Photo by Linda J. McManus

WILLIAM B. BRIDGES
(1934 –)

INTERVIEWED BY
SHIRLEY K. COHEN

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Subject area

Electrical engineering, applied physics

Abstract

An interview in three sessions, in May and June 2001, and an Addendum, March 2004, with William B. Bridges, Carl F. Braun Professor of Engineering in the Division of Engineering and Applied Science. Dr. Bridges received his undergraduate and graduate education at the University of California at Berkeley (BS in electrical engineering, 1956; MS, 1957; PhD, 1962). At Berkeley in graduate school, he worked with John Whinnery and Charles K. (Ned) Birdsall on microwave vacuum tubes. He recalls that work and comments on its military applications. He then went to Hughes Research Laboratories (now HRL Laboratories LLC), for which he still is a consultant. Recalls gas laser work in the early 1960s at HRL and Bell Laboratories and the development of the argon-ion laser. In 1977 he joined the Caltech faculty with a joint appointment in electrical engineering and applied physics, while continuing to consult at Hughes. At Caltech he began working on laser isotope separation and later on far-infrared lasers. He discusses his various graduate students in electrical engineering; his colleagues John Pierce, Hardy Martel, Robert Cannon, Roy Gould, and Sverre Eng; his part in developing an undergraduate option in electrical engineering and in building up that department; his work as executive officer for electrical engineering (1978-1981). Recalls his visiting professorship at the University of

Göteborg, Sweden, summer 1989; technical advisor and board member of Uniphase Corporation, a fiber-optic-communications company (now JDS Uniphase) in the 1980s and 1990s. Comments on the difficulties faced by women in engineering and his establishment of a chapter of the Society of Women Engineers at Caltech. Discusses his involvement with Caltech's Program in Advanced Technologies in partnership with TRW, Aerojet, General Motors, and GTE. Concludes the interview with his recollections of Caltech President Marvin L. (Murph) Goldberger's attempt to set up a study center at the Jet Propulsion Laboratory for the U.S. Army (the Arroyo Center) and his recollections of Goldberger's successor as president, Thomas E. Everhart, whom Bridges knew from Hughes and Berkeley.

The Addendum to the interview concerns Bridges's marriage to Linda J. McManus.

Administrative information

Access

The interview is unrestricted.

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CALIFORNIA INSTITUTE OF TECHNOLOGY

ORAL HISTORY PROJECT

INTERVIEW WITH WILLIAM B. BRIDGES

BY SHIRLEY K. COHEN

PASADENA, CALIFORNIA

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CALIFORNIA INSTITUTE OF TECHNOLOGY

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COHEN: Good afternoon, Professor Bridges. Perhaps we could start out with your telling us about your family background—your mother, your father, what they did, where you grew up.

BRIDGES: OK. I was born in Inglewood, California, just across town here, on November 29, 1934, which I always remind people, was Thanksgiving day. My mother always said she was expecting a turkey but had me instead. You know, that was her line.

COHEN: [Laughter] OK.

BRIDGES: And of course Roosevelt changed Thanksgiving in 1939, to the fourth instead of the final Thursday in November, so my birthday never occurs on Thanksgiving.

COHEN: A little more shopping time before Christmas.

BRIDGES: More shopping time before Christmas—that's right. My father, Newman Knox Bridges, died in the first year of my life. I was eight months old when he died. He had appendicitis and died of the infection. In 1935 there weren't a lot of wonder drugs to keep you alive if your appendix burst, and his did. I was an only child. My maternal grandparents, John and Lila Brown, were basically a blue-collar family; my mother and I moved back in with them.

It was a bad time, the Depression. My mother remarried in 1940, and in fact my stepfather, Hans Johnson, just passed away a few weeks ago. Now I'm the oldest person in my family; it's an awesome responsibility, I guess. But in any case, my mother worked for the Inglewood Union High School District, as a payroll clerk, and my stepfather, Hans, worked first in the aircraft factories during the war and then after the war set himself up as a mechanic to repair brakes. That's pretty much their history. They retired from those jobs ultimately.

My stepfather and I didn't get along particularly well. I avoided him. So in a sense, really, the men in my life who influenced me were my grandfather, who had a garage full of tools and let me have free rein with them, and my great uncle, Milo Tupper. My grandparents' generation was a very large generation; I had lots of great aunts and great uncles and they all lived in Los Angeles. They had all immigrated from Montana in 1919. It was too cold there, so they all came to Southern California.

COHEN: Where did the family come from originally?

BRIDGES: My great-grandmother was French Canadian. My great-grandfather had come from Sweden. Of course, I never knew him; he died before they came to Southern California. I don't even know the family name: they changed their name to Brown on the boat, and no one knew what the old one was. So Brown was that family name. On the Bridges side, my natural father's sister lived in Redlands, so we would see her and her husband—the Larsens—once in a while. They were rather closely associated with Redlands University. My natural father had gone to Redlands for a year before he had to drop out and make a living during the Depression. It was a pretty bad time.

Probably the biggest influence was my great uncle Mike—Milo Tupper. He was a rock hound, and I was always over in his garage cutting and polishing rocks or building things, so between him and my grandfather I learned to use tools. I still enjoy working with my hands—I'm an experimentalist, really. I went to Inglewood High School.

COHEN: And that was a lower-middle-class white community?

BRIDGES: That's right. Then it was a totally white community and now it's a totally black community. I graduated in 1952 and went to the University of California at Berkeley.

COHEN: You must have stood out in your class at high school. Were you a good student?

BRIDGES: Yes. I was the number-two student in class. I had one colleague who had better grades than I had, and he went to USC [University of Southern California]. Most of my buddies went to USC or UCLA [University of California at Los Angeles]. I was the only one who went to Berkeley.

COHEN: That was far away.

BRIDGES: It was far away. Well, actually I had a girlfriend pen pal who was also going to Berkeley the same year. We had corresponded all through high school, so this was a wonderful opportunity to get together. And Berkeley was a good school. And we did get together for a year, and then she met somebody she liked better and…

COHEN: That's how it goes.

BRIDGES: That's how it goes.

COHEN: So you liked Berkeley?

BRIDGES: I liked Berkeley.

COHEN: Did you come in as an engineering student?

BRIDGES: Yes, I came in as an engineering student. Berkeley had a lower division. The first two years it was about half the size of the upper division, because they had to take all the junior college transfers. I always thought that we were sort of the test rats against which everybody else was judged—the junior colleges were judged—when their students came in. The University of California, particularly the Berkeley campus, was supposed to set the tone for the curricula in the junior or community colleges.

COHEN: According to the original master plan.

BRIDGES: Yes. And they did. It worked pretty well. I graduated in 1956 and I was in the top five of my graduating class of 5,000—probably the top electrical engineering student. I had majored in electrical engineering. I decided to stay at Berkeley for graduate school. I had spent a couple of very interesting summers as an undergraduate down at Varian Associates in the Palo Alto area the summer between my junior and senior year and then the summer after my senior year.

COHEN: Now, this was a job? You worked there and were paid?

BRIDGES: This was a job—I was working there and I was paid. I was interested in microwaves and microwave tubes as a senior, so it was a natural job for me. And I learned to like that even more and stayed on at Berkeley and worked for Professor John Whinnery in the microwave tube area for my master's degree, and then I also continued under him toward my doctorate. But at some point in there, John took a sabbatical for a year, and one of his old friends from General Electric Company, Ned [Charles K.] Birdsall, came as a visitor and took over all of John's students while he was on sabbatical. Ned and I really hit it off. And then, of all things, he decided to stay on at Berkeley as a professor, so I became his first graduate student. We found a subject we both liked; it was a natural evolution.

COHEN: At that time, they didn't encourage students to go to other places—I mean, they were happy to have them stay.

BRIDGES: No, they didn't. You know, when I think about that, it is strange, because I always encourage undergraduates here at Caltech to go somewhere else and sample the goodies at another school. But frankly it never occurred to me. There actually are other reasons for that, which I'll get into on a separate tack. But I stayed and worked with Ned Birdsall. We did some interesting things—vacuum-tube related. We were trying to describe how noise works in microwave vacuum tubes. That was a really hot topic at the time, and we thought we had a unique approach to it. Actually what we discovered was sort of a basic phenomenon, and it probably did help in understanding the noise processes in a vacuum tube. Strangely enough, twenty-five years later I got a paper to review on this very high-powered microwave-radiation weapon, and it was the same idea.

COHEN: Can you briefly say what it is?

BRIDGES: Well, it's actually a very simple thing. There's a maximum current that you can put through a vacuum-tube structure; when you exceed that, the tube goes into self-oscillation. We never put a name on it, but later the weapons people called it a vircator, for virtual cathode oscillator tube. And it's funny, because when I read the paper in order to review it, I thought, "My gosh!" You know, it referenced me and my thesis and all that kind of stuff.

COHEN: From twenty-five years ago?

BRIDGES: From twenty-five years ago. I called up Birdsall on the phone. I said, "Hey, do you know anything about this? How long has this been going on?" He said yeah, he was aware of it, and mostly the Los Alamos people and the weapons lab people at Kirtland [Air Force Base] had been working on it. The Russians had worked on it even more. And it was exactly the same physics, except that we had never thought about using that much current and that much voltage and trying to make it practical. I had discovered this oscillating mechanism, but we were thinking of low noise, very wimpy-type microwave tubes. And in fact at some point I went down to Los Alamos and walked into a room of people who all had read my thesis and knew it better than I did, because they had read it recently. It would have been fun to pick up that research and work on it, but it was all classified, and there was no way I could really do that at Caltech, so I just decided not to do it. Maybe when I retire I'll go back and look at that again.

COHEN: Is it still classified?

BRIDGES: Yes. There are competing approaches, so it's not clear that this is still a currently viable weapon, but it sure is a simple way to make lots of high-power microwaves. Anyway, that's sort of a side issue. That's what Ned and I worked on.

I got my degree in 1962 officially; I actually left Berkeley in June 1961, to take a job at Hughes Research Laboratories, in Malibu. It was then the Hughes Research Laboratories of the Hughes Aircraft Company, and of course the aircraft company doesn't exist anymore; the pieces all belong to somebody else. Hughes Research Laboratories is now called HRL Laboratories, LLC, and it's owned jointly by Boeing, Raytheon, and General Motors. I still consult there.

Even after I left I continued a consulting arrangement, so I'm over there once a week.

COHEN: When was [Richard] Feynman there, giving his lectures?

BRIDGES: Feynman was there when I came.

COHEN: Did you have any interaction with him?

BRIDGES: Oh, yes, a lot, as an audience participant. And that was probably one of the really neat things about that job—that Feynman came there. Talk about side benefits! He would come over every Wednesday afternoon at four o'clock and lecture from four to six on a subject of his choosing; that was his agreement with Hughes. Most of the staff members would come into the auditorium and listen to him.

COHEN: And not know what they were going to hear.

BRIDGES: Well, he would choose a series of things. Sometimes he would give the courses that he gave here, except without homework and exams, and sometimes he would use it to try out new subjects that he was interested in, like "Feynman Learns Biology." That was very interesting. He thought he could derive all of the properties of living things from the quantum mechanics of the carbon atom. Now, it didn't work that way, but it was a lot of fun to hear him try. And "Feynman Discovers Astronomy." That was another…

COHEN: Were they recorded? I think his lectures were all tape recorded.

BRIDGES: I don't know whether they were at Hughes or not. Some of them were. Some of them, like the statistical mechanics course that he gave, some of the people in the audience—Ryo Kikuchi, I think, was one—took a lot of notes and they ultimately published a book with his name on it. But it was a tremendous opportunity to hear him talk. It was really enjoyable.

COHEN: Was Amnon Yariv there at that time?

BRIDGES: No. Amnon was never an employee there, but he had consulted. After he came to Caltech [1964], he consulted at HRL, as did Tom [Thomas Conley] McGill. They were over there quite often. Bob [Robert W.] Hellwarth, who is a Caltech alum and now a professor of electrical engineering at USC, also was at Hughes at the time, and when he went to USC he stayed on as a consultant. So HRL is a high-class operation as corporate research laboratories go.

Let me backtrack a little bit. Part of the reason I stayed at Berkeley is that while I was an undergraduate I went on a blind date with a young lady from my high school. She was a year behind me in high school, but I had never known her in high school. But through a mutual acquaintance we went out on a date. And one thing led to another, and we were engaged. Her name was Carol French. She was originally a student at [UC] Santa Barbara, and I talked her into transferring to Berkeley for her last two years, which she did. So my first year in graduate school was the year that she graduated—1957—and we got married at the end of that year. That was part of the reason I stayed at Berkeley graduate school, because she was still there as a senior undergraduate and so it was a natural thing to stay for another year. Then we just stayed on.

COHEN: And they evidently were very happy to have you.

BRIDGES: Yes, I think so. I knew the professors I had worked with as an undergraduate and they knew me. The first year I went there for my master's degree I actually had a scholarship, which was very nice. But then I decided I wanted to try teaching, so I had an appointment as what Berkeley called an associate in electrical engineering, which meant you had a master's degree but not a PhD. And I taught a lecture class. So I had my own students, which was really neat, and I found that I really enjoyed teaching—something I hadn't expected. I taught for two years and finally decided I had better…

COHEN: Had you stopped doing your academic research?

BRIDGES: No, I was doing research and teaching. But I came to the conclusion very quickly that I really liked teaching and that the research was sort of hard and I couldn't quite see my way and whatnot. And that was about the time that Ned Birdsall and I got together and I decided I had

better quit the teaching or I'd never get out of there. So I did, and the last few years I was there I was a research associate.

COHEN: So you quit teaching not because you didn't like it but because you liked it too much.

BRIDGES: I liked it too much. In fact, when I got my PhD I had some offers of university positions, and I thought, "No, I'm an engineer and I really need to understand what engineering is really all about in the real world. Maybe I'll go out for three or four years and then I'll get an academic position." Well, it turned out that I was seventeen years at Hughes before I came to Caltech. But the idea was pretty much the same.

COHEN: What did you do your thesis on?

BRIDGES: It was on the electron-beam instability, which we thought of as a way of understanding noise transport in microwave tubes. And others later took those ideas on into high-power microwave weapon generation.

I came to Hughes. I interviewed at lots of different places. 1960 was really great. I had job offers from Bell Labs…

COHEN: Nineteen-sixty was a wide open time.

BRIDGES: It was a wide open year. We did the grand tour, visiting all the places in the East, and I had job offers from Bell Labs, RCA, and three different GE [General Electric] locations, but I had the offer from Hughes, and Hughes was still doing some microwave tube work. I knew some of the people there. Actually Mal [Malcolm R.] Currie, who was one of John Whinnery's earlier students, was associate lab director then, and that was part of the attraction. The other thing was that it was in Southern California, and of course my parents lived in Southern California.

COHEN: Well, there's something about people who grow up in California—they have a hard time leaving it.

BRIDGES: That's true. And by this time we had one child, a daughter, Ann Marjory Bridges, now Ann Marjory Bridges Foote. And we had another child on the way. So it was natural to be where my parents were and my wife's parents, who also lived in Inglewood. I think in retrospect it was certainly an excellent choice. One can never tell whether it was the best choice or not.

COHEN: Well, you certainly enjoyed the years at Hughes.

BRIDGES: I enjoyed the years there, and I got into things I could never imagine; namely, when I came, the laser had just been discovered at Hughes by Theodore Maiman. And of course that was the buzz around the labs. Maiman had left by this time, and that's a whole different story. I wasn't in the laser activity, I was in this microwave tube group, and the tube work had been going on for a long time. And in fact I ended it, basically, because my boss and I couldn't think of anything new that we wanted to do. By this time Hughes had gotten out of the low-noise microwave tube business, so we were looking for something else, maybe laser-related.

COHEN: This was a place where people had the freedom to just go do what they wanted to do?

BRIDGES: Not total freedom. I worked in a group called the Electron Dynamics Department, and in the section that was dealing with millimeter-wave vacuum tubes, and then these low-noise tubes where I hired in. We sort of killed the low-noise tubes. But I think my boss, Don [Donald C.] Forster—by the way, Don was a recent [1960] PhD from Caltech; he was Roy Gould's student, so it's all very interconnected—Don was interested in getting some activity going in the laser business, or a related area. We started off by thinking, Gee, maybe we could take some of our tube technology and make very high-frequency photodetectors for the laser. So I did that for about six months or so. By this time the helium neon laser had been discovered at Bell Laboratories, and Hughes was busy building some copies to be used around the lab, and I needed one for my photodetector work. But the guy who had been assigned the job of making these copies really didn't know what he was doing particularly, and so I would sort of stand around and watch, waiting until I got my laser out of his production line, and I never did—because they were basically building gas discharge tubes, and they didn't know that technology. But I did know it, so I got involved in that, and the next thing I knew, we were building gas lasers in *my* lab. It was a lot of fun. It was me-too stuff at first, duplicating helium neon lasers, trying to

understand how they worked, and that went on for a couple of years. In the very early days, trying to figure out what lasers were good for, we tried all kinds of crazy things, like shining red light beams from Malibu over to Culver City.

