Computer Aided Design (CAD) Pioneer Workshop
Day 1 Session 2: Early Technology Development (1960-1980)

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Recorded May 1, 2023

CHM Reference number: 2023.0065

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David Brock: Well, thanks again for all your personal introductions. I think the next thing that we wanted to move into in our proposed schedule was an open discussion of early technology developments from 1960 to 1980. We would like to hear from all of you, your perspectives on the most important technological developments for the story of CAD in this period, and the key centers of development for CAD technology in this period especially. I'm curious about the developments happening in university settings, as compared to developments happening in commercial or industrial settings. So this is just sort of an open discussion, open to anyone, and so I'll just throw it open if anybody would like to share some thoughts on what are some of the most important developments we should think about historically from this period before 1980.

Burton Grad: David, one thing might focus this a bit. I was at IBM during the 1960s and 1970s, and CADAM and then CATIA were being developed, and Boeing was involved at some point working with IBM, as was Lockheed, and some of the automobile companies. So, I'd be interested particularly in the technologies that made CAD possible. Was it drafting or was there three-dimensional work? What were the key technologies that allowed the software to get built? Go ahead.

Line Drawings

Brad Holtz: There were a number of things happening at that time. If you want to think about some of the earliest, I'm just going to call them CAD-adjacent technologies, were entirely text based. I'm thinking about the early versions of Nastran and its precursors, and then you have to remember that at the time, and Jon, please correct me here, but you were primarily using ray-tracing or ray-tracing displays, and the display capabilities for the graphics side really didn't become strong until, what, mid-1970s.

Jon Peddie: Late 1970s. Yeah, 1979. I think one of the most significant things that happened for the CAD industry and for the graphics industry in general was in 1962 with the [Jack Elton] Bresenham’s line algorithm, where Bresenham figured out the most efficient way to draw a line from point A to point B, and that had to be one of the fundamental parts of building any CAD program.

Grad: Before I forget, when you give abbreviations or other names, please spell them out because the transcribers won't have any idea what you guys are talking about.

Dave Kasik: So, let's go back for a moment to Bresenham’s algorithm. It was done for stepping plotters, like the Calcomp plotter that could move in one of eight directions, one step. The problem was with original line drawing, and it was strictly for line drawing on a plotter, not for anything else, not for interactive use.

Peddie: I totally disagree with that but carry on.

Kasik: It was adapted for interactive use later for raster displays, but he wanted to do it without having to do any floating point. Jack Bresenham figured out a wonderful way of doing one of eight moves, one unit on a plotter using integer arithmetic. He was brilliant.

Peddie: We owe our careers to it.

Kasik: So, let's go back to a couple of Brad's comments. The technology that was in use in the 1960s and 1970s for doing computer aided design was all based on cathode ray tubes and doing calligraphic displays. No raster displays were apparent, and they were just about all refresh displays until Tektronix introduced successful direct use storage to technology in the late 1960s called the 4010, and then things started changing for the CAD industry. It wasn't ray-tracing, so let's be clear about that. Ray-tracing started in the late 1960s at IBM, and it was actually a technology that was done in the 1930s tracing electron beams and the like. It was a CAE [Computer Aided Engineering] type application and people adapted it at IBM for trying to do shaded images.

Holtz: They were doing vector refresh early on.

Kasik: It was vector calligraphic refresh through the night through the late 1960s when Jon's favorite pixel machine started coming into play and started being useful for computer aided design applications. That's just some of the fundamental technology that did in fact exist in the 1960s and 1970s. I think when we switch to the more formal pieces that Tom [Lazear] and I will do, we'll talk a little bit about some of the evolution of what turned out to be, at least from what I saw, largely derived from industrial companies, rather than from universities, and from commercial companies. The one big exception is Ivan Sutherland's work with Sketchpad started in 1962 for his PhD thesis and is highly regarded in terms of industrial application and things of that nature and influenced a lot of industrial applications. Sutherland did a really nice job on that PhD thesis, and it influenced a lot of what computer aided design was all about.

Brock: I think Jon wanted to get in here.

Ivan Sutherland and Sketchpad

Jon Hirschtick: I just wanted to say I'm glad you brought it up because I'm actually surprised we went as far as we did here without mentioning Sutherland because I think we're going to talk about a lot of things, but I don't think we'll talk about anything else that can compare in enormity of significance in the history of CAD to Sutherland’s thesis for a bunch of reasons that I can get into. This is Ivan Sutherland’s PhD thesis, and we're undoubtedly going to have a recurring theme talking about all the technology that led to certain moments in time, and none of us would be here, including Sutherland, who isn't even here, without building on the shoulders of the people who came before us, both in general computing technology, computer graphics, and CAD technology. But Sutherland’s thesis is a landmark to me because first of all, he had no other CAD systems to look at. Secondly, it wasn't just the world's first CAD system. It was arguably one of the world's first interactive uses of the computer. I'm not going to say it was the first, but there were very few ideas of computers being used interactively. There were very few thinkers about graphical user interface.

It's an amazing work, and the stuff he envisioned, if you've never looked inside it, it wasn't just 2D drafting. He envisioned constraint management, simulation, things that were way beyond his time. For one person to have a vision of all that, let alone to go and implement it with the stone-age tools of computing at the time is just unbelievable. Most things I say I'm not just saying for your benefit here. I say this publicly in other places. People say to some of us here, you're a visionary. They say to me, oh, you're a visionary. Sutherland’s a freakin’ visionary and a lot of our ideas, certainly the ones I've built on, are really more obvious things that are staring you in the face that need to be done. Put 3D solid modeling onto a Windows PC. Duh. Excuse me. Can we use profanity in this history? It’s obvious. What took balls and the complexity was going and doing it and executing it. Mike [Payne] can testify to that. I'm sure many of you can.

