

An Interview with
DOROTHY E. DENNING

OH 424

Conducted by Jeffrey R. Yost

on

11 April 2013

Computer Security History Project

Naval Postgraduate School, Monterey, CA

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Center for the History of Information Technology
University of Minnesota, Minneapolis
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Oral History 424

Abstract

Computer security pioneer Dorothy Denning discusses her career including her Lattice Model for Computer Security, research on database security, intrusion detection, and other areas, such as her influential textbooks. The interview also addresses computer security research infrastructure and collaborators at various institutions where she worked including Purdue University, SRI International, Digital Equipment Corporation, Georgetown University, and Naval Postgraduate School.

This material is based upon work supported by the National Science Foundation under Grant No. 1116862, “Building an Infrastructure for Computer Security History.”

Yost: My name is Jeffrey Yost from the University of Minnesota and I'm here today on April 11, 2013, with Professor Dorothy Denning at the Naval Postgraduate School in Monterey, California. This history is part of CBI's NSF-funded project, "Building an Infrastructure for Computer Security History." I'd like to begin with just some basic biographical questions. Can you tell me when and where you were born, and where you grew up?

Denning: I was born in Grand Rapids, Michigan. I grew up in Michigan, in Grand Rapids. I went to school at the University of Michigan.

Yost: And were there primary interests or aptitudes you had in primary and secondary school?

Denning: Some math aptitude. You know, not stellar; not genius levels, but [laughs]

Yost: You enjoyed math.

Denning: Yes.

Yost: Who were the greatest influences in your youth and adolescence?

Denning: Probably my father. He had his own business. I worked for him, starting at a pretty young age.

Yost: What kind of business?

Denning: He wholesaled building materials.

Yost: When you went to the University of Michigan did you know initially that you wanted to major in mathematics?

Denning: That was my plan, to major in math.

Yost: When you started in college did you have certain career aspirations?

Denning: Yes, I expected to be a high school math teacher.

Yost: As an undergraduate at the University of Michigan, did you have any exposure to digital computers or did you take any courses in programming?

Denning: My summer after my junior year I had a job working for the Director of Radio Astronomy at the University of Michigan. I was hired to do technical typing and miscellaneous office stuff. And after I was working there for a month or so — the director's name was Fred Haddock — he asked me to learn to program so that I could run some computations that I was doing by hand, through the computer. And so that was when I first started programming.

Yost: And what language or languages did you use?

Denning: MAD, Michigan Algorithmic Decoder. And I enjoyed that, so then in my senior year I did take a computer science class.

Yost: Bernie Galler was a long-time friend of our Institute. Did you have any classes with Bernie?

Denning: Yes, he taught the class.

Yost: He taught the class?

Denning: Yes, it was a lecture/lab and he did the lecture. A big class.

Yost: And, as I understand it, you graduated in 1967 with a B.A. in Mathematics.

Denning: Yes.

Yost: Can you tell me about your decision process to go on for a Master's Degree?

Denning: I'm somewhat vague about it but my best recollection is that I tried to get a job teaching in Ann Arbor and I couldn't. I don't remember how hard I worked; maybe I

didn't work very hard to find a job. But I did want to stay in Ann Arbor so then I looked at the second option of going on for a master's and working in radio astronomy to support that. And so that was what I ended up doing. So I had a full time job in radio astronomy and they let me do the master's degree. Since I was working for the university, I didn't have to pay tuition. It was a great deal.

Yost: And initially, in thinking about a career in teaching high school math, did you need to also take a number of education courses?

Denning: I did when I was an undergraduate.

Yost: As an undergraduate.

Denning: Yes.

Yost: And I understand that you did work at the radio astronomy observatory in the programming of simulated NASA satellites?

Denning: Yes.

Yost: Can you elaborate on that topic?

Denning: Well, we had projects on some NASA satellites and what we wanted to know was when these satellites would be in a position to receive radio signals from various sources. And so what my program did was it simulated the path of the satellite and looked for the intersections of that with the area in which they would be able to receive satellite signals from whatever source. So it was looking for the times when — I don't remember the terminology, exactly — but it was something about occultation of radio sources, and so there were areas where they wouldn't be able to receive the signals because of atmospheric conditions and things like that.

Yost: And what did you do your master's thesis on?

Denning: I didn't have to do a thesis, just course work. So I got the math master's degree, but it had a computer science option.

Yost: Can you tell me about the different computer science courses you took and computer-related courses you took as a graduate student at Michigan?

Denning: I only took a few courses. I had the one course as an undergraduate, and then as a graduate student, I think it was a more advanced course in computing; it was taught by Bruce Arden. And then there was a seminar that was jointly taught by Galler, Arden, and somebody over in the computing center. I can't remember his name anymore. And then I took also one or two classes in numerical analysis.

Yost: Can you recall what computers were in the computer center when you used it?

Denning: I'm not sure, but I think it was an IBM 360. It was in that 360-370 range that was running the MTS system.

Yost: And in the course of getting your master's degree, who were the most influential faculty members you remember?

Denning: Galler was probably the number one, and Haddock the professor in radio astronomy. He was just a joy to work for because he was so inquisitive and interested. He was interested in everything I was learning about computers. And then before I left Michigan, my last summer — it was actually before the last summer — but spring term, spring semester, I was a T.A. for Galler for the same course that I had taken from him before. And so I was leading one of the laboratory sections.

Yost: And the title of that course, do you remember?

Denning: I remember the number, 473, but I don't remember the title. It's probably on a transcript somewhere. When I was doing that I think I was still part time with radio astronomy. But then in the summer, my recollection is I went full time with the computing center as a systems programmer and consultant.

Yost: Can you elaborate on the work you did there?

Denning: Yes. Let's see, that summer I was playing around with two — and I really do mean playing around — there were two software packages that I was supposed to evaluate. And one was a compiler generator that could be used for teaching purposes. And I forgot what the other one was.

Yost: And what year did you complete your master's degree?

Denning: In 1969.

Yost: And what were your career plans then, can you tell me about your job search? I saw from your CV that you ended up at the University of Rochester. Can you tell me what different things you considered at the time and how you ended up at Rochester?

Denning: I ended up at Rochester because I got married in May 1969, and my husband was going to Rochester for a Ph.D. so I sent off a letter to the computing center asking them if they had any idea about where I might apply in Rochester for a job. [Laughs.] And they came back and said well, apply to us. So I'm going to say I don't even remember if I went out there and interviewed or not, but that was the only place I applied and that was where I worked.

Yost: And how long did you work there?

Denning: Three years.

Yost: Can you describe your work?

Denning: I was a systems programmer, so I did a lot of odds and ends. This was again something in the 360, 370 range of IBM computers. The main project that I did there was I actually wrote a command interpreter that was called the Easy Control Language. And so instead of using Job Control Language, JCL, which was a pain, you could use the Easy Control Language. So I built this interpreter that just translated into JCL and it got integrated into HASP, so it was transparent to the users.

Yost: Was there a time sharing system at Rochester?

