Jehoshua (Shuki) Bruck Oral History Interview

Interviewed by Heidi Aspaturian

2010 to 2017

Abstract

This oral history with Jehoshua (Shuki) Bruck, Caltech's Gordon and Betty Moore Professor of Computation and Neural Systems and Electrical Engineering, chronicles the life and career of a scientist whose pioneering, multidisciplinary research in information theory and computational science has significantly advanced the field and influenced a generation of students and scholars. Born in Israel to parents who survived the Holocaust and whose story he recounts movingly in the history's Preamble, Shuki (as he is almost invariably known) grew up in a suburb of Haifa and recalls coming of age there in tandem with a very young nation. His early aptitude and enthusiasm for mathematics and science led him to earn BS and MSc degrees in electrical engineering from the Technion (Israel Institute of Technology), where he began working with early computing systems in campus labs and at the IBM-Israel Science Center. After military service, he received his PhD at Stanford.

Shuki's research career—launched at Stanford and IBM Almaden and continued at Caltech, whose faculty he joined in 1994—unfolds as part of a larger narrative about the history and evolution of information science, covering origins in ancient Babylonia (which he explores in his innovative Caltech course IST4, weaving together humanistic and quantitative ap-

proaches), the dawn of the computer age, and contemporary society's ever-increasing dependence on information technology. He discusses his early work on image and signal processing, error-correcting codes, and IBM's first massively parallel computing system, as well as later research into neural networks, biological computation, and data storage technologies. He talks about collaborating with colleagues on restructuring Caltech's computer science department in the 1990s and co-leading the 2000–2004 Caltech-MIT Voting Technology Project. This culminated in his leadership of Caltech's information science and technology (IST) initiative, inspired by a vision of "information as a unifying concept" with the capacity to both bridge and dissolve disciplinary boundaries. Although efforts to establish IST as a Caltech academic division were not successful, the initiative has left a permanent imprint through the construction of the Annenberg IST Laboratory and the creation of multidisciplinary research centers across campus.

In the late 1990s, Shuki embraced entrepreneurship, founding two startups—Rainfinity and XtremIO—based on innovations in Flash storage and data systems that he developed with his students and postdocs. Both were later acquired by EMC. Looking back on these ventures, he offers his perspective on the challenges—and rewards—of translating academic research into commercial success. During this same period, he and his wife, Anat, spent two years as faculty residents in a Caltech undergraduate house—a time he describes as "one of the high-

lights of our life," offering unique and unexpected insights into Caltech student life.

Reflecting on his parents' legacy of survival and renewal, Shuki recalls learning "a very important life lesson from my father: We should continue our life with who we have and what we have." He returns to this theme throughout the interviews, as he considers its meaning for his own life—a steady reminder of the importance of family and of the many opportunities he has been afforded as a student, scientist, teacher, mentor, and colleague throughout his career.

Note to Readers

Oral history interviews provide valuable first-hand testimony of the past. The views and opinions expressed in them are those of the interviewees, who describe events based on their own recollections and from their own perspective. They do not necessarily reflect the views of the Caltech Archives and Special Collections or of the California Institute of Technology.

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Shuki Bruck, 2009. *Photo Credit Peter Mendenhall/EAS Communications Office*

Preamble, Winter 2010

This interview with Professor Shuki Bruck, recorded in 2010 and now published as the Preamble to his oral history, was partly inspired by the 2008 release of the movie Defiance, a film about Jewish resistance and survival during World War II, and its relevance for his own family's experiences in Poland, Belarus, and the Soviet Union under Nazi occupation. Interview questions have been mostly removed so as not to interrupt the flow of the narrative.

Shuki Bruck: When the movie *Defiance* came out, I believe it increased people's awareness about the Holocaust; specifically, a special aspect of the Holocaust where people tried to survive in an active way. I didn't know about the movie when it first came out. I heard about it when I went to some function and talked to Professor Mary Kennedy [Davis Professor of Biology]. I don't know how it came about, but I told her that my father spent time in the woods during World War II, and she asked me, "Do you know the movie *Defiance*?" I said "No," and she said, "I just saw it. It's about the Bielski brothers," and I said, "Amazing. My father was there." She was very impressed by that. The movie is based on an excellent book that I had read before by Nechama Tec, a Holocaust survivor, who is a professor at the University of Connecticut in the United States. My knowledge about this period is not from my father, because people of his generation preferred not to talk about the Holo-

caust. [Tec died in 2023; her book and the movie it inspired is an account of how the Bielski brothers saved the lives of more than a thousand of their fellow Polish Jews by building a concealed encampment community deep in the forest and allying with local partisans fighting the Nazis. *–Ed.*]

So, first, maybe some context: I was born in Israel in 1956. Israel at the time was eight, so my father and my mom were kind of the founding generation of Israel. It was an interesting time to grow up in Israel. I grew up in a place called Kiryat Haim [also transliterated as Qiryat Haim], and my father worked for most his life—at least the life I know, because he did other things before—at the harbor in Haifa, which was then the main harbor of Israel. My father's name is Moshe, and his last name is like mine, Bruck. He spelled it Bruk, and for some strange reason both my brother and I decided to put a "c" there. I don't know why. My brother is older by three years, so I think I'll blame him: It was his idea, and I just said, "Okay, I'll put a 'c' also in it to be the same."

My father was born in 1922 in Nowogródek, which was then in Poland and is now Navahrudak in Belarus. When he was fifteen, his mom died, so he stayed with his father and brother, who was a bit older. At that time Nowogródek had about 14,000 people. Half of them were Jews, and it was a place that was advanced in terms of education; they had a school that was part of the Tarbut school system. At Tarbut they were teaching Hebrew, so my father studied Hebrew in Poland, and he was

proficient in reading, writing, and conversing. In terms of schooling, he just went to elementary school, through eighth grade. He helped his father, who was in the business of leasing apple orchards and then hiring the people who would work there, as well as working there himself, and then doing all the things needed to bring the fruit to the market and sell it.

So that was the way they supported themselves. A very humble life. My father's plan at that time was to try and emigrate to Israel. Israel didn't exist; it was a British colony, Palestine, but he really wanted to go there. He got a certificate, as they called it, that would allow him to emigrate. His brother also got a certificate, and then they thought about going together. However, my father felt that he didn't want to leave his father, my grandfather, and he decided to wait. And now I don't know the details there, but based on what my mom told me, they tried to get a certificate for my grandfather as well. But I'm not sure if he wanted to emigrate or not.

In any case, my grandfather: His name was Shlomo, which is like Solomon, and he was born in 1886. I know that date because in 1957 my father went to Yad Vashem, which is in Israel, in Jerusalem. "Yad" in Hebrew means both "hand" and "monument," and "shem" is "name," so it's a monument or a memorial for those who died in the Holocaust and also a place to recognize those who helped Jews during the Holocaust. The reason my father went there is a sad one. Israel passed a law in 1953 with the idea that if you record the name of someone who died in

the Holocaust, with all the details, this person gets honorary citizenship in Israel. That's a pretty smart idea. And in fact my father went and made out a few of those documents for people he knew, including, obviously, one for his father. There is a link to the document on the Yad Vashem internet site.

My father wrote down the date that his father was killed, as well as some other details—most of it is in Hebrew. For example, he writes that his father was a widower. I did not know he had done that. I found the page online many years later after Yad Vashem digitized its records. Sadly, I found it after my father died and could not share it with him.

So as I said, in 1937 when his mom died, my father was fifteen. In 1938 his brother left for Palestine, and there is a highlight here: The only photograph in existence of my grandfather was taken when my uncle left to go to Palestine. Now, my father did not have this picture; my Uncle David took it with him when he left Poland. One day I found it when I went to visit my uncle, and then I took it and enlarged it for members of the family.

From left, Shuki Bruck's uncle David, grandfather Shlomo, and father, Moshe Bruk, in 1938, photographed in front of the ruins of the old castle of Nowogródek, which still stands today. *Photo courtesy of Shuki Bruck*

So now we are in 1938, and my uncle is in Palestine. My father is sixteen, and he has stayed in Poland. In August of 1939, Germany and the Soviet Union signed the Molotov–Ribbentrop pact, dividing Poland between them. On September 1, 1939, Germany invaded Poland from the west, and the Soviet Union invaded from the east and annexed Nowogródek and its environs to Belarus.

Having Soviets in Nowogródek was not good for the Jews there who had their own small businesses since the Soviet philosophy emphasized state control of everything. But those were small issues; they kind of survived that. And then of course on June 22, 1941, Germany attacked the Soviet Union—the so-called Operation Barbarossa. On July 4, 1941, the Nazis entered Nowogródek. Obviously, this was a major change. They implemented their policy with regard to marking the Jews with a yellow star, limiting what they can do. They also initiated the extermination of Jews starting with old people and children. They had special units whose job was to come in and basically kill people. Those units came to Nowogródek in December, about four or five months after the city was occupied. At that time there were about 6,500 or 7,000 Jews. On December 8, 1941, they took 5,100 Jews, and they killed them in the woods, including my grandfather. I know this because my father told me that his father died in the first *aktion* [a Nazi euphemism for assorted atrocities].

My father at that time was nineteen. He had stayed in Poland because in 1938 when he had the opportunity to immigrate to Palestine, he didn't want to leave his father on his own, and three years later they killed his father and now he was alone. Anyone who was above a certain age or didn't have a profession was killed. The idea was to kill everyone, but we'll get to that. My father was conscripted by the Germans to sew, not because they wanted to save his life, but because they needed people to produce things for the German army. In any case, he was put

into a labor camp within the city, with soldiers and a fence around it. In August 1942, eight months later, there was a second massacre. Afterward only 500 people were left, and again my father was among them. So out of 6,500 Jews, there are 500 left within one year. And the 500 were in this labor camp and working. Now of course they know that this is not Maui, Hawaii; it's not a safe place. On the other hand, it's not easy to escape it. And there are the issues of hunger and health, and all of the other difficulties that they were facing.

Heidi Aspaturian: Did your father ever talk about this period of his life directly with you?

Bruck: Definitely not when I was growing up. It was very uncommon for people of my father's generation. They felt that they wanted to protect the kids, so why should they tell them horror stories, you know? The idea was to create a degree of optimism, but we knew as kids that something had happened. We knew that a lot of our family on both my father's and my mom's side were killed by the Nazis. We had friends of my parents who were considered as family because we didn't have much extended family. We called them aunt and uncle; we'd go to visit them. This was very common in Israel. And then as a kid, you'd notice that somehow when they got into talking about the war, they didn't speak about it in Hebrew so that you couldn't exactly follow what they were saying, although I knew Yiddish. But they didn't want us to understand what was going on. Every now and then my father would say something. He

didn't talk much to my mom about it either, but a little bit. So she told us a little bit.

When he got older he was a bit more open. In Israel there is an interesting project that students do when they are, I think, in seventh grade. It's called something like "Roots: History of the Family"—I forgot the exact name. And so the grandchildren—my brother's daughters, my nieces—got him to talk when they did this project, and it's interesting that it was easier for him to talk about it to his grandchildren than to his children. I think he felt more comfortable talking with them. I think they were very difficult experiences, so the fact that he didn't talk is because he didn't want to consciously confront those memories. Obviously they were always there and haunting him. But it was also just in terms of protecting the next generation. I think this was a very common thing at that time.

But we knew, you know—there were many Holocaust survivors around us in the neighborhood. And I knew that my father was part of an escape from a ghetto and lived in the woods in Belarus with the partisans. When I was really young I thought that everyone did that because, you know, when your father is an NBA player, you think everyone is an NBA player. It took some time until I realized that his experience was not a common thing—that it was a bit different. And my father had friends that he saw from the same shtetl, from the same city, Nowogródek.

It was very common in Israel at that time to belong to an organization related to where you came from. These were called the Children of the Town, and they would meet regularly in Tel Aviv. There were not too many of them, because as you see, there were not too many people left. Actually, my father used to go there. They also had a little newspaper. And we got to know some of these people, and there was a very strong bond with them.

Also, there was, when I was young, a very active process in Israel for finding relatives because so many people didn't know what had happened to their families. And I still remember as a child in Israel listening to the news every hour on the radio. We didn't have a TV or a phone or anything, but there was a radio. At the end of many news hours there was an announcement of people who are looking for other people, and typically when this part came up, there was some type of universal silence, and the whole neighborhood was quiet. Suddenly everyone was listening to see if maybe they could recognize the name of someone who has suddenly showed up.

So we left off in August 1942 with the 500 people remaining in the ghetto, and there are different stories about trying to organize an aggressive escape. So I asked my mom this question: "How did he survive? How did he manage?" Because after the German invasion, his friends had left. They were still able to cross the border to the Soviet Union, so he was there on his own. My mother said there was a lady, an older one, and that in

the first massacre in December 1941 the Germans took her husband and her two children and killed them, and she was left alive because she was very good with a sewing machine. She basically kind of adopted my father, in the sense that she took care of him. If she had some food, then he would eat with her. I asked my mom what happened to her and I'll tell you later because I also did some research on that.

So, August 1942, 500 people were left, working in very difficult conditions. Of course every now and then the Germans killed a few people; this was part of the "normal atmosphere" there. And in May of 1943, almost two years under German occupation, they executed another 250 people out of the 500, so now about 250 people were left out of, maybe, an original 6,500. Every one of those remaining people had lost people very close to them.

