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Daniel James Edwards

Transcript of an interview
conducted by

Christopher Weaver

at

National Museum of American History,
Washington, D.C., USA

on

30 November 2018

with subsequent additions and corrections

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Abstract

Daniel James Edwards begins the oral history by discussing his early family life, education, and his initial study of physics and electrical engineering. Following his academic pursuits at the Massachusetts Institute of Technology (MIT) and his exposure to early computer technology such as the IBM 704, he recounts his engagement with MIT's Tech Model Railroad Club, where he met other members of the *Spacewar!* development group. Edwards discusses the technical difficulties and specifications required to implement several of the game's key features, such as the star-oriented gravity field. He concludes with reflections on his work and thoughts on the emergence and potential of the video game industry.

About the Interviewer

Christopher Weaver is a Distinguished Research Scholar at the Smithsonian's Lemelson Center for the Study of Invention and Innovation, Distinguished Professor of Computational Media at Wesleyan University and Director of Interactive Simulation for MIT's AIM Photonics Academy. He has contributed to over twenty-five books and publications and holds patents in telecommunications, software methods, device security, and 3D graphics. The former Director of Technology Forecasting for ABC and Chief Engineer to the Subcommittee on Communications for the US Congress, he also founded the video game company Bethesda Softworks. Weaver is co-director of the Videogame Pioneers Initiative at the National Museum of American History, recording oral histories and developing new applications for interactive media and public education.

About the Editor

Justin S. Barber provided transcript audit-editing, emendations, and supplementary footnotes to this oral history as part of his broader work into video game history and digital museology.

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Video Game Pioneers Oral History Collection

Interviewee: Daniel James Edwards

Interviewer: Christopher Weaver

Date: 30 November 2018

Location: National Museum of American History, Washington, D.C., USA

Weaver: Good afternoon. Would you mind please stating your full name, where this interview is taking place, and the date?

Edwards: My full name is Daniel James Edwards. This is taking place in the Smithsonian Museum of American History. This is November 30th, 2018.

Weaver: Thank you. The first thing that I would like to do, Mr. Edwards, is ask you about your early life. Would you tell us where you were born, something of your mother and father, and whether or not you have siblings?

Edwards: Okay. I was born on September 4th, 1937, in Bridgeport, Connecticut. I'm the oldest of seven children, six of whom are still alive. I grew up in Pittsburgh, Pennsylvania, moved to Cincinnati, Ohio, from there to the Cleveland suburbs of Shaker Heights, where I graduated from high school. I went on to MIT as an undergraduate in the physics program.

Weaver: Can you tell us a little bit about your parents, what they did?

Edwards: My father started off working at General Electric in Bridgeport, Connecticut. When the family moved to the Pittsburgh area, my father was involved in finance work. We moved to Cincinnati, more finance, and in Cleveland, my father was involved with the treasury of the C&O [Chesapeake and Ohio] Railroad, which was located in downtown Cleveland.

Weaver: And your mother?

Edwards: Mother was a full-time mom. We had the privilege of, later in our life, a live-in maid who helped raise the growing family of kids.

Weaver: I want to talk a little bit about your early life. The first thing is, what do you remember early on about things that sparked your interest in science?

Edwards: Well, in 1945, I was with some friends listening to a radio program, something like *Tom Mix*, when the program was interrupted by a special announcement. We, as kids, were annoyed at having our program interrupted, but the announcement was that the atomic bomb had just been dropped on Japan. I remember walking home trying to get some sense of what in the world was going on with an atomic bomb going off.

In school, one of the things which we had was an art class. I didn't enjoy art very much, so I drew a diagram of a chain reaction; that is, interaction of one particle releasing two particles, which would touch four particles. Got up to about sixteen on my art project. The art teacher looked at this and said, "Uh, you'd better go see the principal of the school."

So, I took my project and walked into the principal's office and explained what I had drawn, and he said, "Hmm. More people need to know about this."

And I had to walk from classroom to classroom breaking in, holding up my diagram as a fourth-grader and explaining what's a chain reaction. So that was one of my first encounters with science and science-related things.

Later on, I was interested in computers. These were just getting started. In *Popular Science* magazine, they had diagrams of an adder [adding device] made out of relays. I took some of the earnings from my paper route, essentially, sent off to Parts Place in Chicago, assembled a bunch of relays, and put together a four-bit adder, which was part of a seventh-grade science project.

