

