Faculty and Researchers   Military Operations Research Society (MORS) Oral History Interview

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Dr. Dorothy E. Denning Interview (MORS)

Denning, Dorothy E.

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INTRODUCTION

*O*ral Histories represent the recollections and opinions of the person interviewed and are not the official position of MORS. Omissions and errors in fact are corrected when possible, but every effort is made to present the interviewee's own words.

Dr. Dorothy E. Denning is an Emeritus Distinguished Professor in the Department of Defense Analysis at the Naval Postgraduate School in Monterey, California. Dr. Denning was inducted into the National Cyber Security Hall of Fame in 2012 and is a renowned expert in the field of cyber security. She is a Fellow of the Association for Computing Machinery, the leading professional society for computing. A listing of Dr. Denning's publications and a more complete background is available at this website: http://faculty.nps.edu/dedennin/.

A previous oral history of Dr. Denning was done by the Charles Babbage Institute in 2013 and can be retrieved from the University of Minnesota Digital Conservancy (http://hdl.handle.net/11299/156519). This MORS interview focuses on Dr. Denning's relevance to the military operations research community.

The interview was conducted on June 19, 2018 in Dr. Denning's office at the Naval Postgraduate School in Monterey, California.

FOREWORD

By Wayne Hughes, FS

Dr. Dorothy Denning became an expert in information warfare as that field grew in importance. Today information warfare, along with cyber attack and defense, is having a major effect on military operations research as well as our planning for future conflicts. As she implies, there are many interrelationships between computer operations, operations analysis, data science, and cryptography in both military and commercial operations.

MORS ORAL HISTORY

Interview with Dr. Dorothy E. Denning; Captain Wayne Hughes, FS, Dr. Bob Sheldon, FS, and Mr. Robert Hayden, interviewers.

Bob Sheldon: First of all, please tell us your parents' names and where you were born and raised.

Dorothy Denning: My father was Cornelius Lowell Robling and my mother was Helen Dorothy Watson Robling. They were both born in the Chicago area. They moved to Grand Rapids, Michigan, where my father started his own business. I was born and raised in Grand Rapids.

Bob Sheldon: Tell us what your parents did and how they influenced you.

Dorothy Denning: My mother raised three daughters, and she did not work outside of the house until my father died. My father ran his own business called Robling Building Materials, which wholesaled building materials. He had his main office in Grand Rapids, and later opened a branch in Grayling, Michigan. I worked for him starting from a very young age. I earned my first bicycle by sending out what we now call junk mail. [*Laughing*] Later I helped with inventory, accounts receivable, and recordkeeping.

Bob Sheldon: Was he an easy person to work for?

Dorothy Denning: I liked my father a lot.

Bob Sheldon: Where did you go to grade school, junior high, and high school?

Dorothy Denning: I went first to Marywood Academy, which was right down the street. It was a Catholic girls' school. In sixth grade, I switched to Michigan Oak, which was a co-ed public school. I started out high school at East Grand Rapids High School, which was close to where we lived. But when our school district joined the city of Grand Rapids, I had to transition to Ottawa Hills High School.

Bob Sheldon: What were your favorite subjects in high school?

Dorothy Denning: In high school my favorite subject was math. I also liked the advanced English class. I enjoyed that one a lot.

Bob Sheldon: The reading or the writing or both?

Dorothy Denning: Both.

Bob Sheldon: What levels of math did you cover?

Dorothy Denning: Just basic levels. There wasn't a math advanced placement class.

Bob Sheldon: What colleges did you consider?

Dorothy Denning: If I remember correctly, I only applied to two: the University of Michigan and Michigan State. I got a scholarship to the University of Michigan

Military Operations Research Society (MORS) Oral History Project: Dr. Dorothy E. Denning

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in Ann Arbor, which was also my first choice, so that's where I went.

Bob Sheldon: What was your field of study?

Dorothy Denning: Math.

Bob Sheldon: Did you study applied math, abstract math, or a mix?

Dorothy Denning: My plan was to be a high school math teacher, so I took math courses that I thought would be the most relevant to teaching high school math. Things like the history of math but not so many advanced math classes.

Bob Sheldon: Any math education courses?

Dorothy Denning: There were some education courses, but I don't think any focused on math. I think they were just general education courses. I had to take a speech class; that was the scariest class for me.

Bob Sheldon: Did you have any favorite professors?

Dorothy Denning: Not until my senior year as an undergraduate when I took a computing class. I really liked the professor, Bernard Galler. He was one of the pioneers in computing.

Bob Sheldon: What kind of computer class was it?

Dorothy Denning: It was tough, way tougher than introductory computer classes are today. We programmed in four different languages, including assembly language, FORTRAN, MAD (Michigan Algorithm Decoder), and SNOBOL (String Oriented and Symbolic Language). All those in one semester, and with challenging assignments.

Bob Sheldon: What was the nature of the programs you wrote for the class?

Dorothy Denning: One was a translator for Morse code. Another involved doing some Lagrange interpolation. I don't remember the others.

Bob Sheldon: I assume you got an A in the course?

Dorothy Denning: I did.

Bob Sheldon: So that motivated you for future studies in computer science?

Dorothy Denning: Before I took that class, I had learned to write a program. It was after my father died. I had a summer job working for the director of radio astronomy, Fred Haddock. I was hired to do technical typing. Then when he realized I had a math background, he had me start doing some math calculations using a hand

calculator. We were computing Doppler shifts. Professor Haddock was always curious about things and became interested in computers. He wanted me to learn to write a program to compute the Doppler shifts instead of doing all the calculations by hand, and then show it to him. So I wrote a program with the help of another programmer, Sally, in the department.