Sutherland had true vision in a way that I think in my 42 years in the business very few people have had or can claim to have, and so I think if there's a gold star on any piece of work we're going to talk about in these sessions, it's Sutherland’s PhD thesis. I love it so much. I actually sought out and met Sutherland. I have the photos to prove it and could tell you more about my conversations, and I remember at the time asking some of the people in this call for contact info, and no one could give it to me, but I found him, nonetheless. Anyway, if you haven't looked at the YouTube videos, or the actual thesis itself, they're online. You can look at it. We can talk more about it. But probably said my share at this moment.

Brock: I think next we had Michael wanted to get in, and then I have Tom, and then Peter.

Chip Design

Michael Payne: Okay. I actually think we're missing something here. But the electrical guys had a problem when they made chips because the chips could get denser and denser, and when I made chips in the late 1960s, they weren't very big. You could do it with a little tape on a piece of mylar. But by the time the early 1970s came along, the density of chips had increased considerably by Moore's Law, for lack of a better word, and so you had machinery. Not graphics tubes, but they were by Applicon, and Computer Vision, Calma. And you took mylar, and you sliced the lines in it, and you peeled off the mylar to make the pattern for integrated circuits, and so the electrical industry software actually led the mechanical probably by about 10 years, simply because of the density of their product, and it wasn't much better for printed circuit boards with multilayers either, so you couldn't do it physically. The other part of it is simulation was there with a product called-- not a product, a research program distributed freely from UC Berkeley called SPICE-- which was used for circuit analysis, and it was a necessary tool. When you were making these things, you couldn't get inside and put probes in them. You had to simulate everything and that definitely was CAD. It's a different industry, if you like, but it's all CAD for circuit simulation. Companies had their own circuit simulation. At RCA they developed their own. That was the thing I mucked with to make it work for what I needed. But SPICE was freely distributed, and it was used in many semiconductor companies in the Valley. And so, let's not lose sight of that electrical had a necessity long before the mechanical market because you could still sort of make things with drawing boards. If you used the right pencil that was.

Brock: Tom Lazear.

Graphics and Displays

Tom Lazear: I'm not sure my comment is even relevant. And we're listening to all that transpired since the thought occurred to me, but way back when we were talking about early attempts at drafting on a computer or outputting graphics in some form or another. In 1963, the company I worked with on major projects had a thousand piping drafters working on the project. I can't imagine trying to coordinate that. So, there was a great push to use this new thing that we had called the computer to aid in that regard. So, after the fun stuff that we did with just computer aided engineering, which turned out to be pretty easy, then they assigned me to produce some software that would aid in that regard.

And so, with tremendous push and passion we looked at every possible way to do it, and found this device called the Stromberg Carlson 4020. You may never have heard of it, but it was a CRT with microfilm and what it would do is you could use this subroutine package and you can make drawings of all kinds and all complexity on the CRT and record it on the microfilm. Then you would take the microfilm to a Xerox process called CompuFlow and run it through CompuFlow and out comes a vellum, perfect, beautiful drawing. I don't know how many people even remember that, but I am very good at picking losers and Stromberg, I don't know whatever happened to the 4020 after that, but we produced a lot of piping isometrics. In fact, that system itself got thrown away after interactive graphics, because it was semi-interactive. This is '1963, we're talking about, right? I wanted to offer that just for remembrance that there was another way beside paper plotters, and it was very, very fast and highly productive in making the vellum drawings.

Brock: Peter Marks, I saw your hand next.

Peter Marks: So, I was going to give homage to Sutherland, so Jon did a much better job. I accidentally met Sutherland on a bus at some conference. I sat next to him, and I think he was asking, "Is anybody still using homogenous coordinates?" and it was just like a delight. It was kind of the same way with Parsons. What I'm going to suggest in terms of history is that I think you could draw several parallel threads and do the history of that. So, there's a university thread that maybe starts with Sutherland's thesis. But you've got RPI, Cornell-- Carl could tell us more about that-- BYU, Movie BYU, etcetera, Gossard's lab at MIT-- Jon could tell us about that. So, we could make a list of universities that were absolutely key. SDRC, which started out with graphics, taking NASTRAN that Brad was talking about, was the leader in graphics for finite element modeling, and then kind of moved over. So, one university thread.

Next there's a company thread, you've got the Boeings, the GM's, it's various alliances with Hanratty, Ford, Xerox, I just to add to what Dave [Kasik] was saying, someone once told me that Boeing was the Errol Flynn of CAD. And I said, "Well, what do you mean by that?" And he said, "Well, they love them and leave them." And so, they made sure that it happened and were influential throughout the whole process.

Then you've got a hardware thread that started out, I'll agree with CalComp Plotters. I think the influence for that research was for the Army. Parson's AMC point to point was there, too. That was kind of the other side of this. Then Tektronix storage tubes. You could go to Chrysler and see all the storage tubes out in the aisles and raster tubes coming in. I remember the first time I saw an ENS Picture System. I mean, this was like Star Wars. I mean, it was just such an awesome piece of art. It was expensive. I think it was 60 grand [$60,000] when 60 grand meant something. And then through the whole thing, you know, we started with mainframes, then we got the VAX, then we got the PDP, then we got workstations. Jon [Hirschtick] and his brilliant, epic move decided to move to the PC. And now we're back to the mainframe again with the cloud.