COHEN: So this was really an invention in search of a purpose.

BRIDGES: Yes, well, people proposed a lot of things at the beginning of the laser—you've read about them in some of these histories—but they somehow presupposed that it was going to be an expensive thing and that it really needed a high-end kind of application. If you had asked somebody, "Would you ever use lasers to read bar codes on cereal boxes in supermarkets?" they would have thought you were crazy, because no one would ever make a laser cheap enough to put in a supermarket. But in fact that's a big application; or cheaper yet, the thing that reads the CD ROM in your computer or in your Sony Walkman. You know, it was hard to believe in 1962 or so that it would ever come to that. And Hughes being Hughes, we were looking for military applications, for the most part.

COHEN: Star Wars is all lasers.

BRIDGES: Oh, well, that's true, but we were nowhere near that power level at that time. I had a technician assigned to me, so it was really just me and my technician, Robert Hodge, working on whatever we wanted to do in the gas laser business. And we had company funds to do it. It was probably the last time I've had that kind of freedom—in those first two years.

COHEN: Did you have to make a progress report or something?

BRIDGES: Oh, yes. We'd write up a paragraph every quarter, but internally.

COHEN: You didn't have to write grants to get money, either.

BRIDGES: That's true. Basically, my boss thought it was a good thing, so we did it. As time went on, that changed, and it got to be more and more…. Most of the funding came from outside Hughes, so you wrote proposals just the same way you do here. And probably the key event in

my life was the argon laser—that was tremendously exciting. It came about in the following way. I was working on internal mechanisms in lasers, trying to figure out how they really worked inside. The helium neon laser was more or less understood at the time, but there was another class of lasers that were originally thought to work the same way. One was a mixture of helium and xenon; that was the infrared laser, not technically important these days. But it was pretty clear after some simple experiments that it didn't work quite the same way as the helium neon laser. In fact, you could make it work in pure xenon, so you didn't need these collisions with helium atoms. I had been working in that general area of trying to understand mechanisms. At some point, we got word through the internal grapevine before publication that a couple of scientists at Spectra-Physics Corporation, which was then just a small company, started up in 1961…

COHEN: Here in this area?

BRIDGES: No, it's actually in Mountain View, California. In fact, it was started by people I had met at Varian Associates; they broke off and started this small company. So W. Earl Bell and Arnold Bloom had just discovered laser action in mercury vapor, ionized mercury vapor; they used a helium mercury discharge. And this was important, because even though it was just the beginning—it was a pulsed kind of tube—it looked like it had a lot more power than what we could imagine from the helium neon lasers. One of the wavelengths was green, and that was then the shortest wavelength of all of the gas lasers. And that's important, because in those days all we really had to work with were vacuum photo detectors. These were all photo-emissive devices, and they were not very sensitive in the red and infrared, but they were very sensitive in the green and blue. So just the wavelength alone made a couple of orders of magnitude improvement in putting together a system; furthermore, this looked like it had high power. Well, we got this information through another laser organization in Culver City, a Hughes organization—there was a laser development department there. So we said, "Gee, that's very interesting. I assume you guys are going to work on it." And their boss said, "Yes, they're going to work on it." So we didn't think anything about it for a month or so, and then I got a phone call from the staff member down there who was going to work on it. He said he was leaving Hughes and the project was dying and that if we were interested, we should feel free to

work on it. So I talked to my boss and it sounded like an interesting thing to do. By this time a paper by Earl Bell had appeared, so it was actually published [December 1963]. So we decided to build one, just to see what it was like, how it worked.

COHEN: This sounds like such an ideal job. You walk in and say, "I feel like doing this."

BRIDGES: Oh, yes, there was a lot of freedom. It had to be justified that this was a good thing if it worked, but there was still a lot of freedom to do things. I built one of these mercury-ion lasers. It worked. And then I continued with what I had been doing before. I was trying to figure out, "Well, what are the mechanisms? It's obviously helium and mercury. Is the helium necessary? How does the energy get from the helium to the mercury? Is it important?" And so I started doing some experiments to see whether I could figure that out. And we reasoned that if there were something magic about the energies—the energy levels in helium and mercury being coincident, as it is in a helium neon laser—that taking the helium out ought to make it not work. I replaced the helium with neon, and it worked. So we figured, "Oh, well, so it isn't anything resonant. There's no magic here." And we next took out neon and put in argon. I'll explain a little bit more about why I did that. It turns out—for reasons I still don't understand—that that substitution didn't work. But we just sort of did it very quickly. Also, you have to understand that I had had helium and neon and xenon on my gas filling station, in pure spectroscopic quality. When we wanted to do the argon experiment, we didn't have an argon bottle, but we were so hurried that rather than get the glass blower to put one on, I sent my technician, Bob Hodge, out looking for an old welding tank of argon, and we hooked it up to a station with a rubber hose, which isn't exactly a model of purity. So anyway, we put the argon in, and the mercury laser didn't work with argon—although we found out later that other people made it work with argon. Then we pumped it all out and refilled it with helium, to go on with some more experiments. And that was probably the most exciting moment of my life. We now had a green spot and a red spot from mercury, and a blue spot, which we had never seen before, on the wall of the lab. The first conclusion was that it was probably from the argon. But then, maybe it's the rubber hose, or maybe it's crud from the welding tank. I didn't know. We were afraid that the blue laser spot on the wall would go away, so we made the measurement, got the wavelength down, and I left Bob with the laser still running and I ran down to the library and

looked up spectroscopic references. We hadn't measured the wavelength accurately enough to use that as the definitive point, but it did look like there were some strong argon lines, which I didn't recognize, and they really weren't identified in the book that I was looking in. But I figured, "Well, it's probably argon." So I went back to the lab and said, "OK, let's see if we can make it go away." So we flushed the tube with helium two or three more times, and it went away. And then we put some argon in again and we reproduced it.

COHEN: You got it back.

BRIDGES: Yes. So then I ran down the hall to get my boss and Mal Currie, the lab director, and everybody to come see this thing. As I recall, this was Valentine's Day, 1964. I recall going home ill, actually. [Laughter] That afternoon I actually got the flu. But we left with instructions to the glass shop: "Make another tube like this, but we won't put any mercury in it." You could make the mercury sort of go away—but never completely—by freezing out the mercury with liquid nitrogen in a sidearm. Anyway, I didn't get back until the next week. I put another tube on the station. This is just a simple glass discharge tube, very simple. I had a little spectrometer. You could measure within a couple of angstroms, and that was good enough.

So the next week we got this thing working. This time we got the glass blower to put a good spectroscopic grade bottle of argon on the station. So we reproduced it, except now, instead of just this one blue-turquoise colored line, we had ten lines. It took a little while to count them all and measure them all, but we had ten lines. And that was really exciting. So then a telegram came to Mal Currie from Ron Knechtli, one of the other HRL department managers who was traveling in Europe. He knew about the laser; he had seen it just before he left for Europe. Well, Ron telegraphed us and said he was visiting CSF, a French company, and that he had seen a laser with red, green, and blue lines, and he assumed it was the same thing and advised us to get our act together and publish. Well, I didn't want to publish it until I really had identified the lines, and that required a very accurate wavelength measurement. I wasn't a spectroscopist, and I wasn't aware of all the spectroscopic literature. So I grabbed whatever handbooks we had. It turns out that if I had looked in a Swedish journal of physics, I would have found a nice monograph on argon—I didn't find that until a year later. So we didn't really have the lines identified very well. We decided we had to measure the wavelength accurately, but the

only spectrometer in the building was way down the hall in somebody else's lab—around two or three corners in a different hallway—and we figured we couldn't really move the laser, which was attached to the vacuum station. And we couldn't move the spectrometer either. So we got out some C-clamps and magnets, and we put seven mirrors out my door, down the hall, down a hundred-foot hallway, through a lab, out through another hallway—it was a terrible thing. And of course we were trying to keep this a secret, but there were all these mirrors on the wall. And we waited till after hours, and then we fired it up. It was a laser, so we could easily get the light all the way down the hallway; that's one of the really neat things about lasers. We took a bunch of photographic plates. And then Art Chester, who was a young Howard Hughes doctoral fellow assigned to me, and I sat down and analyzed the plates and measured the wavelengths. Art was a graduate student at Caltech and he would have his classes. And then he'd go to the library and Xerox the old noble gas spectroscopic literature. And then he'd come over and we'd spend the evening with a microscope, comparing and measuring wavelengths on the glass spectroscopic plates. Art was a theoretical physicist—he didn't work for Feynman, but he was in that same area—and of course I was an electrical engineer. We always thought that if a real spectroscopist walked in, we would have been a never-ending source of amusement because of what we were doing—you know, trying to learn how to do that from scratch. We ended up with 118 lines and published a paper. [W. B. Bridges and A. N. Chester, "Visible and Ultraviolet Laser Oscillation at 118 Wavelengths in Ionized Neon, Argon, Krypton, Xenon, Oxygen, and Other Gases," *Applied Optics*, 4: 573-580, May 1965.] And then we also essentially had xenon and krypton in that station. We tried those and it looked like there was a whole class of new lasers.

I'm going to back up a little bit, because it's sort of important in the evolution.

When I first got that mercury thing going, I was off on a trip, and I met Eugene Gordon at Bell Laboratories. I actually met him at a committee meeting and I told him about what I was doing. And Gene said that one of his former associates from Bell, now at Perkin-Elmer Corporation, was doing the same thing. He was interested in the helium mercury laser. He had tried the neon trick and it didn't work. So all he knew, in fact, was that neon wasn't going to work. Gene had suggested trying argon. It's going to be even worse than neon in plasma electron energy, because it has a lower ionization potential. So when I got back from that visit to Gene, I tried the neon and the argon, and the neon worked in exciting mercury but the argon didn't.

After we got the pulsed laser working and the xenon and krypton ion lines and everything—I had written those up also, as a paper [W. B. Bridges, "Laser Action in Singly Ionized Krypton and Xenon," *Proc. IEEE*, 52: 843-844, July 1964]—I met Gene again at another meeting and gave him the preprints of the papers and we discussed it. Now, this was a pulsed laser. It was high power, it was the right wavelength, but it was operating only with a low-duty cycle.

COHEN: What does that mean?

BRIDGES: That just means it was not continuous in its output. In fact, the average power was in the milliwatts, but the peak power was watts. And at the time we discussed this with Gordon around the dinner table, and I said, "Gee, it sure would be nice if this thing would go continuously." But the input power was very high, because it was high voltage and high current. And I couldn't quite visualize it operating continuously—certainly not in the discharge tube structures that we had. And so after that meeting I went back and continued to work on…. What I was doing was ion laser spectroscopy. Oh, by the way, just incidentally, we found oxygen, carbon, and nitrogen laser lines unintentionally. These materials were just left over in the tube, but there was enough of them around that they would oscillate also. We had to try to figure out what those lines were. The tubes had conventional vacuum tube oxide cathodes. We made them ourselves. These cathodes have a coating, which is barium oxide but starts out life as barium carbonate, and then you reduce it in place. So there was some carbon dioxide floating around in there, and nitrogen. I'm not sure where it came from, but it was there, too. And it turns out that these lasers were very easy to get going once you got a little bit in the tube. In this case, it was not put in intentionally.

And then I got a phone call from Gene Gordon. He said, "You know that argon laser? We have it going continuously." He had even more faith than I had in being able to run it at lower input power. The power output was microwatts, but it was continuous. Gene had access at Bell to high-reflectance laser mirrors—much better than what we had. It lowered the threshold for oscillation. And so he called me and told me about this, and he said, "We'd like to put your name on our paper." And I said, "Well, that's nice, but I'd like to do something. So you go ahead and start writing up what you have. And meanwhile I've got a bigger power

supply. Let's see if I can get a tube going continuously here." And so I did. At first we didn't appreciate how much electrical input power it would take to reach threshold—and how much heat we would have to get rid of. But after blowing up a couple of glass discharge tubes, we finally designed a water-cooled fused-silica tube that would hold together, and we had argon, krypton, and xenon ion laser lines operating continuously with more than 50 milliwatts output, more than 1,000 times the power of the Bell Labs tube.

Gene had sent me a first draft of what he and his colleague, Edward Labuda, had written, and so Bell Labs and Hughes ended up publishing a joint paper. [E. I. Gordon, E. F. Labuda, and W. B. Bridges, "Continuous Visible Laser Action in Singly Ionized Argon, Krypton, and Xenon," *Appl. Phys. Lett.*, 4: 178-180, 15 May 1964.] That was very unusual. I had a lot of people ask me about that, because in a sense Bell Labs and Hughes were competitors. But that's how it happened. One idea led to another and we published together. Nobody cared too much. Hughes wasn't too fussy then about intellectual property. In fact one of the Hughes PR people who worked for Foote, Cone & Belding, which was Hughes's PR company at the time, told me, "Mr. Hughes hired us to keep his name out of the papers." [Laughter]

So the CW [continuous wave] ion laser was published jointly with Gordon and Labuda at Bell Labs. And of course the word also got around within the Hughes organization. And that was it. And that really set the tone for the next several years for me, because there was a group of guys in Culver City, in the Hughes aerospace group that had been interested in a laser line-scanning night reconnaissance system originally conceived by Perkin-Elmer Corporation, and demonstrated by Perkin-Elmer using a helium neon laser. Basically, you bounce a laser beam off a spinning mirror. The laser beam scans a line on the ground, and the airplane moves forward, so you scan one after another, so it's like a TV display. You look at the reflected light and record it to get a picture that looks like a daytime strip map of the ground below. Well, Perkin-Elmer had this idea, but they needed a lot of power, so they developed a "heroic" helium neon laser, six feet long, that put out 100 milliwatts. And it worked. The pictures looked just like daytime photos.

So when we found a green continuous laser, the systems guys at Culver City were very excited about the much higher photo cathode sensitivity, plus the higher power. So we had a delegation from Culver City come up to try to talk us into building them an argon-ion laser they could fly in an airplane. [Tape ends]

Begin Tape 1, Side 2

BRIDGES: OK. So the systems people from the Hughes Aerospace Division wanted 200 milliwatts, and we said, "We think we can do it." Within probably a couple of weeks, we had a tube with 200 milliwatts output, so we called them back. It was not packaged yet; it was still in our lab. They said, "Well, we've been rethinking our calculations. Could you give us 400 milliwatts?" I said, "Well, we'll try." It turns out that the performance was going up with discharge current pretty rapidly, so we felt confident. We did make a tube with 400 milliwatts output, and meanwhile they started working on the mechanical packaging for the tube. We were building the discharge tube at Malibu and working together now with the systems group on an experiment which was funded by the air force. Eventually they called us up and said, "We've decided we'd really like to have two watts." And we said, "Wait a minute, guys. Why this big change?" So my colleague Steve [A. Stevens] Halsted and I ended up going down to Culver City to talk to their optical designer, and it turns out he was doing things that were crazy. He didn't like the Gaussian-shaped beam, so he was blowing it up and then cutting off the tails, just throwing away power. There were a whole bunch of things. And we tried to explain to him that doubling the power in our laser was not an easy thing to do and that he shouldn't just throw it away on the other end.

We came to a pretty good design, and actually flew the system in 1965. It was very exciting, because here was something that went from the laboratory—just a laboratory kludge—into a package and then ultimately into the bomb bay of a Wright Field B-47. And they flew it all around the country and took pictures at night. We saw some of the imagery, which was classified at the time and then kept getting destroyed, so none of it survived. I wish I had some. We had some beautiful pictures; they don't exist anymore. They flew it over one of the air bases here in Southern California to look at parked airplanes. Now, this is at night, and we have this picture of a parked airplane and there's a guy spread-eagled on the ground beside the airplane—one of the mechanics—asleep on the tarmac, figuring no one would ever see him. Well, we saw him, all laid out like that. [Laughter] It was a very nice system. And as a result of that experiment, Hughes got a major contract to build a more advanced version. And that's pretty much what we worked on at the research labs for two or three years, trying to make a really practical thing. It went from old glass-blown quartz tubes to metal to ceramic…

COHEN: But that was never a mission of Hughes particularly—to get into really practical systems, was it?

BRIDGES: It was. That was the interesting balance. We could do all these researchy things; but once something gelled into practicality, there was a lot of pressure to develop it. We were, after all, engineers. And we were making state-of-the-art laser tubes, or actually better than the state-of-the-art tubes. Other people were making them and selling them, whereas we were making them and giving them to our systems people. Hughes did a lot of leveraging of a key technological component into a big system, and a big system was very expensive. Even though the technological component may not have been that expensive, it was the key. There are examples other than this that Hughes was very successful in doing—a natural kind of thing for Hughes to do. It was a real agony of development. We thought we knew what we were doing, and we learned the things that we did wrong. I tried to write some of those up in a recent article on the early days of ion lasers, including some of the failures, too. [W. B. Bridges, "Ion Lasers—the Early Years," *J. Selected Topics in Quantum Electronics,* 6: 885-898, Nov./Dec. 2000.] The bottom line was that about 1971 that system flew very successfully, but the air force decided it was too expensive. And it required a dedicated airplane. You actually had to make modifications to the airframe.