Wayne Hughes: Did you go through a lot of debugging?

Dorothy Denning: This was a real simple program. It was probably less than a page long, so I don't think it took too much effort to get it working. Plus I had Sally's help. That was when I fell in love with computing. It was the summer after my junior year. In the fall I did my practice teaching because I was still planning to be a teacher. That didn't go as well. But then I took a computer course with Bernard Galler in the spring and became even more interested in computing.

Bob Sheldon: Let's get a timestamp. When did you start college?

Dorothy Denning: In 1963. I got my bachelor's degree in 1967.

Bob Sheldon: What were your plans after finishing your undergraduate degree?

Dorothy Denning: I still thought at that point I'd be a high school math teacher. I was dating a guy who had not yet graduated, so I wanted to stay in Ann Arbor. My recollection is that I might have done a little bit of searching to see if I could get a teaching job in Ann Arbor and came up empty handed, or maybe I just heard you couldn't get one. So I talked to Fred Haddock about working for him and staying at Michigan and getting a master's degree. I did that, and Michigan paid for my tuition since I was a full-time employee. I got my master's after two years. During my last semester I was also a teaching assistant (TA) for Bernie Galler and I worked for him in the campus computing center.

Bob Sheldon: Was your master's degree in computer science?

Dorothy Denning: No. It was still in math, but with a computer science concentration. Michigan had formed a new program that was closer to computer science, but I didn't have the right background for it. Galler also advised me to stay in math. I believe he said the math degree would be worth more!

Bob Sheldon: What kinds of courses did you take?

Dorothy Denning: I took a couple more programming courses. One was systems programming. That was all assembly language programming. Another course was advanced systems programming. I also took more advanced math courses like advanced calculus and partial differential equations, two courses in numerical analysis, a course in topology (I found that absolutely fascinating), and one course each in probability and statistics.

Bob Sheldon: What kind of the computer did you use for your computer courses? Was it a main frame?

Dorothy Denning: Initially, I think it was an IBM 7090, and then later an IBM 360. Both used decks of cards for input. Radio astronomy also had its own computer, an XDS 930. After I was working full-time there, I used that computer for the programs I wrote for them. It was a one person at a time computer, and I would sign up to use it for hours at a time. Security was simply a lock on the door.

Bob Sheldon: What kinds of programs did you write for those graduate school classes?

Dorothy Denning: The most interesting assignment was writing a Basic compiler. This was a team project, and my job was to write the subroutines for the matrix manipulation functions in Basic. There was one other student that worked with me. When the time came to test the program, we put into our code a little bell that would go off when our code was running. So here we are with the whole class testing the compiler, and the little bell goes off right before it crashes! [*Laughing*] So everybody knew where the problem was.

Bob Sheldon: How big were those matrices you handled?

Dorothy Denning: The subroutines had to handle matrices of any size, but I think the presumption was that they'd fit in the memory of the computer. In those days, you weren't working with data structures that were bigger than the memory could handle.

Bob Sheldon: Did you have any other favorite professors from your master's program?

Dorothy Denning: I liked the professor who taught numerical analysis—Cleve Moler. And two other professors on the computing end—Bruce Arden and Larry Flanigan. Bruce Arden was the director of the computing center at that time. Galler and Flanigan were also involved in the computing center.

Bob Sheldon: How many professors in the math department taught computer courses?

Dorothy Denning: I don't know. All the classes I took were listed in the math department.

Wayne Hughes: Was there a computer science department?

Dorothy Denning: Not exactly. Michigan was in the process of creating what would eventually become the Computer Science and Engineering Division of the Electrical Engineering and Computer Science Department, but I didn't pay any attention to this.

Wayne Hughes: This is just about the time when there started to be computer science departments—the early 1960s.

Dorothy Denning: Yes. Purdue and Stanford were the first.

Bob Sheldon: What were your plans after you finished your master's degree?

Dorothy Denning: I went to the University of Rochester to be a systems programmer in their computer center. After a year, I was invited to start teaching computer science courses because there wasn't a computer science department. I taught a course first in compiler design. I did that for the business school. And then the electrical engineering department asked me to teach, so I started teaching for them. I taught a course in algorithms and programming languages and then a second course in compiler design. Rochester had an introductory programming class, but I didn't teach that.

Bob Sheldon: What computer languages did you teach there?

Dorothy Denning: I'm sure I taught SNOBOL as that was always my favorite language. I think I also taught PL-1 or Algol, LISP, and Assembly language.

Bob Sheldon: What years were you at Rochester?

Dorothy Denning: From 1969 to 1972.

Bob Sheldon: Did you have any interaction with other universities near Rochester where they were teaching computer science?

Dorothy Denning: I went to a conference on compiler writing that was held at New York University. There I met faculty from several universities who were teaching compilers. I also

went to IBM's SHARE meetings, where all the universities and businesses using IBM computers would get together once or twice every year. But most of the people I met at these meetings were systems programmers working in computer centers rather than teachers. I was head of the Command Language group in SHARE.

Bob Sheldon: Where did you go after Rochester?

Dorothy Denning: In the process of teaching, I realized I wanted to get a PhD and I wanted to be an academic. So I went to Purdue to get my PhD.