And lots of companies have screwed up either the programming language or the hardware transition. I mean, look at a lot of why a company's story, like Tom's story, it was just so embedded in the software that you didn't see the hardware. And then I think we shouldn't forget the international contributions; we should force ourselves to remember the contributions out of the U.K., often out of schools there, out of Germany, France. and today I'm kind of blind today to like Russia and China, but I can guarantee that as we split this world into two economic zones, the AutoCAD for half the world is not going to be AutoCAD. And so, I think I'm just suggesting for history, you could draw these parallel lines and show how they merge together to make progress in CAD.

Brock: Next we have Brad, I wanted to go to you, but both because you had your hand up a moment ago, and but you had a comment in the chat about Asimov. And then I have Jon, and then I have Dave.

Commercial and Military Applications

Holtz: So, the first mention of CAD, whether it's design or drafting, that I'm aware of was [Isaac] Asimov's; I think it was 1956 drafting. And if you'd like, I've got the book and I have the quote from that where he actually describes what we can do. And that kind of set a bar of what concept that people might be looking for going forward. There were a couple of other things that have happened since then. I think if you look at the 1984 Apple ad about breaking the establishment when they're actually talking to the computer. And I've got that reference as well. But if you think about some things external to the industry that set the vision of where we might be, I think that does need to be in our mindset.

I also think that in the early days of CAD when we're talking about the 1960/1970s, a lot of the early drivers were based on problems that had very high return and very low geometry complications. You know, we're dealing with MP-CAD, and E-CAD, we were dealing primarily with lines and circles, paths and straight lines. And going back, Pete [Marks], to your comment on Russia and China. Carl could talk to you a little bit about some interesting things going on in China. In Russia, they've built their own kernels, but they also have an AutoCAD look-alike, and a whole set of things designed to go on an AutoCAD look-alike. But again, there's this whole slew from drafting through design modeling and simulation that is happening there. I just wanted to throw that out.

Brock: Thank you. I have Jon Peddie next.

Peddie: I want to add a couple of parallel tracks, and I'm got to speak before Dave [Kasik] did because he's going to argue with me about this. But I was in a meeting with a fellow by the name of Jim Medlock. Maybe you guys remember him or not, he started a company called M&S, and Jim was a guy who didn't tolerate fools and was very opinionated. And I mentioned to him how fantastic it was what Sutherland had done, and he put his finger in my chest and said, "I did that before that little guy even went to school." His point was that he had been working at GM and that he had worked on a design of a CAD system at GM, which GM did not make public, because it was considered a big trade secret, much like the shading algorithms that were done at Renault and Peugeot. In those days, the car companies really were kind of leaders So, that's one line. Dave's about to blow up, I'm sure.

Kasik: No, I'm not. I'm not for a change.

Peddie: Okay, anyway. So, the other line I want to make and that is, yes, we do have a great debt to Sutherland, I don't dispute that for a moment, but our total debt, our total reason for being here is the military. Computer graphics started because of the military, and basically it was simple stuff of, "Where's that shell going to go that we just launched? And is it going to go where we think it's going to go?" And plotting that type of stuff. And in 1963, going back to Brad's question, there was a guy by the name of Abel who was working on what they called MAGI, and he did ray tracing on a plotter in 1963. So, and I have the images in my book, I can show it to you if you want to see it. The point being is there is not a single genesis for any of this, it's a whole bunch of parallel paths, but they all root back to the military. The military was the funder, the military was the motivation, the military was the ROI. We all started because the military wanted something. I'll shut up now.

Brock: I have Dave and then Michael.

Kasik: Yeah, I can go on about it for a long time, but I did try to summarize some of what we're talking about in the comments that I'll make whenever I'm doing something more formal. So, comment number one with respect to General Motors, the project was called DAK-1, it is documented. Greg Krull wrote a paper about it in 1994. It's available publicly. So, read the article. It's quite enlightening, because General Motors started the journey of doing computer aided design in the late 1950s and then actually engaged in a joint research project with IBM to try to make that all work. There's one big difference, I think, between what happened in the E-CAD world and that goes beyond geometry that started as far as I know, and correct me if I'm wrong, in that Spice and many other early computer aided design and computer aided engineering programs were all done in batch with output that was produced on a plotter or on a microfilm recorder. I worked on both the 4020 and the 4060 for Stromberg Carlson back in the day. It was a fascinating way of doing business. So, that's one thread that I think we can talk about in terms of differentiation between interactive and batch computing evolution. Both of which have some fascinating aspects. Okay, so that's a little bit more about the history of what--certainly what I saw in terms of computer aided design and the like.

I will also agree that the locus for much of the computer aided design, especially in 3D, was done at auto companies not necessarily at the behest of the military, Jon, so, I disagree with you some there, because auto companies wanted to design aerodynamic shapes. They built clay models and then had no way of getting those clay models to do any kind of analysis without figuring out how to make them work with a computer-based situation so they could do more thorough analysis. We can talk about that a little bit later. One of the other things that I think we're missing, and I think we need to talk about, is the evolution of the mathematics that drove the computer aided design business. The one thing that I think Sutherland really contributed was doing constraint modeling interactively. But he was motivated by doing drafting type operations. That's where the money was, and certainly in the late 1950s and 1960s.

Peddie: And it was DARPA money.

Kasik: For Sutherland? Yeah. It wasn't for General Motors.

Peddie: No, they had their own checkbook.

Kasik: Yeah, exactly. But the point that it was all driven at one point by the military, I think, is a little disingenuous.

Peddie: Well, no, I'll maintain that position. I'll say that is the foundation point. I agree with you about the automobile companies wanting good shading programs because there's not a flat or square surface on a car. But the origin of computer graphics traces back to the DEW line, right? The reason we have computer graphics is because we wanted to see if Russian missiles were coming over the North Pole.