I continued to be interested in computers. My father was involved in the Chesapeake & Ohio Railroad. They had an early UNIVAC [Universal Automatic Computer] machine, and I actually got to go down to the office and see the UNIVAC. The UNIVAC was a very large machine. I think the *Star Trek* control console was based on the UNIVAC computer. It certainly looked a whole lot like that. The UNIVAC computer, you could actually walk around inside the mainframe. It was vacuum-tube operated and they had an emergency line which you were strapped to; in case you fell down inside it. It would pull the switch and turn off the electricity.

One fascinating thing about the UNIVAC machine was that the tapes on the machine were metal tapes. They were wound on spools which had square hubs. You might ask why in the world would you wind something round with a square hub? The answer turns out to be they needed a way to sense when you were getting close to the end of tape, and the tape head ran through a bunch of pulleys, through the tape head, on to the other room. When the pulleys jumped up and down, that was the signal that you were getting close to the end of tape.

Weaver: Prior to college, was there anything else noteworthy, either in your science background or your introduction or use of computers?

Edwards: Let's see. I continued in high school to be quite interested in computers and computer-related things. My favorite class was a physics class. I got bored doing the algebra problems where you had to write everything out. I decided it'd be worth trying to solve the algebra problems in hexadecimal. I then had to explain to the teacher the system that I was using to write out the answers to these math problems.

I started off in college as a physics major. I was interested perhaps in being a nuclear physicist, but when I found out what physicists really did in terms of writing research proposals, I switched to electrical engineering because that's where the computers were. At MIT [Massachusetts Institute of Technology], you would think computers would be with the math department. No way. Computers were too practical for the mathematicians, so they let the electrical engineers do things.

One of the projects I did around home when I was in high school was to build a small PBX, private branch exchange, for the house. The single [telephone] line which came in could be routed to four or five telephones which I had scattered around the house, and you could dial from one number to another. So, very early, trying to get into electrical logic, that sort of thing.

Weaver: When you were at MIT, what instructions were you given in terms of how many classes did you take, what labs did you participate in, that sort of thing?

Edwards: Most of it was doing electrical engineering sort of things, but I was able to take an IBM [International Business Machines] 704 programming class, which got me started in really doing some of the programming. Also, on campus they had a TX-0 [Transistorized Experimental Computer Zero] computer, which was brought in from Lincoln Labs. This was a solid-state computer but took up the best part of a room. In order to be able to use the computer, you had to prove that you could write some programs. In this particular machine, the program was entered through toggle switches on the main console. I remember the first attempt that I made to draw a square on the CRT [Cathode-ray Tube display] resulted in two lines of a square and then some random dots and the pattern jumped all over the screen. That said, hmm, not quite what I was trying to do, so I had to sit down and debug that particular program on the sense switches.

Weaver: When you were a student at MIT, were you a member of any clubs?

Edwards: The club that I was a member was the Tech Model Railroad Club [TMRC]. This was in Building 20. It was about two rooms full of telephone relay switches and a main line which went between several towns. There were four or five different control stations, which could run trains and telephone crossbar switches which would connect the control stations with the particular blocks of traffic or on the train setup.

One of the things that we sometimes did was to run imaginary trains around the layout. Underneath the layout was a set of panels and jacks to mark each of the blocks for the computer. With little plugs, you could move it from block to block and make it appear on the map as though a train were going from A to B through the different sections. We called this a J train. In electrical engineering, "I" is real, and "J" is imaginary. So, we occasionally ran J trains around the TMRC layout.

Weaver: How did you become involved with the Artificial Intelligence [AI] Lab?

Edwards: When I was close to graduating, I lost a few credits switching from a physics major to electrical engineering. They were looking for programmers to work on the artificial intelligence project led by Dr. John McCarthy and Dr. Marvin Minsky. They were working on the LISP [LISt Processor] 1 computer programming system at that point.[1] Steve Russell was involved in writing the interpreter for the LISP system. We were running on an IBM 704 computer at the time. One of the challenges was running out of free storage for the LISP processing. Jim Slagle was busy working on his Ph.D. thesis, which was symbolic integration, and he would get his LISP program loaded into the IBM 704 computer. It would run for about forty-five seconds [before the computer was] out of free storage.