Bob Sheldon: Why Purdue?

Wayne Hughes: They did have a computer science department. [*Laughing*]

Dorothy Denning: Rochester didn't have a computer science department, so we were trying to get one started. We interviewed candidates to come start the department and be the chair. One of the candidates was Peter Denning. [*Laughing*] We did not make an offer to him because the committee felt that they wanted to have somebody in artificial intelligence, and Peter was in operating systems. In the end, we didn't make an offer to anybody that first year. I was a little frustrated because I wanted to get a PhD. I had hoped that I could just get it at Rochester and be their first PhD student. Then I ran into Peter at a conference and he said, "Why not come to Purdue?" So I went to Purdue. I think I had applied to Stanford around the same time, but Stanford said it was too late; this was in April or May. I wanted to go in the fall. Peter talked to Sam Conte, who was the chair at Purdue, and Sam said, "Yes. You can come." He offered me a TA position and free tuition. So I went.

Bob Sheldon: How did you like living in Upstate New York as compared to Michigan?

Dorothy Denning: I didn't really like Upstate New York that well. It was okay. The winters were tough. We were in the snowbelt. I didn't mind leaving. I didn't really like Lafayette very much either, but it was very conducive to working.

Bob Sheldon: So you went to Purdue as a PhD student?

Dorothy Denning: PhD student and also TA.

Bob Sheldon: What subjects did you teach?

Dorothy Denning: They had me teaching a data structures course.

Bob Sheldon: How many students did you have?

Dorothy Denning: Probably a couple dozen. It was a sizable department.

Bob Sheldon: How did you pick your thesis topic?

Dorothy Denning: I took Peter's operating systems class my first semester. We looked at security, which I found interesting. So I ended up picking that for my thesis topic.

Bob Sheldon: One of the first steps to a dissertation is doing research. How much available literature was there for you to research?

Dorothy Denning: You could read it all. [*Laughing*] There were maybe a half dozen theses and few dozen papers worth reading. Not a lot.

Bob Sheldon: Did you supplement your research by looking into other topical areas?

Dorothy Denning: My research was mostly what I would characterize as invention. It was coming up with something new. I thought for a while that I had invented a whole new branch of math. I was showing it to Peter and Peter said, "That's lattice theory." And it just so happened that Garrett Birkhoff, who is well known for his work in lattice theory, was a visiting professor in our department at the time. So I read his work and had several conversations with him.

Wayne Hughes: You mentioned the term "computer security" and I'm guessing that's going to be a growing field of interest for you. Is that true or did that come later?

Dorothy Denning: I wasn't thinking long term when I picked it as my thesis topic. But it was interesting to me and I saw my way to doing something original and with some solid theory and math supporting it.

Bob Sheldon: Can you describe lattice theory?

Dorothy Denning: It's a branch of mathematics that deals with relationships among a group of entities based on a partial ordering.

Bob Sheldon: How does that relate to computer security?

Dorothy Denning: That's what I invented for my thesis. I got interested in the question of what I called secure information flow. If you've got information that's classified, you don't want

it getting into the hands of somebody who's not cleared. I wasn't thinking of military classifications when I started out. I was thinking more of sensitive data, maybe financial data. If I'm doing my tax forms, I don't want that sensitive confidential data to get into the hands of people who are not authorized access to it. So I was interested in information flow, where you can only go from lower to higher levels, but I could also see the idea of compartmentalization. So the lattice incorporated both security levels and compartments. Then people started talking about, "This is what the military does too." Other people independently in the military had already worked on this thing, but not as a lattice, just more in terms of what the classification hierarchy is.

Bob Sheldon: Did you take some additional classes at Purdue towards your PhD?

Dorothy Denning: I had to take courses, but none of them were particularly relevant to my thesis.

Bob Sheldon: How long did you take for your PhD?

Dorothy Denning: A little under three years.

Bob Sheldon: Did you have any challenges defending your thesis?

Dorothy Denning: No. It went pretty smooth.

Bob Sheldon: Who was your primary thesis advisor?

Dorothy Denning: Herb Schwetman. His background was operating systems. I think that had always been his area.

Bob Sheldon: Where did you go after your PhD?

Dorothy Denning: Purdue. I had married Peter by then, and we decided to stay. After my PhD, I was an assistant professor.

Bob Sheldon: Were you doing any sponsored research?

Dorothy Denning: Initially, Peter had some grants to do security work, and then I became a co-principal investigator (PI) with him, so we were working together for a while. And then at some point, I started getting grants independently. It was all National Science Foundation (NSF) research.

Bob Sheldon: What was their interest in computer security?

Dorothy Denning: The security problems back then were nothing compared to what they are today. When I started my PhD, Purdue's computers weren't on any external network. It was all isolated. The biggest problems were just insiders misusing their privileges or students fooling around, guessing the passwords of other people. The password issue was the main issue. But NSF-funded work that was further out, including our work on data security. One area involved protecting sensitive data about individuals released in the form of summary statistics, such as census data.

Bob Sheldon: Were your students mainly computer majors themselves or were they engineers?

Dorothy Denning: It was a computer science program so almost all the students were computer science majors. There would be a few other students that would take introductory courses that weren't computer science majors.

Bob Sheldon: How long did you stay at Purdue?

Dorothy Denning: We left in 1983. I went to SRI International in California to work in their computer science lab on security projects.

Bob Sheldon: What were their security issues?