And then they made a decision to escape, because they knew that it was just a matter of a short time until they would all be killed as well. And you know, I talked every now and then with my father about how he actually survived, and I don't want to go into those details. It was a very difficult situation, because someone made the decision about who will die and who will not die, and it was not always the Germans who made this decision, you know. They appointed representatives—the *Judenrat* [Jewish councils imposed by the Nazis and often charged with making life and death choices regarding the fate of their fellow Jews. *–Ed.*]. So these were very complicated situations

that he was never ready to expose to us, because some of those people actually lived in Israel. He always felt that you cannot judge people in those situations, and that was his philosophy.

To create the camp, the Germans had enclosed an area of the city and surrounded it by barbed wires, by walls. So the people who were left started digging a tunnel, and that's not easy—to dig a tunnel. They started it, as far as I know, after the third massacre that happened in May. What they did was to designate the people to dig it: You needed to be a bit smaller and in good shape. And they provided the people who dug it with more food, so they had a whole system for that. The tunnel went from one of the barracks all the way through a field to the outside. The story is that first they dug to a length of about 100 meters, which is something like 300 feet. They had issues with oxygen. They did it all at night, so they had issues with light. But they had an electrician—someone good with electricity—and he connected wiring such that they had light inside the tunnel as they dug it.

How did they get rid of the sand? There are stories about how they actually put the sand inside their clothes and cut holes in their clothing so that the sand would come out slowly. An interesting thing that happened is that this 300-foot-tunnel originally ended in the middle of this grain field. Unfortunately, one day there came a large tractor and cut down the whole field, which meant that they needed to dig all the way to the edge because otherwise they would come out in the middle

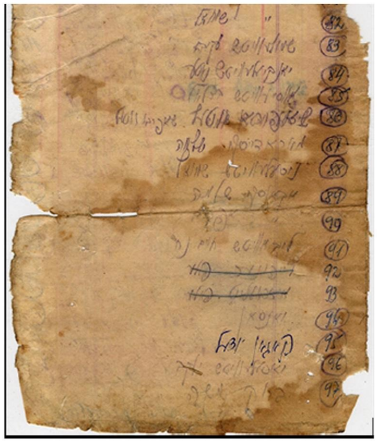
with no concealment. And that actually saved them, because if you look at the history of the Bielski brothers, a couple of months before the escape, the Germans deployed something like 50,000 soldiers to try and capture the partisans. And that's what you see toward the end of the *Defiance* movie, where you see the Bielskis and their group escaping the major attacks by the Germans and moving through the swamps to the very large Naliboki forest. My father was not there yet; he was with 250 people digging the tunnel. The Germans were not successful in capturing the partisans, and by the time the tunnel was finished they had dispersed.

So they made the tunnel twice as long, and the other thing is that their electrician, who was very gifted, figured out a way to turn off the big projector on the German watchtower. They didn't want to turn it off only when they escaped. They wanted to condition the Germans to think that it switched on and off because something is not working. So they turned it off, and when the electrician was called, they ran around and then they turned it on. I read in one of the books on this escape that at some point the Germans started getting suspicious, so they called *their* electrician or someone from the town, and the guy was running around looking at things, and they did the same thing with him. So the Germans thought, well something is just not working properly. This was crucial because you don't want to suddenly turn the lights off and show that it's a special event.

September 26, 1943, about four and a half months after they started, they decide this would be the night that they will escape. It was kind of cloudy because it's September, and they didn't want to wait until it's too cold. Also, it wasn't clear how much longer they can survive. The leaders of the group prepared a list of people who will go through the tunnel, specifying the order in which they were supposed to go out. That was the most emotional point in my preparation for this meeting: I was looking online, and suddenly—I found the list! And I found my father's name on the list. It turns out that in Nowogródek there is now a museum, and that museum has a list of the people who were escaping through the tunnel. This list shows the order in which people went through the tunnel. For every person, there is a name, place of origin, and additional information. Not everything is clear, but it seems like somebody or more than one person continued to annotate the list after the escape. For example, next to number 44, it's written "Illegible name," and it said, "Written on the side." There's the name of someone that it says died after liberation.

So I was looking at this list online, and since it's not alphabetically ordered, I didn't know what to expect, and I found that my father is number 97. He doesn't know about these findings because he died in 2002, eight years ago.

94	Yanson Volf	Novogrudok	
95	Kagan Yudel	Novogrudok	
96	Yoselevitz Yaakov	Novogrudok	
97	Bruk Moshe	Novogrudok	
98	Gurvitz Alter	Lubcha	Written on the side
99	Kaplinski Mordechai		
100	Shelkovitz Kalman	Novogrudok	
101	Illegible name	Zhetl	crossed out
102	Zacharo(e)vitz Mordechai	Novogrudok	
104	Kabak M.(atus)	Novogrudok	crossed out
105	Yukovski G.		crossed out
106	Berenshtein Chaim	Zhetl	
107	Levin Malka		
108	Tsimerman David		
109	Mirski Yosel		
110	Gindin Sholom	Novogrudok	
111	Vilensky Simcha	Novogrudok	
112	Berkovitz (Berkovski) Leah	Novogrudok	



Novogrudok Museum of History and Regional Studies Photo

I called my mom—I talk to my mom almost every day—and I told her I found the list. And we talked a little about that, and then I asked her the name of the woman I described before, the one who took care of my father in the camp. She told me her name is Chaje Sore [Chaya Sarah]**—Sarah is also my mom's name—and I asked her, "Did you ever meet her?" She said, "Yes, she survived," and I said, "Did she go through the tunnel?" She said, "No. She was actually hiding in the camp while they all went through the tunnel, because she was too old for that, and she was afraid she wouldn't survive." So she was hiding. And then the Germans, when they that saw no one was there, they left and didn't find her, and that's the way she survived [read the testimonial of her brother, Eliyau Berkovitz.]

Chaje Sore went to Israel. Before my mother and my father got married, they went to see her and she was very happy to see that

he found a beautiful woman—that's my mom; I'm biased. She was not feeling well enough to attend their wedding, and she died a couple of years later. Then yesterday I was going through the list again and I found her on the list. She's 168: "Ludski, Chaje Sore." Amazing. The additional comment is, "Sore hid in the loft and did not go through the tunnel." There was a notation that another person was killed in the period between the time the list was made and the escape. There are things that are crossed out; there are other escapees who were not found on the list but are mentioned in other people's testimonies. And then there are designations such as "A tunnel digger killed during the escape."

The escape went as planned, with a few hiccups. They went through the tunnel, and then people left in small groups. My father never told me how exactly it worked out when he came out of the tunnel. I know some details, but I'll tell you about the hiccups. The first one: They left a light on inside the tunnel during the escape, which was a big mistake. Why? Because when they came out then it took them some time to get used to the darkness because of the light inside the tunnel, the contrast. The other issue is that there were lamps where the entrance was in the barracks. They were supposed to turn them off when they left, the last ones, and it's not clear what happened, but the barracks caught fire, and because of the fire the Germans noticed that something is going on. And as a result they started shooting, people got confused, and from

what I know, out of 250 maybe around 150 survived and about 100 died. There are different versions of that.

Now my father—that's something he told me a long time ago—he had a gun. It was not a real gun. He made it out of wood. and he painted it with a shoeshine type of cream. So it looked like a gun, but it was a wooden gun. That kind of helped him when he was running around at night. The other thing is that since he and his father were dealing with nearby apple orchards, he knew the area fairly well. Some of the people died because they ran in the opposite direction. There are also testimonies of people who survived by going to the other side of the ghetto and just staying there through the night. A few days after the escape, the Germans stopped looking for Jews in the camp.

My father ended up in the woods. He actually met Soviet partisans, which was very dangerous, but he joined them and was with them for a little while. And then they connected him with the Bielski brothers. At that time the Bielski partisans were in the Naliboki forest. And the strength of the Bielski brothers' operation—although again you would not see much of it in the movie—is that they created a little town in the woods. They had workshops. They had cows. They had milk. They were able to create many different products. They used the skin of the cow and tires of cars to create boots. They had a workshop to fix guns. They had a little operation to produce vodka. There were about 1,000 people there, maybe 1,200. They were valuable to the whole operation of the Soviet partisans in the Belarus

forests, because they provided services like medical services and other services that no one else had. So my father joined the Bielski partisans, I would say in October '43. And he was with them until the day of liberation, which is July 4, 1944, exactly three years to the day that the Nazis came to Nowogródek.

July 4, 1944, is the day of liberation by the Soviet army from the Naliboki forest. In the woods my father worked in the workshop where they made the boots. Everyone had a job, and that was his job. And again, he was on his own. I mentioned to you that a very close person to him was [Shmuel] Oppenheim, the head of the workshop that fixed guns. I knew him very well because he lived in our neighborhood, and we used to see them almost every weekend. His older son (Reuven) died in Israel in '48 in the War of Independence.

Aspaturian: Did your father ever talk about his experience with the Bielskis?

Bruck: Yes. Again, he wouldn't talk much about it. I think it was hard from the food, hygiene, temperature standpoint, this kind of stuff; but it was very pleasant for him, given the fact that he had been for more than two years in a place that every day you can be killed. I'm not sure if later he was in touch with the Bielskis or not. I'm pretty sure he was, but again, he never talked about that. You know, the Bielskis emigrated to the U.S. from Israel. One more word about Oppenheim. He didn't escape through the tunnel. He was able to escape from the ghetto early on—I'm not exactly sure about the date—and joined the

Bielskis then. My mom told me that they had a two-year-old daughter, and that Oppenheim put her under his big coat and just walked out with her. And then his son was a bit older, maybe sixteen or so, so he was helping in the gun workshop. I can't tell you Oppeneheim's age exactly; maybe he was in his forties or even just forty. That's my guess.

Aspaturian: In the Nechama Tec book, it's very interesting. She more or less says that his ability to repair rifles and other weapons was so valuable to the Soviet partisans that it played a very useful role in keeping the Bielski operation legitimate in the eyes of these outside groups.

Bruck: Yes, I read it in her book, and I also know that many people respected him, because beyond everything else, he provided a technical edge to the Bielski partisans because he could do things that no one else could, and they had to have this skill. You can imagine that if you are a partisan you'd say, "What's going on there, with all those kids and women and old people, and they are the majority?" But there were a few people in this group that you cannot do without, including the guy that you bring your broken weapon to, and he makes it work. And that's crucial. And I can tell you that after the war Oppenheim and his wife, Elke, they lived a very simple life, not far from us. He actually worked in a workshop and never owned a car, took the bus every morning—and never was recognized for anything. I don't think he ever cared about it. And

the same with my father. Those are very low-key people, very low-key people.

Aspaturian: So liberation day was July 4, 1944. Did your father ever talk about that?

Bruck: My father never spoke about the liberation; he rarely spoke about his experiences. Again, I studied a lot about that; I would ask him questions, and he would try not to answer. So the main source for me was my mom, because I think she knew some from what he was telling her, and then she knew some from what she heard from his friends, and so on. You know—imagine that in 1944 he was 22, and he had no one, and he had nothing. So it was a very difficult situation. He actually joined the organization that was focusing on illegal immigration to Israel.

Aspaturian: Aliyah Bet?

Bruck: Yes. He joined it in 1944. But first, after liberation the Soviets drafted him into the Red Army. I talked to my mom about that the other day, and she said he told her that for him, being in the Red Army was worse than some of his experiences in the ghetto. The way they treated him. He said, "I'm not going to do that, I had enough of three years of doing this type of stuff, and I want to go to Israel, to Palestine." So how did he get out of the Soviet Army? I don't know. But he did. Then he joined the Aliyah Bet organization. He spent time in in Niederschlesien [on German territory during World War II; ceded to

Poland after the war –*Ed.*], in the area where they built camps for displaced people, and he was one of the counselors in those camps. And that's where he met my mom. She was there with her parents.

Aspaturian: How had they survived the war?

Bruck: How did they survive the war. My grandfather on my mom's side, his name was Abraham. He was a very wise person, and he did something very unusual. He left Poland about two months after the Germans came. Before anything happened. He and his family left everything behind and crossed the border to the part of Poland that was occupied by the Russians. And why did he do that? Because he had four beautiful daughters. They are still beautiful, those that survived. I think he had five or six children. One son—my uncle. The Germans came every evening to look for the older daughters. My mom was the youngest, she was eleven, so that's not of interest for the German soldiers. But her sisters were older. Actually her oldest sister already had two kids. They wanted to meet my aunts—the German soldiers were very upset that they could not find the beautiful girls. They took my grandfather out—this was the beginning of winter—and made him take off his clothes, basically be naked, and just ordered him to do different things, exercises in the snow. So he didn't need many of these experiences to decide that he's leaving.

Shuki's maternal grandparents, Abraham and Rivka, in Tel Aviv, Israel, c. 1966.
Photo courtesy of Shuki Bruck

So in the end, they all went, including my aunt who had two young kids. However, it was very snowy, and they had a wagon with two horses, and on the way Polish people stopped them and took one of their horses. There was one good horse and one old horse. My grandfather begged them to let him have the strong horse, but they didn't listen. And it was snowing hard, so then they were concerned that the two young babies, the grandchildren, will die because of the cold weather, and also were concerned about my mom, the youngest daughter. So her

oldest sister—her name was Pnina—and her husband decided to go back with their two babies in order to save them. They also wanted to take my mom so she can survive, but my mom didn't want to leave her parents, so she crossed the border with them and got to the Soviet side. Back in Poland, my aunt and her children and her husband couldn't leave anymore because by then the Germans had closed the border. They put them in a camp and they all ended up, my aunt, her children, and her husband, in Auschwitz; they were killed there.