Dr. McCarthy outlined the idea for a garbage collector, something which would go through memory and find portions of LISP which had been abandoned during the computation. I got to implement the first garbage collector program, which would go through memory looking for the active lists, noting things which were no longer reachable, collecting all of those into a new free storage list so that the program can continue. [Once a program ran out of storage,] the garbage collector was called. It ran for about forty-five seconds and gave a new batch of free storage for the symbolic integration program to run. It took at least four or five minutes before things sort of ran out of resources on the IBM 704 computer at that point in time.

Weaver: Did you also work on Multics at that time?[2]

Edwards: At that particular time, the CTSS [Compatible Time-Sharing System], which was sort of the predecessor of Multics, was the timesharing system. I remember doing a master's thesis on computers using the CTSS. My wife-to-be came in and typed in the program on one of the Flexowriters connected to the CTSS system. Later on, in the mid-sixties, I transferred from the Artificial Intelligence Lab and did some programming on the Multics system also.

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[1] LISP is the second oldest high-level programming language, invented by John McCarthy at the Massachusetts Institute of Technology (MIT) in 1958.
[2] Multics is an influential early time-sharing operating system which is based on the concept of a single-level memory.

Weaver: Did you know about the hacking scene on TX-0 down the hall?

Edwards: I certainly knew about the programming, but that was about the time that the PDP-1 computer arrived on campus. I didn't do a whole lot of TX-0 programming. Only enough to show that I could be trusted to work on the machine without somebody looking over my shoulder

Weaver: So how did you get involved on the PDP-1 [Programmed Data Processor One]?

Edwards: The PDP-1 was available for staff to work on as part of the artificial intelligence research that we were doing. One of the things that we thought was indicative of a computer being smart was it being able to play some sort of a game. Dr. Arthur Samuel from IBM came through with his *Checkers* program that was running on the IBM 704 computer at that time.

As part of our artificial intelligence research, we were looking at different ways for computers to play games. One of these was a look ahead and evaluate. That is, look at the game board, figure out what all of the next possible moves are, play those out, repeat this going through the game as far as we could, [and] evaluating at each stage whether the position was favorable or unfavorable. Some of these games were fairly simple games, but the game tree got pretty deep. I think it was Dr. McCarthy who articulated an alpha-beta search program which would reduce by a very significant fraction a portion of the game tree to be examined.

We used the PDP-1 to play an African game called *Kala*, which consisted of a board with two rows of six little depressions in it. Stones were placed in each of the depressions. Players would pick up the stones, move them from left to right, depositing in two deposits at either end of the board the stones going to the other side. Where the last stone dropped, it would capture all of the stones on the pit, which was directly across, and the person who had accumulated the most pits won the particular game. We were able to completely solve the three stones in each pocket, six pits on either side game and prove that it was a winner for the first player, as I recall. That was programmed on the PDP-1 computer so that folks could use the light pen to play the game.

Weaver: DEC published a pamphlet on the *Kala* game in 1961. Was it yours?

Edwards: I believe so. I certainly don't have any of the artifacts which go back to that, but I believe that to be some of my work.

Weaver: Did you interact with the undergraduate hackers such as [Peter] Samson, [Alan] Kotok, etc.?

Edwards: Alan was certainly active in the Tech Model Railroad Club. Pete Samson was part of the TMRC. We would do various TMRC-related outings, like going on the very last streetcar run on a particular portion of the MTA [Massachusetts

Transit Authority] in Boston. [We] were able to take home a few souvenirs from the last streetcar. Other folks from TMRC participated in the ride every stop, every line, in the New York subway system. I never got that deep into that part of the MIT Tech Model Railroad Club.

Weaver: How did you learn about *Spacewar!*?

Edwards: From Steve Russell. Steve put together an initial version of *Spacewar!* and showed it off on the PDP-1 and the Model 30 display. At that time, there was a little flickering star in the middle, but the star had no effect on the particular spaceship, and I said, "That star ought to have gravity associated with it."

And Steve said, "Fine. Why don't you implement gravity for the *Spacewar!* program."

I said, "Well, okay. I think I can do that."