Kasik: So, we also wanted to do things-- and certainly at Boeing-- they wanted to do things like figure out if there were people who could reach objects- things on the bridge of a ship. And so, the origin of the term "computer graphics" itself came from Boeing in 1960.

Peddie: That's right.

Kasik: From a guy named Vern Hudson. It was popularized by Bill Fetter, because Fetter was doing the first human modeling animations on a plotter, and so he has a large debt to Jack Bresingham for being able to do movies of people who were trying to reach things on the bridge of a ship. I have images of that particular thing as well.

However, there are a number of other companies that I think led the charge for computer graphics and that includes both in Europe and in the U.S. One of the things that I'm doing as a sideline is collecting stories about the origins of computer graphics. It's published in *Computer Graphics and Applications*. I don't know if I have had contributions from anybody here-- but I have contributions from a lot of different folks who were involved in the early days of computing. It's all available from *Computer Graphics and Applications*. But there are some fascinating stories about how things got started, including Turner Whitted talking about how he did ray tracing. And I'm glad somebody -- I think it was you, Jon -- mentioned MAGI and how the Mathematic Applications Group Incorporated started doing some really sophisticated modeling and the like in the 1960s and 1970s.

Peddie: It was for tank design.

Kasik: Yes, and I've got pictures and everything.

Brock: We had Michael next. And then I wanted to turn to Daniel and Brad briefly.

Payne: Just to support what the other guys were saying, every large company, meaningful large company, in the late 1970s was building its own CAD system. Toyota, Honda, Dassault Aviation, Ford, General Motors, Chrysler. Ford had this thing called PDGS and they even attempted a data management system called the Data Collector. In fact, somebody joined PDGS in their youth and retired from the thing. It lasted longer than many commercial CAD companies. But there was activity in the other Cambridge, the one that doesn't have MIT, but it has the University of Cambridge. And there were two products that came out of that. Medusa was one, which was a pretty good drafting system and however good Carl's [Bass] was, I think it was better. Sorry, Carl.

But there was another interesting product and that came out of a government research center called the CAD Center, which produced a product called PDGS, which we actually sold at Prime, which involved 3D piping designs for oil refineries and power stations. And that was long before there were the other things that we're talking about. So, we're forgetting some of the origins of CAD. And that's why at the Center, there are still a lot of people in Cambridge, England, who consider themselves CAD people.

So, we shouldn't forget that. That was eventually privatized. I was on the first board when it was first called the CAD Center; it was renamed to AVIVA and PDGS is still being sold today. So, that's lasted longer than Computer Vision or Applicon. But we shouldn't ignore either of them because they are the origins of some other companies like Computer Vision and Applicon.

Design versus Drafting

Grad: I'd like to ask the difference between drafting and design. You keep using both words. Is it computer assisted drafting mostly?

Payne: Well, you see you put your designs on the drafting machine or the drafting software so people can see it.

Grad: But it wasn't doing the design. It was doing the drafting *of* the design.

Payne: But that was in the people's head. And in fact, if you look at the drafting that was done for chips you knew what the circuitry had to be and you had to figure out how to lay out the geometry of these little rectangles and pieces of gold wiring, or whatever it was. And the two were sort of rolled into one.

Kasik: So, Burt, one of the big differences is that drafting was a document that tried to capture the design, the general design, but it also captured all of the essential information to manufacture a particular item correctly. They eventually started taking those drawings, the engineering drawings--how many of you took engineering drawing at some point in your life?

Peddie: My first job was as a draftsman; I hated it.

Kasik: Somebody made the comment that you had to try to figure out how to get all of these end drawings together in order to make a product. Well, think about that in terms of a commercial airplane, and you're literally talking about hundreds of thousands of drawings that you need to make this happen. [The drawings included dimension information, included material information, it included everything you needed to actually build the thing. Design, in most cases, was more in terms of the 3D shapes that were then documented in turn by drafters.

Grad: Well, I was trying to separate these functions. We had a pioneer meeting, four years ago on expert systems, in which the programs that they were working on was the logic of the engineering and of the design. But the work that was being done here was recording the design, not doing the design.

Kasik: But doing the design actually was part of the domain that I think we represent. And that is how you make something a three-dimensional shape that meets the criteria, performance criteria, aerodynamic criteria, whatever you need in order to make that object work properly. The expert systems pieces that I worked with at Boeing, certainly, took information and tried to drive the geometry automatically.

Marks: So, the documentation is kind of after you've done the design that's allowed you to build the thing. The decisions have been made, the tradeoffs have been done, the trials. Something like PDGS that was mentioned before. And when you're piping a big plant, because it's pretty simple; pipes can be represented by lines and the rest of that, but plants all the time had, "Oops, we've just welded ourselves into a corner, and we got a pipe running through another pipe." So, interference detection is one of the tasks of design. That's kind of what Dave [Kasik] was talking about. And there's always been this question of, "Is it design? Is it drafting?" Drafting was there, there were customers for it. I mean, we could talk about some obstacles there. Whereas these design decisions were not just geometry, they are a whole other thing--the application of the 3D models.

Peddie: Joel Orr, who unfortunately couldn't get online with us yet, was a proponent of calling it DDD; he always said it was: "Drafting, Design, Documentation." And so, when people talked about CAD, he wanted it to be CAD-DDD <laughter>, and there was a little company in Brooklyn there that adopted that name, and their name is DDDD. But those three components, those are the three 3Ds, and Joel was you know, like I say, always the proponent of that.

Early Engineering Applications

Holtz: So, where you draw the line between design, drafting and documentation depends on what industry sector you happen to be in. It's very different in architecture, piping, manufacturing, and GIS. So, you need to take all of these comments with a grain of salt. PDGS was interesting because I believe it was the first object focused design system. And it had a number of very unique early characteristics.