Now, when my mother and her parents were in the eastern part of Poland before Operation Barbarossa, the German invasion of the Soviet Union in June '41, the Russians knew that the Germans are coming. They did something very interesting. They came to my mother's family and told them, "Listen, you have two options: Either you go back home to Poland, or you get a Soviet passport and you can go anywhere you want in the Soviet Union." Okay, what would you do?

Aspaturian: That would have been a very tough decision to make.

Bruck: Yes.

Aspaturian: Because I think pure chance would have dictated whether or not you jumped the right way.

Bruck: Exactly. They didn't know what to do. So my grandfather talked to my grandma, and told her, "What do you want

to do?" She said, "I want to go home, I never wanted to go to this part of Poland, look how we live. It's a disaster." My grandfather was tired of fighting with her. "First time you did what I wanted, now I'll do what you want." So he told the Soviets, "We are going home." The Soviets said, "Anyone who said that they want to go home, we will deport to the east because we cannot trust you." So they put them on a cattle train and they went for a few weeks within those cabs all the way to the Arkhangelsk labor camp, up near the Arctic Circle. You don't want to see where it is on the map. However, there they were safe, so you know—you never know what is the right decision. They struggled with many health issues and hunger, but they survived.

Aspaturian: The great irony is that if they had stayed in the western part of the USSR, they might have been in an area that was overrun by German troops.

Bruck: Yes. You never know in those situations what is the right decision. In any case, my mom and dad faced many challenges, and they met in Liegnitz [now Legnica, in Poland], which is in Niederschlesien, in the displaced persons camp. My father over there was "more or less like Tom Hanks in LA—a celebrity—because he's a counselor, and my mom was just someone there. My mom told me that he was extremely skinny. This was immediately after the war. He basically was a skeleton, and he was full of lice. So it's good that he met my mom because I think he improved his hygiene a little bit.

In 1947 my father organized a group of young people to go to Palestine, first going to Italy as a group. He wanted my mom to join his group. Now my mom had a very good friend, and she said. "I'm not going to leave her here." So my father arranged that this other girl would join the group as well. And then before they left, my mom told my father that she's not leaving. She's going to stay with her parents because there is no other sibling. All the other siblings got married, and she had to take care of her parents. This was '47, so my mom at that time was nineteen, and her parents were around sixty, and they were not in good health.

So my father left for Italy, and he spent six months in Rome and other places, working on organizational issues related to getting ships and refurbishing them and getting groups organized for Aliyah Bet. He even was able to converse in Italian, and he was very proud to be able to show us how he can do that. Then in 1948, before the establishment of Israel, he went to Israel on a ship—not under his own name but as a "legal immigrant." When he arrived, he first looked for his brother, and then he found him. My uncle was married: he had no idea that his brother is alive. And I guess they were very happy to see each other.

My Uncle David was one of the founders of the city I grew up in, Kiryat Haim, and obviously he helped my father at the beginning and also later on. My father was a very passionate, idealistic person at that time, given all that he had gone

through, and he joined an interesting group that created a kibbutz in western Galilee, not too far from where my uncle and aunt lived. This kibbutz still exists and is doing very well. The kibbutz name in Hebrew is Lohamei HaGeta'ot. It means The Fighters of the Ghettoes, and it consisted of people who were actively fighting or resisting the Germans. They had a lot of pride in that. The leaders in the kibbutz were people like Zivia Lubetkin, who was one of the leaders of the Warsaw Ghetto uprising. So many people from the Warsaw uprising, from the Bielski partisans, from other areas in Europe who were part of resistance groups—they were the core groups that started this kibbutz.

And so he was there in the kibbutz, and again he was very lonely. At some point he went to Zivia Lubetkin and asked for a "bachelor leave of absence." Actually I just invented that; in Hebrew it sounds a bit different. But basically, if you're a bachelor and you're in a kibbutz, it's a small group; you can get stuck there and never find the love of your life. So there was a provision that you can ask to leave for a while to find a wife. And he didn't have a Facebook account, so this was a problem. (Maybe he had, and my mom didn't have.)

In any case he moved to Kiryat Haim, and he lived with his brother and his sister-in-law. They didn't have kids, so they treated him like their child, more or less, although he's more or less their age. And then my mom came to Israel, and I think they met in '51. My mom went out to dance on Saturday night

in Haifa with a friend, and my father went out to dance with his friends in the same place, and they met each other there. And as my mom said, when he saw her, he never left her since this point. He told her that he looked for her, and he never knew whether they will ever meet again. So a few months later in '52, they were married, and my brother—his name is Shlomo, like my paternal grandfather, was born in '53—and I was born in '56.

My father visited us here in 1998 for my son's bar mitzvah. My father, my mom, and my wife's mom came, so three grandparents came for the bar mitzvah. My father died four years later. He had Alzheimer's disease, and when he was here, already in '98, he had moments where he was a bit confused, but he was still extremely functional, and he was very happy. When he was here, I told him, "I can buy you anything you want." You know, my parents were very modest. They never owned a car. When I grew up, we didn't have a phone, we didn't have a TV, but we were very happy. Now we were sitting there in my home and I told him, "Let's go, and get anything you want, anything." And he thought about that. Typically if you asked him something like that, he would say, "I don't need anything, I have a nice family."

And that's something that I can discuss, how people actually survive, because survival is not just surviving the events in the camp. There is a big issue of survival, even after everything is over, because you ask yourself—it is a very deep existential issue—why are you doing it at all? So I think many people that

lived through these traumatic events had major issues to stay functional, to be in families, to be optimistic about the future, and all of that. So I asked my father, "How did you manage all of this stuff?"

And he said that through all that he did, he had one dream. His dream was that he's sitting in a house, a clean house. There is a table, and he has family around the table, and there is food on the table. And he believed that it would happen. So every time we sat down and ate at home, he would look around, and he was very happy. And the same happened when he had Alzheimer's. He never gave up. He always was very kind. He never gave up on life. You could see that this person has some innate strength with regard to survival, and he was always very happy when he sees old friends, even though he no longer recognized them. This was amazing.

So coming to the discussion I had with him during the Bar Mitzvah visit: I asked him what he would like, and he thought about it and told me, "You know, I don't need anything." He never wanted anything for himself. It was true for many people with his background, because at the end of the war they had nothing. He didn't have a picture in his pocket, he didn't have anything, you know. Finally he said, "You know what I want?" I said, "What?" He said, "Shoes." I said, "Why shoes?" He said, "We always had a problem with shoes." Because it was very difficult during the war to get shoes and, you know, without good shoes you are basically dead. He also made shoes when he

was with the Bielski partisans, so obviously he appreciated those kinds of things. I told him, "You know what, we are going to get any shoes you want."

So we drove to the Glendale Galleria. He didn't want anything fancy, he wanted something comfortable; and there was a guy there who was very helpful, a nice gentleman. We got my father a nice pair of shoes, and he actually used those shoes until his last day.

Shuki's parents, Moshe and Sara Bruk, at home at Kiryat Haim in the early 1990s. *Photo courtesy of Shuki Bruck*

Session 1, October 10, 2016

Family history & early upbringing near Haifa

Aspaturian: This is October 10th, 2016, oral history interview session number 1 with Professor Shuki Bruck. I wanted to start by looking back at the history of your family. We know about your parents' experiences during the war [see Preamble], but what else do you know about where your family comes from in Europe? Is there any ancestral line you can trace back?

Bruck: Well, I haven't done any research, so I don't know much. On my father's side, we didn't have any relatives besides my uncle. On my mom's side, there are relatives because my maternal grandfather came from a family of sixteen kids. His mom died in the delivery of number eight, and then the second wife had eight more kids. Only three out of the sixteen survived the Holocaust. His oldest brother went to Costa Rica in the 1920s, and then he brought his family over, and they're still there; it's a very large family, and they're very affluent also. I've never visited them. My brother did, and I will do it one day. They helped my grandfather a lot financially during the years after he came to Israel.

Aspaturian: This is your mother's father.

Bruck: Yes. And then there's an aunt who survived—an aunt from the second group of children. She lived in Haifa, and I loved her dearly, and we used to go and visit her often.

Aspaturian: She was a great-aunt for you?

Bruck: Yes. But I don't know where they're from. Again, I didn't do any research, and I didn't do any DNA sequencing, which I might do one day. Because my father's side is physically a bit darker. If you look at the picture of my grandfather whom I never met, he looks pretty dark, so maybe—just speculation—they came originally from Spain.

Aspaturian: Sephardic roots, perhaps.

Bruck: My grandfather on my mom's side, he had light blue eyes; also my mom has those eyes, so I'm not sure where they're from. Yes, I think the key is that we're here. [Laughter] One day I'll do research on that.

Aspaturian: Yes. Family roots are interesting.

Bruck: Yes. Today I think there are more tools to do a good job on that. I think one of my brother's daughters is interested and has done some work on that. [*SB subsequently added:* We did the 23andme; as expected, my father is from Belarus, and my mother is from the Warsaw region. No major new discoveries of relatives. An interesting fact: Anat (my wife) is very remotely related to me...]

Aspaturian: So after the war, your father helped establish a kibbutz called Fighters of the Ghetto. He left it for a while and rediscovered your mother, and they got married, and you then were born in Kiryat Haim, is that right?

Bruck: No, I was born in a different suburb of Haifa, which is called Kiryat Yam. Kiryat is actually a synonym for the word "town" in Hebrew, and Yam means "sea."

Aspaturian: So, "city by the sea."

Bruck: Yes. Basically, when people came from Europe, they were given a place to live, but it was not a house; it was a tent, or it was something made out of asbestos—something that was not permanent. It was like a transition camp, and people were just put there.

Aspaturian: How many refugees did Israel absorb after the war and immediately after Independence, do you know?

Bruck: Well, when the Independence wars started, there were 600,000 Jews in Israel. Most people don't know what a scarily small number this was. When the British left, all the Arab nations next to Israel, and some others, immediately attacked Israel. And at that time there were less than a million people in Israel. Then when I was growing up—it's like ten years later—there were already about 2.5 million.

Aspaturian: Well at that point most of the Sephardic Jews from the surrounding Arab countries had been absorbed as well.

Bruck: Right. Now my mom came to Israel after the establishment of Israel. My father came before.

Aspaturian: Was your father involved in the War of Independence at all?

Bruck: Yes.

Aspaturian: What did he do?

Bruck: I'm not sure. I know that later he served in the reserves because I remember him going to the reserve army. I'm not sure what he did, and we didn't talk about that. So, not much data. So I was born in Kiryat Yam, which was a next step up after being in a transition camp. My parents had an apartment, but the apartments were very small—just one room; and the shower and toilet were shared for each floor. My brother was already there. Then, when I was about six months old, we moved to Kiryat Haim, where we had a small, single-family home. As far as I know, my uncle helped my parents get this place.

Aspaturian: This was like a new development?

Bruck: Yes. It's walking distance to the sea. It's like Santa Monica of the '50s.

Aspaturian: Were you north of Haifa?

Bruck: Yes.

Aspaturian: Toward the Galilee area?

Bruck: Yes, between Haifa and Acre.

Aspaturian: That's an ancient Arab city, yes?

Bruck: Yes, Acre is a very ancient city, older than Jerusalem. A fantastic place to visit. It's one of our favorites when we go there. Kiryat Haim was a fantastic place for kids especially.

Aspaturian: Do you know how many people roughly lived in this development?

Bruck: Well, there are two parts in Kiryat Haim. There is a high-end part—

Aspaturian: Where you did not grow up, I guess.

Bruck: No. It was there before the part where we were living. It was the first part to be developed, and it was called Kiryat Haim East. And we were in Kiryat Haim West. In Israel for some strange reason, they put the more affluent people *away* from the sea.

Aspaturian: That is interesting. And sounds so strange.

Bruck: Yes. And it's still like this—the more you go toward the sea, the less you have.

Aspaturian: Now I know where to go to get beachfront property.

Bruck: [Laughter] My wife, Anat, grew up in Kiryat Haim, and her grandma immigrated to Israel with her father as a single mom. She came from Poland before the war—maybe 1938—and she was one of the founders of Kiryat Haim. Her name was Rivka, like one of my grandmas. She had a very distinguished position: She was the manager of the local supermarket. At the time there was only place to shop locally, and it was—the supermarket.

Aspaturian: Aha. So she was the town—

Bruck: She was the sheriff. [Laughter]. I knew her very well. A wonderful woman. It's not easy being a single mom with a young child in 1938 Palestine.

Aspaturian: Was she a widow, or was there just no husband in the picture?

Bruck: It's a complicated story, but her husband was sick, and at the end they separated. It's a whole other chapter that is quite complicated.

Aspaturian: So where did your father work?

Bruck: He worked in the harbor of Haifa. All his life he worked there.

Aspaturian: What did he do, exactly?

Bruck: He worked in administration—at least from the time that I was able to recognize what my parents did. He was there for something like forty years. He was responsible for all the cars that were imported to Israel. Israel at that time didn't produce cars and actually still doesn't. The cars came on ships from all over the world, and there are many issues related to customs and liability insurance—damages during transport and so on. So he was the chief guy on that. He never owned a car and didn't have a driver's license, but that was his job. He knew everyone in this business. In fact there's a large, fenced parking lot at the harbor where all those cars are kept, and this area is still called the Bruck facility, although I don't think most people there know who he was. As a child I used to go and visit him. You know, at that time going to work with your dad was a big deal. He would let me talk on the office phone. I almost never saw a phone—we didn't have one at home. So he used to go to some other office and call me on the phone in his office.