As we implemented gravity, it took a toll on the overall execution speed of the program. We wanted to keep it up to 30 frames a second so that it would appear smooth. We needed some way to speed up the overall execution through the main loop of the program.

One of the things which took up some amount of time was interpreting the outlines of the two spaceships that were on the screen. These were in a matrix, essentially, op [operation] codes which would show one half of the spaceship and reflect it to the other side. Every time the [operating codes] went through the main loop, the outline of the spaceship was interpreted once again with an appropriate tilt, depending upon how the spaceship was oriented with respect to the way it was actually moving.

The notion of compilers was alive at that point. COBOL [Common Business Oriented Language] existed. Fortran [Formula Translation] existed. I said, "Maybe we can get some additional speed out of this by taking the outlines of the spaceship and compiling them into code, which ought to operate much faster than the interpreter." So, I implemented the outline compiler, which appears to have been one of the first implementations of a just-in-time compiler in a computer program. I never particularly thought about it at the time. I was simply interested in doing something to help speed up the main loop.

Weaver: Why didn't Steve program that addition?

Edwards: Well, I think, in his words, the nickname "Slug" meant getting someone else to do it. But I also think that was really part of the overall culture that we had. The notion of proprietary programs was left to the big computer companies. I certainly couldn't get in and work on the Fortran compiler. But as the hacker culture, essentially, "software ought to be open" was one of the hallmarks of our cooperative effort. Steve didn't feel like he had to have control over every instant, every instruction that went into that. He invited contributions from anybody who was willing to punch some paper tape and put a feature into the program and let Steve do the curation of the overall program. I think the open-source nature of that led to the longevity of the *Spacewar!* program. There were only fifty-five PDP-1s built, as I recall, so having the source code available may have sparked other people to pick it up and implement on other parts or other kinds of machines.

Weaver: Going back to the just-in-time compiler for a minute, was your theory proved true? And what was involved in the implementation of it that you had not foreseen initially and had to overcome?

Edwards: Did it prove true? Yes, I think it proved true. We were able to reclaim enough time to make the outlines of the spaceships appear and have them move smoothly without being annoyed by overall flickering. So, this small compiler, which ran once when the program was initialized, did save us enough time to do the actual game itself, but also left over enough time for Peter Samson's *Expensive Planetarium* to put up the slowly moving background of stars. Somebody would look at the *Expensive Planetarium* and say, "Why? What's the point of all of that?" The background stars essentially gave you sort of a frame of reference where you could steer your spaceship and having those being real stars I think simply added to the overall program by itself.

Weaver: Do you remember that you had any unexpected challenges in terms of implementing this compiler?

Edwards: I certainly don't remember. I recently went out to the Masswerk website, essentially, where a programmer from Germany did a deep dive on the code for *Spacewar!*, doing much more in the way of annotation of the code.[3] I would have to work to go through and follow my own logic. At this point, sixty-some-odd years has taken its toll on my remembering the details of *Spacewar!* in general and the outline compiler specifically.

There are a number of different variations on *Spacewar!*. When we were experimenting with different things in it, one of them was being able to turn the spaceships left and right. Initially, we thought these are spaceships, you use rockets to both propel the spaceship and turn it from left to right. In some of the initial versions of the program, you fired little rockets, essentially, to swing the spaceship from left to right, but that turned out to be too difficult for the people to accurately control on the controllers; that is, making a little pulse to the left, which would send the spaceship turning to the right and then a counter-pulse to try to make it stop where you wanted it to. That was simply too difficult, so we rationalized by saying, "Number one, this is in the future. We've got computers which can fire those rockets, so we can use something like a joystick to simply point the nose of the rocket from left to right." We would have liked to have

[3] https://www.masswerk.at/spacewar/ (Viewed on July 12, 2019)

had the bombs or the photon torpedoes also obey gravity, but there wasn't enough time left over in the main loop to make all those things on the interface be gravity-conscious. [We] came up with a "photon torpedo" wording to rationalize the decision that we made.

Weaver: How did coding on the PDP-1 compare to your regular work at the AI Lab?