COHEN: To put this whole laser system into it.

BRIDGES: Actually they were minor modifications, you'd think. You know, you'd punch a hole in a bulkhead to run a cooling line through. But it turns out that in the aircraft business that's anathema. You know, you don't modify an airplane that way.

COHEN: By poking a hole in it?

BRIDGES: By poking holes in it. And so the bottom line was they said, "Thanks, but no thanks," and then Hughes sort of lost interest in that work. By that time, I was really away from the business. In 1969 I was a department manager at Hughes, and I had other people running this project under me.

COHEN: Now, I have the impression from having read things that you really weren't too happy being a manager.

BRIDGES: Oh, I wasn't happy at all being a manager. And sometimes I think my graduate students know that I'm not happy being a manager of graduate students, either. [Laughter] I sort of let them alone, because I figure, "Gee, that's what I'd want. If it were me, I'd want my boss to leave me alone and let me do what I want to do." But I'm happiest in the laboratory puttering around, getting something to work, or trying to figure out how it works.

COHEN: So you had a very short career as a manager.

BRIDGES: I was only a manager for a year. I came about being a manager really by request, because there was a major change in leadership at the labs. Up until 1969, we had a dual laboratory, with two laboratory heads. In 1969 those labs were combined, and George Smith, who's also a Caltech alum as you know, became the lab director. And he grabbed my boss, Don Forster, to be his associate lab director, which left Don's department without any leadership. However, at the time they had another department that they wanted to change the leadership of. So the thing was to can the other department manager, shove these two competing laser departments together, and make me the manager of that activity. That was part of the unhappiness, because there were two groups of people that didn't get along, and now I was their mutual boss. I tried very hard to get that to all work together, and I was partially successful. The other thing is, it was the great aerospace depression of 1970, and suddenly everybody was scrambling for money. I ended up having to lay off ten percent of my department, whereas my boss, for years and years and years, had never laid off anyone. So it was an unpleasant time.

COHEN: Now, the Hughes money mainly came from military projects?

BRIDGES: Yes. Our department was funded about forty percent by R&D funds, which were out of the profit on military contracts, and about sixty percent on direct contracts we had with the military. There was no commercial money at all, and honestly no interest in commercial development. Unlike Bell Labs, which ran off Bell Telephone profits and had even more freedom than we had, it was kind of a halfway house: the conferences we went to were all people

from academia or other corporate research laboratories.

COHEN: So now we're coming near the time when you were thinking about leaving.

BRIDGES: Oh, I thought about leaving any number of times, and didn't, until I came to Caltech. There was a time in 1966 when I actually interviewed at Spectra-Physics. This was just a couple of years after the argon laser got started, and Spectra-Physics had picked it up right away and turned it into a commercial product. I thought it would be really great to go up and work with Earl Bell, the discoverer of the mercury laser, so I interviewed up there. But the day I interviewed I found out that what they were interviewing for was Earl Bell's replacement, because he was leaving the company, and I thought, "Gee, this isn't going to be any fun," because Earl was a fun guy to work with. We had talked on the phone a lot. When it came down to it, it was still sort of, "Well, Hughes isn't that bad a place. It *is* in Southern California." By 1965, we had three kids and two sets of grandparents there, so it just didn't seem like a good idea to leave.

COHEN: Were you living over on the Westside?

BRIDGES: Actually, we lived in the Valley until 1963 and then moved to Thousand Oaks. It was an easy commute through the canyon.

I interviewed at Bell Labs a couple of times, but for one reason or another I just decided I didn't want to move the family to New Jersey. Even though that was an attractive opportunity, I didn't want to do it. Probably the closest I came to leaving was in 1967, when I interviewed at UC Santa Cruz, which was a new campus then—very exciting, sort of on the Oxbridge model, very different.

COHEN: People from Caltech left to go up there.

BRIDGES: Right. Francis Clauser was the dean of engineering, and he was from Caltech. And John Whinnery was on leave from Berkeley and thinking of being there. And they recruited me. I went up and visited, and I thought, "This is really great—it isn't that far away." And Francis and John were just wonderful people to work with; I would have enjoyed that. But for some

reason I didn't do it; I changed my mind. And that was an excellent decision, because shortly after I decided against it, some state commission decided that Santa Cruz should not have an engineering college, so John went back to Berkeley and Francis closed the books and turned out the light and came back to Caltech. I would have been very unhappy. I would have been stuck there as an engineer without a department. So it was very fortunate I didn't do that.

COHEN: Then you came back to Hughes.

BRIDGES: Yes. Actually, I never left.

COHEN: Now, what year did you become a [Sherman] Fairchild distinguished scholar here?

BRIDGES: That was in academic year '74-'75.

COHEN: OK. So that was some years later.

BRIDGES: That was after I had been department manager at Hughes. In 1969 and 1970 I was department manager, and then I resigned. And that's always an awkward thing, because if you've been a manager, then how do you go into another department? For a while I was on George Smith's staff. I was just disconnected, and I was doing some odd things for George. And in a way that sounds good, because you're working for the director of the lab; in another way, the director of the lab doesn't own any lab space or have any facilities or any budget, so it was sort of frustrating. In 1971 we had a fourth child, who died a few days after birth. It was tragic, and I was sort of a basket case for a long time. That's when I was on George's staff. So I'm just as glad I wasn't in a managerial position or doing something really important right then, because it was really tough.

COHEN: Sure.

BRIDGES: By the way, even before being a department manager, I wasn't doing just ion laser work. We had hired other people who now had more involvement. By this time, I was the senior scientist, and I would get grabbed to do other things, even though I liked the ion laser

work. There was a big classified program that Hughes had—from 1967, roughly, through the 1970s—as a subcontractor to Avco Corporation, trying to develop what was then called a gasdynamic laser. That was really the first of the weapons-grade lasers, and something that really did generate enough power to do some damage, and Avco had asked Hughes to be a subcontractor to help them with the systems side of things. But it turns out, I think, we made a bigger contribution to the laser physics side, because they thought they knew what they were doing but they didn't. And so during the late sixties I spent a lot of time with that project and traveling back to Avco for regular meetings. And they would come out to Malibu.

COHEN: Where would that have been?

BRIDGES: Avco was in Everett, Massachusetts, which is an industrial, grungy suburb of Cambridge. [Laughter] It was a lot of fun working on that project, but I was doing that in parallel with other things. Then I became department manager and was responsible for the project, and it was a major engineering project by that time. Then I got out of it, sort of completely, when I was on George's staff.

COHEN: I guess working for one of these big companies—if you're unhappy, you can go somewhere else within the company.

BRIDGES: That was true at Hughes. There were a lot of people who left Hughes because they were somehow unhappy with Hughes. I wasn't, in a sense, that unhappy with Hughes; I was just unhappy with being a manager. It didn't strike me as being something I'd consider fun at all. But it was awkward. We had a whole ex-department-managers' alumni association there. Not everybody left. I got involved in another department, doing some things that I thought would be interesting. But then, again, there was a request from management. They had a project that a couple of other guys had started, but one had left and one had gone off on other things. This was in the adaptive optics area, which is now a hot area in astronomy. This was 1971, though, and my first reaction was, "This project is impossible." But then I talked to one of the theoreticians there at Hughes who had really been pushing this, and he convinced me that it was possible, although I still thought it was like black magic. The bottom line is we ended up building a simple demonstration system. It really did work. We sold the idea to DARPA [Defense

Advanced Research Projects Agency] to make a more advanced system. And so I was in the adaptive optical business for a few years then, and in fact it blossomed into some major contractual stuff. Then I found myself managing that and not being back in the lab again. And that's when I had the opportunity to come to Caltech.

Did you ever know Nick [Nicholas] George? Nick had been a consultant at Hughes in the early days, so I knew Nick very well. I knew Amnon [Yariv] very well. Anyway, Nick said, "Well, you know, we've got this Fairchild program at Caltech. You ought to think about that." So I said, "Well, that sounds pretty good. It would be interesting to get away for a year. Maybe what will happen is I'll leave and they'll have to put somebody in to manage all these programs, and then when I come back, I'll be off the hook." So we did that.

COHEN: You moved here to Pasadena?

BRIDGES: No, I didn't move to Pasadena. I commuted from Thousand Oaks.

COHEN: They gave all these wonderful things to the Fairchild scholars.

BRIDGES: I know, I always felt that the decision to commute was sort of bad. But I had three kids in school in Thousand Oaks, and it was hard to pull them out and move, so I commuted. Nick invited me to teach his optics laboratory, and I did that. I did some scientific work that was probably of no particular note. But I rediscovered—seventeen years later—that I really did enjoy teaching. I had, from my time at Berkeley, just forgotten how much fun it was. So I went back to Hughes, but I left Caltech with the word, "Hey, you know, if there's another opening, I'd really like to do that. I think I would do OK as a professor."

COHEN: So you really enjoyed your year here.

BRIDGES: Oh, I did.

COHEN: But you came in the morning and you left at the end of the work day, so it was hard to be part of the community.

BRIDGES: It was hard to be part of the community.

COHEN: That was a fantastic program.

BRIDGES: Right. And I got several of my buddies in as Fairchild people after that, and really enjoyed them, because they came from far away and moved here. And we did have some good interaction.

I went back to Hughes, and sure enough they had put somebody in place in these programs, but then the guy—just before I got back—left and went to DARPA to manage the programs from the government end. But somehow I managed to stay out of getting back into that same old slot. However, there was now a new slot—a new problem that had come up—and that was the hydrogen maser, which was an old idea. It's used as an atomic clock—you know, a standard—and it had gone on and on and on. You could even buy hydrogen maser clocks, but they came with a packaged PhD, because they were so complicated to run. Well, by this time Mal Currie, who had been the former director of the laboratories, was DDR&E [undersecretary for defense research and engineering in the Defense Department]. He was the top technical guy in the Department of Defense. He was convinced that the Global Positioning System [GPS], which was just ready to be launched, needed hydrogen maser clocks in each satellite, and he figured that his old establishment was the ideal place to do this. Well, we thought this was the craziest idea we had ever heard of, because we knew the reputation of hydrogen masers. My boss, who had worked for Currie, came into my office and said, "Currie is twisting our arm to take this clock project, and I think it's crazy." And I agreed with him—it was crazy. But it was one of those things; we couldn't say no. It was not politically agreeable to say no. So we took on the job of making a space-borne hydrogen maser clock. Fortunately we were able to hire a real expert in hydrogen masers from Williams College, Harry Wang, as the head of the project. I got assigned to solving engineering problems with this hydrogen maser. Well, it was fun. I was learning a new trade, completely different. By the way, on that project Harry did some wonderful work in packaged, reliable, stand-alone masers, but we never did fly one on a spacecraft. The need for it fortunately disappeared.

COHEN: Are those the same clocks that the astronomers now read?

BRIDGES: Sure. JPL [Jet Propulsion Laboratory] has a big hydrogen maser project. The theory was that you needed a clock that accurate so that when World War III happens and you can't update the clocks for two weeks, they'll still work. And my feeling was, "If World War III happens, I'm not going to worry about updating clocks on GPS. Forget it." What they've got up there now works just fine on a day-by-day basis. The clocks get reset daily, I guess. But we did this technical work, and meanwhile my friends here got me a position, and I left in 1977 and came here.

COHEN: Maybe that's a good place for us to stop.

BRIDGES: Yes. [Tape ends]

WILLIAM B. BRIDGES

SESSION 2

June 13, 2001

Begin Tape 2, Side 1

COHEN: So now, you got out of working on that hydrogen maser.

BRIDGES: Yes, more or less.

COHEN: And your friends welcomed you here to Caltech.

BRIDGES: Right. Although actually I continued consulting at Hughes on the hydrogen maser project—one day a week there while I was here at Caltech. But I didn't bring any of the hydrogen maser work here. It didn't seem appropriate for students.

COHEN: Now, when you moved here, did you move your family here?

BRIDGES: No, I continued to live in Thousand Oaks for two years. It was 1977 when I came here, and in 1979 my youngest son graduated from eighth grade, so he would be ready to start high school at a new place and my middle son had graduated from high school and was ready to start college, so '79 seemed to be a good time to move, and indeed we did. We bought a house in Altadena. Actually I think we bought it a little early and then had to sell our house in Thousand Oaks. So for about three months I was, of course, commuting from Thousand Oaks. I would work during the day, and then I would drive up to Altadena and water all the plants in this empty house and then drive back to Thousand Oaks. I did that for a few months, and then the family moved over in the fall of '79.

COHEN: Who was here to greet you in the department? I mean, what was the idea of what you were going to be doing?

BRIDGES: Well, it was a joint appointment in electrical engineering and applied physics. My

training and my degree were in electrical engineering, but people would have considered most of the laser work applied physics. I don't know if I said this on the tape before, but Amnon Yariv and I actually had been graduate students together at Berkeley. We were contemporaries.

COHEN: Yes, I think you did mention that.

BRIDGES: And we worked in the same area of lasers and electro-optics.

COHEN: He was involved with Hughes a lot, too.

BRIDGES: Yes, he was a Hughes consultant. So was Tom McGill. So I knew Amnon. I knew Tom McGill. I knew Roy Gould, through my boss at Hughes—Roy was Don Forster's advisor. And in fact we had gotten Roy over to Hughes doing some consulting, too. So I knew a lot of people. Nick George, who was a professor here then, was also involved in the lasers and optics business, and so it was expected that I would go into lasers and optics. And indeed that's what I tried to get started initially. I probably didn't negotiate a very good deal. You know, the usual thing is that when you attract somebody, you give them a start-up package and everything.

COHEN: Right. Well, this in some sense was your first experience with academia.

BRIDGES: Yes, it was. And so, naive me—our division chairman, Bob [Robert H.] Cannon, assumed that I was a senior guy and that I would just bring my millions of dollars with me. And I assumed that if Bob Cannon thought that was true, I probably would just do that. Well, it didn't work out quite that way. It turns out that most of the contractual people in the government that I knew at Hughes were not really involved in funding academic work. We did development work—or, in the parlance, we did 6.3 money work, whereas the academics used 6.1 money. Everybody in the government support business knows what those mean: 6.1 is basic research; 6.3 is really breadboard and brassboard demonstrations. And so I found myself running around Washington trying to figure out who I should talk to.

COHEN: So you came here and realized you had no money to work with.

BRIDGES: Right. Now, I did have lab space. It turned out, both fortunately and unfortunately, that shortly after I came here, Professor George got an offer from the University of Rochester to be the director of the Institute of Optics, which is a very prestigious position in the optical business, so he left. And I had looked forward to working with Nick; instead, I basically helped him move and then moved into his lab space. I also inherited all the junk he didn't want to take to Rochester with him, so I ended up with a shop with a drill press and a few other things like that. It was sort of bits and scraps.

COHEN: How about students? Did students go with him, or did he have students here?

BRIDGES: Actually, Nick gave his students the choice. They could either go with him to Rochester—I don't know how he worked this out, but he guaranteed them that if they wanted a Caltech PhD, they could do the work at Rochester but he would arrange it so that they got a Caltech PhD—or they could stay at Caltech and find another advisor. And they divided—a couple of them went with him to Rochester.

COHEN: Did they get Caltech degrees?

BRIDGES: They got Caltech PhD degrees. In fact, I was on the committees for both of them, even though they weren't really my students. And another one decided to stay at Caltech, and I took him on as a student. We had things in common. That was Mike [Michael J.] Kavaya, and he eventually got a PhD with me.

At the beginning it was a struggle to figure out what was appropriate in the way of research that students could do. That's another thing: I probably was naive in figuring out how professors work. From my observation of my colleagues, it's more that the professor sticks in the office, talks to the students, tells them to "go to the lab and do *blah, blah, blah*, and come back and tell me how it worked out." And then, if they don't do it—you know, for six months he doesn't hear from them—then he'll go in and kick them a few times and then it starts working again. And I had never worked that way at Hughes.

COHEN: So this is how you saw people working here?

BRIDGES: Yes, and I still do, as a matter of fact. In fact, one of the frustrations at Hughes was that I really liked to be in the laboratory myself and I kept getting tugged into management and being a project head and all that kind of stuff. And somehow I figured that I could come to Caltech and get students going but still work in the laboratory myself. That was probably the most frustrating thing, because I very quickly learned that you really can't do that. Your first obligation is to make sure the students are doing the right thing. And you can't stand there and look over their shoulder. And you can't say, "Get out of the lab. You're bothering me. I'm busy doing something." The only time I ever really took heart that that might be possible was when I was reading a biography of A. A. Michelson, who apparently at one time when he was at the University of Chicago went in to [Robert A.] Millikan, who was then the head of the Physics Department at Chicago, and said, "I don't want any more students. They're incompetent. They get in my way. They mess up the laboratory. I'm not going to have any more students." And I guess Millikan finished the last of Michelson's students and then left him alone in the laboratory after that. I always thought that that was probably the way I really ought to operate, but that wasn't the way I operated with my students. So I had to figure out what kinds of things would be appropriate.