But if we go back to the focus of this time period, which is 1960s through 1980, in the early days, the companies that were building systems, were doing just that. They were building systems. They may have been designing chips. They were building computer systems, the hardware, in many cases the furniture, the monitors, the software and everything involved. At some point in time, depending on which section of the industry you wanted to look at, there was this split between companies that were building software and putting them on systems by other people. And then we went and had not just hardware, but we on the hardware side we broke up and there were folks building hardware workstations and then there were just the computers and then the monitors and the other stuff. And on the software side, you know, people were building entire systems and then they were building software that sat on top of operating systems and you get this focus over time on your areas of expertise. And I think that the clearest example of this in my mind is if you look at the path that Intergraph took going from building furniture and building their own chips, standardizing other chips, and then in 1994 betting the bank on what was Windows NT at the time, and moving forward and said, "From here, we're going to be going on standard workstations and it's all going to be on this particular operating system."

Peddie: Just to add to that for a second, and that was the demise of Silicon Graphics.

Marks: Yeah, they were actually a client [of my company] at the time, and we didn't see it coming. In terms of all these parallel paths that we've got, probably another one is solo contributors, guys like Mike Brittle that kind of just kind of [did their own thing]. You know, there is a scale at which you can write a CAD system yourself, and those guys probably needed nothing. And I also think that we're missing the component software. Now this picked up a little bit later than the early times, but Hoops is an example of that. Way back in Cambridge, Michael may have some thoughts about he and Ian Bray and Alan Gray worked on stuff like that.

Peddie: Just to add one other point about splitting the world in two, Peter mentioned that the big CAD company in China is Z-CAD, and Z is free almost. But if you go to China, that's what you're going to stumble over.

Holtz: Yes, but guess where that came from?

Peddie: Carl Bass?

Carl Bass: Yeah, it was mostly stolen.

Payne: And there was another guy who helped steal software for that venture, whose name should be anonymous.

Marks: This is jumping ahead a little bit, but there was a period of time, a couple of decades after this when what CEOs heard was total product definition and they got PDM and 3D and stuff. What they heard was, "I can move manufacturing any place I want." Now it's not so easy, but a whole bunch of systems were sold for that and to start up manufacturing. I'm going to-- like the IBM ThinkPad went from Japan to Mexico to China where it now resides. And given the politics today, there's this whole kind of future that we're going to get to maybe tomorrow that's pretty interesting.

Brock: I just wanted to make sure to go to Daniel for a comment that he made in the break that will not be represented in the transcript.

Llach: Thank you, David. I was building on Jon Peddie's point of the military origin of computer graphics and CAD, and that resonates with the histories I've looked at. The contracts at MIT for computer aided design in 1959 were funded by the U.S. Air Force with the specific purpose of more Air Force per dollar. So, there was a clear intent to mobilize computer technologies towards the production of military artifacts. There's something I want to add to that, which kind of complicates the single origin story a little bit, and it's the fact that those contracts at MIT emerged from existing research on numerical control.

Kasik: Right.

Llach: And that numerical control research was really the foundation for what later became CAD research. And numerical control research was aimed at automated manufacturing and there was a lot of industry involvement there, in particular the Parson's Aircraft Company in Michigan. This relates to Dave's point of industry involvement. Since the 1940s it involved trying to get machines to produce parts [automatic ally]. And it was the many problems that these people encountered in automating those parts [manufacturing] and producing the information required to cut parts using a milling machine that led them to think of, "Okay, what could we do with computers to improve the process. And I think that's an important and interesting element here.

Brock: And just to talk about that point, Daniel, if I'm not mistaken, the numerical control program that MIT was using was the Whirlwind computer, was it not?

Llach: Yes, yes.

Brock: Which was, itself, funded by the Air Force, so you kind of have this loop. You know, Sutherland at Lincoln Laboratory was paid for mostly by the Air Force using the TX-2 computer, which was paid for by the Air Force.

Llach: If I may add something to that, the TX-2 computer itself was more based on the SAGE system, the Semi-Automated Ground Environment, trying to kind of use these ideas of interactivity and computer graphics in a more even context.

Other Development Centers

Peddie: You guys are leaving out Manchester. Manchester did a lot of this preliminary work also.

Marks: Also, the Royal Air Force was a leader in some of the early analysis stuff. I will say, I'm going to moderately disagree, Jon. I had like a lot of government funded stuff, too, but I think it's passionate people like the Parson's that are looking for money. And in the old days, it was either the government or a big company. Today, it might be venture capital-- And so, you always need somebody to say, "We're going to take care of your living expenses for the next couple years while you build this thing." But I don't think the visionaries came out of Dayton for the Air Force or something like that. I think it was the visionaries looking for money and support wherever they could find it.

Peddie: I'll disagree.

Marks: Okay.

Peddie: I mean, think about VR. VR and AR totally came out of Wright-Patterson Air Force Base. And why? For pilots. Sutherland gets a lot of credit for his VR. you know, Damocles Sword thing, and so forth. But that was a lab project and-- interesting, and innovative, but VR got its tick from the Air Force.

Marks: Yeah, when I was in Cincinnati, a lot of people wanted to go to Dayton. Not so much because it was the Air Force, but because they could get to work on cool stuff.

Peddie: And they still can.

Kasik: Yeah, so ironically, the display equipment that Sutherland used for the Sword of Damocles-- is the name of the project for his VR stuff-- came from surplus Air Force goggles, or some sort of Air Force funded piece that he scrounged.