Aspaturian: So you could pick it up and talk to him?

Bruck: Yes.

Childhood in a young nation; dawning awareness of family experience in the Holocaust

Aspaturian: What was it like for you growing up as a child in this very young country with such a history? Were you aware of it?

Bruck: Well I knew the history, and I knew that it's a young country, but it felt like this was the norm. I think today people have much more access to things that are not in their immediate vicinity, but at that time, you know—we had loving parents, we had food, we had friends, we went swimming on our own from a young age, we had our bikes. Who cares what the age of the country is, and if there are wars. Just have fun. [*SB subsequently added:* So as a young child, I was not aware of it. I think our parents worried much more than we did as young kids. I believe that the first time I became aware of it was before the Six Days War (June 1967). I was 11 years old; I listened to the radio (no TV). I had maps, and I studied the dangers of having Syria, Jordan, and Egypt all getting ready to attack Israel. It is the earliest memory I have of existential worry. Perhaps a different and earlier memory of concern is the rationing in Israel for foods like eggs and milk and meat, so there were stamps that you got, based on, say, how many kids you had, how old they were, and so on.]

Aspaturian: Was this largely because with so many people pouring into the country, the agricultural infrastructure had trouble keeping up?

Bruck: Yes. It was not set up yet. Initially in Israel not much was imported, and agriculture was much more complex than today. In fact agriculture was a key economic activity in Israel.

Aspaturian: It was centered largely in the kibbutzim, I believe?

Bruck: Yes, but there were other forms of settlements that had agriculture, because all the food was produced locally. The number-one export of Israel during those years were oranges with the stamp "Jaffa."

Aspaturian: I remember those growing up.

Bruck: This was already going on before Israel was established.

Aspaturian: Were there food shortages that you were aware of growing up, or did things never become that difficult?

Bruck: Well, what people like us did because we had a small yard was that we always had something going on in the yard. And at that time, I loved the yard work. We used to have tomatoes and carrots and potatoes—many things, and I typically took care of them.

Aspaturian: When you talk about your dad's experiences during World War II, you said that you knew from childhood that

he'd been, as you put it, "in the ghetto and in the woods," but that it was like having a Dad who's an NBA player where you think everyone's father had exactly the same experiences as yours.

Bruck: Yes.

Aspaturian: When did you become aware, to some degree, of what your parents had actually gone through? [see Preamble] Was it when you were still young, or as you got older—do you recall?

Bruck: So I think a big deal in Israel was the Eichmann trial.

Aspaturian: Oh of course, 1961, '62.

Bruck: And it was on the radio, all of it—

Aspaturian: You would have been *very young* though.

Bruck: Yes. About five or six. I remember that. I especially remember the voice of the prosecutor, Hausner, because he had this very penetrating voice. As a child you could really get scared when you listened to this guy.

Aspaturian: Gideon Hausner, was that his name?

Bruck: Yes, exactly. You know this history?

Aspaturian: Yes, a bit.

Bruck: There was no TV, so we just heard the voices on the radio, and then I think through those years I slowly realized that most of the people I knew had parents who went through a different experience. And also I realized that our family was basically killed, most of them. Our parents never told us directly, "Let's have a seat and let me go through the list of all the people that were killed." I don't know anyone who did that. And in school, typically, we didn't learn too much about the Holocaust—maybe a bit about Anna Frank and Janusz Korczak, who was a teacher of kids in the Warsaw Ghetto; it's a very interesting story.

Aspaturian: Oh, he went to Treblinka with them, I believe; he wouldn't leave the children? [Janusz Korczak, a renowned Polish-Jewish physician and educator, established a center for more than 200 orphans in the Warsaw Ghetto under the Nazi occupation. Rejecting numerous opportunities to escape, he chose to accompany the children to Treblinka, where he was murdered with them. *–Ed.*]

Bruck: Yes. So there were things that related to kids in one way or another, and it was only in high school that we started reading things like Viktor Frankl's book *Man's Search for Meaning*, the heavier things like that.

Aspaturian: You were kind of shielded from this as a younger person.

Bruck: Yes.

Aspaturian: In the development in which you grew up, were the families largely immigrants? Or were there a fair number of Sabra families?

Bruck: I think the majority were immigrants. And everyone knew some other language, because the immigrants were from all over.

Aspaturian: Did you speak Yiddish in the home?

With mother, Sara, and older brother, Shlomo, at home in Kiryat Haim in the mid 1960s. *Photo courtesy of Shuki Bruck*

Bruck: Yes.

Aspaturian: Polish? Russian?

Bruck: Yes. I'm bilingual—well, I acquired Hebrew and Yiddish as first languages at home and acquired English at school and became trilingual. I fully understand Yiddish; however, I'm not able to speak it right now, but if I have no choice, I will make the effort to speak.

Aspaturian: But you can understand it?

Bruck: I fully understand it. It's pretty interesting, because I don't think about this language and I don't read in this language, but I fully understand it. If I speak to my mom, and she speaks in Yiddish to me fast and complicated, I understand everything.

Aspaturian: Your parents spoke to each other in Yiddish?

Bruck: Yes, they did. If there was no one at home, they'd speak Yiddish. So that's their comfort language. When we were there, they tried to speak Hebrew and switched to Yiddish when they didn't want us to understand. That's why we know the language. [Laughter] But they had many other languages they could move to. They moved to Polish if it's really a secret.

Aspaturian: I see. Which you could not follow.

Bruck: This one I couldn't follow.

Early love of reading leads to childhood career as "librarian's assistant"

Aspaturian: So what was school like for you as a child and a young teenager? We were talking beforehand about books, and you said that the library gave you a new sense of what you could do with your brain. I think that is how you put it.

Bruck: Yes, the public library. It was about the size of my office; it's not like a huge library—

Aspaturian: What would that be, about 15 by 10 feet?

Bruck: Maybe twice that. You would just go and get books and leave. There was no place for reading. And so my mom enrolled me in the library when I was in first grade, and I fell in love with books. The library was open four times a week, so I read four books a week.

Aspaturian: You could take out one book at a time, I think you said.

Bruck: Yes. Then the librarian noticed that this kid that reads a lot, so she offered me to be her assistant. I would go there and help with receiving new books and glue on the pocket that holds the identification card and write things down and use the due date stamps. Also I helped when kids came who wanted to read a book, and I talked to them about what they would like.

Aspaturian: How old were you when you started doing this?

Bruck: Probably in second grade.

Aspaturian: [Laughter] You're a seven-year-old librarian's assistant.

Bruck: [Laughter] Yes. I knew all the books: where they are, what they are, and I could offer them a selection of books because I read a lot. In return for my services, I was able to take out more books, especially for the weekend; I was able to get three books then. Because I read so much and I took care of the new books, I was also the first to read the new books, so I could tell the other kids what they're about. [Laughter]

Aspaturian: Do you recall what you liked to read?

Bruck: I read everything.

Aspaturian: But were there some things that you were happier to find more books about than others?

Bruck: Even today, I read everything, so I don't have any favorite. I read everything that the library could offer. I still read a lot, and I really enjoy it. And, returning to your original question, the fact that the librarian offered me kind of a job made me realize that I can support myself by using my brain. That was the first insight I had on that. And it really impacted me.

Aspaturian: It's sort of like the epiphany Richard Feynman had when somebody said, "He fixes radios by thinking about it!"

Bruck: [Laughter].

Aspaturian: Were there a lot of books for kids written in Hebrew?

Bruck: Yes, I think there were quite a few. There were different series. There was one called *Chasamba: The Absolutely Absolute Secret Group*, and I remember it's about a group of kids, and they do brave things.

Aspaturian: Children always love books like that.

Bruck: I read all of those. And then there were many books that were translated from English to Hebrew. Yes, it was fun. I also was a kid who would think every day. I was very organized as a child, and there is an expression in Yiddish, *alter kopf*, which means "old head" or "old mind." Because I had this more mature perspective on certain things when I was younger. Of course I was a kid and did many things that kids do, but I also used to have a plan on most days, like a schedule.

Aspaturian: From a young age?

Bruck: Yes. And I wrote it down. And part of the schedule—my mom still always reminds me—was that I would think at certain times of the day. I used to walk on the street behind our

house—it was a very narrow street—and just go back and forth and think, and the neighbor will ask me, "What are you doing?" And I said, "I'm thinking." And he said, "Good."

ASPATURIAN: Where did this idea come from? From something you'd read, or was it just—?

BRUCK: I have no clue. It sounds a bit strange.

ASPATURIAN: It sounds interesting.

BRUCK: It sounds like a Caltech professor, because you see some of us walking around looking like we are lost, but I did it already as a kid.

ASPATURIAN: But to have a meta-perspective on your cognition from an early age is unusual.

BRUCK: [Laughter] I really enjoy daydreaming, and I still do. The problem now is that I don't walk enough, so I do my thinking while driving the car, and that's not very safe.

"I really loved mathematics from a young age"; early educational & life experiences

ASPATURIAN: Were there subjects at school that particularly interested you from an early age?

BRUCK: I really loved mathematics from a young age.

Aspaturian: What did you love about it?

Bruck: I don't know. It was just that it was like magic to me.

Aspaturian: What was magical?

Bruck: It was—you know, I always did puzzles from a very young age. And I liked it as a subject. This was really my favorite subject, and I tried to get anything I could to learn more about it. This was in elementary school. And you know, at that time there was no Wikipedia—we're talking about the early '60s. So I had a Wikipedia system. And it worked this way: During the week if I had different ideas or terms that I didn't fully understand or wanted to learn more about, then I will write it down on a piece of paper. Now on Saturdays, my parents used to go and have tea with my uncle and aunt.

Aspaturian: Your father's brother.

Bruck: Yes. And my uncle and aunt had an encyclopedia. So while the adults were drinking their tea, I was doing the Wikipedia thing. I just kept looking at the huge encyclopedia, you know, and ended up doing what we do today: When we look at one item, there are seven more items that suddenly we want to learn more about. It was not hypertext, but it was hyper-uncle. [Laughter] So I was a very curious kid.

Aspaturian: Were you unusual in your school in this? Did other kids share your interests?

Bruck: I didn't realize that I'm unusual in any way, and I still feel like this. It's kind of strange, but I always focus on the inside, and I never check to see what's going on. Are other people doing something else? Even today, I am always driven by my own curiosity. Of course I will be aware of what other people are doing, but it's not the reason I will do certain things. Now when I was still in high school, I ended up also taking classes at the Technion [Israel Institute of Technology, in Haifa] and I'm not sure how I got there, and I'm not sure in which grade, maybe tenth.

Aspaturian: Does the school system in Israel run from kindergarten through twelfth grade like it does here?

Bruck: Now it does. Kindergarten when I grew up was not mandatory, and the mandatory education went up to either eighth or tenth grade. Here you have to justify why you would want to leave school early, before twelfth grade, and it's also the same now in Israel. I'm not sure when the change happened. So because I was in the western part of the settlement, there were also many new immigrants who came from northern Africa. They were in high-rise buildings—apartment houses—not single-family homes like we were, and they were living right next to the sea. About half of the kids in my elementary school were from those families. Many of them stopped studying at the end of elementary school and didn't go on to high school.

Aspaturian: Was there a sense of divisiveness that you were aware of between the Ashkenazi families and the Sephardic arrivals from the Middle East and North Africa?

Bruck: Our next-door neighbors, they were Sephardic.

Aspaturian: From?

Bruck: I think maybe Egypt, but they were for a long time in Israel. And we had other neighbors. The new kids—

Aspaturian: These were the North Africans, from Tunisia, Algeria?

Bruck: Yes. They were immigrants who just came, and I think there was some tension there, because we had a little bit more than they did. We lived in single-family homes; they had an apartment. Some of them were supported by the government in terms of income. So typically if there were fights between the kids, it would be between those two groups.

Aspaturian: How about Arab kids? There's quite a population of Arabs in the Haifa area.

Bruck: Haifa is a very interesting place. You know, in most of Israel, even today, there is no public transportation on Saturday. When the Shabbat starts on Friday afternoon, there are no buses or trains until it resumes on Saturday evening. But Haifa is special in this way: In Haifa there is public transportation on Saturday. This is the status quo that is still in place. I

think one reason for that is the large Arab population. Another is that most of the people in Haifa were blue-collar workers, and they didn't have cars. Some of them had to work over the weekend, because most of the industrial facilities there operated 24/7. So we were able to use buses and so on.

Six Day War & its aftermath; interactions with Israeli & West Bank Arab populations

I never felt any issue with Arabs as a child. Again, everything was local. My first interaction with Arabs was after the '67 war. I was eleven at the time. We went on trips to visit the occupied West Bank, and the Arabs in all the cities there—East Jerusalem, Jenin, Nablus, Beit Lehem, Jericho, and Hebron—were very happy with the fact that Israel was there and not Jordan. Also, it felt very safe.

ASPATURIAN: What do you remember about the Six Day War?