An idea that I had had while I was still at Hughes—which I was trying to talk the Hughes people into funding, and which they allowed me to work on a little bit—was to do laser isotope separation. This was a big thing in the industry at the time, or at least so everybody thought, and I had some ideas that were different from what anyone else was doing. So I started pursuing that at Hughes, and I thought that would be a good thing to do here. I thought maybe I could get some Department of Energy funding for laser isotope separation, and I worked at that for a little while. And in fact I was the beneficiary of a big block grant that Caltech had from the Department of Energy. I actually got a small piece of that offered to me: "Well, here. Why don't you take this and do it?" So I got one student, Andrew Gabriel, started on it. But then one of my friends, who had originally been at Hughes and then went to Los Alamos, and I got talking over beers one evening at a conference. I told him what I was doing, and he said, "Oh, you don't want to do laser isotope separation. There's no future in that." His comment at the time was, "Look. We're separating so many uranium isotopes now, because the government has this contract with TVA [the Tennessee Valley Authority] to take electric power. They don't want any more separated uranium, but they have to run all of Oak Ridge as sort of a dummy load, to

use up the TVA power that they've agreed to take." And he said, "No one wants this project to succeed. They just really want to know whether you can do it or not, to make sure that no one else can do it." Because when work on laser isotopes started, the mystique was that two terrorists in a garage could buy a laser and make a uranium bomb. It turns out that after billions of dollars of government money, I think we've proved you can't do that. So it didn't look like the government was going to be interested in funding still another approach to isotope separation. But I got involved in that and I got one student out. He did a very nice job of understanding the basic physics of this idea, but we never carried it through to the next step of trying to actually separate real isotopes. We were working at separating hydrogen and deuterium, which still might be of interest, but it's too easy to do by other means, so this was probably too expensive a thing to do.

Mike Kavaya was then working at JPL on a project involving what's called acoustooptic spectroscopy, or spectrophones. It's a way of detecting trace contaminations in the atmosphere. And I knew the guy that he worked for, Mike [Michael S.] Shumate. He was an old friend from times past. And so we worked out a deal where Mike Kavaya would actually do his experimental work at JPL, where they had all the equipment, and we would use that as his thesis topic. It was a nice piece of work. Unfortunately, about a year before Mike was to finish, NASA decided they weren't interested in what are called point sensors—that is, equipment that measures the contamination at the location of the sensor. They wanted only remote sensing systems to measure contamination, say, in the upper atmosphere or something like that. So one day they came in and said, "Mike, your project's over. We're taking all your equipment." And that was a bit of touch and go, because he had done experimental work but it wasn't quite finished yet. My view is that students should have their experimental setup still working as they're writing their thesis, so that when they come across something that isn't right, they can go back and do it over again. With Mike we didn't have that privilege.

COHEN: That also shows you a shortcoming of trying to do something at JPL.

BRIDGES: Well, it was only the first of many problems that I had with students at JPL. It was a necessity, because I didn't have an operating lab; I was still working on the leftovers from Nick George. But I figured this was a good way to at least get started with students—to have real

equipment that they could work with at JPL. Mike was lucky that the experimental work was sufficient, even through the writing stages and the critique stages.

COHEN: Where has he gone to?

BRIDGES: Mike now is a manager at NASA Huntsville [Marshall Space Flight Center]. He left here and went to work at JPL after he got his PhD. He then worked with a small laser company in Denver and then had an opportunity to work in a group at NASA Huntsville. He eventually became the boss. My first student—the one who did the laser isotope separation, Andy Gabriel—also worked at JPL. Then he went to 3M, and then he came back to JPL, and then I lost track of him. I don't know where he is. Andy was a pretty contentious guy. I'll just give you a brief one-liner on the flavor of his politics and his contentiousness. He used to refer to Ronald Reagan as the "left-wing pinko president."

COHEN: [Laughter] OK.

BRIDGES: Andy was waiting for the return of the gold standard. I mean, it was really a bit strange. And it's funny, because he came back after a couple of months at 3M and said, "Ugh. They're all screwed up. The management is just terrible there. I told them that...." And I thought, "Oh my god! How's this guy ever going to hold a job?"

COHEN: Maybe that's why you don't know where he is.

BRIDGES: He may still be at JPL; I just haven't had any contact with him. Another student, Randy [Randall K.] Bartman—whom I can now safely refer to as my graduate student emeritus, since he never did get his degree, even after working years and years and years and years—is still at JPL. He's a manager there. And that's another one of the evils of JPL: the quicksand swamp phenomenon. Randy was working with a laser group at JPL, and he had formerly worked, I think, a couple of years for Fred Culick in copper vapor lasers, which wasn't one of my particular interests. He then was working with this group at JPL on copper vapor lasers. We tried to find a project that was suitable—looking at really sort of a hybrid kind of microwave vacuum tube. Somebody had reinvented the wheel, and basically I wanted a student to show

that, yeah, it works but it doesn't work like this guy says it does. So we started off on that project, and it had a fairly nice tie with JPL; we got some funding from JPL to work on it. But what happened is that the group that Randy was working with at JPL had sort of a wild manager, and Randy spent most of his time keeping his manager out of trouble by saying, "No, no. I don't think that is within the laws of physics. We can't say that." Randy spent more time helping other people and not himself. Randy was probably—at the time, certainly—the most advanced and brightest of the students, but this was early in my career and I didn't recognize his lack of self-interest. He would help anybody else. He was great with my undergraduate students, but I didn't realize how deep he was getting in. In fact, at one time when I thought he was making progress—this is now about 1979 and I had been here two or three years—I actually got a grant from JPL to do a nice postdoctoral study for Randy on another subject. That was something I ended up giving back to JPL, because Randy never graduated—he didn't get his degree and so we never got into this new field, which was supposed to be his postdoctoral stuff. Randy is still there. He's now married, with a family, and he's a manager.

COHEN: Well, maybe he's happy that way. So never mind.

BRIDGES: Yes, but I always felt bad that I somehow didn't crack the whip more and get him his degree, because he was unquestionably bright enough. He knew enough stuff. It was a matter of buckling down on the project and writing a thesis. So I lost Randy.

COHEN: And during this time were you trying to get other funding?

BRIDGES: Oh, yes, we were going out. Although JPL seemed like a good source, for this initial round of students—I guess I took on six students right at the beginning,, and they needed a place to work. We did as much as we could here on campus, but JPL was a little better. I also wanted to get involved in the far-infrared laser business, and I took on two students there. One was a young new applied physics student, Mark Richards. And another student—Arthur E. T. Chiou—was a physics student who had come here to do work in high-energy physics and then decided that that wasn't really what he wanted to do. But he had already passed all the physics exams, so he wanted to stay in physics but work in applied physics. So I took him on. And both Mark and Arthur were working on the far-infrared laser stuff, and I was their engineer. I was in the lab

with a drafting machine, doing the drawings. Then I'd give them to the students and they'd take it over to the machine shop, and I'd get a grade from the machinist, a B-. He'd correct all my mistakes in the drawings and then build stuff, and then the students would put it together. Students today don't have any mechanical drawing facility. Something that Caltech used to have and eliminated from the undergraduate program was the ability to communicate with machinists. I always thought eliminating that was a bad idea. I mean, you don't have to teach them how to be artistic draftspeople, but you should teach them how to use AutoCAD or something like that. Otherwise, how the heck are you ever going to communicate with the craftsmen? Anyway, so I was the drawer.

Mark admitted that he was the black sheep in the family. He came from a family of musicians and he was the only scientist, and they thought that was pretty weird. But somehow he developed an interest in geology, so after the first year with me he said, "Look, I'm going to transfer to the geology graduate school," and he got a geology PhD.

COHEN: Did that suit the artistic nature of his family better?

BRIDGES: I guess so. I don't know how he tied those two together, but he just basically said, "I'm interested in geology, and my family will be happier." So that was that. Anyway, that was my first round of students. Of those, Andy Gabriel, Mike Kavaya, and Arthur Chiou all finished with their degrees, and they're all happy somewhere. Arthur Chiou was sort of worrisome, because he wasn't a citizen. He was Burmese Chinese; his family had moved from Burma to Taiwan. But Arthur for a while did sort of a funny postdoc at IBM. They had a program that would take on noncitizens. This was during the era when you had to fight the Department of Labor to testify that this person was absolutely irreplaceable by an American citizen.

COHEN: That's still in some sense going on.

BRIDGES: It's still in some sense going on, but it was worse then. I was worried that Arthur wasn't going to get a position, but he did. He eventually got work with the Rockwell International Science Center and now he's a professor at a Taiwanese university [National Chiao Tung University]. So Arthur's doing OK; he's happy with that.

COHEN: Now, you were teaching at this time, too.

BRIDGES: Oh, sure. I've taught every term. The teaching was fun. I was doing a class that had been initiated by Nick George—the demonstration lectures in optics. It was like a freshman physics course but in the sophomore year and only on optics, which is sort of shortchanged in the physics department here now. And it was a lot of fun—although Nick took all his stuff with him, so I had to scramble around to get all the equipment to do the demos. It was a bit tough at the beginning, but it was still fun. I ended up making a lot of demo equipment myself in the lab. That's one advantage of being handy.

COHEN: EE [electrical engineering] has the most students of any department, doesn't it?

BRIDGES: Yes. Well, this was actually an applied physics class. In the first class I taught, there were something like seventy students, which is about a third of the sophomore class. It's still a popular course. This is APh 23, and then the APh 24 laboratory sort of followed—similar experiments except they're not demonstrations, the students now have to do them. And that was a lot of fun but very time-consuming. Because it was so popular, we had lab sections that ran every day from one to four o'clock, but in reality they would run from one o'clock to whenever the students finished, which was typically 6:30 or so. So I'd get these phone calls from Linda [Linda McManus, Bridges's wife—ed.] saying, "When are you coming home?" I'd say, "Well, I'm trying to get the students out of here now," because they didn't want to leave until they finished what they were doing. And I insisted that they keep an industry-type engineering notebook, which meant that when they left the lab, they were finished. The write-up went as you went along. You just basically kept a patent notebook, because I felt that that was a very important thing for students to learn how to do in applied physics. Ultimately it has to be understandable by somebody a year or two from now—maybe even by yourself a year or two from now—which means that you have to put in figure captions and you have to explain what you are doing. Even if it's crude, it has to be a narrative explanation, not a formal report.

COHEN: That's interesting to me, having done so many chemistry labs. If you did that, the notebook would be a little bit dirty before you left.

BRIDGES: Oh, I didn't care what the notebook looked like, as long as it was legible and as long as I could read it. And I would grade it that way. I ended up reading all the notebooks. I had TAs, but the TAs and I actually worked the laboratory as it was going on, and then I read all the notebooks before the next lab period.

COHEN: So you taught this course plus another course?

BRIDGES: Three courses.

COHEN: In the whole year?

BRIDGES: Yes. They were each one term. The demonstration lectures were the first term, the lab was the second term. I think the first year I was here I had the third term off, but then we got involved in a whole different subject. When I first came here, John [Robinson] Pierce was the executive officer for electrical engineering. I don't know if you know him.

COHEN: I remember him.

BRIDGES: John's actually a very famous person. He's very famous at Bell Labs. He was the director of Bell Labs' Communication Sciences division, and he retired and then came to Caltech, which was his alma mater, as a professor of engineering in 1971. And of course I knew John. In fact John was on a godlike level when I was a graduate student; he was the god of traveling-wave tubes. But of course for other people he was the god of acoustics and the god of electronic music—an incredibly brilliant guy. Not the best-organized person in the world. As executive officer he was sort of a disaster. In fact, before I came here, when the appointment was in the works and had gone through but before I left Hughes, I got a phone call from John. He said, "My wife tells me I can't be executive officer anymore, because it's taking too much time. I think you ought to be executive officer. Do you want to do that?" This was when I was still in my lab at Hughes. And I said, "No! I don't want to do that. [Laughter] I'm coming here so I can work in the laboratory and do some science and get away from this stuff." Well, what happened is that shortly after I came, John resigned and we sort of floated without an executive officer. Well, you can do that for a while, I think, as a department. One of the other things when

I first came: Hardy Martel used to have these dinners once a year. He'd invite a bunch of the better students and the EE faculty, and we'd get together and just shoot the breeze over a barbecue dinner on what was good and what was bad about the EE department at Caltech. And one of the things that became abundantly clear to me is that we had a whole bunch of students who were only interested in digital electronics, and all the rest was just…. They didn't think about electricity and magnetism; they weren't particularly hot on circuit theory. And we had no major in electrical engineering at that time. It was engineering and applied science, and somehow the students took anything they wanted to take. I made the comment at one of these parties that that's not what industry expects an electrical engineer's degree to look like. In other words, there's a certain basic kit of tools that EEs should have, and that's what industry looks for. And this was way too narrow into digital electronics. I mean, yeah, it's good stuff, but you've got to know other things, too. Well, I made that comment, and several of the EE faculty said, "We agree with you, but what can we do? We're stuck with this major that has no requirements," which is what the E & AS [Engineering and Applied Science] major still is, as a matter of fact. It's 126 units of anything.

COHEN: That's very peculiar.

BRIDGES: Look at the requirements in the catalog. It's just so many units of anything within the Division of Engineering and Applied Science. And it's presumed that the student and his or her advisor will sit down and make a rational program. Well, we had advisors and we did that. But the students would say, "No, I'm not interested in electricity and magnetism. I'm not going to take that course." And my reaction was, "How can you be an EE without taking that course?" And the answer was, "Easy. Look what the catalog says."

COHEN: Now, this doesn't take into account the core curriculum, which they had to take as part of being at Caltech.

BRIDGES: Well, the core stuff is university—physics, chemistry—but we're talking about what I would consider a major in electrical engineering. They thought they were EE majors, but they really weren't, at least from the viewpoint of someone from industry. So it started a discussion: "Why don't we have a major here in electrical engineering?" The EE faculty said, "We'd love to

have that, but our colleagues will never agree. And then we'll also have to make up new courses to fill in all the blanks." I said that was true. So anyway, at one point we proposed this to Bob Cannon, who was the division chair at the time. Bob was a good soul, and he said, "If that's what you want, I think we can put it through. But you have to have an executive officer to get it through. You'll never get it through the engineering faculty unless you have someone to push it." And so he made me the proposition that if I would be acting executive officer, he would entertain our putting this major through.

COHEN: He made it sound non-threatening by calling it "acting." [Laughter]

BRIDGES: I suppose. That was a farce, because he had no executive officer. Pierce had already quit, and we were sort of drifting along. So I agreed to do that. This is about a year and a half after I had come here—it was late '78 when the discussion started. So we put together a program. We identified some new courses that we would construct just for undergraduate EE majors. I agreed to teach one of those—a course in radio communication, electronic communication. So that was what I would teach in the third term.

So we got this thing through the division. The division thought it was very funny, because their attitude was, "Where are you going to get any students to do this? You're asking students to volunteer to fulfill a whole bunch of requirements when they can still graduate with a BS in engineering and no requirements." And we said, "Let us worry about that." We got the program through, and then Cannon conveniently forgot the "acting" part, and so I got stuck being executive officer [1978-1981]. And the rest, as they say, is history, because the EE major was very popular. In fact, at one point in the mid-eighties it became so popular that EE was about the same size as the rest of the engineering division. It's fallen off since then—I'm sort of glad to see that. But I think it did prove the point that students wanted direction. They did not want to be left drifting. And if you put together a good program, they come to it. I think the new ECE [Electrical and Computer Engineering] option is pretty much in the same boat. Students would love to have a computer science option, and would flock to it unbelievably fast, but the computer science faculty doesn't want to do the major.

COHEN: Why?

BRIDGES: They're afraid it would be too much of a teaching burden and they're too small. And that could be true, in fact; there are not that many of them. EE was sufficient to do the job, and we did it. But anyway, I found myself back in administration again. I did that for three years.

COHEN: Now, you of course still continued teaching all this time.

BRIDGES: Oh, sure. Everybody in the engineering division teaches all the time. That's their first order. Sometimes you take a term off, but rarely. That's just the way we are. Engineers are always their own worst enemies. We teach too many courses within the engineering division. Everybody has to have their own version of what could be the same course if only they would all get together and agree [on what it should be]. I think we have way too many courses that are too similar, but no one seems to be able to fix it.

COHEN: Cannon left after a little while, didn't he?

BRIDGES: Oh, yes. He was only here five years. I think Bob was folded and spindled and mutilated by the engineering division faculty. [Laughter] He was a really nice guy, a very good-hearted guy, but he didn't know where the land mines were, and there were some terrible blow-ups within the division that really got to Bob. He was a Stanford professor who then went to the government.

COHEN: He went back to Stanford, didn't he?

BRIDGES: He went back; he's at Stanford now. I think he's retired now. But he had done a thing in the Department of Transportation [1970-74, US assistant secretary of transportation for systems development and technology], and he probably put a lot of stock in organization charts and formalism and all that. And, man, that didn't work with the Caltech faculty! But anyway, we got the major through, and I think the students were much better off for it.

The next evolution for me administratively—in fact, how I got out of being executive officer—was that when Cannon left [1979], Roy Gould became the new division chair. Roy was in applied physics. And something that Roy and I had known all along was that the EE faculty was aging and had not replaced themselves at all. In fact, you probably know a lot of the people

who were here when I came. But there's nobody left. The entire EE faculty has changed. I'm now the oldest guy, from 1977.