Denning: Yes, it was the IBM.

Yost: Okay. Had you given any thought to computer security, up to that time?

Denning: No, not really.

Yost: So that wasn't an issue that people discussed at the computing center?

Denning: Not very much. I mean, there was a concern about students at the school getting unauthorized access, but I don't think it was a big problem.

Yost: I understand that you met Peter Denning, who was visiting Rochester and some other schools?

Denning: He came to interview. Rochester, at that time, didn't have a computer science department and they wanted to establish one so they interviewed a number of candidates.

Yost: At what point did you start to consider going on for a Ph.D. and what motivated you?

Denning: Probably after maybe a year at Rochester. First the business school, and then the electrical engineering department asked me to teach, so I was teaching courses and I enjoyed it and I realized I needed a Ph.D. So part of the reason why I was on the search committee that interviewed Peter and all the other candidates was [that] I would be their first Ph.D. student. [Laughs.]

Yost: Can you tell me what courses you taught at the business school?

Denning: Believe this or not, this is in 1970 approximately, the business school had a course in compilers. That's just incredible. So that was the first course I taught. They asked me to teach it, so it was apparently on the books. They might have had one other course on their books, which would've been like an introduction to programming-kind of course. So I taught it there [in the business school]; and then the electrical engineering

department got interested, so they actually took the compiler course and moved it over to electrical engineering. So I taught it over there along with a course that was an introduction to programming languages and data structures. Actually, it wasn't the first course that students would take; it was more like a survey of different programming languages and data structures. So those two courses, I had to create them both from scratch.

Yost: And were there other EE courses that you taught besides that one?

Denning: No. They had something like an introductory programming course, but I never taught it.

Yost: Can you take me through the thought process that you went through in considering graduate schools and how did you come to decide on Purdue?

Denning: Well, I was really holding out at Rochester for a while, and then it was looking like nothing was going to happen because whoever they might want for a department chair was not matching the backgrounds of candidates that were coming through. They really wanted an AI guy and they were not interviewing any AI candidates. [Laughs.] So I did start looking; I can't remember exactly when. But it was in the spring of 1972 and I was out on the West Coast and I went over to Stanford to see if I could apply there because that probably would've been my first choice. And they said I was too late. And that kind of discouraged me because I felt like it was probably too late to go anywhere.

And then Peter had suggested that I look at Purdue because I had run into him at a conference. And so I contacted the department there; Sam Conte was chair. Sam offered me a position as instructor, and also said I could come join the Ph.D. program that fall. It seemed like a good opportunity so I took that.

Yost: As you were entering graduate school, had you given any thought to what area of research you might do?

Denning: The first semester there I took Peter's course, operating systems, and one of the topics in that course was security. And we had to do a term project so I chose security for my term project and that sold me. So that's when I started working on security.

Yost: Do you recall that term project?

Denning: Yes, it was on capability architectures and so I got pretty excited about Bob Fabry's work.

Yost: From that course forward, had you pretty much decided that would be your research specialization?

Denning: Yes, I chose that as my thesis topic then.

Yost: Okay. And who initially was your advisor?

Denning: Peter was initially my advisor and at some point we decided that we were interested in each other [laughs], so I then asked Herb Schwetman to be my advisor.

Yost: Can you talk about Dr. Schwetman's research?

Denning: You know, this was not his primary research interest area, but he was willing to step in and do it. He seemed like a good person to work with. None of the people on my committee were security experts or worked in the area of security.

Yost: I take it that other than Peter, at that time, there were no faculty that were interested in computer security at Purdue?

Denning: No.

Yost: When you arrived, was Scott Graham a graduate student there yet?

Denning: Scott came at the same time I did, I think.

Yost: Did his interest in computer security have any influence on you?

Denning: I don't think it probably had much influence on me. It was really the course I had with Peter and the project that got me interested in security. But Peter, Scott, and I

did a joint paper for a conference, early on. I think I was the principal author but they worked on it with me.

Yost: You mentioned Fabry's work, as you were beginning to work in this area, can you discuss the most influential publications and research in this area?

Denning: When I first started working in this area, I was looking for something that would be different so I started looking at information flow. At that time I wasn't aware of anybody that was doing any work in that, which, you know, is what the graduate student is looking for. I said okay, where can I carve out a niche? And it wasn't really until I was substantially through my thesis that I started discovering other work— like the Bell-LaPadula model—I was not aware of that in the beginning.

Yost: And with information flow, were you thinking about it within the framework of classified documents?

Denning: No, not at all. I was thinking of it in terms of a future where you would be using tax preparation software and you would be submitting your data to a service, probably running on some time sharing computer, and how could you make sure that the sensitive information that you provided did not get into the hands of people that shouldn't have it. So that was where I was coming from.

Yost: Were you aware of any of the writings by Willis Ware, such as the Ware Report of 1970?

Denning: You know, I can't remember when I might've run into that.

Yost: So it could've been later.

Denning: Yes. The things that I remember from my early days are like the work on capability architectures, the work at M.I.T. on Multics security, Anita Jones had done some work. It was mostly thesis-related work in academic research projects. Can't even remember what Anita Jones had done. Jerry Popek, who then was at UCLA, I can't remember where he got his Ph.D., but his thesis was on security.

Yost: What did you think of the Multics security design?

Denning: Well, it seemed very interesting. I think when I first started working on my Ph.D. I thought I would do something more in the architecture area. And this is where Herb Schwetman was extremely influential because when I started talking to him about some of my ideas the first thing he asked me was what was my model, and that was what really kind of sent me back to the drawing board, trying to come up with some abstractions for things, not just think about design but think about some fundamental properties.

Yost: Could you elaborate on that?

Denning: So I went out and I spent several months thinking about information flow and I formalized some ideas, and I actually had some theorems and proofs, and I was very excited. And one day I decided I'd show them to Peter; so I showed them to Peter and Peter told me, 'oh, this is lattice theory,' which was kind of discouraging to me. In a way that was a bad day because I thought I had just invented all this math [laughs] and here it already existed. But fortuitously, Garrett Birkhoff, who wrote a book on lattice theory and was known for lattice theory, was visiting Purdue so it provided a good opportunity to learn more lattice theory.

Yost: So was he *the* expert on Lattice Theory then?

Denning: He was one of the experts in lattice theory at that time; he had a textbook on lattice theory. So I got it out of the library and read it; and realized that I hadn't really invented any new math. [Laughs.]

Yost: And he was a visiting professor in the mathematics department?

Denning: No, he was in computer science.

Yost: Do you recall when you first became aware of the 1973 and 1974 papers that Bell-LaPadula wrote?

Denning: No. They're probably cited in my thesis. [*Sound of a file drawer opening.*]

[Long pause.] Yes, cited in my thesis so I knew about it before I finished my thesis.

Yost: At this time, what did you see in the lattice model that wasn't in existing models for computer security?

Denning: Well, like I said, at the time I was doing it, I wasn't aware of any other model on information flow. And even the Bell-LaPadula model is really not an information flow model, but rather an access control model. It just controls access with two properties.