Peddie: Well, it came from Bell Helicopter. Bell Helicopter and FOCO were the ones who started that, and he scrounged that stuff.

Kasik: Anyway, there were lots of things that I think we're going to get to again and again, but I think the comment about the computer aided manufactured from Daniel is quite true. The work that Doug Ross was doing at MIT in the late 1960s certainly influenced what happened at General Motors. What is definitely the key instigator is that the requirement of defining complex shapes is something that is really difficult to do in a computer aided drafting environment because it's basically a 2D representation. When you move off to 3D and have to design complex surfaces that are aerodynamic for either for the Navy or shipbuilding, for aerodynamics, for aerospace or aerodynamics for auto, the whole world changes in terms of how you have to define those things. And that's where the computer aided design comes in.

Mathematics for Lines and Shapes

Grad: But where's the mathematics come from, though, to do that?

Kasik: So, there's actually an interesting thread, and I've got some information about where the mathematics generally came from-- certainly in the late 1960s and 1970s it came internally from the companies that actually wanted to build things.

Peddie: Also, a lot of came from Cambridge…the Cambridge program.

Kasik: And also the CAD Center. Thanks for adding that, Jon, because the CAD Center was a big deal with Malcolm Sabin in terms of what happened with defining complex shapes from Pierre Bezier at Renault. It was also absolutely critical in defining surfaces for automotive work from Steven Koons at Ford and Bill Gordon at General Motors.

A guy named Oberhauser, also with Ford, did a lot of work. And there was some work about splines which was also really interesting. We're going to talk about that a little, but I'm not sure when that will come up, but I think the whole notion about how the mathematics was made is worth discussing. So, I disagree, Ken Versprille did not invent splines, B-splines.

Holtz: B-splines.

Kasik: Yeah, so he might have done V-splines, but his name doesn't appear any place in terms of the evolution of B-splines.

Peddie: The NURBS [Non-Uniform Rational B-Splines]

Holtz: I'm sorry, it was NURBS. Ken was NURBS.

Kasik: He also didn't do NURBS. Ken might think he did, but I have not seen any evidence to that effect. I need a reference other than Ken.

Holtz: His thesis.

Kasik: When?

Holtz: I'll have to pull it out. It should be in Dave Weisberg's book.

Kasik: Okay, I didn't see it in Dave's book. I'll take a look. Anyway, there is lots of stuff that happens in terms of getting the math right. When it comes to systems in Europe, a lot of the work I understand was done initially at Dassault Aviation, that begat CATIA, was done in response to computer aided manufacturing requirements.

Payne: That's correct.

Hirschtick: I was just going to add another person I can't believe we've gone so far without mentioning is Pat Hanratty. Because he definitely deserves a mention here.

Marks: I mentioned him as part of GM. Just very briefly.

Hirschtick: Very briefly. I'm sorry, I shouldn't say "not mentioned" but not dwelt on, because he also was a colorful figure as was his work. Others here can probably say more about it. I was lucky enough to know him-- may he rest in peace-- and talked to him a fair amount about his experiences in the industry. And there was a lot of code that stemmed from his. I'm trying to think if he was the first commercially available software that was sold. I don't know that, but it would be close to there, which is an interesting development.

Peddie: I think MCS made the first commercial CAD.

Hirschtick: Okay, but he definitely deserves a mention here. Another product that probably squeaks in before 1980 is CADAM. And I kind of choose them as another commercial offering that's sort of emblematic of a generation with hundreds of CAD systems we could talk about all day long, but like what deserves a tick mark in this era in terms of telling this story? Certainly, CADAM and Pat Hanratty and his various named products. You know, MCS, Adam, and whatever he called these things. And he had a company before MCS, too. And the famous stories of him, I guess selling numerous exclusive source code licenses or something. I've heard about that.

And the other thing we mentioned is there's a lot more people in the research community. Of course, I'm not the only one who knows these things, but we got to give a mention to David

Anderson of Purdue, who was doing research certainly before 1980. He wrote a really seminal paper and a system called Metaphor, which was a really interesting thing. We mentioned Gotthard at MIT. Cambridge University, I think, Mike, a couple people touched on, but you really have to draw a big circle around Cambridge University in the U.K. as being a major center of thought. And if you look at concepts that last, well, there's a lot of talk about different ways to model 3D geometry, certainly the boundary representation, for which I give the folks in Cambridge a lot of credit, if not for dreaming up, certainly for hardening into something that could be used en masse, and we'll get to in later chapters of the story beyond 1980, But certainly there's a lot that goes there. Tokyo University, another place. We mentioned Utah. Rochester, of course. People like Rakisha and Volker. You know, I'm just digging this out from memory. So, just seeding, I know there's others here who can add a lot to those just fleshing out some of the story there.

Peddie: I'd like to make a sidebar comment. But this feels very much like a salon and reminds me very much of the roundtables we used to have at COFES. I like the feeling of this. The interactivity of it.

Lack of Diversity

Hirschtick: And I'll make another side comment. If you look at the faces in this video, it's a pretty sad statement about the lack of diversity in our industry. I mean, this represents precisely one very narrow demographic slice here. It’s the realities of our industry, but it's worth noting in today's world.

Brock: Definitely.

Grad: Were there any women involved, besides Carol Bartz at Autodesk?

Hirschtick: That's an interesting question. Who were the earliest women involved in shaping the CAD industry? There were women who worked in it when I got into it in 1981. Certainly, there were women who worked in the industry. But in terms of a leader from the 1960s through 1980s period, I'll give that some thought and come back to you on that.

Peddie: On the hardware side, there's a lady by the name of Mary Whitten, who built the first frame buffer. And she's still going strong, and she's running the history group at SIGGRAPH right now.