COHEN: So you've hired all new people then, I would assume.

BRIDGES: That's right. And we also felt that we were too small and we wanted to grow. Well, the bottom line is that in twenty-five years we're exactly the same size as we were when I came, but it's a hundred percent new people. So when Roy became division chairman, he and I talked about this, and I said, "Look. If you will replace me as executive officer, I'll run a search program, and we'll try to...." Because it was very clear that EE was going to just disappear. So that's what I did. Hardy Martel agreed to be executive officer, and I agreed to run a search. And actually Roy was very helpful. Roy came with me, and we did a lot of traveling around the country. At the time, there were no electrical systems people in the department—none at all.

COHEN: Now, was the department here really different from other departments around the country?

BRIDGES: Yes. Well, besides being incredibly small compared to—I mean, the EE department at MIT is bigger than the whole engineering division at Caltech.

COHEN: And that's probably true at Illinois.

BRIDGES: Yes. And so you cover all of the aspects of EE. Then it was devices, systems, computers. We had none of that. There was a separate computer science department that was sort of struggling when I came here. It's still struggling. But it was very clear that people were leaving or retiring from the EE department. And we had no systems people. We had some device people, and that was it. So Roy and I got on the road, first of all to talk to our colleagues at other schools to get advice about what to do. I mean, if you were small and you were going to institute systems activity, how would you do it? And our colleagues were very generous in giving us advice. We would clearly not do the same thing that we would do at a large university—try to cover all waterfronts—but try to pick the most exciting aspects. So that's what we did. The search was under way.

COHEN: So you were looking for specific fields, not just hiring people and letting them do what they wanted.

BRIDGES: No. We weren't looking for that. Roy and I are both device people.

COHEN: Now, what does that mean, "device people"? You'll have to explain that.

BRIDGES: Oh, we work with things like—in our day—vacuum tubes or transistors or lasers or modulators or such things. Systems people—and I say this jokingly for the future historian or whoever hears this—are people who draw a block diagram with an input and an output, and it's got X as "in" and Y as "out," and then they hook a lot of these blocks together and figure out how they work, but they never have a clue what's inside the box. What's inside the box are devices wired together by circuits. We were devoid of systems people. They would be people in the controls area: you know, how you make a control system, like the thermostat on your furnace, or the controls that connect the wheel to the tail of a modern airplane—that kind of thing.

COHEN: But everything's a computer chip now, isn't it?

BRIDGES: It is now, yes. And so the controls people in fact were in a revolution of going from what we'd call analog control to control where everything goes through a computer and the computer supplies all the outputs. And it was a challenge, because here you had two device guys trying to figure out what are the hottest areas in systems and then who are the hottest people to go hire.

We did the search. Our first hire [1982] was Bob [Robert J.] McEliece, who came from Illinois, and Illinois was one of the places we visited. In fact, we talked to Bob about this activity and I think we piqued his interest. I think he was also interested in living here. His then wife—he's remarried now—was interested in leaving Illinois. So maybe he was just too easy. But we ended up hiring him. Roy and I felt we were probably persona non grata at Illinois for a while. We also had some good advice from a contemporary of mine who was a professor at MIT, and he gave us some names. To be honest, we did catch a couple of faculty with unbaited hooks; some people wrote us and said, "Hey, we'd like to come to Caltech," and we looked at

them and said, “Gee, this looks pretty good.” And that was Demetri Psaltis and Dave [David B.] Rutledge, who both volunteered their services without us having to search. So those were the easy ones.

COHEN: And you were given this many positions to fill?

BRIDGES: No. We were given the positions one at a time, to replace the people who were retiring or leaving or dying, and that was happening pretty fast. So the department never grew in this process. I think we may have grown from fifteen to seventeen, but then we’d fall back to fifteen again. No, we weren’t given a blank check or anything. The blank check was offered but was never signed. That’s an interesting incident. While I was executive officer, but before doing this search, we had an engineering visiting committee come.

COHEN: You know, let me just interject this. You came here and in two or three years you appeared to be running the show.

BRIDGES: Yes, that’s the way I felt, much to my dismay.

COHEN: Was it because it was a vacuum? Or did people recognize immediately that this was good?

BRIDGES: No, I don’t think that. I think it was more of the vacuum. No one wanted to run the show, and no one *was* running the show. And the show was rattling around and getting ready to fall apart. And that’s one thing I can’t stand to see happen. I try to get in and do something and then get out when I can. While I was executive officer, though, we had this visiting committee meeting, and Si [Simon] Ramo was the head of the visiting committee. Have you ever met Si?

COHEN: Yes.

BRIDGES: My description of Si is, when he walks into the room with a number of other people, everybody looks at him and knows who’s in charge. I made this presentation on what we thought we ought to do with getting some communications people, some systems people, and

that I thought we could probably live, ultimately, with five appointments. Bob Cannon was standing next to me. And Si looked up and said, "Well, five sounds about right for the communications, but then you need another five more for control and another five for…." something else. I could see Cannon sort of blanch, because Si had just doubled the size of the department. Si looked at him and said, "You're going to do that, aren't you, Bob?" And Bob said, "Well, we'll look at it." And that was the blank check we never got. We got those appointments, but they were basically only in exchange for ones where people left and retired. But that was enough for me to get out of being executive officer and run this search for a few years.

COHEN: Who was Caltech's president at this time?

BRIDGES: When I came here, Bob [Robert F.] Christy was acting president. And then, let's see—Murph [Marvin L. Goldberger, Caltech's president 1978-1987]. We also hired P. P. Vaidyanathan. He controls signal processing. Excellent guy. And that was sort of lucky. It was part of the search, but it turns out that his professor at Santa Barbara was a contemporary of mine at Berkeley and knew him. He called me on the phone and said, "This guy is good. He's better than I am."

COHEN: In all your searching, did you ever see a woman?

BRIDGES: No.

COHEN: They didn't exist.

BRIDGES: They didn't exist. And I always felt bad about that. I felt bad when I was a graduate student at Berkeley, or undergraduate even, because I kept thinking, "Hey. This is interesting stuff. Where are the women? Is this only interesting to men?" I couldn't understand that. I never did. I still don't. It's a mystery. Every once in a while you see some hope. This is a little off the subject, but one of my undergraduate advisees came—and I use her all the time as sort of the arch-prototype of what I expect. She came with some advance credit from a British university. She's Iranian—Avideh Zakhor. Very squared away. She knew what she wanted.

And I said, "Well, I have a policy that I don't let you overload the standard amount until you get all As. When you get all As, you can do anything you want to do." So she didn't overload the first term. She came back with all As. The next term, she said, "I want to take sixty units." I said, "Do you think you can do it?" She said, "Yeah." She did it. She graduated with a 4.1 average in three years. She made it look easy. She went to MIT. You know, it was funny. She was a typical brilliant student—applied to ten graduate schools. I said, "What are you doing that for?" She said, "Well, I don't know if I'll get in." I said, "You'll get into every one of them. It won't help your decision at all. Just decide where you want to go and apply." Well, she didn't do that, but she was accepted everywhere. She worked for a very famous guy at MIT in the controls area—Alan Oppenheim. I tried to get the faculty here interested in hiring her back, but they didn't go for it. By that time, I was out of the search mode, and the systems guys who were here, like Bob McEliece, were now running the search for more systems people. Avideh ended up at Berkeley, and she's doing very well. She's a full professor at Berkeley now.

COHEN: OK. So we at least have one engineer. [Laughter]

BRIDGES: Well, yes. And in fact I was reminded just today—there's a business card on my desk from somebody who stopped by last week; it said, "Sorry to have missed you, Arati Prabhakar." She's my other super example. Arati, I think, went to Texas Tech—a small school in Texas. I met Arati when she was a junior at Texas Tech. She called up and wanted to visit the EE department here to see if she wanted to come here to graduate school, and I picked her up at the airport, because she didn't have a car. She's just a delightful young lady, and very squared away. She's got a Texas drawl, but she's East Indian by birth. She came here and worked for Tom McGill. She got a PhD and then she decided she didn't want to do the traditional thing, like going to Bell Labs in solid-state physics. She went to work for the US Congress… [Tape ends]

Begin Tape 2, Side 2

BRIDGES: …in the Office of Technology Policy. She did very well there. And then she went to DARPA as a program manager and worked her way up the DARPA system. And there's where she really learned to sling viewgraphs—that was something else! And then she ended up a Clinton appointee as head of NIST, the National Institute of Standards and Technology, with a

$17-billion budget. Not bad!

COHEN: So these are really exceptional people.

BRIDGES: Yes. And the thing they had in common is that they made it look like it wasn't unusual. But there are other women students I've met—I got involved in the Society for Women Engineers here, too. A lot of women look uncomfortable in engineering. They think they want to be engineers, and they like the subject matter, but they look around and think, "There's nobody here like me." And that's tough to take. It's not just being given opportunity; it's also feeling comfortable in that opportunity. And Avideh and Arati both felt comfortable from day one, and so they made the most of it. If we could figure out some way to make women students or young women employees feel comfortable in engineering, it would help a lot. That's why I got involved trying to get a Society of Women Engineers chapter.

COHEN: So then, you had now finished your recruiting?

BRIDGES: Yes. Then I sort of backed away from management. I felt I'd done what I wanted to do—with the undergraduate major and also getting the department back on a regular track of reproducing itself.

COHEN: What was happening to the rest of engineering? Did you have anything to do with that?

BRIDGES: Well, not really. I like to think of myself as an engineer as well as an electrical engineer or applied physicist, and so I was always concerned about the rest of the division. And of course Roy, who was a very good friend as well as a colleague, would tell me about his problems as division chair. So I knew what was going on in the rest of the division. But in a sense, it's not my call. The other disciplines are sufficiently different that they should call how they want to grow or diminish or restructure or whatever. I haven't always been happy with what I saw. The one place where I did get involved was in the undergraduate board. There was an undergraduate board or council—I forget what it's called now. A group of us would get together and try to figure out what to do with the major subjects in E & AS. Well, E & AS is the general engineering major. So for a while I did my best to try to restructure that a little bit to

make it a little more sensible, and in particular to encourage the mechanical engineering folks to have their own major, because ME was very popular. I felt that they would have benefited by structure. And I think the thing there was about half of the mechanical engineering faculty felt that that was a good idea and the other half didn't. And it didn't happen, twenty years ago. It's happening now. The mechanical engineering department is now making proposals to have a mechanical engineering undergraduate major.

COHEN: Is that because new people have come in?

BRIDGES: Right. It was more the young people who wanted to have it. I think the older faculty thought, "Why do we want to go to this bother, when it's just going to mean teaching more courses?"

COHEN: Now, as an engineer, were you really separate? How much did you have to do with the physics department and the mathematics department?

BRIDGES: Very little with physics and mathematics.

COHEN: Chemistry?

BRIDGES: Chemistry, yes.

COHEN: So your students didn't take courses there. Well, they had to take some courses.

BRIDGES: Well, the institute requirements, but not advanced physics courses. See, I have both applied physics students and EE students working for me. Oh, by the way, I should say that Arthur Chiou, who was my student who came from physics—we tried to keep him in physics for a while, and then I got a call from their curriculum committee in physics. They were trying to appoint a committee for his thesis exam. They said, "We don't understand what he's doing. This is too esoteric for the physics department. Why doesn't he transfer to applied physics?" So the bottom line was, yes, he did transfer to applied physics and got a degree in applied physics. Infrared lasers were somehow not of interest. Or the physics department wasn't wildly

enthusiastic about them.

COHEN: Aside from your work in the engineering division, what did you do for the institute as a whole?

BRIDGES: I was on committees. In fact, the way I get to know people outside of engineering, or even within engineering, is to serve on committees.

COHEN: So you don't mind doing that. I mean, some people don't like to do committee work.

BRIDGES: Again, it's sort of a responsibility. Somebody's got to do it. And if you're going to do it, you want to make sure it gets done right. So for a while I was on the Health Committee. That's how I got to meet people in biology. And what other committees did I serve on in the early days? The patent committee [Patents and Relations with Industry] for a while, but we never did anything on that. Now, I think, it's probably more important, but at the time—in the late seventies or early eighties—I don't think the institute was aware that patents could actually be used to make money. What I was told was that Robert Millikan did not want to have Caltech's name ever associated with patent litigation, and for that reason he had a separate organization that was run by a subcommittee of the trustees, and all patents became the property of that committee. And therefore if a patent was ever dragged through the courts, Caltech's name would not be associated with it. I think the trustees at some point said, "Why are we doing this?" They threw out the committee and said, "We want to make some money! Let's drag somebody through the court." [Laughter] And that's the way we operate now, just like any other organization. But in the early days it was not a very important thing.

COHEN: So you were on the Health Committee for a while.

BRIDGES: Yes, and that was mostly trying to figure out how to improve the health service here for the students. Typically the biggest problem was that students would never go there. They were afraid to go when they were sick. When I was an undergraduate at Berkeley, I actually did get sick. I got the measles one year. We had a hospital on campus, so I went over to the hospital and they said, "You've got the measles. You're stuck." "But finals are coming up." "Too bad."

I was immediately in a hospital room and isolated from everything. We don't do that here. I mean, if aspirin doesn't do it, then they refer you to a local doctor.

COHEN: I don't think they do very much here in the health area. Well, they must have an infirmary or something to keep a sick kid overnight.

BRIDGES: No, not really. If the kid looks like he needs to be kept overnight, he gets sent off to the hospital. I believe that's the way it was when I served on this committee, and I think it's still that way now.

After I got out of the executive officer/search mode, then I felt a little freer to volunteer for other committees, so I got involved in Freshman Admissions. I was on that committee for six years, three as a member and three as the chairman, because I felt that that's the raw material that Caltech has to work with. Before I served on that committee I would get informal grousing from faculty members who said, "Well, it used to be better in the old days." Things were always better in the old days.

COHEN: Of course.

BRIDGES: Where we interviewed everybody. But now we're not doing that. So I got on the committee and discovered how they were doing it. And in fact I don't think there's really any choice. The old days, as near as I understand them…

COHEN: When the faculty went to different places.

BRIDGES: They would go all around. Bob [Robert V.] Langmuir, who was a professor in the EE department when I came, would basically take the month of March off and travel throughout the Midwest in a rental car. And that's a marvelous thing to do, but I don't think you're going to get the faculty to ever do it now. And that's what had happened; the faculty was no longer doing that. This was getting delegated to postdocs and graduate students, or not being done at all—and that's not a good thing to have happen. So the guy who was the head of admissions at the time—I've forgotten his name now—just stopped it and went through a paper file reading, with the idea that he could attract the faculty to read, seriously. So that's what we did and I think that's

probably the only way to do it that makes sense.

Admissions was good. But then, after I was on admissions, my colleague Dave Rutledge was on UASH [Undergraduate Academic Standards and Honors], and he would tell me some of the horror stories from UASH. And I finally decided, "Well, look. I've been responsible for getting these kids here, making the decisions on the front end. Where did we go wrong?" So I volunteered to do UASH for five years, two as chairman, to see how we screwed up on admissions, which is basically, I think, the main problem—you somehow don't read the file right and the student really just isn't ready for Caltech or isn't suited to Caltech. Sometimes they come here and play video games, but that's different. A lot of times we screwed up on admissions.

COHEN: Now, I see here that you then went to Göteborg, Sweden.

BRIDGES: Oh, yes.

COHEN: I think maybe we should stop here and leave that for next time.

BRIDGES: OK. Sure. [Tape ends]

WILLIAM B. BRIDGES

SESSION 3

June 26, 2001

Begin Tape 3, Side 1

COHEN: We were going to talk today about some of the things you've done outside Caltech. Visiting professor at the University of Göteborg.

BRIDGES: Right.

COHEN: When did you do that?

BRIDGES: That was the summer of 1989. I took a five-month leave and went to Sweden for most of that. And then on the way home, I swung by England, where I gave a keynote speech at the Ninth Quantum Electronics Conference for the British, which was really quite an interesting experience, too.

COHEN: Let's get back to Sweden. What did you do there?

BRIDGES: I enjoyed myself. And I also learned that Swedish professors have a different life than we do. Really, getting to Göteborg was at the behest of Sverre Eng. He was a professor at Chalmers [University of Technology in Göteborg]. But Sverre is also a staff member at JPL. And I had always wondered, "Well, how can you do this? You're running this group in Sweden and you're a staff member at JPL." And he said, "Oh, they're very independent. They take care of themselves." It was Linda who probably made arrangements with Sverre that we would have this sabbatical, because, you know, I'm always too busy to get away. But she just did it. So the next thing we knew, we were headed for Sweden. In fact, Sverre was there for about a couple of weeks and then he and his wife took off for a round-the-world tour, and there I was with his group. And amazingly enough, it ran like clockwork, even though that summer they were preparing to host a major European optics conference. His students and postdocs and all those people just worked in his absence, and he expected it all to be in good shape when he got back,

and it was. I attended the conference in early September. It was quite amazing. But, of course, European professors are different. "Professor" there meant he was really a department head, and he had several professionals working for him in addition to his students and postdocs. So it was a group, but it functioned very nicely without him, which is maybe shocking, but.... [Laughter] Anyway, it was quite an enjoyable time.