Dorothy Denning: SRI is a research organization that does work sponsored by various government agencies and companies. We worked on security problems of interest to our customers.

Bob Sheldon: Who were the research sponsors?

Dorothy Denning: When I first came to SRI, I worked on a project that was funded by an unnamed agency to develop a tool to detect insider threats. The methodology we were using analyzed the logs that were kept on an IBM 360. Because of my systems programming experience at Rochester, I had the background needed to work with these logs. We looked for indicators of abuse or maybe somebody who had broken in and compromised the system. We were doing some of the very earliest work on intrusion detection or misuse detection. Later, I was a co-PI along with Peter Neumann on a Navy grant to do real-time intrusion detection and on another one from the Air Force to do multilevel database security. For that project, we were concerned with databases that have different classification levels of data in them and

users who are cleared at different levels. The goal was making sure that classified information doesn't get to people who aren't cleared for it.

Bob Sheldon: This was still pre-Internet days?

Dorothy Denning: Not really. SRI had been on the Advanced Research Projects Agency Network (ARPANET) well before I got there. Even at Purdue, we had been on the Computer Science Network (CSNET) since 1981. Both were early stages of what was to become the Internet.

Bob Sheldon: Did you travel to the customer's office to discuss your results?

Dorothy Denning: Yes. I also had a security project for the Army, which I believe was funded by the Communications-Electronics Command (CECOM). I remember going to Army offices in New Jersey. The database security work was funded by the Rome Air Development Center (RADC) in Rome, New York, which I also visited. The intrusion detection work was funded by the Space and Naval Warfare Systems Command (SPAWAR). I also had an NSF grant and did some work for NASA and a private company.

Bob Sheldon: How receptive were these military customers to your ideas about computer security?

Dorothy Denning: They were very receptive. We had no trouble getting funding.

Bob Sheldon: So your ideas were successfully implemented.

Dorothy Denning: I don't want to say they were just my ideas. They were ideas that were developed with colleagues at SRI, especially Peter Neumann, Karl Levitt, and Teresa Lunt. We also partnered with Roger Schell and others at Gemini on the database work for RADC.

Bob Sheldon: Where was your SRI office located?

Dorothy Denning: The SRI campus was in Menlo Park, California, but we moved buildings while I was there. We were originally co-located with the Artificial Intelligence lab, but then we moved to a different building.

Wayne Hughes: Was it your impression that the military people were anticipating more intrusions and more need for security, or were they mostly focused on minor security problems?

Dorothy Denning: The military was very into security from the 1960s.

Wayne Hughes: We could even go back to World War II where there was computer security involving breaking into the Japanese mail.

Dorothy Denning: That wasn't considered computer security. That was communications security and code breaking. I think the computer security issues didn't arise until we had time-sharing systems, where you had multiple users sharing the same computers. Then we got networks and the problems got way bigger. Initially, the computers were big, expensive things and you spent millions of dollars on a computer, so you'd have multiple people using them. The holy grail in the military was always multilevel security. The idea was to have all of the data on one computer, even though it was classified differently. And have all of the users be able to use it, even though they have different clearances. And you want to keep that data separate and make sure that it doesn't get into the hands of people who aren't cleared. The military started working on that issue in the 1960s.

Wayne Hughes: I guess I was thinking there was cryptography involved.

Dorothy Denning: Cryptography wasn't a big issue then. The issue was access control.

Wayne Hughes: I'm looking at your books on cryptography.

Dorothy Denning: Yes, there's cryptography books, but that whole area was really separate from computer security. It was about communication security. It wasn't computer security. It had very separate and different people working it. The code breaking stuff was all math and maybe some engineering. Engineers built the devices to do it. But it's very separate from computer security. Computer security really arose from the insider problem, and then when computers got connected—the remote intruder problem. Of course, after computers were networked, cryptography became essential as well, and the fields of computer and communications security came together into what is now often called cyber security.

Bob Sheldon: Were there any well-documented insider threats that you read about in the literature?

Dorothy Denning: The real computer crime guru was Donn Parker. He started documenting cases of computer crime and interviewing the

criminals from the very early days. But most of us researchers were just interested in theory and technology. Donn was actually out there talking to and collecting data from the guys that were committing the crimes and the companies that were getting victimized. The early cases were all things like embezzlement, fraud, sabotage, and theft of intellectual property.

Bob Sheldon: Did Donn Parker work at SRI while you were there?

Dorothy Denning: Yes. He was actually at SRI before I got there.

Robert Harden: How did you have the opportunity to interview hackers?

Dorothy Denning: That was very interesting. At that point, I had left SRI and was now working for Digital Equipment Corporation (DEC). The reason why I transitioned from SRI to DEC was I found it really stressful having to bring in money at SRI, having to go out and get all these grants. I also wanted to do something a little different. I thought I wanted to work on user interfaces. So I left SRI and went to DEC, where I initially worked on the user interface for their email client. I was there a few months and then this hacker sent me an issue of this "zine" (for magazine) that he edited and wrote called *W.O.R.M*. It had a review in it of my book *Cryptography and Data Security*. In particular, he was really interested in how you could compromise security in statistical databases. He picked this stuff right out of my book and had written about it, and he wanted to interview me for his publication. At that point, I had really not paid much attention to the criminal side and what people were doing and who they were. I had really just been focused on security. I thought this would be an interesting opportunity, so I said, "Yes." Then after he interviewed me, I was kind of surprised by the questions he asked. They were very thoughtful questions, and it was a good experience, so I turned the tables and interviewed him. Then he helped me get in contact with others, so I started interviewing other hackers.