Yost: Can you discuss the basis of the information flow model with different individuals?

Denning: Well, the model was less about individuals and more about data so the assumption is that every data belongs to some kind of classification, okay? And that the classification structure forms a lattice and that information can only flow in one direction through the lattice. So it can only flow from lower to higher, or equal classifications. So the whole classification structure of the DoD did get incorporated into the model, but just as an instance of a lattice, so you could have a lattice like where everything — a simple lattice is just things are sensitive or not sensitive. You say, 'oh, I have two points in the lattice.'

Yost: Do you recall at what point you started considering that classified document structure of the federal government?

Denning: No. Sometime during the period before I finished I would've become aware of that, maybe through participation in conferences or something of that sort. Or from reading more papers.

Yost: Can you describe and assess Butler Lampson's early work on computer security and to what degree was it influential to your thinking and work on the topic?

Denning: Well, sort of the main thing that I remember is the access matrix model — which everybody got all excited about — because you could look at it from either the capability architecture point of view, or the access control list point of view. And then that lead to some interesting theoretical studies that were done on what was called take-grant models. So that seemed pretty interesting then.

Yost: In choosing your dissertation topic, how were you seeking to position yourself career-wise? Were you thinking about that?

Denning: The whole reason I went for the Ph.D. was because I had decided I wanted to be an academic full time. And so there was never any question in my mind that I would do anything other than be an academic.

Yost: Were you aware of ADEPT 50 system at the time?

Denning: Clark Weissmann's stuff. Yes, I remember that but if you ask me what it was about, I can't remember.

Yost: Okay. What about Hydra?

Denning: That too; but again, I think that might have been a capability architecture but I don't really remember that either.

Yost: The work that was being done at Case Western by Ted Glaser and his colleagues?

Denning: Again, I would've been aware of it. At the time, you could've quizzed me and I would've known what it was but not anymore.

Yost: You mention that you just, without knowing others' work on lattice structure, came up with that. How long did that take? Can you take me through that process when you came up with that?

Denning: No, I couldn't tell you; too long ago. But I just remember the joy of creating all this math [laughs] thinking it was pretty cool.

Yost: A number of people that got into computer security did not have as much formal mathematics training. Did you see that as a real advantage, did that help?

Denning: Well, you know, the math I ended up using in security is not math I studied. So lattice theory is not something I had studied; and in fact, one of the more difficult math courses I had taken at Michigan was a course in algebra. The other math that has been particularly relevant over the years is number theory. I never studied number theory, but that's essential for cryptography theory. Numerical analysis stuff I never really used much, but it did give me a good perspective when I was teaching introductory programming, you know, what happens to errors and stuff.

Yost: Without anyone on your committee being in the computer security area, did that make it more difficult or were you getting advice from people outside of Purdue, or Peter?

Denning: I didn't get any advice from people outside of Purdue, but I certainly talked to Peter.

Yost: And what year did you defend your thesis?

Denning: 1975.

Yost: And then the following year you published an article in *Communications of the ACM*?

Denning: I think that was — yes — from my thesis.

Yost: Do you recall the reception to that article?

Denning: It was very, very good. I had also presented it at the Operating Systems Conference, the Symposium on Operating Systems Principles. It was received very well at that conference. And today, it's probably still one of my most-cited papers.

Yost: And was that an IEEE Computer Society or ACM conference?

Denning: ACM, SIGOPS.

Yost: So, as a graduate student were you involved in SIGOPS?

Denning: I joined ACM when I was still at the University of Michigan. I don't know when I might've joined SIGOPS, but probably when I was at Purdue. So I would've been a member of SIGOPS; I'm sure I would've been a member of SIGOPS at the time when I went and gave the paper at the conference.

Yost: Do you remember specifically what type of reactions you were getting, any specific feedback?

Denning: Just very positive.

Yost: Do you know of instances where the model was used in practice?

Denning: When it came to the practice there was a second paper that I did that showed how to integrate it into the compiler. I think that might've had a greater impact on the practice part than just the original paper. But while I was at Purdue, I remember at least a couple of people at other universities said that they were implementing it. So I thought that was pretty cool. I never implemented it.

Yost: That's great. Do you recall what universities?

Denning: No. And then when I was here, somebody was visiting NPS and Peter and I had lunch with him; and lo and behold he was telling me how he had put this into some program verification tool that they provide, and there's a website that I can even go to and see what they were doing to it. Wow, that's pretty neat.

Yost: That's great.

Denning: Then, you know, over the years I would from time to time hear from people that had implemented it.

Yost: And upon completing your doctorate, did you become an assistant professor right away?

Denning: Yes.

Yost: What courses did you start teaching?

Denning: Well, let's see. I was teaching when I first went to Purdue. That's what paid the bills. [Laughs.] They had me teaching a course that was — I don't remember all the courses that I taught but I know I taught a survey of programming languages course. I didn't teach compilers at Purdue; I taught a database course. I'd have taught a data structures course; and then I started a security class, which I taught. Those are the main things I think I taught.

Yost: Do you recall roughly when you started the security class at Purdue?

Denning: In the late 1970s sometime.

Yost: And were there a lot of students interested in it?

Denning: There were about a dozen, I think, the initial time I taught it. I started teaching it as a seminar, and then it was a regular course.

Yost: To your knowledge were there many computer security courses across the country at that time or was it one of the first?

Denning: It was one of the first, but it wasn't *the* first. I know Jerry Popek was teaching something at UCLA. Probably a few others.

Yost: Matt Bishop became one of your graduate students at some time.

Denning: Yes.

Yost: Can you discuss him and his research as a graduate student?

Denning: He was very interested in the Take-Grant Model. So he pursued that and did a nice thesis where he took that model and he looked at it in the context of Unix, as he was also very interested in Unix and Unix security. He mostly did all this on his own initiative. I never suggested a topic or anything to him; so he worked on his own. Great student.

Yost: Did you have any other graduate students that you taught at Purdue who worked in computer security?

Denning: Well, Mayer Schwartz did his thesis on security. Peter was his advisor. I might have been on the committee but I wasn't his advisor. I think I only had one other Ph.D. student when I was at Purdue and she didn't finish; she left. Got married. That ended that.

Yost: And during your time at Purdue, did any additional faculty come to Purdue that came to focus on computer security or existing faculty move into that area? Or were you and Peter the only ones?

Denning: By the time we left, Peter really wasn't working in security anymore.

Yost: As I understand the mid- to late-1970s he had already made the transition to concentrate on some of his other research interests.

Denning: Yes. He had always been working on other things. I mean, his thesis was in memory management. So he was always more broadly across all of operating system areas and system performance. I'm trying to think. I can't remember when Sam Wagstaff came. He had a background in math and in cryptography, but I think he came at right around the time that we left. And then Gene Spafford, of course, came after we left. Let's see, who else; there's a bunch of people there now. [Mikhail] Mike Atallah was there when we were there; but he wasn't working in security at that time. He got into security probably after we left.