BRUCK: I remember it vividly because there was something like three weeks of talk on the radio about the fact that the Arab nations were going to come and throw us into the sea. I loved swimming in the sea, but my parents didn't know how to swim. [Laughter] So I didn't like this idea, but they kept talking about it, and, as you know, Israel was attacked by Syria, Jordan, and Egypt, and even Iraq sent troops. I had this large map, and it was a bit scary listening to the radio and looking at the map, because before the '67 war, there was an area of Israeli coast just

north of Tel Aviv that at the time was only nine miles wide between Jordan and the sea. So the *fact* that they can throw us into the sea—I was not sure how exactly you do this with two million people, but that felt a bit—

ASPATURIAN: It was more than rhetorical.

BRUCK: Right. For the '67 war, we actually built shelters. Before it, there were no bomb shelters in Israel, but in the weeks preceding the war we built shelters in the back yard. There were volunteers who came to do this, and I helped them. We just dug into the sand and then built a frame inside, so when there was an air-raid siren we just went into this hole.

ASPATURIAN: This must have been quite an experience for your father, having done this—

BRUCK: He was not there. He was in the army, in the reserve. Everyone went to the reserve army. We were kids, so we were at home with our mom. And I remember the sirens during the '67 war; it was kind of fun, I must say. We went in this hole with all the neighbors and so on, and there were some Syrian airplanes that came and tried to drop bombs on the oil refineries that were not too far from where we lived. We saw them. I remember seeing the airplanes dropping bombs, but we were not in danger, as far as I could tell. And then it was euphoria after the '67 war, because in six days it was all over.

Aspaturian: For the record, Israel annexed the West Bank, the Golan Heights, and Sinai. Am I missing anything?

Bruck: In six days. Yes, it was definitely a very unusual event. We went to visit Jerusalem and all the other cities.

Aspaturian: You went to East Jerusalem?

Bruck: To East Jerusalem. The Arabs were very happy to get good customers.

Aspaturian: Was this your first trip to Jerusalem?

Bruck: I think so, but I'm not sure. My parents didn't have a car, so we didn't go anywhere. Most of the trips at that time for kids in Israel were organized every year as field trips by the school. Some of them included overnights, and we would go and spend time in different places in Israel.

"Whole notion of religion was, I would say, more respectful and open than it is today"

Aspaturian: Was your family religious?

Bruck: In my immediate family, my mom and dad were not religious in the extreme sense. There was a whole spectrum of being religious in Israel, and everything was fine. No one was critical of anyone else. My grandfather on my mum's side; he was religious. He went to pray in the synagogue three times a day. He had a hat; I'll show you a picture. But he worked; he did

not expect the state to support him like some of the ultra-Orthodox today. He was able to support himself. My father didn't have a hat or a yarmulke, and my parents didn't observe all the restrictions of Shabbat. They only went to the synagogue during the High Holidays.

So that was a common and accepted kind of solution to the range of religious practice. Of course, when it comes to food, in Israel during those years it was extremely difficult to find food that was not kosher, and then there were the other restrictions for meat and cheese. We didn't mix that at home, but we didn't have two different sets of dishes.

ASPATURIAN: You just had one kind of meal or the other?

BRUCK: Yes. So again, it was very acceptable. People did whatever they thought was the right thing and they lived with one another without serious religious disagreements. There was a synagogue on our block, and we could hear them singing and so on. It was all very relaxed. I think today in Israel, people take the differences in the practices of religion too seriously and it leads to a schism. In essence, religion is a personal spiritual choice; one must respect the choices made by other people. There's something I learned from my grandfather about respect —this is jumping ahead.

ASPATURIAN: That's all right.

Bruck: When I served in the military, I was an officer, so I had my own car, which I used to drive when I came home for the weekend. I would drive to Tel Aviv to spend time with my grandfather, and when I left, he used to walk out with me to the car, and he always told me, "Have a safe trip, drive carefully." Now, he was very religious, and you're not supposed to drive on Saturday. And for me this story is a very important lesson in terms of how you practice whatever you believe in and how you respect what other people want to do, practice, or believe in; and he did it within the family, which is even more difficult. He never said anything; he was just very happy that I came to visit him. So in this sense, the whole notion of religion was, I would say, more respectful and open than it is today.

"I loved math & science & did well academically": high school classes at Technion; summer program at Weizmann Institute

Aspaturian: How about from a historical perspective? Were you interested in archaeology or regional history or anything like that growing up?

Bruck: I couldn't stand history. But today I love history. I have talked to other people about that. It seems that many people didn't appreciate history when they were young, and they really appreciate it today.

Aspaturian: Why do you think you disliked it so much?

Bruck: The way it was taught was very mechanical, so we needed to remember dates and all the chronology, and there was no depth in that sense.

Aspaturian: This was all through school? You didn't even have good history teachers in high school?

Bruck: Especially in high school, yes. You see in Israel, they teach the Bible every year in those twelve years, and so we heard it many, many times over and over again. And we needed to learn pieces of the Bible by heart. My father knew a lot of the Bible by heart, and so typically, when I thought I had the assignment memorized, he would check if I remembered correctly. But he didn't look at the Bible; he did it from memory.

Aspaturian: He knew it all.

Bruck: Yes. I was a good student, but I didn't like the idea of learning things by heart. That's what I liked about mathematics —that there's a logical structure involved.

Aspaturian: In high school, were you ahead of your class most of the time in subjects like math and science?

Bruck: I loved math and science and did well academically. At that time, elementary school was eight years, and then four years of high school. Also we didn't walk between classes: We were always in the same class, and the different teachers came to our class.

Aspaturian: That's interesting.

Bruck: This was how it worked in elementary school and also in high school. In the last two years of high school, they divided the classes according to who they determined was good in different topics.

Aspaturian: They "tracked" you. That's what we call it in this country.

Bruck: Yes. So there was a math and science type of class, and there was a biology class, a literature class, and so on.

Aspaturian: Biology, of course, is science, so when you say math and science, you mean math, physics, and chemistry?

Bruck: Maybe math and physics. And biology—that's how it was called—was more like biology and chemistry. But we studied it also. So this was a mixed group, and we studied the advanced math involved. I had fantastic math teachers in elementary school. They were all overqualified by far. They were mainly immigrants from Eastern Europe who had tremendous understanding of math, and also they brought with them the system of how to learn things. So we did proofs and very formal mathematics already in elementary school. And of course in high school.

Aspaturian: I'm surprised you didn't have talented history teachers as well.

Bruck: I don't want to go all the way and say they were not talented, but maybe the area in the brain related to history grew only when I was forty. [Laughter]

Aspaturian: Maybe later on.

Bruck: So to the Technion. During high school some kids were given the opportunity to take evening classes at the Technion in mathematics.

Aspaturian: How old would you have been, fifteen or sixteen?

Bruck: Yes. This was not for a grade or for credit, or whatever the words are that people use today. It was for fun and curiosity. I used to take two buses to get to the Technion, and I think it was like twice a week. And then between junior and senior year, I spent three weeks at the Weizmann Institute. Again, they had this program, and I went there, and it was very competitive and a lot of fun.

Aspaturian: That's in a suburb of Tel Aviv, I think?

Bruck: It's in the city of Rehovot that is south of Tel Aviv.

Aspaturian: This aptitude for mathematics, can you trace it back at all in your family?

Bruck: I don't know anyone that has an aptitude in mathematics.

Aspaturian: Really?

Bruck: Yes. None of my cousins. My parents didn't have the opportunity to learn, so maybe they had it, but we don't know. But my brother doesn't have it; I don't know anyone in my family that has it. My kids don't have it. They are good, but this is different than just being good. My brother's three daughters —my nieces—I think they're good. One has a PhD in biochemistry, and one is in medical school, but it's not a mathematical angle that is their strength. It's their gift to have other gifts. Same with my kids. They were good at math, and they have many nice gifts. My son loves science and biology and so on and is very good in math—he was even a math tutor for a while —but it's not something he will enjoy the way I do.

Aspaturian: What appealed to you so much about mathematics, can you remember? Was it the theoretical, the abstract, or the applied aspects?

Bruck: I loved the puzzles.

Aspaturian: You loved the ability to solve things—

Bruck: And proving things—the fact that I can understand something, put it in my brain, and just think about it without any paper or pencil, and then suddenly see how it all works out. I still enjoy that. And also the sense that there is a solution, and that it's clear, that it's true. It will always be true. It will be true today; it will be true in a thousand years. There is some perfection, some completeness in the way we reason about math; there's a beauty with that. That's why we've made so much

progress in mathematics, because the evolution is always a step forward; there are no steps back. We always move forward, because we know that everything we have done so far is correct. I really love this part, and it kind of speaks for itself. You don't need to raise your voice to convince someone that it's true; it's just there. It has its own life.

Aspaturian: Do you recall what you were taking as a high-school student at these Technion classes?

Bruck: Yes. I studied probability, which we studied in high school, and combinatorics, which we didn't. In fact those are the two things that I use a lot in my research. Also the Weizmann Institute—in fact at Weizmann I was studying quantum physics [Laughter]

Aspaturian: For three weeks!?

Bruck: Yes. In the '70s, I could choose computers or math or physics, and I'm not sure why, but I decided to do physics.

With parents during high school years. *Photo courtesy of Shuki Bruck*

Aspaturian: A lot of discoveries were made in that era, so maybe that was it.

Bruck: Yes. I enjoyed that. Also the committee that was testing me to decide who will get the opportunity to be there asked me many questions in physics.

Aspaturian: This is to go to the Weizmann program?

Bruck: Yes. It was a very competitive, nationwide process.

Aspaturian: Where was the competition held?

Bruck: In the Weizmann. I took buses there and went on my own actually. They asked me *many* questions in physics. At the time I *knew* physics, not like today. [Laughter] I'm not using it as much. Also I had a great physics teacher, and I really loved physics as much as mathematics for the same reasons. The beauty in physics is that there is a way to map physics problems to mathematics, to think about the physics problems within the mathematical framework and then go back to physics to verify the solutions. Of course, it's all about approximations, but you still have a sense of correctness because of the mapping to the mathematics. The physical reality might be completely different than what we know; still, we can explain and predict physical phenomena. For example, gravitation: We knew how to describe it, but we didn't know why it happens. And only recently at Caltech, with the LIGO project, are we getting more of a sense of what's behind gravitation. Because it's an amazing system, that suddenly the moon can communicate with Earth, and how does it do this? How can it tell the water to go up or down in the ocean. Unbelievable. I was always fascinated by those things.

Aspaturian: So did you apply to the Technion as a result of this program, or did they come to you and say, "We want you to be a student"?

Bruck: So in Israel there is mandatory service in the army, and that's an interesting story by itself. At my time Israel had a program that temporarily exempts about 200 kids from going into the army. Instead they go to college first, and then they serve in the army. And I did very well in my matriculation exams.

Aspaturian: High school exit exams.

Bruck: Exactly. The grades there used to be the key for everything, because during my time, we didn't have SAT exams. Also if the matriculation grade point average was at a certain level, like an A+, then you didn't need to take the entrance exams to the university.

Impact of 1973 Yom Kippur War

Aspaturian: In what year did you take the matriculation exams?

Bruck: In '74. So I was a senior during the Yom Kippur war.

Aspaturian: This would have been 1973. What do you remember about that?

Bruck: It was scary.

Aspaturian: Yes, I bet.

Bruck: Well, the scariest part—my brother joined the army in '71. He was in tanks.

Aspaturian: Where was he?

Bruck: In the Sinai desert. So this was the scary part for me: We didn't hear from him for quite a few weeks. The news was not good because Egypt and also Syria surprised Israel. The reserves were not ready, and the Israeli army is based mainly on reserves. So the few people that were in Sinai at the time, including my brother, were supposed to stop, to slow down, the advance of the Egyptian army.

Aspaturian: Was he on the Bar Lev line?

Bruck: Yes.

Aspaturian: Yes, that's right, the Egyptian army overran it.

Bruck: We were not sure if he's alive, and during those weeks we saw army people coming to tell families about someone who was injured or died, and there were a few on our street. So when they walked the street, we would hope that they will not stop at our house. And we had other family members in the army; my cousins were involved. The whole atmosphere was very tense. Most of my brother's unit was killed or injured, which was common for people who were in the regular army, not reserve, and were in combat units [*See also Session Two*].

Many of those units were in really bad shape. Luckily my brother survived.

Session 2, October 17, 2016

Yom Kippur War results in deferral of Technion university education for military training

Aspaturian: When we left off, I think you were at the Technion as a high school student, and you had been temporarily exempted from military service.

Bruck: So in Israel at that time, there was only one program like this. I think now there are many different programs, but back then they tried to identify 200 kids who could contribute to the army in a different way than being in combat units or other positions. They let them study at university right after high school, but then, in return, you're supposed to serve longer—maybe three or four years more—after you get a university degree.

Aspaturian: What is the standard term?

Bruck: At my time, it was three years for men and two for women. I'm not sure about the context in which I applied for this program: I was a good student, and I think my parents were a bit uneasy after the experience we had with my brother, who

served in the military in a very difficult war and luckily survived. The Yom Kippur war, which some people call the '73 war, was a very difficult war for Israel. Thousands of soldiers died, and especially in the armor—in the tank units.

So I think I applied and based on my grades—there was no exam—I was accepted into this program. I also applied and got accepted to the Technion, but we ended up deferring our studies after all. So many soldiers had died in the Yom Kippur War that the army said, "We want first to take those 200 kids and train them as soldiers and then after a few months we will let them go back and start their studies in their universities in the second semester, not the first semester."

ASPATURIAN: How old were you at this time?