Bob Sheldon: Were these criminal hackers or just hobbyists?

Dorothy Denning: I think most of the people I talked to could be put in the category of hobbyists, but they broke into systems, which is a crime. This particular kid said that when he turned 21 he stopped because "Now the risk of prosecution is too high." I think most of the people that I talked to were probably basically good kids.

Bob Sheldon: And they were good at computers.

Dorothy Denning: Mostly. But there was one kid I went and interviewed in Denver. It was a sad case because he was living in a garage. He had all these computer manuals and other kinds of things. He really wanted to eventually get a job with the CIA, but he was having trouble. He wasn't such a good programmer; he was probably never going to make it.

Bob Sheldon: Did you characterize the psychology of these hackers? Was there any commonality?

Dorothy Denning: These kids, they were all curious. They were all adventuresome. They wanted to get in to show they could do it and impress their fellow hackers.

Bob Sheldon: Did you still live in California when you did that?

Dorothy Denning: Yes. DEC's office in Palo Alto was just a few blocks from SRI's campus in Menlo Park.

Bob Sheldon: How was the DEC work environment?

Dorothy Denning: It was an exceptional environment, with a highly talented and close group working collaboratively on projects.

Bob Sheldon: What other kinds of projects did you work on at DEC?

Dorothy Denning: Nothing else significant in the security area. Besides the email work, I managed our export program, which exported our hardware and software to researchers both within the US and in foreign countries.

Bob Sheldon: How long were you at DEC?

Dorothy Denning: Four years. I was at SRI from 1983 to 1987 and DEC from 1987 to 1991.

Bob Sheldon: Where to from DEC?

Dorothy Denning: Georgetown University.

Bob Sheldon: Did you intentionally want to go from the West Coast to the East Coast?

Dorothy Denning: No. I intentionally wanted to go back to academia. DEC wasn't a very good match for me.

Bob Sheldon: How did you like the academic environment at Georgetown compared to Purdue?

Dorothy Denning: I loved Georgetown!

Bob Sheldon: What classes did you teach?

Dorothy Denning: I developed and taught courses in cryptography, information warfare, telecommunications, and computer literacy. I also taught the introductory computer science class. Georgetown had a very small computer science department, with only four or five faculty and hardly any students (maybe 15 or 20) when I got there.

Wayne Hughes: I assume one of Georgetown's appeals was the students?

Dorothy Denning: I was attracted to everything about Georgetown. There was just something magical about it to me. Also, it wasn't really a computer science school. It wasn't an engineering school. I wanted to have more exposure to students and faculty in other disciplines. I got involved with the Science and Technology in International Affairs program within the School of Foreign Service and helped form the Communications, Culture, and Technology Program. I advised student theses in both of these programs.

Bob Sheldon: Was the computer literacy class intended for non-computer experts?

Dorothy Denning: Yes. I even had basketball players in the course.

Wayne Hughes: When you got into cryptography, did you research cryptography in World War II and what was going on in the Battle of the Atlantic and Pearl Harbor?

Dorothy Denning: Not very much. I read David Kahn's book, which is wonderful. In my book *Cryptography and Data Security*, I have a little bit in there about the Enigma. But it was more about how it worked than its significance in the war. I have just finished reading *Code Girls*, which is about all the thousands of women that got involved in code breaking during World War II in the US. Women in Dayton, Ohio built over a hundred of the code-breaking "bombes"—American versions of the British code-breaking machines that were used to break the Enigma.

Bob Sheldon: Were most of your students at Georgetown grad students or undergraduates?

Dorothy Denning: Almost all the students who took computer science related courses were undergraduates since our department was too small to support a graduate program at that time. But the information warfare class had both undergraduates and graduates from across campus. I also taught a course on miscellaneous cyber issues such as privacy and free speech that was mostly for graduate students.

Bob Sheldon: Did you have any military students?

Dorothy Denning: I think I had a couple who were in the military.

Bob Sheldon: You came to Georgetown in 1991. Was it after Desert Storm?

Dorothy Denning: I came in July, so it was just after.

Bob Sheldon: Was there any sense at Georgetown about their interest in defense issues?

Dorothy Denning: Not among the people I was involved with. At that point, I didn't know people in national security affairs that would be more interested in things like that. I was mostly focused on the computing stuff.

Bob Sheldon: Did you have some sponsored research?

Dorothy Denning: I don't think I had any sponsored research at Georgetown. While I was chair of the department, I was paid for 12 months of the year. After that, I started doing consulting in the summers. I did patent work.

Bob Sheldon: Who were you consulting for?

Dorothy Denning: Law firms. Expert witness kind of stuff about cryptography-related patents, specifically relating to work that I had done earlier. That's how they had contacted me because my work was considered prior art in these patent litigations, meaning my work was already available to the public.

Bob Sheldon: How long did you spend at Georgetown?

Dorothy Denning: From 1991 to 2002, 11 years.

Bob Sheldon: Did you get involved in more of the computer security issues for the government?

Dorothy Denning: I did some consulting for both the Department of Defense (DoD) and FBI.

Bob Sheldon: What were their topics of interest?