Edwards: Coding on the PDP-1 was much more interactive than the work that I did at the AI Lab. When I was working on the garbage collector, essentially the entire LISP interpreter and the garbage collector part of it took up four racks, or four trays, of cards. So, you sat down at the key punch, punched up cards, had to put serial numbers at the end of each individual card to put the deck back in order when you invariably dropped a tray of cards and had the cards all over the floor. The card decks would be put across the counter to the operators of the IBM 704 computer. They would schedule a run. Middle of the night, you would get out a listing which was three-quarters of an inch or an inch thick which gave the results of the compilation and then a couple of pages of results from running your particular program. You got to sit down and figure out, "Well, that didn't quite work. What did I miss?" And repeat that particular loop for months and months. As I recall, it took about four to five months to get the initial garbage collector working to the point where Jim Slagle could continue for an extended period of time on his symbolic integration program.

With the PDP-1, our programming was done with a Flexowriter, which was a typewriter which had a paper tape punch associated with. The turnaround time between putting together a run of the program and getting some feedback was much, much shorter. The person who was writing the program was actually sitting, flipping the toggle switches, loading the paper tape, watching the screen, then scratching his head and saying, "What's going on there?" We were sitting down and iterating [instead of waiting for other people to run the program like in the AI lab]. So, the program development process on the PDP-1 with the *Expensive Typewriter*, the high-speed punch-paper tape, was much shorter than the punch-card way of doing business.

Weaver: Can you tell me about the public debut of *Spacewar!*?

Edwards: The public debut of *Spacewar!*, I believe, was at an open house probably in May of 1962 when there were a number of labs giving demonstrations. As I recall, that was probably the first introduction to a larger audience of *Spacewar!* program.

Weaver: Do you know anything about the relationship between *Spacewar!* and Digital Equipment Corporation [DEC]?

Edwards: I really wasn't involved in working with Digital Equipment. Alan Kotok was the one who had the much deeper connections with Digital, so Alan, working with Steve Russell, was the primary link, as I recall, between *Spacewar!* and DEC.

Weaver: Did you have any hand in spreading word of the game?

Edwards: Not really. The others in the team, essentially, were much more involved with the DECUS, DEC Users' group organization, than I was.

Weaver: So, I imagine that creating a just-in-time compiler in order to implement a star with gravity took a substantial amount of your extra time, spare time.

Edwards: Mm-hmm. [Affirmation]

Weaver: Why did you do it?

Edwards: The joy of working with a computer! Getting the feedback, trying to, one, understand the problems we were working on and then say, "How can I do that? It's not impossible. I don't have to wait for somebody else. I can figure this out myself. I can try it out. I can iterate through it. I can get it working. I can contribute to the overall project." The computers really had sort of a special grasp on me as a vehicle for taking an idea and turning it into reality like having a Lego set which was much richer than red, black, and blue blocks which stacked one upon another.

Weaver: When you were doing this, understanding that you obviously had played the game and had fun, could you have imagined what kind of an industry would spring from what you were doing?

Edwards: Not in the *slightest*. The industry was, in fact, making progress from the analog Harvard computers to the digital computers. With the big 704 downstairs in the computer lab, lights in Cambridge would sort of dim when all the vacuum tubes in that computer were fired up. The idea of having a machine that I could work on individually I think certainly exerted a great pull on me. The exceedingly good fortune of being able to spend time on a machine that cost $100,000-plus in 1962 when my monthly salary was on the order of $400 was certainly a very fortunate thing to come to pass.

Could I envision on how it would grow? No way. At this point, my iPhone has got more computer power than all of the computers that were involved in putting together the manned to-the-moon mission. That includes the mainframe computers, the computers that were onboard the spacecraft, all of the support computers. You could run all of those programs on your iPhone today and have time to spare. I had *no* idea that things would move that fast.

Weaver: Speaking of computers and evolution, what did you do when you left MIT?

Edwards: Well, one of the things that I was involved with, while at MIT, I took a sort of evening job with Bolt Beranek and Newman {BB&N}. One of the projects we worked on there was an idea I had for using a telephone as an input to computers. This was back in the day when touchtone hadn't been invented or widely distributed yet, but you could dial numbers on a telephone. As you dialed those numbers, relays clacked at the central office. You could attach an audio transformer to a telephone line and listen for the clacks or the pulses. As part of that project, a patent was drawn up called Data Dial in, oh, probably 1964, plus or minus, at BB&N. I think the patent on that was actually granted in 1972 or 1973. That was long after my short term at BB&N terminated.