BRUCK: Eighteen. And, you know, it was mandatory to do this; it's not like you have a choice. So when we came to the first day in the army, we didn't know what we would be doing. It turned out that the army decided to train us as tank soldiers—those of us who were fit to do it—because so many people in the tank units were killed or injured in the recent war that they needed more people to fight with tanks.

ASPATURIAN: Was this a local unit or did you go elsewhere in the country?

BRUCK: Israel is very small.

ASPATURIAN: But, I mean, did you stay in Haifa or go elsewhere?

Bruck: The training was in the center of Israel. Israel is so small that when people ask me "Where are you from in Israel?" I tell them from the north, from Haifa, but everything is so close together that the distance between Haifa and Tel Aviv is like between Caltech and UC Irvine. So everything is local. We went through all the basic training, and they told us that after six months we would be able to leave and start to study at the universities.

Aspaturian: Were these 200 of you trained together, or did they disperse you?

Bruck: No, we were together at that stage. And many of my friends date from that time.

Aspaturian: There must have been some women among these exempted 200? They wouldn't have been in the tank units though.

Bruck: No.

Aspaturian: They went somewhere else for their training?

Bruck: I think the women maybe just went and studied, but I'm not sure.

Aspaturian: I have a question for you about the politics at that time. I know the war was very traumatic for Israel. When the Israeli and Egyptian generals actually started talking to each other for the first time at Kilometer 101 in the Sinai after

[Henry] Kissinger [US secretary of state, 1973–1977] brokered some sort of temporary deal, do you remember feeling anything about that? Thinking, there might finally be some sort of breakthrough? Or was this not something that was—

Bruck: I was not very optimistic at that time, because it was such a difficult war, so there are many other feelings I think that were much stronger. And I think the reason for the negotiations is that the Egyptian Third Army, as they called it, was surrounded by the Israeli army, and that situation could not remain; it needed to be resolved. So I think this was the driving force.

Aspaturian: Yes. Did you lose friends or family members in that war?

Bruck: Neighbors yes, and my brother lost many of his friends. Basically about half of the people in his unit died. He still has very close contact with those who survived, and I know many of them. Three thousand people in a population of three million is a dramatic number. It's very hard to imagine the scale of the loss even now. And then I ended up in tanks too. I went through basic training, and after that we started learning how to do different roles.

Tank training & service with IDF (Israel Defense Forces) unit in the Sinai

So in a tank, there are four positions. There is a driver, there is a guy who operates and aims the big gun, there's a guy who does everything else, and then there is a tank commander. We got trained to do the three basic positions. The commander training is offered at a later stage.

Aspaturian: What does the commander do?

Bruck: Everything. He tells everyone what to do. He is looking outside and telling the driver where to drive, and he can guide the big gun also, because the guy that controls the gun is inside the tank where he can't see much. It's kind of an interesting and scary gadget—like fifty tons, a big thing.

Aspaturian: What was your position?

Bruck: I did all of those positions as a soldier. First you study all this and you practice, and after that, we were put in a unit in the Sinai desert next to the border with Egypt, where we had training in the unit itself. From that point I served on the Egyptian border in the Sinai, from '74 to '78, almost four years

Aspaturian: You did not go to school, in other words; you stayed?

Bruck: I'll explain what happened. So many tank commanders and officers had been killed that they offered some of us the opportunity to train as commanders of the tanks. So I was selected for that, and I did that; this was also in the Sinai desert. Toward the end of it, they offered to train me as an officer. But by that time they'd already told every one of the 200 kids that there is a change of plans, and instead of staying six months in the army you will stay a year. At that point I felt that I should just serve out the period that I'm supposed to serve and not go back to school first. Only about ten or fifteen of us decided to stay in the army.

Aspaturian: Why did you make that decision, do you recall?

Bruck: It was an odd decision, but I was quite happy in what I did there, and somehow in an odd way I enjoyed it, you know? There was the fact that I had the opportunity to be an officer and to keep learning and improving what I'm doing, and I said, "This is fun, so I'll keep doing it," and I did very well. I stayed, and in fact many of the 200 who were originally with me ended up, of course, in high tech, as professors in Israel and all over the world, so I know many people from this period—this group of people that are mathematically and scientifically inclined and who spent so much time together. I still know many people in the Technion, Tel Aviv University, and the Hebrew University from the time that we served together in the army.

Aspaturian: Were you in the Sinai the entire time?

Bruck: Yes. I served in Sinai, and I was promoted very fast, so that after two and a half years—which today is unheard of, but it was different times—I was a commander of a company of tanks. A company of tanks includes 11 tanks and other supporting elements. Overall, it has about sixty soldiers, and depending on the mission, it can even have a hundred soldiers. I was responsible for daily activity including the training of the unit. We served on the border and there were different events that we had to deal with.

Recalls Egyptian President Anwar Sadat's "unbelievable" 1977 visit to Israel

However, in general, those years were relatively peaceful, not completely but relatively, and also there was an unbelievable event when [Anwar] Sadat [president of Egypt, 1970–1981] offered to come to Jerusalem to discuss a peace agreement.

Aspaturian: Yes, he told Barbara Walters in a television interview that he would go to Jerusalem.

Bruck: Right. I still remember that. He is probably the most impressive leader outside of Israel that I witnessed in my lifetime. Because suddenly a guy who led Egypt in a war that I think was relatively successful from the Egyptians' viewpoint is very courageous in leading his country to peace with Israel. He initiated that. He said, "I'll come to Jerusalem," and I remember —we couldn't believe it.

Aspaturian: Where did you hear this?

Bruck: We heard it on the radio because I was in the army at the time, stationed on the Israeli side of the border, confronting the Egyptians. And then we saw it on TV, and I still remember this picture with the airplane landing and the door is opened, and Sadat is standing there. This is something I will never forget. Unfortunately he paid with his life for his courage.

I was able to learn a lot about myself in the army, because I think by being responsible for many people, you learn a lot about yourself. Also, in my unit there were people from all walks of life in Israel—there were none of those 200 kids that went to the universities — and this was a fantastic experience for me. That's one of the benefits of the army, or some kind of national service, that I think can help any country. Of course, armies in general have some more extreme goals, but I think the key is that it's almost the only opportunity to meet people who are outside your social sphere—the sphere that you carefully build in terms of who are your friends, your workplace, where do you buy your groceries and all of that. The army really gave me a very good sense of how to interact with and appreciate people from other backgrounds and with different points of view. Because, as you know, at the end of the day, prejudice is a result of ignorance, and ignorance can be alleviated if you get to meet people from other countries and other cultures.

Aspaturian: Did you have any interaction at all with your Egyptian counterparts on the other side of the line?

Bruck: No.

Aspaturian: Sadat's decision to go to Israel was not popular in his own country. So there was nothing after that visit either, between '77 and '78? No back and forth?

Bruck: There was nothing, you know. Actually, Israel as part of the agreement withdrew from the Sinai desert.

Aspaturian: Oh yes. But that was later, after President Jimmy Carter brokered an agreement [Camp David Accords, fall 1978].

Bruck: Yes. I think the withdrawal started in '78. But I was already out of the army at that time.

Turns down prospect of a military career & returns to Technion

Aspaturian: Did you ever contemplate a military career?

Bruck: Yes, I did. I was offered many opportunities; my commanders tried to convince me to stay. I'm not sure why, but they thought I will do very well in the military.

Aspaturian: Were you tempted?

Bruck: I remember having interviews and discussions with very highly ranked officers who tried to convince me to stay. However, I really felt that my calling was to go back to school, and that's what I wanted to do. It is a sharp change. It's very

hard to explain it because you get to do some things very well after four years in the army. You get a lot of positive feedback, and you don't worry about geometry, calculus, chemistry, and physics and all that. You're operating at a different level of consciousness. Completely different. Also you have a lot of responsibility.

And after the mandatory three years I was getting paid. Because of the distance, I could only come home every two or three weeks, and only for a couple of days, but when I came home I had a car from the army and I had income. I was young, and I felt very important. [Laughter] And typically we flew on an airplane because it was far, so I felt really special and important. You know when you're twenty, twenty-one, it feels really unusual to get off the plane and have a very nice jeep waiting for you; and it's yours, and you go and do whatever you want.

Of course, today I really don't care about that, and honestly, I'd feel very anxious if someone would ask me to do the same thing now, because I'm not sure how I had the guts to lead a unit with eleven tanks. Technically it's a complex system, but I loved the technical part, to really understand how everything works. There are many, many details there that were quite challenging intellectually.

But I decided to go back to school, so I had to apply again to the Technion. There was an entrance exam to the Technion, but if one had a high school GPA above some number, then one would get accepted without it. And I was very lucky because I

don't think I could have passed the entrance exam after four years on tanks, because I forgot everything. It's a completely different mindset, and it kind of erased many things I studied in high school. There were a few more times in my life when I applied twice: I applied twice to Stanford, and I applied twice to Caltech.

ASPATURIAN: We'll get to those. So you started at the Technion in '78 or '79?

BRUCK: '78.

ASPATURIAN: You would have been twenty-one at that time?

BRUCK: About twenty-two.

"So I applied to electrical engineering & got accepted"; adjustments to university life

ASPATURIAN: Did you know what you were going to study when you got there?

BRUCK: In the Technion you have to declare your major when you apply. It's still true, and there are some departments that are very, very selective, and some that are less selective. So you can apply to a less selective department and get accepted, and maybe if you apply to a more selective department you will not get selected. My goal was to study mathematics as my major,

and I was planning to apply to the mathematics department. I didn't have anyone that I could consult with.

Aspaturian: No advisors.

Bruck: Yes. So I don't know whom I talked to, maybe the son of one of my neighbors who was a bit older than me. He asked me, "So where are you going to go?" I said, "To the Technion." He said, "Which department?" I said, "Mathematics." "Mathematics? Why?" I said, "Because I really like math." He said, "It's really easy to get accepted to the math department because not too many people apply." So I said, "Where is it difficult to get accepted?" And he told me, "Electrical engineering." I said, "What is electrical engineering?" And as he tried to explain it to me, I said, "That sounds interesting." So I applied to electrical engineering and got accepted. [Laughter]

Aspaturian: So you really didn't know?

Bruck: I didn't know what it meant—I mean I knew that there is electricity, radio, and all of this stuff, but I had not been exposed to any of that.

Aspaturian: Did any of what he was telling you about it, if you can remember, seem to appeal to you because of what you'd been doing in the military?

Bruck: Maybe; that's a good point. I don't know. I think you give me too much credit, because I think it was more of a superficial decision.

Aspaturian: You wanted to see if you could get into the "most difficult department"?

Bruck: Yes. And also, my head was still somewhere in the Sinai desert when I made this decision, so I didn't really pay too much attention to it. I just wanted to get it over with. In fact it was my mom who got the Technion forms for me. I filled them out, and she went there and submitted them.

Aspaturian: You didn't consider physics?

Bruck: Not at that point. I did physics, as we discussed, in the Weizmann Institute. [*Session One*] I really loved—I still do—the balance between the purity and the applicability of math. I think it's a great invention that allows us to do things independent of reality but also to find interesting ways to connect them to reality and use those connections to improve our insights.

So I ended up in EE. I remember that I had a month or so of vacation before I started in '78, and you could test out of chemistry in EE. Especially the lab. I'm not good with chemistry labs. I always felt that I might cause some fire and explosion.

Aspaturian: Blow something up?

Bruck: Yes. So I decided to try to test out of chemistry. I got an old chemistry book, and I just couldn't get myself to concentrate. I did my best, I tried to study, and then I went to the exam. I left after fifteen minutes. I was not used to sitting for so

long, and indeed my whole mindset was very different. The first semester was very difficult for me.

ASPATURIAN: Were you older than most of the students?

BRUCK: Maybe a year only, as most had been in the service. And I could always tell which students were like I was—those 200 that started immediately after high school, and you kind of knew who they were right away. They're younger, and they are more fluent with the material, and they have their own style. I was obviously older, and it took me awhile—I would say the first semester—to understand that I'd forgotten everything. [Laughter] But I did very well; I was not sure how well I will do. You know, every time you move to a new stage, then you are not sure.

I remember—I didn't tell you this—that after elementary school, which lasted eight years, I was supposed to go to high school, and one of the neighbors said, "I know that you were a very good student in the school here, but it's not clear that you'll be a good student in high school." I said, "Why is that?" He said, "Because it's a completely different level. You get kids from all over the area." And, you know, my parents didn't go to high school, so I thought, "Okay, maybe I should pay attention to that." And my best high-school report card was the first term in high school. I was so impacted by this comment that I started very seriously and diligently, so all my grades were A+. After that, I felt I could let go. [Laughter]

Aspaturian: You can slack off a little?

Bruck: Yes, because when we went to high school, everyone kind of knew what they enjoyed in life, and they just focused on that. So there were topics that I didn't have good grades in, like English. I didn't like the teachers.

Aspaturian: That raises an interesting point. When did you first start learning English?

Bruck: In fifth grade. And the problem with the English classes was that we didn't converse. We studied Shakespeare and Frost and all of this, but I couldn't ask for a coffee or anything like that. So I didn't like the English teachers we had because it was so passive. So it was common that if you like math and physics, you have good grades in those. And then the rest are okay—no one really cared about that. But as you get closer to the matriculation exam, if you want to get accepted to a good university you suddenly pay attention to all the classes and study seriously for the matriculation exam. So this was the system there.