COHEN: Where did you live? In Göteborg itself?

BRIDGES: We started off living in a little residential hotel, walking distance from the campus, for a couple of weeks. And then when Sverre and Gerd left on their trip, we moved into their apartment for over a month. When they came back, we stayed in a small hotel again. That was really quite an interesting experience. This is probably getting off the path, but we were there just in time for midsummer's. We had been there about a week, and we didn't realize what midsummer's is like in Scandinavian countries. We were the only occupants of this small hotel, and there was a young woman, maybe twenty-one or twenty-two years old, who was in charge. And she came in before the weekend after midsummer's and asked if we would mind if we just took care of ourselves over the weekend. She and her boyfriend were going off for a trip and the refrigerator was full of stuff. And we said, "Oh, yeah. Sure. We can manage that." We had breakfast in the hotel regularly anyway. Then when the weekend actually happened, we realized that it was a good thing the refrigerator was stocked, because there was absolutely nothing open. It was like World War III had happened, and all the inhabitants of Göteborg were dead. The buildings were still there, but there wasn't a soul. Even the little market down the street was gone. So we realized that these people take vacations very seriously. We survived the weekend on *crème fraîche* and Rye Crisp and caviar, basically. [Laughter] But it was an enjoyable experience. I interacted with Sverre's students, who were all working in the optical electronics business.

COHEN: And language was no problem?

BRIDGES: Oh, no. They all spoke English. The only time we ever got into a "Swedish only" situation was when we traveled in the countryside. On the weekends we would take off in Sverre's car and get as far as we could get, and stay someplace and then come back. But in the

city, with Lin and her red hair, they would usually start off—it depended on whether or not it was August—the rest of the time we were there they would start off in Swedish and she would say, "I don't speak Swedish," and then they'd speak English. During the month of August, however, they would switch from Swedish to German, and then to English when they discovered she didn't speak German either. There are a lot of German tourists in August. And then finally, around the beginning of September, the Swedes come back into town from wherever they've been all summer long, and the place looks inhabited again. And of course there was no summer school at Chalmers, so I was interacting just with the graduate students and postdocs. It was really a very enjoyable experience. I got to do some thinking on my own and learned that I could run my research group here with a fax machine. It worked very well. I would send one fax a day and I would get one fax a day, and I would keep track of what they were doing. In fact it may have even been better, because it forced us to read each other's thoughts once a day.

COHEN: And focus.

BRIDGES: And focus, and put it down on paper—drawings and that kind of stuff. Actually the work went very well that summer. I had three active graduate students that particular summer, and I think we made a lot of progress.

COHEN: Well, that shows good organization on both ends.

BRIDGES: Yes. But I was really quite amazed at Sverre. He subsequently retired from Chalmers and became full time at JPL and just this last year has retired from JPL. So he's now fully retired. He and his wife live here in Pasadena. Actually, I think Sverre is Norwegian originally, educated in Sweden. For many years he worked for Hughes in the semiconductor division and then he went to Chalmers as a professor. Their two sons both live in the United States—in fact, one of them works at JPL and the other works for Bell Labs—and their daughter and her husband are still in Sweden.

COHEN: So then you went to England on your way back. You mentioned that.

BRIDGES: Oh. Well, we were traveling. We started our travels by going to Oxford for this

British quantum electronics conference. And the conference organizer there, Colin Webb, asked if I would give a talk on lasers. He warned me that this was a keynote talk and it should be humorous rather than technical, so I did my best to be humorous. Under the circumstances it was probably OK. Lin sort of felt for me most of the dinner. Before the talk, we were seated at high table, and I was sitting next to the lord mayor of Oxford, who was a woman lawyer wearing the chain of honor. In fact, when we saw her at the cocktail party from a distance, Lin thought, "That is the most garish necklace," and then when we got closer we realized that it was the badge of office for the city officer. [Laughter] But she was very stiff and formal. And of course Linda was sitting with Colin at the other end of the table, and they were just having a ball telling jokes and whatnot. But I gave the talk there, then stayed for the rest of the conference. It was quite an interesting meeting, more like the old days at Hughes—or even before Hughes, at Berkeley, where professors and their students would go to a nice informal meeting that we used to have, which has now become too formal. In this case, most of the attendees were British faculty and their students, which I thought was quite refreshing. Everybody got a chance to talk and interact with the community, and that was a pretty good thing. There were a few foreign visitors, but mostly they were from England. When we first arrived, we stayed the weekend at Jesus College, where Colin has his appointment. Then we moved to Keble College for the conference, and when we checked in at Keble I said, "Do you have a room with a double bed?" And the porter brought himself up to attention and said, "Sir, Keble College was established for young men of the cloth. We don't have double-bed accommodations." So I said, "Oh, OK." So Lin and I had separate rooms, with a foot of concrete between our beds. It was interesting that the place still worked that way. Then we did some touring in England and came back to the States.

COHEN: And your group just went on? You hadn't been missed too much?

BRIDGES: Well, I did lose track of them for the month of September, because I was without a fax machine. But they did OK. They were self-sufficient folks.

COHEN: But that in some way did separate you from other kinds of obligations. That's what's good about a leave.

BRIDGES: Yes. The telephone didn't ring at all. People didn't know my telephone number. I

would occasionally get a fax, and even mail. And it was nice to listen to other people's ideas, to listen to Sverre's students. They weren't working on exactly the same things I was working on, but we could certainly converse, because we were all in the same business of optical electronics. So I think it was a good experience. And I spent time in the library there that I would not have spent at Caltech. I love to spend time in a library, and I rarely do. I dread the day that libraries will be all on-line; it will help you to look up exactly what you want, but you will miss the paper that just happened to be published next to the one that you were looking for. I'll go to the library and do a random walk through technical things, in addition to looking up specific references. Paper libraries you approach a different way than electronic libraries. So I would spend some time in the Chalmers library getting to explore things that I didn't otherwise.

COHEN: So now we've got you back here, and we were going to talk about some of the consulting that you probably picked up again at this time.

BRIDGES: Well, actually, for twenty-five years my consulting has been largely at HRL, as it's now called, just in whatever was particularly current in the optical electronics business. I still consult there, but not as much as I used to.

COHEN: How much time do you spend there?

BRIDGES: Well, never more than a day a week. When I first came to Caltech, I was over there, oh, maybe three weeks out of four. Now it's probably more like two weeks out of four.

COHEN: Now, you mean just one day in the week.

BRIDGES: Yes, one day. So I spend maybe twenty days a year at HRL, and I'm currently working on automobile antennas, which is an interesting change. This is a General Motors project. It's a satellite antenna that's supposed to disappear into the car so that it doesn't bother the stylist to have some big thing on the roof. General Motors is quite interested in direct satellite broadcasting for music and news to cars, which you will then subscribe to and pay ten bucks a month to get music anywhere in the United States, with CD quality. And they say no advertisements, but I'll believe that when I see it.

COHEN: You mean just as something good in the car to entice people to buy it.

BRIDGES: Yes. It's a big thing right now. General Motors is interested because, although they're not the company that's doing the…. The satellites are already up there, as a matter of fact, for one of two competing systems. But GM will have to offer the radios, and they are making deals with the systems company on the details of the systems. General Motors is behind one of the companies, and then other car companies are lining up behind the other company. So there will be some real competition, I think.

COHEN: Is there any other company you've done consulting for?

BRIDGES: Over the years, yes. For a while I consulted with Spectra-Physics Corporation on a new development in the manufacture of argon-ion lasers. That went on for a couple of years as they were putting together a very nice product. And I kept telling them that they really ought to sponsor a little research in this area, too—internally in the company. And that all ended very suddenly in a lawsuit; another laser manufacturing company, Coherent, sued them for infringement on a patent. The next thing I know, I was no longer a consultant to Spectra-Physics, I was a consultant to the Spectra-Physics lawyers. This went on for more than a year in a big patent battle between Spectra-Physics and Coherent. The stakes were the survival of Spectra-Physics. If they lost, they probably would have been out of business. They didn't lose, Coherent lost, and both companies are still in business. Unfortunately, it cost both companies enough money that neither of them could afford starting up a little research effort on the side.

COHEN: So it was really destructive in the end.

BRIDGES: I thought it was very destructive. They should have come to some kind of settlement. Their lawyers advised them to settle at the beginning, but the company personalities on both sides were so adamant that each was right that they wanted to fight the other right down to the mat. And they did. By the time that lawsuit finished, a couple of the key people with whom I had been consulting had left Spectra-Physics, and so I never resumed my consulting with Spectra-Physics. Shortly thereafter, though, I was asked by an old friend, Milton Chang, who's a Caltech alum as a matter of fact, and a very well-known person in the optical field. He's now a

multimillionaire and entrepreneur, but even at the time he was pretty wealthy, having left Caltech as a graduate student and been one of the principals in a company called Newport Corporation, which ended up, and still is today, a major supplier of research equipment to the optical electronics business. Milton was chairman of the board of Newport, but he was also using some money to back a small laser company in the Bay Area called Uniphase Corporation. And then Newport and Uniphase were going to do something together, and Milton felt it was a conflict of interest for him to continue on the Uniphase board. So he called me up and asked me if I would like to serve in his stead on the Uniphase board. Uniphase then made argon-ion lasers and helium neon lasers. So I agreed to serve on the board. I figured, "Well, I know about ion lasers and helium neon lasers. I'll be a technical member of the board and I'll learn something about business." It was probably less than a $20-million-a-year business, all sort of under one roof. We held our board meetings in a little wallboard room off the manufacturing floor. That was 1986. At the beginning I never thought it would be as exciting a ride or experience.

COHEN: Really?

BRIDGES: Yes. I see you don't invest in the stock market, or you would have recognized the name. Today the surviving company—well, let me build up to it. So I started serving in 1986. The president and CEO of the company, Dale Crane, was another old friend who had worked at Hughes in the manufacturing division, and that's where he got involved in the laser business. Then he left Hughes to go to Spectra-Physics, and then he left Spectra-Physics to start this company [Uniphase] in his garage. And Milton bankrolled it. We went along for several years, with the company growing nicely. It was not a publicly traded company; the stock was all held internally. I basically got paid in stock—a small amount of cash, but most of it was in Uniphase stock. At one point there was a decision made that maybe we should sell the company. Dale owned about a third of the company and Milton owned a third of the company and all the employees owned the other third. Maybe now was the time to cash in—and in fact we began negotiating a deal with another laser company. Right in the middle of that, something happened to one of the product lines. The product started to go sour. And Dale, the president of the company, was also the chief engineer. So he basically just dropped this sale flat to go solve the technical problem, which he eventually did. It saved the company in that regard, but the board

members realized, “Wait a minute. We’re facing a one-man company here. If we’re going to sell the company or go public or do anything in the sort of sophisticated high end of the business, we need a CEO whose full attention is on that.” By the way, by this time Milton had left Newport Corporation and rejoined the Uniphase board, so I had the pleasure of serving with Milton. He didn’t ask me to leave. In fact, I had no financial interest except a small amount of stock I had been paid.

COHEN: Well, you obviously were enjoying it.

BRIDGES: Yes, I was enjoying it, and apparently we were doing OK. But this glitch prompted the board to think, “Look. What we really need to do here is hire a CEO to basically run the company, and either take it public or sell it, and let Dale be the chairman of the board.”

COHEN: And do his thing.

BRIDGES: Yes, do his thing. Dale was very grumpy about that. And probably the most unpleasant thing I’ve ever had to do was sit with my fellow board members—all of them knew Dale personally—and say, “No, Dale. We’re going to overrule you. We’re going to hire a CEO.” He was really unhappy about that, but that’s typical of founders of companies.

COHEN: Well, it’s their child.

BRIDGES: It’s their child. It’s a very dangerous thing, though, if you have to control everything in your company, because you can never grow bigger than a certain size. You have to delegate things. The bottom line is that we went out and did an executive search, and we hired a fellow by the name of Kevin Kalkhoven. Kevin was from the computer business. He knew absolutely nothing about lasers, but he was a very sharp, quick guy and he knew about business. And the rest, as they say, is history. Kevin got on board, learned enough about lasers to at least know what the product of the company was, and then started thinking, “Where do we go from here? What’s our next product?” I won’t bore you with all the details, but probably the first key thing was that there was another company, a little arm of United Technologies on the East Coast that was being spun off from United Technologies, and Kevin thought, “Well, you know, they make

a different product; that would diversify our product line. Can we buy that company?" It was $10 million. At this time Uniphase did about $25 million or $30 million a year in sales, or something like that, so it was a big deal for the board. And we ended up buying it. It's now called UTP, Uniphase Telecommunications Products division. That was the first of many acquisitions, and in fact from that moment on, every board meeting was an adventure, because Kevin suddenly got this vision of being the Sears Roebuck of the photonics business. He once told the board that his ambition was to be the world's largest merchant supplier of photonic products for fiber-optic communications. As a matter of fact, the company is, now. After digesting UTP at $10 million, the next acquisition was a piece of IBM Zurich that made lasers; that was $45 million. And then a big piece of Philips Corporation—Philips Optoelectronics at Eindhoven. Uniphase is now an international business, moving out of San Jose to the world. And after that I've almost lost track. We picked up little companies here and there, and then there'd be the next big one. But every board meeting was exciting, because Kevin would have some new acquisition which was at least three times bigger than the last acquisition, which we had worried was too big. The company was just going crazy. At some point along the way, he took Uniphase public. In 1993, I think—September of '93—it went public. The offering was eight bucks a share. It's split six times since then. In 1998 I resigned from the board, because basically Kevin needed a board slot for a business-oriented person. It was clear that they no longer needed technical advice on the board; the company was much too big for that. It was a lot of fun. I stayed on for another year on their technical advisory board. I attended all the board meetings, but as a technical person. And then there was a merger—it was counted as an acquisition, but it really was a merger between equals—of Uniphase and a company called JDS Fitel, in Canada. And the surviving entity is JDS Uniphase; it's a several-billion-dollar company.

COHEN: Is it still headquartered in San Jose?

BRIDGES: I believe it is. Yes, it would have to be, because that was the surviving entity. But they now have a lot of subsidiaries. After that, they acquired a major optical coating facility in Santa Rosa and another laser manufacturing company in the Bay Area. That was a multibillion-dollar transaction.

COHEN: It must have seemed very quiet when you came back to Caltech after all this. [Laughter]

BRIDGES: Oh, well, all this was done with four meetings a year, maybe five. You know, one-day meetings. I'd fly up to San Jose for a board meeting and fly home thinking, "Oh, my gosh. What's he going to do next time?" Kevin left the company shortly after the merger with JDS Fitel. I'm not quite sure why. He's obviously a very wealthy man. I wondered how he could have kept going exponentially, but he did. It went on for another year of major mergers, stopped only by this latest stock market crash, where the stock has gone down by a factor of more than ten from its peak. A year ago this March, it was $140 a share, up from $8—unbelievable! In fact, in the calendar year 1999 the stock went up by a factor of ten. It's a major, major stock market company now.

COHEN: That's finished, for the moment, anyway.

BRIDGES: For the moment, it's in bad shape, like all the rest of the industry. There's nothing wrong with the company; the whole industry is under a cloud now, because the bubble burst. I'm sure it will come back. Inevitably the world will be completely wired with fiber optics, but it's going to take a while.

COHEN: I just read in the paper yesterday or the day before that fiber optics is finished, but that's not true?

BRIDGES: Oh, no, that's not true. It's inevitable. But it needs some leadership at the systems level. It needs another Ma Bell, or Ma Fiber, kind of thing, which the government won't allow anymore. I mean, they broke up the telephone company. AT & T could have done this, by the way, before they were broken up, but they're too conservative and they chose not to do it. What we need now is somebody who realizes that you can make a switched communication system with very high bandwidth, and you can put incredible services into every home in the country. The telephone will be trivial. There will be two-way video, all of your cable TV, things that we can't even imagine. It's doable technically. It's probably doable financially. But I'm not sure that there's the leadership to do it. What we need is a John F. Kennedy who will say, "By the

end of the decade, we will have broadband communication into every home and every classroom in the country." And we could do it. I mean, there are some things that have to be developed, but you could do it and you could do it very well. Unfortunately there's no government agency like NASA that would take over the leadership of those telecommunications things; it will be left to industry. So you're going to have the telephone companies—which already have some fiber, but mostly twisted-pair—into your home trying to sell you DSL [digital subscriber line], which is really lousy and very limited, but they don't have the fibers into your home. And you will have the cable companies, who have a coaxial cable into your home but no switch network, so you can't talk back to anybody, and they want to sell you broadband on top of their cable. Then you have the satellite people like Hughes DirecTV. They want to put your computer on their satellite. And these people are going to duke it out in the marketplace. And the obvious end solution—the most obvious to me—is just to wire it all up with fiber optics. But none of them will do it.

COHEN: So there needs to be some entity above them?