Dorothy Denning: For DoD, I was on various committees. One of the most interesting was a computer network defense/computer network attack (CND/CNA) committee that was managed by the Institute for Defense Analyses. The committee was co-chaired by retired Air Force

General Jim McCarthy and Vice Admiral Dave Frost in 2000–2002. We were under the Independent Strategic Assessment Group focused on Joint Task Force (JTF)/Sub-Unified Command Issues. We were involved in making the recommendations about how the military would handle cyber. Then it was being talked about as computer network operations (CNO), which included CND, CNA, and computer network exploitation (CNE). We reported initially to the commander-in-chief of US Space Command. Then when US Strategic Command (USSTRATCOM) was assigned the CNO responsibility in 2002, we reported to the commander of USSTRATCOM. We looked at various CND/CNA issues relating to policy, roles, organization, technology, and operations and recommended two possible JTF organizational options, one as Dual JTF/Sub-Unified Commands and the other as a Single JTF/Sub-Unified Command.

Robert Hayden: Was this your first real involvement with the military?

Dorothy Denning: No. I had been on several different task forces.

Robert Hayden: But at that high level?

Dorothy Denning: That was probably the highest level, where there were people that were pretty high up on the advisory committee.

Bob Sheldon: Did they take your suggestions seriously?

Dorothy Denning: It wasn't me personally, but yes. I would say this committee was influential.

Wayne Hughes: Did you have any connections with the National Security Agency (NSA)?

Dorothy Denning: Yes. I spent three weeks at NSA reviewing one of their crypto algorithms. There was a chip that came out called the clipper chip. It was very controversial. Basically, you could use this chip to encrypt and the government would be able to get access through keys that were held by the government. So the FBI, if they were doing a wiretap, and the communications had been encrypted with the clipper chip, they would be able to get the keys to unlock the communications. I was serving as an advisor to the FBI at the time. When the chip was announced, I supported it, which did not make me very popular with many people. Also, the method, or algorithm, was classified. So in

order to try to boost trust among the public, they put together a group of five cryptographers, which included one of the developers of the Data Encryption Standard and myself, to study the algorithm and make a determination of whether we thought it was secure. They briefed us on the algorithm and I spent three weeks at the NSA with a team of people that they gave me to run various tests on the algorithm. I represented our committee there. The other committee members gave me suggestions for tests to run. I might have been the only one cleared to do that. That was very interesting. It was one of the highlights of my career.

Wayne Hughes: The reason why I wondered if you looked back at World War II and Enigma and the other code-breaking efforts was I was thinking that knowing that history would be useful in considering what the Chinese might be doing today and what the Russians have been doing today and giving it some perspective.

Dorothy Denning: Yes. I just wasn't thinking about things like that back then.

Wayne Hughes: I don't think that you need to know ancient history to re-discover that kind of mind. So often we hear that nobody breaks our code; we give it away, making that human side of security almost as important as the technological side.

Bob Sheldon: MORS held a workshop on information operations around that time. As part of that workshop, we were allowed to consider computer network defense but not computer network attack, since that topic was classified above the level of our meeting. Did you deal with any silly issues like that?

Dorothy Denning: I tried as much as possible to stay away from classified stuff. Even here at the Naval Postgraduate School (NPS), I've tried to stay away from it because I don't want to feel those kinds of restrictions on me. The public and other academics talk about this stuff all the time.

Robert Hayden: Around the timeframe of your work at the NSA, it's my understanding that was when you appeared before Congress or the Congressional subcommittees. Did you have to do any preparations for that?

Dorothy Denning: Yes. The most challenging one for me was the first time that I testified before Congress. I was asked to testify on the Federal Aviation Administration's (FAA's)

plans for augmenting the Global Positioning System (GPS), in particular, on the question of whether the FAA's planned differential GPS correction signals could be encrypted with a strong commercial algorithm. I knew nothing about the GPS system at the time. Zero. But I thought, "This sounds like an interesting problem," so I agreed to it. I probably spent a month or two preparing and learning about GPS and the issues involved so that I could testify.

Robert Hayden: Did it get easier with the additional times you had to testify before Congress?

Dorothy Denning: Yes. The others were more in tune to my background. I think the second time I testified on cyber terrorism and I had just written something that covered cyber terrorism before that. The others were on the clipper chip.

Bob Sheldon: How were the people in Congress to deal with? Were they antagonistic?

Dorothy Denning: No. Nobody was ever antagonistic.

Bob Sheldon: Did they treat you just as an expert witness that they wanted to gain from your knowledge?

Dorothy Denning: When I testified on cyber terrorism, I don't think they liked what I said. This was around 2000, before 9/11. They really wanted me to say that cyber terrorism is this big scary thing that we need to do something about right now or we're all going to die. And that's not what I said. [*Laughing*] I still say that we have to worry more about bombs than bytes from terrorists.

Robert Hayden: That goes along with what we learn in operations research. Most of the time the customers have in mind what they want us to say. At the end of it, that's not how it comes out.

Dorothy Denning: Yes. They liked the other panelists better because they were telling them how scary chemical and biological weapons were. I was the cyber person.

Wayne Hughes: To relate this to the operations research field, I've said, taught, and believe that once you tell the sponsor or customer what he wants to hear instead of what he needs to hear, you're no longer an analyst; you're a prostitute.

Bob Sheldon: The tradeoff we have with computers and network security is between making it easy for the users to use it versus making it secure against the bad guys. The more secure we make it, the harder it is for users. How do you look at that tradeoff?