Technion & IBM offer initial exposure to computer engineering in late 1970s

Aspaturian: What was the Technion like in those days? I was very surprised to read that it is one of the oldest universities in the region; it was founded under the Ottomans in 1912.

Bruck: Yes, it is the first university established in that area. Most Israelis will tell you, if you ask, that it's the Hebrew University because it's in the ancient city of Jerusalem, but in fact they were established at more or less the same time, except the Technion was first. It was established by Jewish people from Germany, and Germany at that time was what the US is today in science and engineering. Even [Robert A.] Millikan spent time there as a postdoc.

So there was this tradition and rigor, and we still had probably one of the founders of the EE department, [Franz Heinrich], Ollendorff who is a German-Jewish guy, there when I was a student. We could see him walking in the corridor. He was *very old*. Actually I'm not sure how old he was, because you know how you say that and then discover that he was younger than I am now. [Laughter] I don't know, but I think he was older. In any case, I really loved studying at the Technion. Computers were new at that time, and there was no CS department in the '70s, but the Technion did establish a track called computer engineering.

Aspaturian: This was while you were an undergraduate there?

Bruck: Yes. You could declare in the EE department that you were interested in the computer engineering track, and they selected just a few students. I would say it was at that time like a pilot program. I decided to do it, and I remember that some of my friends were a bit concerned about doing it, and when I asked them why, they said, "Well, we heard that your diploma

will say that you got a BSc in computer engineering in the electrical engineering department," and they felt that it's a less —

Aspaturian: Inferior?

Bruck: Inferior to having just the electrical engineering degree. And I told them at that time that I think it's actually a benefit, not a drawback.

Aspaturian: What made you think that? What about this appealed to you?

Bruck: For some strange reason, the two areas that I focused on as an undergraduate were communications and computers. I felt that that's the future, and it wasn't clear to me why. I definitely didn't like power systems, even though the field was interesting. And there is another secret here: I'm very bad in drafting and making pictures and so on. At that time in the Technion if you wanted to be an EE major, you had to take a mandatory class in drafting. And suddenly not only I could study computer engineering, but in computer engineering you didn't have to take drafting.

Aspaturian: So you could opt out of something you weren't good at.

Bruck: Yes. I didn't like the idea of sitting there and making lines with a pencil and making sure it's very neat.

Aspaturian: What was the state of the discipline in those days, computer engineering?

Bruck: I'll tell you about my first job.

Aspaturian: Were you still a student at that time?

Bruck: Yes. What happened is that when I started studying as an undergrad, I felt a bit lost because for a while I had been responsible for the lives of many people, and suddenly here I am walking around with books and notebooks, and that's all I'm doing. So something was missing: I needed some responsibility; I needed to feel a stronger validation than I got from just going to class and taking exams. Also, I wanted to make some money. And I always like practice, not just study. Applying ideas.

So I had a friend I knew from the 200 who also went back to study at the Technion, and when I started he was in his senior year. Actually I still see him every now and then. So he told me, "I have a great job." I said, "What are you doing?" He said, "I'm a computer operator." There is no job like this anymore—he operated the IBM System/34 computer. He said, "It's in Acre." Which is quite far. "It's with a factory that produces paints."

It was part of Tambour, the main company that produces paint in Israel. He told me, "I operate their computer. It analyzes and controls the inventory of materials used for production." As well as managed the financial planning and accounting. Then

he said, "I'm going to leave because I'm graduating soon. And there is an opening." So I said, "You know what, let me go with you and see what's going on."

We went over, and then I fell in love with this job. First, the computer room was a huge room. Next to the large computer there was a screen with a keyboard next to it, the only one in the building. Everyone else had only either punch cards or large floppy discs. The only screen with a keyboard in the building sits next to the big computer and belongs to the computer operator. Every hard drive was bigger than a washer. I needed to keep exchanging the storage disks based on the application that was running on the computer. The disks were heavy; I used both two hands to lift them.

ASPATURIAN: This is the late 1970s?

BRUCK: Yes. And then there was a very large printer. At that time magnetic tape drives were a very important part of the computing infrastructure. All the data including the backups were on tapes. And my job was to run computer jobs. During the day people entered data through punch cards or floppy disc, and then I needed to process the data, run the different applications and process the backups. Typically, I would get there at around three in the afternoon and leave whenever I was done. I did this three nights a week.

ASPATURIAN: Was this a state-of-the-art machine at that time?

Bruck: I think so.

Aspaturian: Really? I'm asking because I remember using a PC a few years after that. Not for anything that significant.

Bruck: This was a mainframe. The PC at that time didn't have a hard drive if you remember. I also used it.

Aspaturian: I didn't use them in the late '70s. This would have been the early 1980s.

Bruck: But also in the early '80s, I think, it still didn't have a hard drive. DOS is a diskette operating system. Basically you come with your own diskette, which has the operating system on it. You put it in the computer and you reboot it using your operating system. There was no hard drive inside. And it couldn't run complicated jobs.

Aspaturian: That's right, I remember.

Bruck: A few years later I worked with more advanced machines. Not of course what we have today, but I was able to program and have a terminal and to run programs on my own without an operator. But when we studied programming at the Technion, we wrote our programs on punch cards, put them into a big computer, and got the result as a printout. If you had a bug, you could see it on the paper printout. Sometimes you got too many pieces of paper and it was not clear why.

Technion's intellectual environment & Israel's emerging corporate R&D sector

Aspaturian: What kind of professors at the Technion were involved in this very new field? Were they younger people? Older people who had moved over? Do you remember whom you worked with and how they influenced you?

Bruck: I need to think about it.

Aspaturian: Two things occur to me. First, this was a brand new field. And second, Israel was a brand new country. Still, already by that time—

Bruck: When I started studying at the Technion, Israel was thirty.

Aspaturian: Yes, and the scientific infrastructure was quite sophisticated.

Bruck: Yes. In the 1970s there were many large U.S. companies, like Intel and IBM, that had started operations in Israel. As you remember, at that time this technology was concentrated in only a few companies. There was DEC [Digital Equipment Corporation], which has since disappeared but was an important force then.

Aspaturian: Were these companies anywhere else in the Middle East? Or was it just Israel?

Bruck: I have no idea. You know, at that time, the Arabs banned companies that were doing business with Israel. So there were some products, like Coke and Japanese cars, that we didn't see in Israel at that time. People said, "Wow, where can we find these products?" "Well, it's banned to market them in Israel because their companies are afraid to lose business."

So this was a fantastic experience for me, to work with a mainframe at the Tambour plant. I learned a lot because you almost sit within the computer and you see all the different pieces, how they interact. It's not like today when it's all in a small box—an iPhone, a PC, or a Mac. So the way you produce data is that you actually print it out. By the end of the evening there was a box full of printouts, and—what do you do with it? The Tambour headquarters, where all the white-collar people worked, was in Jerusalem, so this was the protocol: After I was done with the processing, I took a cab—because it was too late for public transportation—to a nearby plant, where there was a truck waiting for me. I would give the truck driver the box, and he would drive that night to Jerusalem to deliver it to the headquarters.

Aspaturian: How often did this happen?

Bruck: Every day. This is the beginning of the internet. [Laughter]

Aspaturian: Not quite.

Bruck: [Laughter] Well the beginning of the internet is the Silk Road in China; they moved ideas.

Aspaturian: That's one way of looking at it.

Bruck: And then after that, the cab will take me home. I learned a lot from that, and with this combination of actually doing computer work and studying, suddenly all the classes related to computers became very intuitive and, in a sense, easy for me because I was very hungry to learn more about the topic. In general, we didn't have access to books the way we have here, because there were no books in Hebrew on the subject, and our English was not great. I read the English-language books in the library— it was very unusual that I will buy a book because they were very expensive. I learned about the idea of a text for a class only when I came to the US. We didn't have it then in Israel.

Creates "from scratch" an integrated computer system to holistically manage Technion bioengineering experiment

So I worked for two years in this place, and then I decided to do something a bit more complex, and I started working on campus. I'm not sure how I got to it, but I think that someone posted a job opening in the bioengineering department.

Aspaturian: They had bioengineering already.

Bruck: Yes. There was a professor who had just came back from the U.S., and he was doing experiments with a CNS connection. He did vision experiments with squirrels where he installed single-neuron electrodes in their brains. He showed the squirrels different pictures, and measured the activity in the neuron. What he wanted to do is control the whole experiment from a PC. He wanted to use the PC to control the screen that showed the images to the squirrels, and then to collect and analyze the pulses coming from the squirrels' brains and show those results on a different screen.

Aspaturian: He wanted to use the computational power of the PC to pull this together?

Bruck: Yes. Computational power both for calculation and to control the whole experiment.

Aspaturian: I understand. Was this something new, relatively speaking?

Bruck: I built the whole system from scratch.

Aspaturian: You designed the system for him.

Bruck: Well, we bought pieces. We bought a PC, and then I figured out a way to connect it to those screens. We had a monitor that was not a computer monitor, but I found a way to connect it. It even had colors. I found a way to control it from the PC.

Aspaturian: Who was this guy?

Bruck: His last name was Gur. His first name was Moshe, like my father, and he had a nickname; we called him Moggi.

Aspaturian: Everyone in Israel seems to have a nickname.

Bruck: Yes, if you don't have a nickname it means that no one ever calls your name. [Laughter] Yes, he gave me a great opportunity, and it was very challenging, because at that time the standards for connecting between computers, monitors, sensors and other peripheral components were still in infancy. Today, when you buy a new printer, you connect it to your computer, and it figures out how to talk to the printer.

Aspaturian: By and large, yes. It takes over the process after you press a couple of keys.

Bruck: Right. So at that time people would say, "Okay, I'll buy these components, they fulfill my requirements, but we're not sure how you get them to talk to each other; we'll figure it out. So I had to figure out, first, how to make the computer talk to a piece of equipment that basically generated pulses. I was able to do that, collect those pulses, and turn them into data. And then figure out how to connect the same computer both to the screen that would show things to the experimental squirrels and to the screen that showed whoever does the experiment the results of the data analysis. Because the monitor displayed only

characters, remember those? You couldn't look at graphs on them.

Aspaturian: I do. It seemed very sophisticated, but in retrospect it was very simple.

Bruck: Yes. And at that time there was no hard drive in the computer I worked on. But I learned a tremendous amount about how to deal with these issues.

Brings Technion-acquired hardware & software expertise to University of Eindhoven as exchange student; reflects on first encounter with Europe

In fact in '81—that's the first time I left Israel—I went on a student exchange program for four months to the University of Eindhoven in the Netherlands. They still have those programs in Israel. It was like a SURF [Summer Undergraduate Research Fellowship] project.

Aspaturian: Where is Eindhoven?

Bruck: In the southern part of Holland. At that time I was already with Anat, my wife. We started living together in 1980.

Aspaturian: Had she grown up in the same neighborhood?

Bruck: Yes.

Aspaturian: Because you said her grandmother was sort of the mistress of the local supermarket [*Session One*].

Bruck: Yes. [Laughter] She grew up in the more prestigious part of town.

Aspaturian: Was she also at the Technion?

Bruck: No. Anat is two years younger. We went to the same high school, and she was a teacher—teaching at the kindergarten level. So she went to school at the same time I went to the Technion. When we were students, we lived together in a place we rented not far from the Technion, and we both worked. When I got together with Anat, she was a cleaning lady; that's how she supported herself as a student.

Aspaturian: Not in her grandmother's supermarket, I take it.

Bruck: No. Her grandma was old at that time.

Aspaturian: And then you went to Holland together in 1981.

Bruck: We went to Holland for four months together. The reason I bring it up is that it relates to my work in the Technion bioengineering department. Eindhoven had a very interesting lab with a lot of equipment, like voltmeters, and other things that they used to monitor experiments, and they had a computer. I think it was a Commodore, one of those. And what they wanted me to do was to figure out a way to control those complex experiments from the computer and to do it 24/7, so

they don't need to always be there. So I needed to figure out how to connect a computer to this equipment from the back since there was no ready-made way to connect it. I even had to build a circuit to interface between the computer and measuring instruments.

Aspaturian: So you were designing both hardware and software for this project.

Bruck: Yes. I had fantastic training in the Technion.

Aspaturian: Sounds like it, yes.

Bruck: So I was done after a week or ten days with the four-month project. And it worked. They were very happy.

Aspaturian: Were they surprised?

Bruck: Yes, very surprised.

Aspaturian: How is it that nobody there could do it, or was this just—?

Bruck: You know at that time, in 1981, to be able to write software *and* build a circuit it was like, Okay, who can do that? They were electrical engineers. They didn't know much about writing software.

Aspaturian: Was the Technion a pioneer in his area compared to most of the world? And if so why?

Bruck: I'm not sure. We had teachers that came from industry to teach us.

Aspaturian: Industry in Israel or in the United States? Canada? Britain?

Bruck: Industry in Israel. I need to look a bit more into the history. But we had great training as students because we did projects that included both hardware and software, and I really enjoyed those. And so in addition to working in the bioengineering lab, which I did until I graduated, I had my own freelance startup. The first category was the work we did for people who needed to connect devices they didn't know how to connect. For instance, they have some kind of a computer that they got from an uncle, and they bought a printer, but they have no idea how to print things out from the computer, because there were no standard plugs or interfaces.

Aspaturian: And certainly no software that just took over and did it for you.

Bruck: Yes. You need to kind of figure it out. So I became an expert in those types of things. And also I, with a friend, took on a few larger projects of building whole systems.