Grad: Good.

Marks: Totally different thing, but Lynn Allen was a phenomenon for Autodesk for many years. She would have a thousand guys wanting to buy AutoCAD.

Hirschtick: Yeah. Yeah, but Peter, I think we're talking 1960s through 1980s now.

Marks: Yeah, yeah, you're right. You're right.

Hirschtick: And I don't think she'd even want to be associated with the 1960s.

Marks: Absolutely not.

Hirschtick: But you know, just keep in our timeframe here according to the agenda.

Holtz: And Carol didn't come until mid-1980s.

Bass: 1990.

David Hemmendinger: What about Hilary Kahn at Manchester? She started the CAD group in the late 1960s there. Do you know anything about her?

Peddie: Never heard the name.

Hemmendinger: Oh, you could look her up in Wikipedia, which I just did. Okay. I only know what I just read on Wikipedia.

<u>Sutherland Influence</u>

Brock: I did want to return, if I could, briefly with a question of my own about Sketchpad and the influence of it and Sutherland's work on it. I'm wondering about the mechanism of the influence. How was it influential? Was it through people's direct experience? Was it through references to it? Was it from people talking about it? Was it people seeing early CAD systems and people saying, "Hey, this is like Sketchpad." Any thoughts that people had about the way in which it was influential, I'd be very interested to hear if anyone has those.

Marks: I have two quick thoughts. One is that I think there were two paths of influence. One is through people like Jon [Hirschtick], who studied this stuff, saw the thesis, and were inspired by it. But that's a pretty small number. Then there were people like myself, who didn't read the thesis, but sat in the company that bought one of the first Picture Systems and were blown away, I mean, this was just like IBM mainframes used to be set up on a high stage and people, at every company that had one, would walk by it as if it was the holy shrine of their advanced technology. The VNS Picture System looked like the Starship Enterprise had been landed some place in your company, and I think it was influential in that way. Beyond that, I think as we got low-cost CAD systems where people could get their hands involved, like Tom

Lazear's early Apples and stuff like that, that probably became the dominant influence propelling the thing forward.

Bass: I think CAD has always had this weird dichotomy. It's always been aspirational. Let's go back to what Jon said early, whether we're half-way there or a quarter-way there. On one hand, it's been totally amazing what people have been able to do with it. And on the other hand, it's been amazingly frustrating that there's always this aspirational belief. And so, the aspirations of the industry have always way exceeded what the commercial products provided.

I think in the early days everyone was moving around entities of lines and circles and RX and text, and all this stuff, and manipulating and managing it has always been painful, and continues to this day to be painful. And I think there was always this marker out there when someone said, "The computer could do more. It can help manage these relationships. It can constrain it in certain ways." And that was always the homage to Sketchpad. So, any time someone said, "Oh, you shouldn't have to change everything manually", and there was some degree of automation involved, everyone always referenced Sketchpad [and Sutherland] as the first person who had the idea that it was going to go beyond a purely documentation exercise for recording where the lines and the text goes.

Payne: You're completely right, Carl. But computers merely work…

Bass: Mike, I'm just going to write that down, because I don't think you've said that to me in 40 years.

Payne: But seriously, people have more imagination than a computer. And there's always a way that a computer will break, much as you think your software is lovely, there's always somebody that uses it in a strange way. The first bug that we ever had reported in SolidWorks was a curious shape, but you couldn't figure out what it was. And it didn't work. And we asked the guy, "What is this shape?" And he said, "It's a bone implant." So, you wanted to say, "Why don't you use a bone implant product?" And he said, "There aren't any, so I used this one." And I think that people expect computers to do everything for them, and they can't. So, I'm not being bug eyes about it, But I think you're right. Don't record that bit, Carl.

<u>**Revisitng NURBS**</u>

Kasik: First of all, I wanted to offer a little bit of clarification from the controversy that I was causing about NURBS versus B-splines versus splines. Splines started in the 1940s. B-splines started in the late 1960s and traced back to splines. Rich Reisenfeld was the grad student who did that work at the University of Utah. And Brad is correct about Versprille doing non-uniform rational B-splines, which is yet another permutation of generalization of B-splines.

So, it looks like we have the thread that I didn't realize about Versprille's involvement there. Thank you, Brad. So, that's number one.

Number two, there's an interesting comment about changing things that have mutual dependencies. There are still just a few constraint-based systems that are practical and useful. Part of that is because as Michael points out, constraints can be broken. Right? They don't always work the way you want. It's the same reason that expert systems can break because there are constraints that you apparently just can't solve correctly. What I'm surprised that nobody has mentioned so far is the role of configuration management in terms of taking a bunch of computer-based assets, figuring out how they're all related together to make a single product. Because with all of this design and drafting and everything else, ultimately you want to put into something that represents a building, or a ship, an aerospace product, an automobile, or whatever. And doing so is a pain in the butt. Right? And keeping it up to date and configuration managed, would you all consider that to be part of computer aided design or not?

Marks: I can answer that question in that someplace in one of the documents I put a little thing about four thinking styles and we use language, we use graphics, we use analytical representations. The three of those make a kind of a digital protocol. And to me, all four of them, I mean, this group is focused on geometry because of time constraints, but things like the data management systems, product data management, configurations for those are absolutely part of it. Part of the SDRC history, I mean, Al Klosterman, and Rick Briggs and I kind of sat down and said, "We need to add this to the design system." And it's clearly part of it, though I don't think we're going to have time to really trace the history of it.

Kasik: I agree, I just want to make sure that we don't lose that train of thought. Because it's that whole thing about how to keep the configuration management is a really big deal.