Dorothy Denning: That's what always bothered me about computer security and why I tried to leave the field a couple of times. I just hated all the stuff we had to do. To this day, I hate passwords. I especially hate what they make you do here—changing it every 90 days. And we have to have this stupid password string. And the data does not support that! That's what really galls me is the data does not support doing that. Even the National Institute of Standards and Technology has now come out and said that you don't need to change your password every 90 days. You don't necessarily need a 15-character string that nobody can remember. You can solve the whole problem in easier ways. That annoys me. Some things we put people through are not necessary.

Wayne Hughes: Those directions about the security come from off-campus. Right?

Dorothy Denning: Yes. It's at least a Navy thing, if not a DoD thing.

Bob Sheldon: Did you interact with any professors in other departments at Georgetown?

Dorothy Denning: Yes, I was part of the School of Foreign Service with the Science, Technology, and International Affairs department. I was on their faculty board or something like that. I also helped start the Communication, Culture, and Technology department, which is a master's degree program, so I worked with faculty and students there too.

Bob Sheldon: In your interactions with other faculty at Georgetown, how did they feel about your work?

Dorothy Denning: I don't think my interactions with them were related much to my work. It was more related to campus things like hiring. When I first arrived at Georgetown, I chaired a task force to develop a plan for information technology across campus.

Robert Hayden: How did you get involved with the editorial boards you are on or have been on?

Dorothy Denning: I was invited.

Bob Sheldon: Was it because of your English background, because you were good at English?

Dorothy Denning: No. I was generally well known in my field. In fact, I started one journal.

When I was at Purdue, I was chair of the Special Interest Group on Operating Systems for the Association for Computing Machinery. The group was interested in having a journal, so since I was president at the time, I was the one that put together the proposal for the journal. We got it accepted. I did not want to be the editor in chief, so I found somebody else to be editor in chief. But I served as an associate editor for a few years.

Bob Sheldon: You're terribly prolific. I can't imagine how you can write so many papers and books.

Dorothy Denning: Peter has written more. I don't see how he can write so many! [*Laughing*]

Bob Sheldon: Do you write quickly, and does it flow naturally?

Dorothy Denning: No. It's hard. It's a lot of work for me to write.

Bob Sheldon: Do you have some good peer reviewers in your community that you trust to help you out?

Dorothy Denning: Yes. I have over the years. It's been different people.

Bob Sheldon: You came to NPS after Georgetown. How did that happen?

Wayne Hughes: I think we can say that was an interesting problem on both sides, because Peter and Dorothy were going to go anywhere together. That involved some negotiation. We found places that they both could continue to contribute.

Bob Sheldon: What was it about NPS that appealed to you?

Dorothy Denning: Several things. I knew a number of people here who I liked and respected. I liked Monterey. And coming into this department, I liked the challenge it was going to be for me to teach students that were from very different backgrounds from what I had taught before.

Bob Sheldon: How was it teaching students here as compared to Georgetown?

Dorothy Denning: They're both very good, but nobody beats the students here. In maturity and discipline and interest in learning. They want to be here. They want to learn. They do their work on time and they show up. If they're not going to be there, they let you know. No other place is like that.

Bob Sheldon: Have you supervised any thesis topics?

Dorothy Denning: Lots. One of them—it ended up being a classified thesis, so I can't say a lot about it—was especially noteworthy. The student, Major Brian McCool, did some network analysis of advanced persistent threats that had been attributed to a foreign country. The data was classified, so the thesis had to be classified. Major McCool put together a network showing how all these different operations were connected through such things as IP addresses, URLs (uniform resource locators), domain names, malware, and so forth. It also lent some insight about how you might counter these different threat actors based on that, and where you could apply the most leverage. I thought that was maybe the most impressive thesis, just in terms of all the analysis and work that he did. There was another very good one on supply chain threats. The students, Majors David Abel and Kyle Fox, went out and collected data on incidents of malware in the supply chain. This was mostly public domain, although there was a classified chapter with classified data as well. They analyzed the data to determine whether they were hardware or software, where they had come from, and so forth. That was pretty interesting.

Wayne Hughes: I want to point out for our readers that any thesis in the Defense Analysis Department is going to be very operations oriented and very practical; not computer science, but applications of computer science.

Dorothy Denning: Yes, they're all very practically oriented.

Wayne Hughes: I've had a couple of thesis students from Defense Analysis and they were just a delight, because they have such interesting subjects in special operations and the kinds of things they've done.

Robert Hayden: At this point in your career, now that you're at NPS, you've received numerous awards. How did you feel when you were inducted into the National Cyber Security Hall of Fame, which recognizes those who "had the vision and leadership to create the foundational building blocks for the Cyber Security industry"?

Dorothy Denning: It was a nice honor.

Bob Sheldon: Did you get any death threats for that?

Dorothy Denning: No, I got some death threats when I was defending the clipper chip. [*Laughing*]

Bob Sheldon: You had a fairly high profile. Your name was known, and they knew where you live, and they had your email address.

Dorothy Denning: I don't do anything controversial anymore. [*Laughing*]

Bob Sheldon: What did you teach here at NPS?

Dorothy Denning: I taught four classes. Conflict and Cyberspace; that was one I started when I first came here, and I kept teaching that every year. I taught a class on Computer Network Attack and Defense, which focused on the technologies. I also taught a class called Trust, Influence, and Networks that focused on human social networks. And I started a class on Terrorist Financing, but I only taught that twice before turning it over to another professor. The Conflict and Cyberspace class was not focused on military operations, since much of that is classified. We have international students and I wanted to keep the class unclassified.