Yost: In 1977 you and Peter co-authored a paper on certification of programs for secure information flow; how did that paper advance practical applications of the lattice model?

Denning: Well, that was the paper that I think more led to people implementing it, because it really spelled out how you could implement it with the compiler. So that was in my thesis. Peter and I were, for the summer, we were in Cambridge, England, and so during that time when I was there I was writing up that paper for publication. Peter was right there, too, and he offered a lot of suggestions on how to organize the paper. Peter's a better writer than I am; especially at that time he was. And so he put a lot into making the prose better, so he became a co-author.

Yost: In the late 1970s you began publishing a substantial number of articles on security concerns with statistical databases. What led to this research?

Denning: I think it was Mayer Schwartz. I probably had a mild interest in the area. I can't remember how it all transpired. But anyway, he started working on some security issues there, and then Peter and I both got involved and we did a joint paper. And then I just continued to stay interested in that area and continued working in that area, even after Mayer graduated.

Yost: Did you get a sense of how this research was impacting practice with databases?

Denning: I did get a phone call from somebody who said that they were implementing some of the ideas. I remember I had one idea that was published in one of my papers called “Random Sample Queries.” And some company or organization had called me and told me that they were implementing it; they wanted me to come out and do some consulting for them. I didn’t want to travel or whatever; I can’t remember, maybe I was just busy writing my book. And so I didn’t do any consulting but I remember somebody was implementing something.

Yost: In 1982, you published an important and influential textbook, *Cryptography and Database Security*. Can you tell me about how you got started with that project and give me some context for your writing of that book?

Denning: Well, I had already started teaching the course in security and I didn’t feel like there was a good book. So part of it was that when I finally did start writing it, the real purpose was to create a textbook that I could use in that course. And so the students did review a draft of the book and provided a lot of valuable input to the draft that affected the final version of the book.

Yost: And so it very definitely was created as a textbook?

Denning: It was definitely created as a textbook. Right around the time I decided to do that I had read Hofstadter’s book, “*Gödel, Escher, Bach,*” and had become really excited; and Peter and I had gotten to know Doug and had several events at our house in his

honor, where he came; and I think that also inspired me to write my own book. So that, plus the idea that I could write a useful book for my students got me going.

Yost: What year was it that you left Purdue for SRI?

Denning: 1983.

Yost: Can you tell me the context of that decision?

Denning: Peter had an offer to be the director at the new Research Institute for Advanced Computer Science at NASA Ames in Mountain View. So I needed to get a job in the area.

Yost: Did you look first to see if there were any positions with universities?

Denning: I looked at Stanford. I interviewed at Stanford and was turned down. And the only other places I looked were research labs in industry. I only looked at two or three.

Yost: Can you describe what SRI was like when you arrived?

Denning: Well, you know, I had very little interaction with people at SRI, other than in the computer science lab where I was. And the computer science lab was and has continued to be a very active research environment with a strong emphasis on security

research, and application of formal methods to security. We were at the cutting edge of a lot of research areas in security.

Yost: How many people were part of the computer science lab at that time?

Denning: I don't remember the exact size but there were maybe a couple dozen or so.

Yost: And roughly how many working in the computer security area?

Denning: I don't know, but several. I don't remember the numbers at all.

Yost: Roughly half, or [pause]

Denning: I don't know.

Yost: Are there particular people who were there working in computer security that you remember?

Denning: Peter Neumann was certainly the person that I knew the best and he was my main point of contact when I was still at Purdue. I worked with him extensively while I was at SRI. Karl Levitt was also there when I came, also a great person to work with.

Let's see, who else? John Rushby. I can't remember now when John came; I think John was there before I was there.

Yost: And was Donn Parker there too at that time?

Denning: I didn't know Donn Parker very well when I first arrived, as he was in a different part of SRI, but we did over the course of the time that I was at SRI work together on some projects; even co-authored a paper together. Donn was an important bridge for me from the sort of theoretical academic environment to what's really happening out there in practice, in terms of both computer attacks and also what industry was doing to defend against them.

Yost: Do you recall what type of work Peter Neumann was doing?

Denning: Well, Peter had done a lot of the work on the Provably Secure Operating System, PSOS. So that work had already been done before I came. And then he, of course, was also well known even back then for his work on risks, and I think he was already putting out the Risk Digest. He's been doing that for a long time. And his book on risks.

Yost: And Karl Levitt?

Denning: Karl was very instrumental in one of the projects I got involved with, which was an intrusion detection project, because he had thought that would be an interesting

area to get into and had some contacts in the Navy. We got funding and Peter and I were the co-PIs on the project, but a lot of it came from Karl's initial ideas.

Yost: What about John Rushby?

Denning: John was also doing work that used formal methodologies; and he was especially interested in reliability of computer systems.

Yost: Was the general model at SRI that the researchers were coming up with potential projects and applying for funding or were they getting contacted by different parts of government?

Denning: I think the projects probably evolved in a collaborative kind of way. I'm just thinking back on intrusion detection. Karl was certainly instrumental there but there was also somebody in the Navy who was very instrumental; H.O. Lubbes. So it's probably interactions between H.O. Lubbes and Karl, you know, that started getting the ball rolling, and then Peter and I put together the proposal and got the funding. But I think that's often the case, where there's a mutual interest in some area.

Yost: And this is for the IDES work?

Denning: IDES work, right. I also had a big project there, Seaview, in data security. And that was done initially through Air Force funding. But that came after there had already

been an Air Force-sponsored workshop and Woods Hole. That was looking at database security and maybe even other things.

Yost: Do you recall what year you received the funding for IDES?

Denning: Hmm. My guess would be probably around 1985, but I don't remember exactly.

Yost: And who again funded?

Denning: It was a SPAWAR award through H.O. Lubbes.

Yost: So that wasn't funded at all by Becky Bace's NSA program [pause]

Denning: I didn't know Becky Bace back then. She was at NSA back then?

Yost: Yes, she ran a research program that funded some work in intrusion detection and then transitioned to Los Alamos for a bit, but I wasn't sure if that was one of the projects that she had funded.

Denning: Right, no. And then we got the funding branched out later.

Yost: Can you compare and contrast the research environment you had at Purdue versus SRI and what it was like; how it was similar and different in terms of doing computer security research?

Denning: Well, in an academic environment you can work on whatever you want, okay? In a place like SRI, you work on where you can get funding. So that's probably the big difference. And you can do some initial work on something maybe without funding, with some seed money or something. But your time is all accounted for, by project. I didn't like that. [Laughs]

Yost: So basically, pretty much all your time has to be paid for.

Denning: It all has to be accounted for, every hour.

Yost: Was that a similar model to RAND or are you familiar?

Denning: It's probably like that at RAND. Yes. It's like that here. It's like that throughout the government. Every hour has to be accounted for, charged to some project; most universities you don't do that. Except during the summers, you have like a grant that covers your time during the summer.