I was part of the staff running the Artificial Intelligence Lab at MIT. I got interested in the Multics timesharing program that was the follow-on to the compatible timesharing system. [I] spent some time writing a couple of the subroutines which were in the Multics system. So, I got a firsthand introduction to the real challenge of putting together a very large computer program. I remember sitting down with the team in probably the fall of, oh, 1965 or so, where "Corby," Fernando Corbató, was the head of this Multics group, went around the room and said, "How long is it going to take you to complete your particular part of the next iteration?" People scratched their heads and tried to come up with numbers in the fall of 1965. I think it was April Fools' Day in 1966 before all those commitments were realized and the next iteration of Multics was released. Being able to accurately forecast how long it's going to take to build a computer program was an inaccurate science, to understate it.

After I left MIT, I joined the computer security research project down at Fort Meade in Maryland. Willis Ware had put together the Defense Science Board Task Force on Computer Security. Part of that was a technical panel trying to make predictions about what would be needed, what were the challenges in computer security. I got to play in that particular sandbox. Unfortunately, my name on the final report is listed as Daniel K. Edwards instead of Daniel J. Edwards, but, still, an introduction into computer security.

One of the sandboxes we got to play in was some of the penetration testing on early computer systems which were intended to keep classified and unclassified portions of a machine separated. They really wanted to use the benefits of timeshared computer systems. Since the timeshared computer systems were very expensive to put together, the idea of using these for both classified and unclassified processing was very popular with the administrators.

One of the things we got to do in computer security research was to see is it possible to keep a classified and unclassified part of it separate. I remember the look on the security officer's face when I was able to go up to him and say, "Is this your password to log on to this timesharing system?" I had done a little bit of research and found leftovers in the drum memory of the computer which turned out to be the login and password list and reclaim that.[4] So, having fun with computer security was sort of my next step in the computer odyssey which I was on.

[4] Drum memory was a magnetic data storage device invented by Gustav Tauschek in 1932 in Austria. Drums were widely used in the 1950s and into the 1960s as computer memory.

Weaver: Did you ever do anything else with games or the game industry?

Edwards: I played games. I certainly didn't get involved in the game industry. Trying to build computers. Understand the threats that were involved in computers. One of the things we wanted to do was build a way of protecting the ARPANET at that time sending classified information back and forth between various military posts. How could we do that securely? One of the issues that we had to deal with was, what are the threats that we had to protect against. The notion of computer programs which would masquerade as doing something useful but have an intended but hidden side effect was one of the threats that we dreamed up. I coined the term "Trojan horse attack" to describe that particular set of problems that we envisioned for computer security. That appeared in internal papers in the late sixties. There was a computer security conference at Princeton University about 1972 where I think the particular "Trojan horse" description made it to the wider computer security community.

Weaver: So, was "Trojan horse" a term you coined?

Edwards: Yes, that was a term that I coined in some of our research and study in computer security.

Weaver: Did you, whether assigned or not, come up with any other patents?

Edwards: No. The Data Dial patent was the only patent which I was involved with. One of the things that we were trying very hard to do was to get commercial manufacturers into the notion of building machines which could support secure operating systems. Corbató and the Multics system was one of the very first machines which tried very hard to separate execution of sensitive portions of the code from the run-of-the-mill portions of the code. The ring system for assessing where different portions of the program were run and the boundaries between that was put together as a result of the Multics computer security effort. The NSA [National Security Agency] working with industry to encourage other folks to put those sorts of things into commercial machines and get them so that they had multilevels of protection.

I remember Roger Schell, who was working with the Air Force at the time on rings of protection, essentially, going out to Intel when the 8086 microprocessor was first released. The 186 was just being wrapped up at that point. Roger Schell went out and talked with the chief engineer or chief architect of Intel, trying to convince him to add the things to the Intel line of processors. He said the 286 was too far along to make that impact, but the impact was put into the 386 line of computers. Those "rings of protection" continue to exist in computers to this day.

Weaver: What would you say to a young person to stimulate their interest in science or engineering today?

Edwards: I would say if you can dream it, you can do it. If you have an idea, try to figure it out. Try to use the resources which are at hand. Think about what you would need to do your dream. It can be done. The amount of resources which are at hand are totally mindboggling. Pick it up and do it. Have fun.