Marks: And the simulations that go along with a product, too.

Kasik: Okay, and I'll add one little piece. And that is about the genesis of a lot of this -- B-splines and non-uniform B-splines--also traces back to Syracuse University where Rich Reisenfeld-- and here's an important lady's name and that's Elaine Cohen in terms of the mathematics involved, who is still Rich's wife in Utah. But they all started at Syracuse as did Versprille. And Steve Koons was part of that, and Bill Gordon was also; he was actually Reisenfeld's PhD advisor.

Converting Design to Drawings

Holtz: Yeah, just real quick, and I'm got to step away for a half an hour, but I just put a link in the chat to a five-minute video where a professor basically says, "You know, I can show you in two minutes exactly what I mean and what I want," and it's going to take you a day or two to actually make that design happen on a CAD system. And we're still working on dealing with that today. It's a short, parataxis video. But the idea is very, very simple. And the question is, you know, "Why does it take us that long to actually get that into a usable system?"

Peddie: To that point, then, I'd like to add you want to do what Brad is saying specifically is think about Allen Kay, because Allen Kay's idea was you could exactly do that; instead of sketching on a napkin, I could sketch on a tablet and that would get into the computer and be a real model. And the computer would figure out what the geometry should be because your sketch wasn't that accurate.

Holtz: Well, the Jupiter Project by Medlock's team at Intergraph, which eventually wound up somewhere else, was an early stage of you can sketch something and then it converts that into actually solidified 2D and 3D geometry.

Bass: But the interesting thing about that vein of work is that it's never really materialized into anything meaningful.

Holtz: I agree.

Bass: You know, now just reflecting upon it, and the first point is that drawing is a specialized skill. The second thing it focuses on is the kind of naïve way that researchers like those at PARC would have done this, if they somehow thought that this was an interesting thing to pursue. Where it turns out that the physical requirements, the engineering requirements, whether structural or optical or fluid, are way more important. And if you look at the things that are being done today in generative design, it's actually way more interesting than just converting what people draw. Now that we're looking at the history of it, it is just a little bit of a carnival trick.

Marks: I've got a question to the group, was the first NURBS-based system built within this 1960 to 1980 timeframe? I know Al was saying that Les Spiegel and Wayne Tiller, of SDRC, moved to that pretty early and that was like right at the end of this time window. Did anybody actually have a commercially successful system before that?

Kasik: Boeing tried to build such a system, and that's the one that failed. That was the system that I built, and it was in the early 1980s.

Marks: Was GeoMod the first one that had any commercial traction?

Kasik: I think it was to my knowledge. So SDRC did a really nice job. Wayne Tiller is still active as well with some of the Boeing map guys.

Marks: And Les Spiegel was important, too.

Payne: I'm not sure that we should speak about NURBS as being the ultimate perfection of geometry, because it's not. We will never solve the problems of the mismatch between geometry and topology, however hard we try, and however many PhDs in mathematics you've got. There will always be cases that don't work. I have a favorite example that you can't model, called the World War I German Helmet, with the spike on the top. You can take the piece of metal, you can put it in a press, but you can't bloody model it.

Peddie: If that were true, we wouldn't have the Utah Teapot.

Payne: Well, they had a press to make the damn things, okay? But they didn't model it first, because you can't make it.

Peddie: A similar problem we used to have in GIS, when you use polygons for GIS, talking about topology, you lay one polygon over the other, and now you have three polygons. What's the one in the middle belong to?

Payne: Well, that's right. I mean, take the case of a cylinder. Stupid, simple cylinder, put it at an angle and have it touch the piece of paper, and you've got an innie-outie problem, because BREP says you have.

Peddie: Every edge, yeah.

Payne: Right. Every edge has to have two surfaces.

Kasik: So, what's your suggestion on how to do it?

Payne: Well, some bright person in a university, or not, will figure out something that will supersede BREP.

Peddie: No, it's going to be Chat CAD. Exactly.

Payne: Oh, yeah, there you go.

Brock: Thanks, everybody for rejoining, and we're happy that we're joined by an additional person, Joel Orr. Joel, could you maybe just introduce yourself for about five minutes, and your connection to the story of CAD?

Joel Orr

Joel Orr: Thank you, David. Sure. I came in, as I suspect that some of you have as well, through one or more backdoors into the world of CAD. I was involved in mathematics for a while, but I think mostly I came in as a dilettante. Someone who is interested in everything, but not for long. I wound up initially in what we all used to call computer graphics, just creating pictures on a computer was such a big deal. And in the beginning, we weren't sure whether business graphs and charts would be a major part of this, or whether it would be engineering work. Those were all big questions. And so I got involved in the…let me just stick to what I remember of your hierarchy, David, the introduction of new ideas along these lines. Mostly not my ideas, and how things would work, and what the implications of new technologies were and so on.

And there were lots of big thinkers initially. I was delighted to meet many of them and be influenced by them. And I wound up bringing home-- well, I wouldn't bring home bacon to my house--but in the area of helping people make the large decisions about investments in the large systems that were in the tens and hundreds of thousands of dollars. Wait, there's another guy who just showed up here that is vaguely familiar. Hi, Carl, you too have done this. So I wound up producing some publications and speaking a lot, when I found out people would pay me money for just talking. That was great. That was much less work than writing and so on. And then I stuck with that for a long time, and then took a break some years ago, partly for health reasons and partly for just life cycle reasons. And here I am back, and it's all Jon Peddie's fault, because he invited me to come back.

Peddie: I pulled him back.

Orr: Yes. He invited me to come and play with him, and so we're playing together now. I think that's it.

Brock: Let's end the 2nd session here.

END OF DAY 1 SESSION 2