BRIDGES: I think so. I think it almost needs a presidential mandate that this is a good thing for the country and we will do it, and we could. But I just don't see that happening—not in this administration. I'm not sure I see it happening in any administration. It's too bad, because it would make more of an impact on our daily lives than going to the moon ever did. Just imagine what you can do: Schools are closed because of snowing. Don't worry, just dial up the classroom. There's the classroom right there in front of you—two-way communication between you and the teacher and every other person in the class. You could do that. Or maybe if you're in a rural area, just don't bother to build a schoolhouse. Everybody works from their own home, with the same kind of quality and services, or even better. If you want to go to the library, just *click!* and there's the whole class in the library looking at that reference.

COHEN: [Laughter] This is too much. You don't have to get out of bed in the morning.

BRIDGES: Well, you know, hopefully this frees you to do other things. It's not like the "labor-slaving" devices that they made for the housewife that were supposed to make your day so much easier and ended up giving you a bunch of junk you had to repair all the time.

COHEN: So that was quite fun for a while.

BRIDGES: Oh, yes. It was a real kick. I resigned pro forma, because my appointment was really to the Uniphase Corporation and it ceased to exist when the merger took place.

COHEN: I hope it left you comfortable.

BRIDGES: Oh, it did. It would have left me a lot more comfortable if I had sold all my stock about March 2000. But then again, a lot of other people would be heroes today if they had done that, too. No, we're OK.

COHEN: So, anyway, what connections do you have now?

BRIDGES: None with JDS Uniphase.

COHEN: And your Hughes connection? That continues?

BRIDGES: That continues; that's been a long-term consulting thing. Actually, I have a subcontract from Hughes—HRL Laboratories LLC—so I have two connections. One is consulting, and that's the antennas. And I'm also working on electro-optic modulators for them, but with Caltech as a subcontractor, on a big DARPA program they have.

COHEN: OK. Well, now, of course with your retirement you can do whatever you want.

BRIDGES: Right. My contract with HRL actually goes, at the present time, a year beyond the date I retire. So I'm presumably on the hook for doing that. And I have to do it myself, because I don't have any more students. But that's OK. I'm having fun doing that now. And there may be future contractual business with HRL. I'm going to have to make it work, with two houses, you know—one here and one in Northern California. That's why I'm waiting for all this fiber-optic stuff. I could talk to people without ever leaving home. That would be great.

COHEN: We mentioned the Society of Women Engineers, and you said you wanted to talk about

that separately.

BRIDGES: Well, when I first came to Caltech—I guess all my life I've wondered, "Why aren't there more women in engineering?" When I was a student, I think we had exactly one woman out of 500 electrical engineers in the graduating class. And I always thought, "This is interesting stuff. How come women are not interested in it, too?" I guess I probably had girlfriends who were equally bored with engineering, which I never understood either. But being a naive engineer, you know how it is. I had met a few women engineers at Hughes. In fact I served in the Optical Society with one particular woman, Valerie Olson. She and her husband both worked for Hughes, and they both had intermediate management-level jobs. And she had all kinds of hair-raising stories about trying to be a technical person and a woman at the same time—unbelievable things. When she worked at Litton Industries, she asked to go to a conference, and her boss said, "No, you can't go to the conference." This went on conference after conference, and at some point she just said, "Look. All the other people at my level are going to these technical conferences. How come I can't go?" He said, "It's company policy. The company can't pay to have women travel to go to a meeting." She said, "Why not?" And he said, "Well, because it could be abused if men took their secretaries along for nefarious purposes." I think that was about the end of her relationship with that company. She came to work for Hughes.

COHEN: Well, do you know the stories about the early astronomers—why they couldn't have women up at the observatory?

BRIDGES: No! It must have been the same thing. Oh, gee!

COHEN: They didn't have two sets of restrooms, or something like that. [Laughter] And this was not so many years ago.

BRIDGES: Well, I'm sure there are places where that goes on today. Anyway, it just seemed to me that something ought to be done. There was a Society of Women Engineers chapter here that was inactive, so I recruited a couple of my undergraduate advisees who were women and we got a chapter going again and tried to get speakers who would come and talk to the women students,

because it seemed to me that the women felt uncomfortable being in engineering. It's one thing to have the talent to do it, but you have to feel comfortable. And I think it was simply that they would look around and say, "Gee. There aren't very many people like me here. I'm uncomfortable." The turning point was a young woman chemical engineer here, Isabella Lewis. She was in my undergraduate optics class. She was very good, and I asked her to be a teaching assistant for me. I always used undergraduates as TAs in APh 23 and 24, because I figured that graduate students don't understand this stuff, they've never had it before, but the undergraduates have had it from me so now they know how to deal with students. Izzy and I got to know each other pretty well, because we'd talk during the lab sessions when we were both in the laboratory together. She was clearly a very good student, very personable, active in undergraduate affairs and everything, and when she got to be a senior I asked her, "What are you going to do?" She said, "Oh, I'm going to go to graduate school." I knew some chemical engineering professors who were writing recommendations and getting her off to the very best—I think Stanford was where they thought she should really go—and at the last minute she bailed out and decided not to go to graduate school. She got a job as a laboratory chemist for a company in Southern California. I talked to her, and the reason was that she just really felt uncomfortable. She didn't feel it was her place to be a researcher in chemical engineering. And I thought, "That's terrible. This woman has all the technical talent, personality, everything." She would have been dynamite as a graduate student and a professional, but somehow she felt uncomfortable doing it. So anyway, that was the genesis of trying to reactivate the Society of Women Engineers. Some of the evening meetings were, I think, quite successful, although maybe in an unpleasant way. I got Valerie Olson to come over and give a talk to the students, and it turned out, as luck would have it, that Valerie had come to a critical point in her life right at that time and she decided to share it with the students. Namely, she had been offered the presidency of an optics company, but it was in Mississippi, and it meant that she and her husband and two teenage boys would have to leave Southern California. He would leave his job at Hughes, where he was a middle manager, and she would take the presidency, and she didn't know whether that was a good thing or not, because he was probably unemployable in Mississippi—certainly in his business. And she said, "But this is what's going to happen. This is a two-career kind of decision." I saw a lot of glum student faces at that meeting, because they realized, "Yeah that could happen. If I'm going to be a professional and my husband is a professional, we have to make a choice

sometime, and it's going to be very painful." As it turns out, she decided to stay at Hughes and not take the opportunity. But it was a real dose of realism for the students. I'm not sure that was a good way to get them enthusiastic about being engineers.

COHEN: But that's the real world, certainly.

BRIDGES: But it was the real world. The other ambivalent situation was that I had a couple of young women engineers from Hughes Missile Systems come over and talk about their jobs, and they were incredibly enthusiastic. I mean, they were dynamite! They were really good presenters and all that. The only trouble was that they were talking about designing missiles and taking them out and shooting down airplanes and all this kind of stuff, and I could see that some of the women students didn't think that would be a good career—to design things that killed other people. We didn't invite anybody from the aerospace business after that. [Laughter] They were really enthusiastic, and they made a great pitch: "This is a great job. I really enjoy it. Here's what I do," but it did create some negative feelings. I think the Society of Women Engineers went on for a few more years. I stopped being the advisor after a while.

COHEN: This was just a Caltech group?

BRIDGES: This was a Caltech chapter. The last couple of years I think they did a good job of putting on a sort of "evening with industry" at the Athenaeum. It was exactly what was needed—to develop an old-girl network like the old-boy network, where the students get to see some of their potential future employers and talk to them about jobs. But I don't know what happened. I guess I got involved in another activity at Caltech, the Program in Advanced Technologies [PAT]. Did I talk about that before?

COHEN: No, I don't think so.

BRIDGES: That was a major time sink, about 1985 or so.

COHEN: That wasn't one of your original committees.

BRIDGES: No, it wasn't. It was something I was asked to do by the division chairman, Roy Gould. The development office had started it here. TRW was interested in giving some money to Caltech for young faculty research, and so this sort of grew. I wasn't involved in the very early genesis of the program. Roy was running it out of the division chair's office, but then he asked me to take over, once it was getting to be a time sink. The idea was to try to find five companies that would each give a million bucks, over a five-year period, so we would have $1 million a year for five years to support the work of young faculty or innovative new work by older faculty—you know, directional changes, something to give you some freedom of action. So we put this together. We got four companies; we never did get the fifth company, although we did a lot of on-the-road stuff trying to get people interested. TRW, Aerojet, General Motors, and GTE were the companies, and every year we would make a request for proposals and young faculty would write about what they wanted to do and how much they wanted for it. Then we'd have a meeting here with representatives, one each from those companies, and go through the proposals, and we would fund them. Every year we funded about half of the proposals, and we also had four graduate fellowships that we funded every year. I think PAT was really quite a successful program. We did not get to renew it, however; that was a problem. I learned a lot about fund-raising. We tried to get people to re-up for another five years. TRW was happy to do it. By that time, General Motors had acquired Hughes, and what they wanted was for Hughes to go in fifty-fifty with them to buy one slot, and the Hughes guys didn't want to get involved. So that's where it petered out. Aerojet got into big trouble. During the first five years, they were the subject of a greenmail takeover by a stock manipulator, and they had severe financial problems. They closed their corporate headquarters in La Jolla and closed some facilities up in Sacramento. I think Caltech actually probably loaned them money for a while to keep the program going. And GTE decided that their main interest in PAT was for a division of the company that they had just sold to Siemens. So we tried to get some other people involved in PAT, but it just died. Even though it was successful, I think it died because of the particular circumstances of the original sponsors.

COHEN: Maybe these programs have a limited life.

BRIDGES: This one could have gone on, because we continued to bring new young faculty in.

And I think it was instrumental in getting some of the young faculty an initial piece of money that they could play with to get them going. I'm quite happy with the way the program ran. It took a lot of time, because I had to deal with four companies plus a whole bunch of principal investigators plus a bunch of committee people. But it was fun. One thing I learned, though, is that if I were ever to do a program like that again, I would insist on a different kind of funding. It turns out that most of the companies funded it out of their charitable fund, the same fund that they'd use to fund the Boy Scouts and the Girl Scouts and the opera and all that. Well, that's fine, but it doesn't develop any connection at all between the young faculty and the company. What I would have wanted—and I didn't know this until after we got into it—I kept trying to get the young faculty together with people in the company. And my representatives, who were all at the vice-presidential level in these companies, would all say, "Oh, well, yeah. He should see so-and-so." I'd call up and hear, "Oh, so-and-so hasn't worked here for two years." There was a disconnect on the company level. The people I was dealing with there didn't know who would be the beneficiaries of this work. And I felt that for a program like that to be successful, it has to come out of somebody's technical budget in the company. Either they don't want you at all or they love you and will continue to pay for it. And they will get the information, and the young faculty would get the benefit of outside criticism. That was the other thing I wanted to see. Having come from industry, I felt it was very important for young faculty in engineering to understand what the real world was all about. And having a tie with somebody in the real world was valuable. That was the frustration. I did a lot of traveling to the companies to try to find the people that their vice-presidents couldn't find who would be interested in what the Caltech people were doing, and I wasn't really successful in doing that. That was, I think, the failing of the structure rather than just money woes. If I were to do it again, I would try to make the program person-to-person on the working level—and maybe it would have to be smaller to start with. Those are the successful relationships we have—the ones that faculty members find on their own. Maybe that's the only way to do it—to have them find it on their own, rather than do it as a program.

COHEN: Well, I think in these big companies probably when you get to these upper levels you have management that doesn't really know about all this kind of stuff.

BRIDGES: They didn't know how their own companies were organized. In some cases, their job was giving out money from the charitable fund of the company, which is not a good connection.

So PAT went on for five years, and that was an interesting experience. I think that's why I got out of the Society of Women Engineers, because PAT monopolized my life for a while.

COHEN: We're at "honors and awards." So how about boasting a little bit?

BRIDGES: Oh. Well, I'm a fellow of both the Optical Society… [Tape ends]

Begin Tape 3, Side 2

BRIDGES: I'm a fellow of the Optical Society of America and a fellow of the Institute of Electrical and Electronics Engineers. I'm a member of the National Academy of Engineering, and then a member of the National Academy of Sciences. The latter two, my colleagues elected me—I had no idea. Well, I guess even the other two. Somebody…

COHEN: Somebody has to sponsor you. Were you in the engineering academy before the academy of sciences?

BRIDGES: Yes. I was in the engineering academy in 1977, the year I came to Caltech. I suspect that my Caltech associates were responsible for that, rather than my Hughes associates.

COHEN: At that time I don't think that academy had been in existence very long.

BRIDGES: I think it came into existence in 1964. Then I was elected to the academy of sciences in 1983.

COHEN: Do you go to the meetings? Do you have anything to do with these things?

BRIDGES: I'm sorry to say I've never been to a national meeting of either of the academies. They're in Washington.

COHEN: I know. I go sometimes. You should go. They're fun.

BRIDGES: Linda keeps bugging me to go. One year—I think it was when George Bush senior was in the White House, his wife gave a tea for the academy, and Linda said, "Why didn't we go?" And I said, "Well, I didn't know it was going on." When you're teaching, taking a week off during class time I just didn't think was a responsible thing to do, because these aren't highly technical meetings.

COHEN: No, no, no. It's a big party.

BRIDGES: And so maybe now that I'm not teaching, we'll go.

COHEN: I think it's a good opportunity to go to Washington.

BRIDGES: Oh, we love Washington. Now that we don't have the commitment of a teaching schedule, we'll probably go to the academy meetings.

COHEN: Are you more active in your own professional organizations?

BRIDGES: No, I'm less active now.

COHEN: Didn't you just win something recently from one of these organizations?

BRIDGES: Well, some years ago I got the Quantum Electronics Award from LEOS [Lasers and Electro-Optics Society]. Because I'm an electrical engineer, I started off with IEEE, really before there were any laser conferences. There was a big physics meeting starting in 1960—the year of the laser, literally—but I wasn't involved in those. But when the engineering side of things got involved, I was one of the founding group for the first laser engineering conference, CLEA, the Conference on Laser Engineering and Applications—that was 1967. I have subsequently been involved in all kinds of committees—the paper committee and then the program committee. I think I was chairman of the 1971 CLEA conference. So you go through that rank of doing all the grunge work on getting conferences going. But then I also got involved with the Optical Society. One thing led to another, and I ended up serving on the board of directors and then I was elected president. Actually I was elected vice-president, because they

get you for four years. You become vice-president, president-elect, president, and past president. And you have to do something each one of those years. Between the vice-president and past-president year, you're supposed to visit every local chapter and give a talk. There are some thirty chapters in the United States, and one in Canada, in Quebec City. And I did. I have a whole memorabilia book of getting on an airplane and going and giving a talk to a chapter. The most interesting one was Quebec, because the audience either didn't speak English or they didn't want to admit that they spoke English. So I gave my talk in English, and the Q & A was done in French with an interpreter who gave me the synopsis of whatever the question was. It was interesting. There's a very popular optics school there—Laval University.

COHEN: Now, let's see. How many of Caltech's presidents have you lived through here? You came when Harold Brown was here?

BRIDGES: Yes. Harold Brown was president when I was here as a visitor and a Fairchild fellow. And then when I came here, Bob Christy was the acting president. And then Murph [Goldberger] and Tom [Thomas E. Everhart, president 1987-1997].

COHEN: I was just going to ask you what your feeling was about these people. I mean, Everhart certainly was very interested in the engineering division; that's the impression I have. Murph maybe was not so interested. How did you find this?

BRIDGES: They were incredibly interesting personalities. Being president of Caltech must be a terrible job. [Laughter]

COHEN: They all seem to like it.

BRIDGES: Any administrative position at Caltech is a terrible job, because you've got this tradition of very independent faculty members. It's like herding cats. It's hard to get anybody to do anything for the good of the higher cause when they're interested in their own work. "Go away and leave me alone!"—that's the typical professorial attitude here. "Give me money and space, and then go away and leave me alone." So it's tough. I have enjoyed all the presidents, but they're all very different personalities.

COHEN: Do you want to say a little bit about that? You can start with Murph Goldberger.

BRIDGES: Well, I think I just shook Harold Brown's hand.

COHEN: And then he was off.

BRIDGES: Yes, he was off. It would be interesting to talk to people about Harold Brown, because I had the feeling that as president he was here in a holding pattern until the Democrats could get elected in Washington, because that's exactly what happened. And I have the feeling that that was always in the back of his mind.

COHEN: But he did have some things that I think he pushed here.

BRIDGES: Oh, as I understand it, he was the one who put the present organizational structure together, because before Harold Brown it was pretty much run in the Millikan mode. Lee DuBridge [president, 1946-1968] ran it. I guess he was the outside man and [Robert] Bacher [chairman of the Division of Physics, Mathematics, and Astronomy, 1948-1962; provost 1962-70] was the inside man. If you wanted something, you'd go talk to the president or the provost and you got it or you didn't get it—that was it. But there was no substructure, and Harold Brown put a substructure together.