Yost: Obviously, a good portion of your time is spent teaching.

Denning: Right, a lot of time is spent teaching but you have to keep track of so many hours spent teaching, so many hours spent on this research project, or that project.

Yost: So there's a complete accounting of all that here?

Denning: Yes, throughout the government. It's not just here. I had some NSF money, I think, also, when I was at SRI.

Yost: So, obviously, developing projects...it takes time to develop a project so that's obviously not paid for.

Denning: Right, that's what the overhead covers.

Yost: Covers getting that next project.

Denning: Right.

Yost: Can you elaborate on the development of the IDES project, and what it accomplished, if it had significant applications in practice?

Denning: It originally started out with just an abstract model. So I did that, mostly. Peter Neumann also contributed to the project. And then we hired some people to work on the project and build a prototype. So we'd built a prototype, and then the project took off,

really took off. I mean, I was leaving before we even finished the final reports there; and SRI ended up doing a lot more with it over the years. But I know it had an impact. At least one person; Paul Proctor, told me that it was a strong influence in the development of an intrusion detection system at SAIC.

Yost: You mentioned another major project that you were involved with at SRI on database security. Please tell me about the origins of that?

Denning: Well, that had evolved out of some earlier work — I think there was like a workshop at Woods Hole on database security. The workshop might have been broader than that, but I was in a working group at the workshop. I'm pretty sure that we were focused on database security, and I had some initial ideas about view-based data security at that time. Those ideas got developed more in conjunction with that workshop and then when I went to SRI. At SRI, we put together a proposal to the Air Force for work in that area.

Yost: And were scientists at SRI just given the task of getting funding for the research you do or was it more of a management structure where you're getting it approved to do certain applications for research?

Denning: Well it's kind of a collaborative process between the directors of the lab that you're in and yourself. I can't remember the exact structure in our lab but Jack — and I forgot his last name — was I think the main director and Karl was like an associate

director; and Peter was I don't know, associate or assistant director. And so we had sort of collaboratively decided we were going to bid on this Request For Proposals and put it together. We already had ideas for how to do this. We also joined forces with Gemini Computing, which was down in Monterey, headed by Roger Schell. He wasn't the president of the company; I can't remember his name. But anyway, Roger was our principal point of contact and s the proposal was a joint effort between SRI and Gemini. So we had a very strong team.

Yost: How many people were involved?

Denning: Initially, it would've been Peter and I, and Roger; and when the funding came in we hired people to work on the project, and Gemini had a couple people working on the project. But at SRI, after my first year or two, when we started getting the money for IDES and Seaview, we hired Teresa Lunt. She had been working at Sytek, and she came over and s worked on both of these projects with me. She was great, and she had had some experience doing some actual intrusion detection work at Sytek They had done some kind of experimental thing, I think built something.

Yost: And do you know if she's still active in computer security?

Denning: I haven't been in touch with her. I believe she's at Xerox PARC.

Yost: The Seaview project was to develop a relational database system with an A-1 TCSEC classification. Did it go through the testing for that?

Denning: I don't know, I was gone. I'm not sure; at least the research grant that we had would not have included actually going through the formal certification process. That's an expensive thing. But we were supposed to develop the theory; I don't even think we had to develop a prototype, it was just at the level of specifications. So we were tasked to develop a formal model and specifications and verify the specifications, but we didn't have to actually submit it for evaluation. Now, SRI may have taken it further after I left, I'm not sure what they did.

Yost: And then in terms of...what was the plan? That Gemini would build it or they would oversea contractors?

Denning: No, no. Well, maybe Gemini was thinking of implementing some of it later. I don't know. But it was not part of the funding that we actually build it. I don't think the funding went beyond developing specifications for it.

Yost: During your time at SRI, on your CV, you have that you led an SRI project to assess the vulnerabilities in a major computer system and recommend a security plan.

Denning: Yes.

Yost: Can you talk about that?

Denning: We evaluated a system at NASA.

Yost: And can you elaborate on that?

Denning: I don't remember what it was exactly. [Laughs.] I think it was a Unix-based system. I remember John Rushby had a lot of interest in Unix security so he helped on that project.

Yost: And then there's also listed "developed a prototype user interface on an IBM PC."

Denning: Oh, yes, that was my fun project. That was probably before we had money for Seaview or IDES. But they did have money to build formal verification tools. PCs were just coming out then, and so there were some in the lab and all you had was a DOS interface, initially. And they wanted a graphical interface on a PC that could work with their verification tools that would be running on a server. So I built this little window system that had multiple windows. You could edit in the windows, and you could probably do some copy/paste, simple editing, and you could rearrange windows. It was all kind of fun and then, of course, Microsoft came out with real Windows. So it never got productized or anything but it was enjoyable working on it.

Yost: Interesting. What was your opinion of the work that had been done to that point on formal verification and the National Computer Security Center with the development of criteria in the Orange Book?

Denning: What was my opinion? I don't know. [Laughs.] I don't remember what my opinions were at the time.

Yost: Did you think it would have a greater influence on industry than it did?

Denning: I can't remember at what point I really realized that it probably wasn't having much impact. You know, at some point you gradually discover that a lot of what's going on in research labs and academia doesn't have much real world impact, and that probably happened more when I was working at Digital. One thing that really hit me hard when I was working at DEC was — I wasn't involved with it — that there was on the East Coast a project to build an A-1 secure VMS. And, you know, they spent years and a lot of money developing this thing, and at the very end they scrapped it.

Yost: And that was the project that Paul Karger and Steve Lipner led?

Denning: Steve Lipner was leading that project, yes. Paul might've been working on that project. It was the realization that there wasn't enough of a commercial market for it to justify the money that would go into continuing it and updating it and maintaining it, and everything else. Then it was hitting me how fast technology was moving and how slow

the process of being able to design and develop provably secure systems was. A very slow process and the technology's rolling out way faster, providing functionality and services that people want to be productive. And security taking a back stage to that.

Yost: In 1987, you left SRI to become a principal software engineer for Digital Equipment Corporation. Could you tell me about that shift?

Denning: The shift was because I found it very stressful at SRI to have to be responsible for raising money all the time. And so DEC offered the opportunity to work someplace where I didn't have to fill out time cards and I didn't have to worry about raising money.

Yost: And where was the DEC facility?

Denning: Palo Alto, less than a mile from SRI.

Yost: What type of projects did you work on for DEC?

Denning: I started out working on a project with another guy to do some enhancements to an email system. Part of the reason I went to DEC was I wanted to do something besides security. So we were doing that while at the same time thinking about a future system, what kind of properties we might have. So some ideas could be tested out on the system that was already in use there. It was an in-house developed email system.

Yost: As a computer security researcher in the 1980s, were you regularly attending conferences?

Denning: Yes.

Yost: Did you go to the first IEEE Symposium in 1980?

Denning: Yes.

Yost: Can you discuss that event?

Denning: Well, it was pretty exciting for me. I was a young researcher and there were some big names there like Marty Hellman, and I can't remember who all was there. But it was just a nice opportunity to meet these people.