Weaver: And if you were going to try and help someone find their creative spirit, their innovative spirit, their inventive spirit, would your answer be any different?

Edwards: I would try to help them answer questions, but not give too much information, try to point them in the right direction, express enthusiasm for not only what I was doing, but, more importantly, what *they* were doing, what they were accomplishing with the tools and toys that we have today.

Weaver: You said that you were the eldest of seven. What did your six siblings do? And the other part of the question was, you said that your mother was a full-time mother, but my understanding is that she was a graduate of Cornell.

Edwards: That's correct.

Weaver: Which, to the best of our understanding, given the times, was somewhat noteworthy in and of itself.

Edwards: Let's see. Yeah, Mom was a full-time mom. I was four years older than my next sibling, so that by the time the third and fourth kid arrived, the household was quite full. As I say, when we were living in Cincinnati, we had a maid who lived in a subdivision not too far from us come and help the family. When we moved from Cincinnati to Cleveland, she moved with the family and lived up on the third floor of our house there, helping take care of all of the kids.

My mom was somewhat active socially with my father, but really I'm not even sure what major she graduated in at Cornell. Cornell was one of the schools that they wanted me to go to. We made a trip to Cornell when I was in high school. My grandfather, paternal grandfather, was chairman of the Alumni Association at Cornell around the turn of the century, as I recall, and having me as a Cornell graduate was one of the things. But I was interested in MIT and the family was well enough off such that they could afford to send me to MIT. A semester tuition back then was $900. We were all in a lather when it went up from $800 to $900 at the time, but I was blessed, essentially, with a very supportive family, allowing me to explore my initial interest in nuclear physics. [They] supported me all the way when I made the transition from physics into electrical engineering.

Weaver: And briefly, were any of your other siblings in science?

Edwards: Let's see. Not really. The four-year difference between me and my next youngest sibling sort of isolated me from their particular world; that is, when you're in junior high school, having a fourth-grader hang onto your coattails was not something which I particularly looked forward to.

But even in junior high school, I was interested in technical sorts of things. One of the things we did in high school was become interested in airplanes. A group of three or four of us put together something called the Great Lakes Aviation Association, which was a group of junior high-schoolers at that point. We, as a group, went to the airport in Cleveland, had a tour, essentially, of the cockpit of a DC-6 at that time, which was wall-to-wall instruments, dials, and all that sort of stuff. [We] said to ourselves, "Wow. That's awfully complicated. Isn't there some way to simplify that sort of thing?" And we sat down as a group, wrote off to Kollsman Instruments, and got catalogs of airplane instruments, trying to understand what they were. As part of our cover letter, we said we were the Northeastern Ohio Aeronautical Association. "We're interested in redesigning the cockpit of the DC-6. Could we have one of your catalogs?"

To our utter surprise, about seven months later, somebody showed up at our junior high school, called out the president of our organization, had him go down to the principal's office. This was a representative from an aircraft manufacturer saying that they had found out that we were interested in redesigning the cockpit of a DC-6; were we interested in a contract to work on that. Being absolutely floored seventh- and eighth-graders, we politely declined that. This may have sounded like an apocryphal story, but a number of months later, in *Aviation Week* magazine there was a blurb which said that a contract had been let from Boeing to Kollsman Instruments to work on the cockpit of the DC-6. Second paragraph, an offer was made to the Northeastern Ohio Aeronautical Association, but it was turned down for undisclosed reasons. [Laughter.] Part of the fun that we had is junior high school students trying to get involved in technical sorts of things.

Weaver: Dan, I know you have children. How many children do you have, and what do they do?

Edwards: We have three children and nine grandchildren. Our oldest is a full-time mom who runs her own yarn-dying shop through Etsy and does hand-dying and selling of yarn. Second daughter is an artist, full-time mom, but also taught art here in the Washington, D.C., area. Our son is working in the computer field with Red Hat Software. He went to University of Maryland, graduated in electrical engineering He has been in the computer field and worked together with my brother-in-law, who is extremely involved in interesting technical work derived from work that Nikola Tesla pioneered many years ago. Jonathan, our son, graduated from school. He is technically oriented, currently works at home, and lives in the New York City area.

Weaver: Thank you very much.

[End of interview]