Murph was interesting, and of course very controversial. And I got a little bit involved in that. You may remember when.... The first I had heard about it, I was on the faculty board. And at the meetings there are the president's announcements. Usually the president just gets up and says a few things about raising money, *blah, blah, blah,* and then the meeting goes on to the real business of the faculty board. Murph got up at one meeting and said, "And then I've also signed this agreement with the secretary of the army for a studies center."

COHEN: Oh, the Arroyo Project.

BRIDGES: Right. And the room got silent. And it was like, "Wait a minute. You what? Well, wait a minute. Tell us more about this." This was the first time the faculty board or anyone outside of Murph had heard that Caltech was going to put together an army studies center. And

that faculty board meeting stopped right at that point, and the discussion went on. For the next forty-five minutes we never got to any other business. "What did you do? You shook hands? You have a memorandum of understanding? We're going to do this with JPL and it's going to involve classified work?" Oh, it was just—you know, the whole thing blew up. And why Murph asked me, I don't know. When it was clear that this was going to be a big controversial thing, he asked me if I would look into it and make a report to the faculty on what was actually happening, because they weren't going to believe him. He wanted somebody else to do this. So I looked into it, and I made my report orally to the meeting of the faculty and said, "Here's what's happened. Here's what's going on. Here's what's going to happen in the future." And I think by that time JPL had already hired a guy.

COHEN: Can you summarize? What was supposed to happen?

BRIDGES: Well, as I recall, this was at a time of a slight slowing economically at JPL. Just as a little background, the army is probably the low-tech service. They had no outside agency to look into basically army problems.

COHEN: You mean like what RAND does for the air force?

BRIDGES: The air force has all kinds of people. I mean, there was not only RAND but there was Lincoln Laboratories for radar, SAMSO [Space and Missile Systems Organization] for missiles and everything. And the navy had a navy studies center at the University of Rochester. The army had nothing, so I guess the army wanted to do this. And how they ever asked Murph I don't know, but they did, and he said, "Yeah, we've got some really bright people." You know Murph.

COHEN: Enthusiastic.

BRIDGES: "Yeah, we've got some really bright guys out at JPL. They'll put this together for you." So that was the plan—that it would be at JPL, that it would do classified work, and of course JPL does classified work anyway. But there was a large segment of the faculty that thought, "Wait a minute. JPL is in the spacecraft business. What do they know about army

problems?" And I think the answer was, "Just about zero." Well, that means you're going to have to hire new people at JPL, so that doesn't solve JPL's economic problems. And I think Hans Liepmann was the one who put it best. He said, "Caltech should never undertake anything unless we have an unfair advantage"—almost the opposite of Caltech's honor system. [Laughter] But the idea was that Caltech shouldn't do something unless we are clearly better than everybody else at that particular thing—unless we have an unfair advantage. And it didn't look like we had anything to offer the army, really, except some bright people, but not anything special. There were some parts of the faculty who thought classified work was terrible, but of course it was already going on at JPL anyway. But I think the larger misgiving of the faculty was, "If we're not good at this, we shouldn't undertake it." Anyway, it was sort of going along at that level when I was asked to look into it and see what was happening. By this time, JPL had hired a guy—I've forgotten his name now—who was going to be the director of this army research center. And they decided to give it a name, the Arroyo Center, and it was to be located at JPL. At least that's what I told the faculty. And shortly thereafter, the words "Arroyo Center" were used on the *MacNeil/Lehrer News Hour*. By the way, this was never supposed to be called the Caltech Army Studies Center—it was going to be JPL. But I think Jim Lehrer asked some guest about "Caltech's Arroyo Center for the study of army problems," and the next day that was the buzz on the campus and Murph just got dumped on. Then the next thing was that the director of the Arroyo Center they'd hired decided he didn't want it on the JPL campus. He wanted to be closer to Caltech. He wanted to rent buildings right up on Colorado and Lake Avenue. That's where it was going to be, so that the staff members of the Arroyo Center would have full faculty privileges at Caltech. By that time, I had made my report, and I was out of it. And then the next big thing after that was the famous closed faculty meeting where Murph got a vote of no confidence. And the Arroyo Center got sold off somehow and left Caltech. But that was a very exciting time. Coming from industry and having worked on classified stuff, I didn't have quite the baggage that some faculty members might have had. But I certainly agreed with the attitude that Caltech should never do anything just because we're good. We should do it because we're better than everybody else. I think that was the majority feeling.

COHEN: So that was quite a tarnish for Goldberger.

BRIDGES: Well, yes. At the time of the no-confidence meeting, Robbie [Rochus E.] Vogt was the provost. And I had the feeling that the next morning, or maybe that afternoon, there was going to be a Luger on Murph's desk from Robbie. And what I thought was that Murph would probably pick it up and say, "Hey, thanks for the gun, Robbie." But this vote of no confidence didn't faze him—maybe it did, but it sure didn't appear to. Whereas for Robbie and a lot of other people, a vote of no confidence would have been a call for resigning as president.

COHEN: Well, I know Murph. So he made a mistake, he'd do better next time.

BRIDGES: Right, and that's probably what it takes. You have to be like that, or you won't survive as president of Caltech. Murph was an interesting guy. He was very generous. He did the Caltech Amateur Radio Club well. And I'm thankful for that, as the advisor to the Caltech Amateur Radio Club. We got antennas put up and a budget that allowed us to do things. I think the first year he was here, he gave away flying lessons to the first hundred students that wanted to have a pilot's license and then discovered afterward that that was a pretty expensive proposition, so that program didn't continue beyond the first year. I wish he had had a little more interest in the appointments in the engineering division, because I think we could have used some engineering faculty. I've told you about all those, with the Ramo visiting committee and all that. But I always enjoyed Murph.

COHEN: Then you got Everhart, who should have been interested in engineering.

BRIDGES: Right. Well, I always worried about that, because I'd known Tom since I was a graduate student. When I was a graduate student at Berkeley—my last year at Berkeley, actually—Tom joined the faculty as an assistant professor, from his PhD at Cambridge. He was assigned to teach a senior communications class, and so was I. I was an advanced teaching assistant; they called it "associate." We actually taught lecture classes. We were responsible for a group of seniors and giving lectures and exams and grading the students. It was very different from Caltech, where you don't do that as a graduate student. The theory is that you have many sections of each class, so the professor teaches one section and has assistants who do the same thing he does. Well, in this case, I was assigned to teach the second section, and Tom was assigned, as his first assignment, to teach the first section. And I don't know how much of this to

believe, but Tom says he didn't understand the material at all, so he came to me. And I had had the benefit of having taken that class from a professor about three years before, so I had a pretty good set of notes, and I knew what I was going to teach—the same thing I had learned. So I shared those with Tom. Tom always tells people that I taught him to teach when he first came to Berkeley.

COHEN: Well, maybe you did.

BRIDGES: The truth is, I let him use my notes, which I had written from another professor. But that was my last year teaching at Berkeley.

COHEN: So you already knew him when he came here.

BRIDGES: I had met him there, and I stayed at Berkeley another couple of years to finish my research and then left for Hughes. And of course Tom had been a Hughes fellow. He had Hughes arrangements and knew people at Hughes. And as a Berkeley alum I would get called back to Berkeley. We used to have these government/industry/university meetings of alumni who would come to advise the EE department chair—which was Tom—on problems. And it was interesting, because in the early 1960s they had a lot of problems. Students had changed a lot, and some of those meetings were really very telling. We would say, "What's the problem?" The professors would say, "Well, we're discouraged. The students don't want to learn engineering anymore. They just want to go demonstrate. We can't tell them anything. We can't have required courses. They don't want requirements anymore." I think the alumni's advice was, "Just keep doing what you've always done. It's much better if this generation of students will eventually figure it out."

Let's see—what else after that? Tom was department chair at Berkeley, then he went to Cornell, and then from there to Illinois. When he was still at Cornell—and I think it's when I first came here and Bob Cannon was just leaving as division chair—we tried to convince Christy that Tom Everhart would have been a good division chair for Caltech. And in fact we were moving in that direction just about the time he left to go to Illinois as provost, and we figured, "Well, he's probably not interested in being division chair at Caltech." [Laughter] So we didn't pursue it. But I was happy to see him come to Caltech.

COHEN: The engineering faculty got on very well with Everhart, I'm assuming.

BRIDGES: Well, as much as the faculty is going to get along well with anybody. It's like, you know, "Give me space, give me money, and then get out of my hair. If you do that, we'll get along just fine." I think my biggest worry was that because Tom was an engineer—and the first president of Caltech who was an engineer—knowing Tom, he would bend over backwards not to show favoritism to engineering and as a consequence we would get less than we'd get in honest argument with Murph. Murph would listen. So I don't know how we fared all told in that regard, but I've always enjoyed Tom.

COHEN: And now you've got David Baltimore [Caltech's president, 1997-], who's had four years here. I was surprised to hear that at commencement—when he said he's been here four years.

BRIDGES: It's hard to believe. When he first came, he met with the engineering faculty in groups. And one of the faculty members asked him, right up front, "You've been at MIT. What do you know about engineering?" And he said, right up front, "I don't know anything about engineering." He basically had no contact with engineering colleagues at MIT. He's a very honest person, and very up front, so I take him at his word. He obviously knows a lot about universities. In a sense, you don't have to know the details of engineering to know how to deal with faculty.

COHEN: Well, his interest is certainly biology.

BRIDGES: No question about it, and he's obviously very, very good at what he does. Baltimore gave the physics colloquium, and his topic was—I don't know the exact name, but it was basically about why biology is different from physics. It was very interesting. He was going to explain biology to physicists, and what he said convinced me that he really understands biology research and that it really is different from physics. He was saying, "Look. You have physicists who at age twenty-five make an astounding breakthrough—Richard Feynman, for example. That will never happen in biology."

COHEN: I went to that talk.

BRIDGES: You did, OK. He really convinced me that you just have to pay a lot of dues in biology. There is so much infrastructure that you have to know before you can even define a problem, much less solve it. And I believe that.

I think the trustees are right. This is the decade—or era, however long it goes—of excitement in biology. And I think Baltimore gives us a good position, as a person who really understands biology and can take the institute farther into that arena, and as an attractant to young biologists to come here. I think it was an excellent decision, unless he decides to go shake hands with the secretary of the army again and do something. [Laughter] That would be bad. Other than that, I think Caltech's doing the right thing.

COHEN: So it's been a good run for you here.

BRIDGES: Yes. I've quite enjoyed Caltech. I look forward to maintaining a contact here somehow; hopefully I'll maintain an office—though they need some space over in Moore Lab [the Gordon and Betty Moore Laboratory of Engineering].

COHEN: They may give you a small office, but something.

BRIDGES: Well, I've got an office and two labs. The challenge over the next year is to try to figure out how to sort through the junk and get rid of it. Astronomers probably don't collect quite as much junk.

COHEN: You'd be surprised.

BRIDGES: Because you're using a big facility that somebody else is responsible for. The trouble is that here everything's done in my lab, and so all this junk just collects.

COHEN: Space seems to be an overriding problem here.

BRIDGES: Right.

COHEN: Well, thank you. [Tape ends]

WILLIAM B. BRIDGES

ADDENDUM

March 9, 2004

When I read over the final version of my interview, I realized to my dismay that the singularly most important event in my life had been omitted, namely, meeting and marrying Linda J. McManus. My life and outlook on both personal and technical matters changed for the better since that event occurred. So here's how it happened….

After twenty-five years of marriage, and a few years living in Pasadena, my first wife decided she no longer wished to be married to me. We separated in March 1983, and divorced in April 1986. When we separated, I moved into a condo in Orange Grove Village in West Pasadena and began to accommodate to being a bachelor. I was teaching a new (for me) course in electromagnetic theory for seniors and graduate students, which partly took my mind off being alone, but it was probably fortunate that I had only one graduate student at that time to worry about, William M. Bruno, PhD '86. My two sons stayed in the condo during their summer vacations from college; my daughter was in medical school in Chicago and stayed there during her vacations.

In mid-1984 I agreed to take on the management of the Program in Advanced Technology (PAT) [described in pp. 66-68 of the interview transcript]. This program was expected to involve a lot of paperwork, meetings, dinners, etc., with faculty and industrial committee members, so Caltech Corporate Relations offered to help out with what was needed in the way of personnel. Linda J. McManus was the Events Coordinator in Corporate Relations, and I met her as we set up the initial meetings of the PAT.

Anyone who knows Linda knows that she is attractive, energetic, and outgoing. I was attracted to her immediately. And the attraction evidently worked both ways. I know that I hung around the Corporate Relations offices a lot more than I could really justify for setting up meetings. I'm sure we supplied no end of amusement to the rest of the CR staff, all of whom were housed in one big room with the usual cubical dividers. You could overhear any conversation, if no one else was talking, and the office became unusually quiet when Linda and I were talking in her cubical. Once when I asked Linda a question, we got an answer from the next cubical before Linda could answer. This was followed by a sharp intake of breath, from the

same cubical.

Eventually, I got up the nerve to ask her out on a date. She accepted. I picked her up in my car, a 1972 Porsche 914 coupe, custom painted bright raspberry pink. (I had bought the previously-owned car some years before and intended to repaint it, but somehow the color grew on me). Linda admitted later that she had expected me to drive an old station wagon and was impressed by the pink 914. I had to admit then that I did own an old station wagon, but had given it to my son Bruce just a month or two prior.

There followed many other dates, and we fell in love. We discovered that we liked many of the same things (like tent-camping, hiking), but also that we both brought different interests to each other. Linda really likes to travel, and had trekked all over Europe when she was in college. I was a timid traveler, who was uncomfortable if I didn't have a fully booked itinerary; I really hadn't done much foreign traveling. I later learned you could drive through Ireland all day, then start looking for a room in the late afternoon, and actually find a great accommodation.

We were married at Caltech's Athenaeum on 15 November 1986. We booked that date more than six months prior, and it was the only date available for months in either direction. As we approached the date, I learned to my horror that it was also the date of Interhouse, an old Caltech tradition (which was probably why that date had not been booked before we took it). For the Interhouse party, the undergraduates spend weeks fixing up the "décor" of the student houses. "Fixing up" may mean making a swimming pool of the living room, or turning the patio into a jungle maze. (For more details, check out the movie *Real Genius*). It was considered the big bash of the year. We had our evening wedding planned for the west steps of the Athenaeum, with guest seating on the lawn, right next to the student houses. I called Chris Brennen, who was then Master of Student Houses, and said "Chris, what have we done?!" He thought for a minute, then asked what time the wedding would be. I told him it would begin at about 6 PM. He immediately replied, "Oh, I wouldn't worry about it; the students will never get their act together before 9 PM." Actually, the wedding was a big success (planned by Events Coordinator L. J. M.), and our guests enjoyed the explosions and flames that occasionally broke out during our reception. Some of them actually went over to see the party decorations. Unfortunately, Interhouse was discontinued by the administration, for safety reasons (namely, off-campus people who crashed the party), a few years following our wedding. I think this was a great loss for the creative expression of students; I would put Interhouse on a par with Ditch Day.

I was teaching "Demonstration Lectures in Optics," APh 23, the term we were married. I had to tell my class why Professor Demetri Psaltis would be giving my last two lectures, since I would be on my honeymoon. I asked Linda to come to that lecture, so I could introduce her to my students. Linda said she would come, and perhaps bring some of her co-workers from Corporate Relations. The lecture was held Friday afternoons in 102 Steele, a big lecture hall. At the end of the lecture I told the students about the wedding, and I asked Linda to stand up. A whole row of women seated in the back of hall stood and blew me kisses; I was left flapping around, trying to explain which one was Linda, and that I was not a polygamist! Linda has a great sense of humor, especially if it results in flustering me.

After our honeymoon in the Caribbean, we settled in to life in the condo. Linda continued as Events Coordinator for Corporate Relations, and I began to think about new directions for research. I took on three new graduate students in 1988 (Finbar T. Sheehy, PhD '93, Arthur E. Sheiman, PhD '93 and Yongfang Zhang, PhD '93). In 1989 we took a five-month sabbatical leave to Chalmers University, Gothenburg, Sweden, plus a one-month driving vacation of England. Linda had a big hand in the sabbatical; Professor Sverre T. Eng of Chalmers (and JPL) had been prodding me to visit his group there for a few years, and Linda decided to take him up on it. Before I knew it, we were booked. Linda resigned from Caltech, to continue her events coordinating as a private consultant. I had fun running my graduate students by fax from Sweden. I would send a fax at the end of the day, they would read it when they arrived in the morning, and then send me a return fax at the end of their day. This discipline resulted in more daily interchange than when I was physically present at Caltech!

Linda and I have had many adventures and travels together: An official visit (as President of the Optical Society of America) to China in 1988, stopping in Japan to climb Mt. Fuji; trips to England, Ireland, Scotland, Denmark, Germany, Austria, Switzerland, Australia, Tasmania, Saipan, Hawaii, and Jamaica, some on business, some vacations. And we will be in Italy and Germany this summer. We are just completing a retirement home in Nevada City (Northern California), an adventure in dealing with architects, contractors and subcontractors that has extended over almost ten years. For the time being, however, we look forward to splitting our time about equally between Nevada City and Sierra Madre, so we can stay in touch with our family and our friends at Caltech.