Yost: And was that an event that you attended every year?

Denning: For some years; at least 10, I think.

Yost: And could you tell me a little bit about the environment and atmosphere at the event?

Denning: Well, it grew. There was probably only 25 or 30 people at the first one, then it grew into a few hundred. But it was never huge. It wasn't like going to the RSA Conference where there's tens of thousands. It's only in the hundreds. So you did get to know the people. When I went back for something a couple years ago - it was probably the 30-year celebration - I didn't know most of those people. [Laughs.] It's a lot of young people there now.

Yost: Did you stay active in SIGOPS?

Denning: No.

Yost: Were there other computer security meetings in the 1980s that you regularly attended?

Denning: Well, I also went to the first CRYPTO conference down in Santa Barbara in 1981, and then I became president of the association.

Yost: Can you tell me about the history of that conference?

Denning: Well, somebody at UC Santa Barbara — I can't remember his name — started it, and also Dick Kemmerer at Santa Barbara was involved. That first conference was also very small. And then people wanted to keep it going so they formed the International

Association of Cryptologic Research to perpetuate it. David Chaum also was a key figure in getting the society going.

Yost: I see on your wall there's the –

Denning: Oh, yes; from 1984.

Yost: Crypto '84.

Denning: Yes.

Yost: Crypto '84; looks like there's maybe 30 or 40 [pause]

Denning: 1984. There's more than that. Looks like it's more like 80 because you got the two groups; couldn't get it all in one picture.

Yost: Oh, okay. At first, I thought it was just two pictures of the same group.

Denning: Yes, that was a fun meeting because I ran the San Francisco Marathon on Sunday morning and then flew down to Santa Barbara, where I was president of the IACR at the time.

Yost: Wow!

Denning: [Laughs.] You know, I was so charged up from the marathon that it didn't hit me until the next day.

Yost: You mentioned the email system at DEC; what were some of the other projects that you worked on then?

Denning: Well, my main responsibility was actually what we called it the Export Program. The hardware and software that we had developed on personal workstations went out to six institutions for research projects. Three of them were in the United States and three were overseas. I was responsible for that program. We really did have to deal with export controls and just making sure everybody had what they needed and all that sort of thing. And then we also had a conference every year — maybe two — at least one, where they came to DEC for a meeting. So I organized all that.

Yost: In talking to Peter yesterday I understand that you interviewed a number of hackers.

Denning: Yes, there was a [pause]

Yost: When did that start?

Denning: That started when I was at DEC.

Yost: So you didn't do any of that when you were at SRI?

Denning: No. It started because a hacker came to me, to interview me for his zine and he was a member of the Legion of Doom. And so he interviewed me and then after he interviewed me I thought it would be interesting to interview him. The reason why he wanted to interview me is he had read my book and in his zine he had written a whole article, I think it was about the tracker threats against statistical database. So he had written a very well done article on that.

Yost: Do you recall who that was?

Denning: He went by the name of Sir Francis Drake. [Laughs.] So anyway, there was the interview, and I thought it would be interesting to interview some more hackers, so I did. I think Richard Stallman at M.I.T. helped me find people to interview.

Yost: When you were at SRI, Donn Parker was involved in interviewing hackers, wasn't he?

Denning: Yes, he had interviewed people in prison.

Yost: Did his work have any influence in your interest in the area?

Denning: Oh yes. Yes, definitely. And when I interviewed all these hackers, I wrote it all up. I generally treated them fairly favorably and Donn correctly pointed out, they're not all like that. [Laughs.] The people I interviewed were not the ones sitting in prison for things like embezzlement and financial fraud.

Yost: Did you have a good deal of freedom about what type of research you did while you were at Digital Equipment?

Denning: Well, yes and no. You know, I realized it turned out not to be a good match. So I left and decided it was really time to go back to academia so I could do my own thing and not have to worry about it. Because the lab I was in at Palo Alto was really focused on distributive computing and advancing things in that area. And I really wasn't working on that.

Yost: Was DEC supportive of your doing a research project with hackers?

Denning: Yes and no. [Laughs.] I was called to the East Coast to meet with a guy who was the head of security on the East Coast, who wanted to remind me that some of these hackers had broken in and downloaded Digital's proprietary software and they were not too happy about that. [Laughs.] But it was a friendly visit.

Yost: So they didn't necessarily like a favorable treatment.

Denning: Yes. I mean, this was a subset of people that I interviewed and it wasn't the whole story so I started writing more about the other side of things after that.

Yost: Then you were at DEC until 1991.

Denning: Yes.

Yost: And then you returned to academia at Georgetown.

Denning: Yes.

Yost: Can you take me through that decision and process?

Denning: Decision? Well, I knew that I wasn't properly matched at DEC and I actually hired a career consultant who told me, after going through all these tests, she said go back to academia. I should have been able to figure that out myself. [Laughs.] So, I started looking around and saw the ad for Georgetown; they were looking for a department chair and I thought oh, that sounds pretty interesting. I probably looked to see what might be available in the area where we were living and probably came up empty handed. I was not willing to commute an hour. So you have to understand that Berkeley, for example, would've been out of the question, and many other schools. And NPS would've been out of the question while I was living up there. Anyway, so I did start looking at ads and the-

Georgetown ad — I don't know — it just sounded like that might be a good place so I applied and got the job.

Yost: When you were working at SRI and DEC did you miss teaching?

Denning: No.

Yost: But you missed the freedom of research?

Denning: Well, at SRI I didn't miss the freedom so much as I just found the needing to get money all the time to be emotionally stressful. And then at DEC, yes, I did really want to be able to do my own thing. I was getting more interested in issues that had to do more with the cyber crime side of things and the policy issues and so on.

Yost: When you started at Georgetown, what courses were you teaching?

Denning: Oh, what did I teach first? I might've taught an intro course.

Yost: So it was later that you taught courses on information warfare and cyberwarfare?

Denning: The information warfare course and an encryption course came out a few years later. Keep in mind we are a very small faculty — just five. And just undergraduates. So you gotta cover the basic courses. [Laughs.]

Yost: At that time, Georgetown computer science department was just undergrads; they must have [interrupted]

Denning: They have a graduate program now.

Yost: Was there anyone else there that was also working on research in the computer security area?

Denning: No.

Yost: Was the setting of Washington, D.C. influential?

Denning: Very definitely because I got more involved with policy issues and less with doing technical work in security.

Yost: When you say “got involved with policy issues,” can you elaborate?

Denning: Well, I got involved in the whole debate about wiretapping. [Laughs.] And then the debate about the Clipper chip.

Yost: Okay. Had you had an interest in policy before that?

Denning: Not really. [Laughs.] Not that much. Well, I started to get an interest in it at DEC when I started interviewing these hackers and issues were being raised about censorship and free speech on the internet. So I got involved in the beginning of the Computers, Freedom and Privacy Conferences. Peter and I were both on the steering committee for the first one of those.

Yost: Can you tell me more about that conference?