Bob Sheldon: Do you have a way of profiling or characterizing some of our adversaries in the cyber domain?

Dorothy Denning: Yes. I've just recently written a set of articles on Iran, North Korea, Russia, and China for *The Conversation*. Before retiring, I covered them in my Conflicts and Cyberspace class. I had a whole class on Russia and China and one on North Korea and Iran. In 2005, more than 10 years ago now, I had some funding for unclassified research on assessing the cyber threat of foreign countries. The research led to a thesis by Lt Jason Patterson and Lt Matthew Smith that assessed Iran and another by Lt Christopher Brown that assessed North Korea. But all of the research was open source, so it lacks a classified perspective.

Wayne Hughes: I think you make a good point though. In operations research, we could try harder to distinguish the personalities of the opponents. We sort of collectivize them and have a generic opponent as opposed to taking advantage of knowing that, for example, the North Koreans are not going to do things quite like the Chinese would. We could do more of that and I think Dorothy has done a valuable service in her domain, talking about cultural uniqueness. Is it true they really tend to be special and different?

Dorothy Denning: Yes, they look a little different. In China, it's almost all espionage. I don't really worry about China shutting down the grid. I just don't think that's where China is at. They're also blocking information going into their country, but usually that doesn't have much impact outside China. Russia, on the other hand, they've done some pretty nasty stuff. They've shut down power in Ukraine. I think they have the highest capability. But the other thing that really distinguishes Russia is all the false information they disseminate both within Russia and throughout the world; Russia is much more advanced in this area than any other country. North Korea seems to really be about its image. The most serious attack coming out of North Korea had to do with this movie where their dear leader is about to be assassinated. They didn't like that and launched attacks against Sony Pictures. Iran also launches destructive attacks, but most seem to be retaliatory in response to things that have been done to Iran such as the Stuxnet operation that damaged centrifuges.

Bob Sheldon: Wayne speaks positively about the international students that he gets in his department. What are your feelings about the international students at NPS?

Dorothy Denning: I love the internationals. They were excellent.

Bob Sheldon: How is their mindset different in your classes?

Dorothy Denning: They just see the world differently from the US students in practically everything. It was especially noticeable in the class I had on Trust, Influence, and Networks. When the international students would speak up in class, they always had something different to say from what the US students were saying. And I think the US students benefited from hearing their views (and vice-versa). There were also some very interesting interactions among the international students from countries that were sometimes adversarial, for example, between Indian and Pakistani students.

Wayne Hughes: Sometimes we have a problem that you've got to be unclassified if you teach international students. And I think Dorothy shares my view that the reward is worth

having to stay unclassified. To teach our US students that there are different perspectives from the international students. Often wise perspectives.

Bob Sheldon: You have continued on as an emeritus professor here at NPS. What have you done with your spare time since retiring?

Dorothy Denning: I do a lot of reading. I've helped on one thesis and there's another one I'm going to help with. I've done some writing. There's a series of articles I wrote that I just told you about that I did since retiring. I'm helping with department activities, with promotions and tenure and that kind of stuff.

Bob Sheldon: For the benefit of our readers who aren't savvy on the cyber domain, do you have recommended books or articles that are more accessible?

Dorothy Denning: There's a lot of stuff just coming out. I just saw today that David Sanger has a book coming out called *The Perfect Weapon: War, Sabotage, and Fear in the Cyber Age*; I'm sure that's going to be good. There's a whole bunch of good ones that came out recently that would be good for people who aren't experts in the field.

Robert Hayden: How important have mentors been in the course of your career?

Dorothy Denning: I would say that mentors were very important for me at Michigan, and there were a couple of people at Rochester. I feel really lucky because I have throughout my whole career been encouraged by men to pursue the things I've pursued. Not too many women were involved, but where there were, they were encouraging too. But mostly men. I never had a man tell me not to do something. Beginning with my father. He was disappointed that I didn't want to run his business, but on the other hand he was glad I was interested in math and all that.

Bob Sheldon: So you never encountered a glass ceiling?

Dorothy Denning: No. But I wasn't too ambitious. I wanted to be a high school math teacher, get married, have kids. Then I wanted to get a PhD and teach and then get tenure so I could continue, but that was it. I never wanted anything more than that.

Bob Sheldon: Did your undergraduate courses in teaching help you later?

Dorothy Denning: I think it was mostly irrelevant. I think my teaching was probably influenced more by the teachers I had, and observing them and following what they did, than anything from a course. I don't even remember what we did in the course at Michigan, but it was things like using audio-visual equipment. We also read some educational philosophy.

Bob Sheldon: Do you have any recommendations to younger members of our community?

Dorothy Denning: Follow what interests you.

Wayne Hughes: I think Dorothy's field of information technology and information warfare is still booming. It's going to continue to grow. And we in the operations research community need to be aware of new opportunities, and especially aware that information warfare, cyber warfare, computer science, and computer technology are for young people. That's where all the creativity comes from, and we need to get out of their way, and allow them to make some mistakes as they develop a lot of things that we in the military still need.

Dorothy Denning: I absolutely agree. It's the young people that will move this forward.

Robert Hayden: How have you been able to keep up with it?

Dorothy Denning: I can't. That's part of the reason I retired when I did. [*Laughing*] I don't want to feel obliged to keep up.