Denning: The first conference came about because, well, when I was still working at DEC, one of the other things I actually did was I helped defend a hacker who was being tried in Chicago. I went to Chicago to help with the defense. The government ended up dropping their charges. He had not actually hacked into anybody's computer but he was publishing a magazine called *Phrack* and he had published a document that some other hacker had stolen off of the Bell South computer system. So this raised all kinds of issues about who is guilty here. And the hacker who broke into Bell South and took it, he did get tried and convicted but the question of whether just publishing it should be a crime or not came up. And we demonstrated that the material that was in the stolen document was mostly in the public domain. The stuff that wasn't in the public domain — there were some names and phone numbers — had taken those out before it got published. So that got me in contact with some other people that were interested in these free speech issues and then we decided to have this conference. The idea was to bring together government and law enforcement with cyber people. And so it was all pretty interesting and we had director of the FBI come out. Well not the director, he was assistant director in charge of

the technology division. So he came out and gave a keynote talk; that was my invitation. And then we also had panels with people from law enforcement. So it was a very interesting conference.

Yost: Who provided funding for this?

Denning: I don't remember funding, but people did pay to go.

Yost: Okay. You became director of Georgetown's Institute for Information Assurance [GIIA]. Can you tell me about the origins of that institute?

Denning: It just came from conversations with a guy who was basically running the computing facilities at Georgetown and thought it would be a good thing to do. So we decided to do it and we put up a website and that's about all we did. We had some meetings, got people together. But we never actually did anything as a group so it ended up being [just an] exchange of ideas. Might have had some talks.

Yost: And the law school, and the medical center?

Denning: Right, so there were people from all over campus that we had involved, but that ended up being more a sharing of what people were doing.

Yost: I saw that you — I think it was in one of your books, in an author summary — that you testified before Congress on computer security.

Denning: Yes.

Yost: When did you first do that, do you recall?

Denning: I have this written down somewhere, but maybe the first time was in 1993?

Yost: And what was the context for that?

Denning: Clipper chip.

Yost: Can you summarize your views on the Clipper chip?

Denning: My views now or my views then, or what? [Laughs.]

Yost: Both.

Denning: At the time, I was serving as an advisor to the FBI and the FBI was getting concerned about organized crime using secure telephones and their not being able to wiretap them. This was on top of just the advances in technology just going digital that was making wiretapping more difficult, in any case. So anyway, this was a concern and

NSA had developed a chip called the Clipper chip that would provide strong encryption but also had hooks in it so that the government could get access to an encrypted phone call. AT&T was coming out with a secure telephone device that was going to have a DES chip in it, and they talked AT&T into putting in a Clipper chip instead. So, when all this went public — I didn't really know about it until it went public — in the spring of 1993, so about 20 years ago now. And the reaction from people outside the government was pretty negative for lots of reasons. You know, the Big Brother aspect to it; there was industry concern that it was all a hardware solution, they wanted to be able to develop and sell software encryption products; there was also in the background, issues about exporting encryption technology. And so one of the selling points of the Clipper chip was that this is going to be exportable because the government could get access and it would provide stronger encryption than the stuff that was generally exported. At the time, the only exportable crypto was 40 bit and this had an 80 bit key, which was much stronger. And it was not mandatory. And that was a key factor for me, because it was not being forced on people. NIST developed a standard for it, the key escrow standard. But anyway, lots of people were not too happy about this so as you can imagine there were lots of conferences, and panels, and people talking about it, and testimonies in Congress about it.

Yost: I remember seeing many articles in the *New York Times*.

Denning: Yes. And because of my connection with the FBI, [I] got involved in the very early days. Then also somebody from NSA, Clint Brooks, right at the time it was

announced, he actually came down to Georgetown and met with me to explain the technology to me. They wanted it to go public and so I wrote a little description of what it was and put it out there on the 'net. So I got associated with all this and got asked to testify, and be on panels, and so on. My view at the time was that we needed to be concerned about all this. I didn't think it would be good for law enforcement to lose their ability to do wiretaps or the NSA to lose its ability to do intelligence collection, so I generally supported it and took a huge amount of heat for it. The standard was developed. Interestingly enough, industry also came up with software approaches to what was being called key escrow or key recovery. And the final chapter in the book, I guess, it ended up the whole project died. Nobody ever bought the AT&T phones except for the government. The justice department had promised they'd buy some and they did. But there were a lot of problems with it; it was a costly solution. So in the end, cryptography export controls got relaxed. So key recovery is a feature in many products for storage encryption, but not for real time communication intercepts.

Yost: When did you first become interested in studying information warfare and writing about it?

Denning: Well, I don't know. [Laughs.] I can't remember. I remember when I taught the first class, so it was sometime in the mid- to late 1990s, at Georgetown. I guess I must have gotten involved in some working groups or something where the topic was coming up, and Winn Schwartau had this book on information warfare and so he was talking about it at conferences. So I didn't invent the term or originate it. But then I started

seeing the possibility for a new course at Georgetown so I did that. I had the course first and it was kind of like at Purdue, where I was teaching a course and decided to write a book for it.

Yost: Is it difficult to research and teach on the topic of offensive information warfare, given that the government's involvement in this area is really classified?

Denning: Well, it can be, but you just have to use open sources and keep it open; and you have to make sure that what it is that you're publishing isn't something that you think the government would want classified. So I've never worked on anything where I thought what I was doing, the government would want to classify it; which doesn't mean they wouldn't, but [pause]

Yost: Did you have to ever voluntarily or were you ever asked to pass your writings for review before they were published?

Denning: Only in cases where I was publishing a paper that was funded. And the funding agency may have required review. I think that's probably fairly common.

Yost: So you wrote *Information Warfare and Security* primarily as an undergraduate text?

Denning: It was a graduate course. It was dual level but most of the students were graduate students.

So most of them were not computer science students. I was involved in three other programs at Georgetown by the time I left. One was the Communication, Culture and Technology program, and I was one of the founding members of that program. And then there was also another program on Science and Technology and International Affairs. That was part of the School of Foreign Service. Many of the students that I worked with and taught in my last years at Georgetown were from those two programs.

Yost: In writing that book did you also see a much broader audience than just for —

Denning: Just the students in the class. Oh yes, sure.

Yost: I imagine that book sold quite well.

Denning: Not a huge seller. [Laughs.] I don't remember the numbers but not huge.

Yost: You received the Association for Women in Computing's Ada Lovelace Award for leading contributions in cryptography and computer security. Can you talk about the meaning of this award to you, and did you feel there were more opportunities or hurdles for women in computer security research in the 1970s?

Denning: I never felt like there were any hurdles for women throughout my career, at any time. I felt that I was welcomed.

Yost: And can you talk about the meaning of that award?

Denning: Well I felt that it was a very nice recognition but the fact that it was a women's award didn't mean anything special to me. But the fact that it was named after a person that was very influential to the field, that made it special.

Yost: In looking at what happened in industry and what's really took off in industry, it's products such as RACF. IBM's RACF and ACF-2 use access control technologies that are far short of high assurance. Can you discuss why you think that occurred? Was it just demand driven?

Denning: Demand driven, yes. What you see out there in actual products in security is demand driven.

Yost: So people don't want the added expense or the slowing down of processing?

Denning: Well they don't want that, but where I saw the real failure of the work that was being done to build verifiably secure operating systems back then is that okay, so fine, you come out with a box and it would be verifiably secure with respect to only those properties that you verified. That doesn't mean that it couldn't be hacked. That, to me,

was always very important but more fundamentally, this box might not support all the apps that people have in the meantime developed and written that run on some other platform. So who's going to buy it, right? They've got all these applications out here running on IBM 370. Why are they going to buy this other machine and then they have to start all over with their applications and everything else.

Yost: So the technology is continually evolving . . .

Denning: The technology just rolls out.

Yost: . . . and there's no way for formal verification to keep up.

Denning: I don't think so, except in a very limited context where the requirements are really truly limited and will be static and fixed for an extended period of time. So when you look at the small components in a control system or something like that, there's merit to doing that. I absolutely think there's merit to establishing as strong a statement as you can about this security of something but you do have to realize the limits. And to think that we could have a whole internet that's provably secure is just absurd.

Yost: In looking back at the history of computer security, what do you think are the most important lessons that can be learned?

Denning: Well, the threat is always evolving, and the threat's changing. So whatever you're thinking in terms of the context and the models that you have aren't going to model the reality down the road. That a lot of the problems that come up, they come up because people think outside of the box in terms of how to attack something. Okay, so you can't break the crypto. Fine, get a key logger on the machine, pick up the keystrokes, get the password, and now you can decrypt it. It's all these things that happen and that people do that are sort of like outside of the model, so to speak. That's not to say that we can't do better. I think of it as like okay, the day that you can eliminate all crime, all the crime in the world — forget computers — but just all the crime that takes place. The day you can eliminate that, then you expect to eliminate it in cyberspace.

Yost: And obviously that day will never come.

Denning: [Laughs.] It'll never come.

Yost: What do you see as the greatest accomplishments of computer security over the past four decades?

Denning: Well, greatest accomplishments. Certainly, the cryptographic inventions were instrumental in things. When you think about it, it's really pretty remarkable that we can go out and use cyberspace today. That everybody is gravitating towards it. We use it more and more, depend on it more and more; that the security has kept up and been good enough to allow that because it's had to take giant strides; you know, back when I got

into this field we didn't even worry about networks. Time sharing systems were the only thing you worried about. And there you mostly worried about passwords, and authorization, and access control, and that was pretty much it. You know, there was concern about malware or code that hadn't been verified and that you couldn't trust. So there's always been concern about untrusted code but the concern wasn't that it was going to fly in over the internet and a user was going to click on a link and it would be downloaded on their computer. That was not the concern. You knew what all the code was that was running on the machine and you could isolate it, like in the Multics architecture. So the whole environment and the fact that industry has responded to the demand and the need to have antiviral, and intrusion detection, and provide cryptographic services. There's been a large community that's come forth to address the problem in today's world and try to think about the future so that we can have better platforms in the future. That's going to be hard to do. I know Microsoft, just as a company, has come a long, long way in terms of making their products better.

Yost: Some people have commented to us that researchers today don't have a very long term view of research that has gone on in computer security in the past and might in some ways be reinventing the wheel and having little understanding or appreciation of the early research. Do you agree with that?

Denning: I have no idea. I don't know what the young researchers are reading but it's quite plausible because the volume of stuff to read has just gone up exponentially. You know, back when I got into this field, you could read *all* the research papers. You could

read all the theses. Now, today, that's just out of the question. And so it's a challenge, the environment for the people who are getting into the field now. It would be much harder I think to find a thesis topic today.

Yost: Earlier, I think you mentioned the RSA conference and how it's just grown. Is that a conference that you regularly attended?

Denning: No. I mean, I went to a couple of the early ones when it was small. And then I've been in and out of it in recent years. A couple years ago I was on a panel. Maybe it was last year I was on a panel. So I went up for the panel, came back, and it was like a zoo. I can't handle zoos. [Laughs.] Anything that big is too big for me.

Yost: What do you see as the greatest computer security threats, moving forward?

Denning: Well, the biggest threats are that the states are going to be looking at ways that they can take offensive operations in cyberspace to meet their objectives. And so I don't know where that will all lead. I don't know. For the most part, we as individuals are very much impacted by the military capabilities of other states and whether or not we'll be any more impacted by that in cyberspace, I really don't know. But, other states have strong militaries, and many states have nuclear weapons, and yet, from the individual's perspective it doesn't matter much. If we go about our lives and the state is not our threat, then we're out walking in the street. We don't worry about a nuke falling on us. In cyberspace, whether we have to worry too much about the state threat depends on what

else is going on; obviously, if we're at war with another country the whole thing changes. The non-state actor is another matter because some of them are just crazy people and you don't know what they're gonna do. Many people feel self righteous and justified in attacking anything. So there are lots of attacks taking place. There are a lot of people that see it as a potential to make money so the criminal threat is a big one. So we definitely, as individuals are impacted by those kinds of things. Terrorists, right now, don't have capabilities to do much. Anonymous is a bigger threat than Al Qaeda, on line.

Yost: But some governments are [interrupted]

Denning: Governments have serious capabilities. I would assume we have some serious capabilities. And China's apparently got some very serious espionage capabilities. So, if what's being reported is true they are stealing a lot of intellectual property, so that can have an impact on us as a nation. Certainly it can have an impact on the business whose stuff they take.

Yost: In reading your book, *Information Warfare and Security*, I got the real sense that in addition to just doing some path breaking work specific research, you've really become a generalist in the computer security field. Was there a time in your career when you consciously decided you wanted to look at bigger picture issues?

Denning: I think it happened more gradually. It probably really began to happen at DEC and especially when the hackers asked to interview me, and I got involved in some of these other issues; and then at Georgetown.

Yost: At Georgetown you first taught on many different topics.

Denning: Yes. The thing is since I am more of a generalist now, I couldn't do the detailed kind of technical work I used to do.

Yost: Looking back at the start of your career and the lattice model, what do you see as the long term impact of that model?

Denning: I really don't know; honestly don't know. I'll be absolutely straight; I never really cared. [Laughs.]

Yost: But it was important and it advanced your career at the time.

Denning: I wasn't even interested in advancing my career. I've always been driven by what was intellectually interesting to me.

Yost: It was that.

Denning: It's always been that.

Yost: Okay.

Denning: So I never thought I had to save the world or anything else. [Laughs.] I might have thought that but realized there was no chance.

Yost: Your career has been very prolific and varied in the computer security field. I undoubtedly missed some things. Are there topics that I haven't brought up that you'd like to discuss before we conclude?

Denning: What else have I done? I don't know. [Laughs.]

Yost: Well thank you so much. You've been very helpful.