Aspaturian: Was this within the university, or was this independently?

Bruck: No, outside.

Aspaturian: You contracted out to companies, individuals?

Bruck: Individuals. So I always did those type of things outside of the academic activity, and I think those experiences really helped me in terms of having a deeper and broader view, even as someone just starting out. Of course it evolved later. I kept this balance between the two activities.

Aspaturian: I wanted to ask about your first exposure to Europe when you were in the Netherlands. What was that like for you?

Bruck: It was—I think for the first three days I couldn't close my mouth or something! Imagine going out of Israel to Europe for the first time. It was very different—not only the lifestyle, but also the culture was very different. We lived in the university dorms, and we had a fantastic experience with the students there. It was a great group of people. We shared a flat, as they call it—it's a floor, and I think there were five or so couples there. Every evening the five couples took turns cooking dinner for everyone else.

Of course, my contribution to cooking was to get out of the way or do whatever I'm told to do, because Anat is a great cook. We had a lot of fun. I learned to play some variation of bridge there, and we played until very late at night almost every evening. So at many levels it was a very different culture. You know they drank beer there: I don't drink much beer, but they drank a lot of beer. They had a big refrigerator just on our floor,

and we were on the route of the beer delivery guys, so they would show up every few days or once a week to load the refrigerator with beer.

ASPATURIAN: No wonder nobody else could do what you were doing.

BRUCK: [Laughter] No, they were fine. It's just that it was a very different culture. We had a great time. Because I was done with the project within a very short time, they gave me another project that was bigger, and we agreed that I'll work on it something like three days a week and then travel the rest of the time.

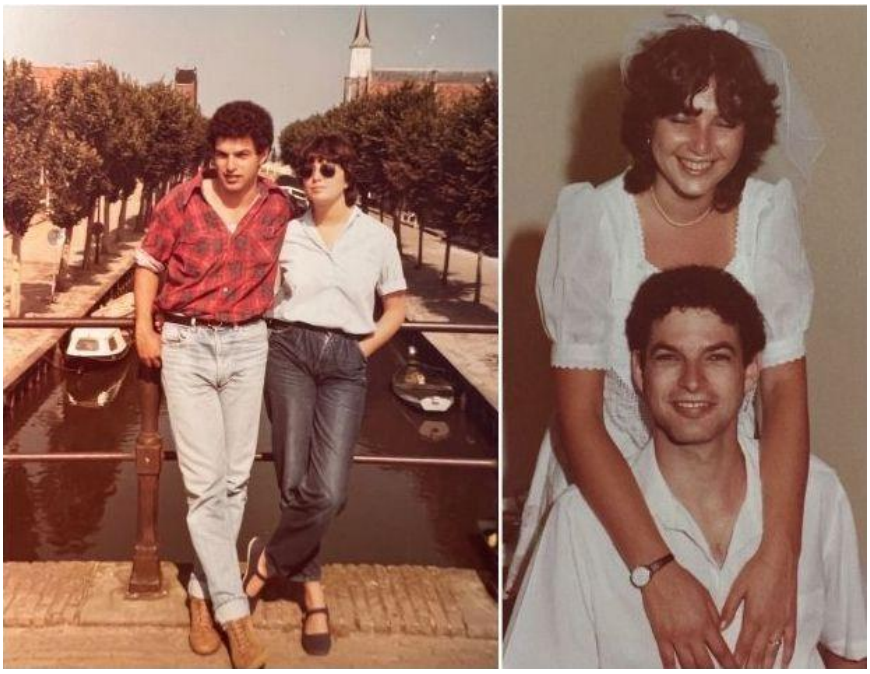
ASPATURIAN: Did you go elsewhere in Europe?

BRUCK: We went to many other places later, but at that time we went everywhere in Holland. This program in Holland had exchange students from all over the world, so they used to organize what they called excursions. It's not a word used much in the U.S., but they love this word in Europe. So we went on excursions, typically over a weekend, with exchange students in other universities all over Holland. It was fantastic. Anat and I also went to other places, like Belgium and Luxembourg, and Germany.

ASPATURIAN: You went to Germany. Was that difficult for you?

BRUCK: No. In fact one of the guys who lived on our floor was from Holland, and, as you know, Holland had had Indonesia as

a colony. His mom was Indonesian and his father was Dutch. We became very close friends with him. His girlfriend was from Germany, so we went with them to different places in Germany, and I discovered that I understand German because of the Yiddish. Overall, the good experience in Europe led me to considering studying abroad.



At left, with Anat in Eindhoven, in summer 1981, and at right, wedding day in Haifa, in August 1982. *Photos courtesy of Shuki Bruck*

Applies to US schools for graduate study; more on Technion environment

So when I came back later that year to the Technion, I decided to apply to grad school in the U.S.

ASPATURIAN: What made you decide you were going to go to the United States?

BRUCK: I felt a tremendous thirst for knowledge, and I felt a bit confined in Israel. And maybe the experience in Holland affected that. I felt like when I was a child and waited for the weekend to read the encyclopedia. Suddenly I had this type of feeling again—that I want to be in a place where it's very easy to access and to interact with new ideas.

ASPATURIAN: Did you have many professors from the United States at the Technion?

BRUCK: Yes. There were many people in the Technion who had done their PhDs in the U.S. It started very early; for instance, if you look at Amnon Yariv [Summerfield Professor of Applied Physics and Professor of Electrical Engineering] here; maybe he was one of the first to study in the U.S., and he was born in Israel. But there was a group of Israeli students at that time at Stanford, including people from the Technion. You would hear about how students who did well went to the U.S. to do a PhD, and you would say, "Oh wow, that's interesting. I have no idea what it means, but it sounds exciting."

The due diligence that we did at that time was not like what students do today. We didn't have the internet; we didn't have anyone to understand what's going on. It was even a challenge to get a little catalog of each university, although they had a few in the library at the Technion at that time. I still remember that the only one with a color picture on its cover was from Stanford. That was one of the reasons I applied there. I remember thinking at some point, "Should I apply there?" And I don't know who told me, "You have to apply, it's a good school." I said, "Okay, I will apply."

Aspaturian: Did you have any professors at the Technion who particularly mentored you; anybody who stands out in your mind there?

Bruck: We didn't have much interaction with the professors.

Aspaturian: Really? Such a small place?

Bruck: It's not small. You know how many students are there in EE today? At that time, probably it was half that number. Today there are 400 students in each year, so there are 1600 just in EE.

Aspaturian: So you are saying that the faculty was rather distant from the students?

Bruck: Yes.

Aspaturian: It sounds more like a European than an American model. I'm surprised.

Bruck: I don't think I ever talked to professors one-on-one during my undergrad time. Well, I talked to this guy—

Aspaturian: The squirrel guy.

Bruck: Yes. I worked for him, and I did a couple of final projects in the signal-crossing lab so I talked to the professor there, but very briefly. And the fact is that it didn't feel unusual at the time. Of course, now I talk to undergrads all the time. I think it's important—maybe it's important to me; maybe the undergrads don't feel it's important. [Laughter] But I think this current generation, especially in the U.S., feels comfortable getting advice from everyone that they can get advice from.

Aspaturian: I think the internet probably has something to do with that too; it has knocked a lot of barriers down.

Bruck: Well I talked to students also twenty-two years ago when I came here, and at that time the internet was not as prominent.

Aspaturian: No, but it had started. So you were applying to universities in the United States.

IDF service results in wedding on crutches & delays graduate study at Stanford

Bruck: Yes. One thing I didn't mention is that while I was an undergrad in the Technion and having fun working at my different places, I also served in the reserve army as a commander of a company, which means that probably I spent two months of every year in the army.

Aspaturian: But it wouldn't have been the Sinai anymore because the Sinai had gone back to Egypt.

Bruck: No, not the Sinai.

Aspaturian: Where were you?

Bruck: So my unit was in the north, but we did training in the south, in the Negev.

Aspaturian: What was that like?

Bruck: It felt like Sinai, very similar. Now I remember—I even went back to the army with a friend for two months after my freshman year. A general I knew, who was the commander of the largest training base in the Negev, asked us to come and help him review and revise the training plans. So, we spent two months there. It was a good experience. Everything is integrated in Israel: I am still in touch with him and still see him. In

fact, his son will be a postdoc at Caltech, and I had nothing to do with it. He will work in CMS. Maybe he is here already.

Aspaturian: You'll have to find out.

Bruck: I'll have to find out. Yes, so I served. This was the most difficult part for me, because it was unusual to work at the level I did and to study full time. The service in the reserve really was very difficult to manage because you come back after missing classes and missing exams. I think the reason I was able to manage it is because I was young. [Laughter]

Aspaturian: Yes, you had more energy. Are you the sort of person who doesn't need a lot of sleep?

Bruck: I was then, maybe even today. In the army you are almost trained how to operate without sleep, but in any case I didn't sleep much during those years because, as you understand, at the time I had to wake up early and go to school and then I worked late and came home late. Yes, I think I probably didn't need much sleep, at that time. I believe today I can still manage it, but I'm not sure I want to manage it.

Aspaturian: This seems to be a common denominator among a lot of Caltech faculty.

Bruck: [Laughter] Well, when I get excited about an idea, then I don't care much about being asleep. It could be. So in my senior year, which started in '81, the PLO [Palestine Liberation Organization] was occupying the southern part of Lebanon.

They had got there through a sequence of events. They had been driven out of Jordan during the Black September (9/1970) conflict, also known as the Jordanian Civil War, and they ended up in Lebanon. Their goal was that to gather strength and at some point attack northern Israel. And I was in one of the reserve units in the north.

ASPATURIAN: Were you on the Golan or were you—

BRUCK: No, in a reserve unit you just keep all the tanks and everything else away from the border, and then when you decide to use them, you mobilize. So because I was an officer, I used to go quite often to the base there to work on planning for the case that the PLO would decide to execute their plans. Also the Syrian army was in the eastern part of Lebanon. So it was a complex situation. The goal for my unit was to make sure that the Syrians in Lebanon will not interfere if Israel needed to confront the PLO. Now I'm fast-forwarding—I got accepted to grad school at Stanford and other places.

ASPATURIAN: Where else had you applied, do you remember?

BRUCK: I remember I got accepted also to CMU [Carnegie Mellon University], but when I looked at pictures that I found of Pittsburgh, first of all, all of them were black and white.

ASPATURIAN: That pretty much describes Pittsburgh at that time.

BRUCK: Also it seemed pretty cold there.

Aspaturian: Also true.

Bruck: Yes. So I said I'm going to this place with a color picture. [Laughter] This was in my third year. And then, June 5th, 1982—it's a complex way of starting the war—the Israeli ambassador in England, [Shlomo] Argov, was assassinated; I don't know if you remember that.

Aspaturian: No.

Bruck: In any case the PLO started firing on the northern part of Israel, and my unit was assigned to face the Syrians. A couple of days later we entered Lebanon, and we fought the Syrians all the way up to near the Beirut-Damascus road, and I got injured in this war. This was the night between June 10 and June 11. I just had to spend a few months to recover. I cancelled the plan to go to Stanford.

Aspaturian: Where was the injury?

Bruck: In the legs. This happened in a well-known battle called Sultan Yacoub. You can look it up online. There were many casualties, and to this day there are still three Israeli soldiers missing in action. You know, it was a very difficult experience, but at the end of the day I think Israel did what it was supposed to do. So the helicopter flew me—

Aspaturian: You were airlifted off the battlefield?

Bruck: Yes. Well, it was complex because after I was injured, there was no way to evacuate anyone. We were surrounded, basically. It took quite a few hours until we were able to get out of there.

Aspaturian: How long had you been in Lebanon before this happened?

Bruck: About five days. We didn't sleep during those days. And yes, I was airlifted from there and ended up in Tel Aviv, in the largest hospital there, Tel HaShomer. I was there for a few days and had surgery and all that, and then at some point I went back home with Anat. We got married in '82.

Aspaturian: After this incident?

Bruck: Well it had been planned for August, because we were supposed to go to Stanford right after the wedding. Everything was planned and during the war our parents met with the caterer and so forth. When I was about to be deployed on the northern border Anat asked me, "What do we do about the wedding arrangements?" I said, "We are going ahead with it; I'll come back." I came back, the wedding was as scheduled, and I was on crutches.

We didn't have a choice but to cancel the plans to go to the U.S. The first problem was that I hadn't graduated, because I had left the Technion before the finals of the last semester. And I was not in good shape to start a new life in the U.S.—I was in a

recovery mode—so we cancelled it. I took the exams only later, in the fall of '82, and then I didn't know what to do.

Undergrad TA experience; enrollment in Technion's master's degree program

Aspaturian: When did you formally enroll in the master's program at the Technion?

Bruck: The master's somehow happened, probably because I need to do more than one thing at a time. [Laughter] I think that's one reason. But I didn't know what to do really, and the Technion was extremely helpful. In addition to what I already told you, I was a TA during my last year or two as an undergrad, and I loved it because we actually conducted recitation sessions [i.e., review sections for large lecture classes, usually presided over by a graduate or undergraduate teaching assistant. *–Ed.*]

Aspaturian: Do you think that your experience being a commander in the military helped you as a teacher at this young age?

Bruck: That's a good question. For sure; I think all the time. Because in my training, I became used to explaining things to very large groups and to communicating with the commanders who reported to me and to the bigger group. All that felt very comfortable to me, so to go into a class and to explain a concept —this was fantastic, even more exciting. I felt very comfortable with it.

In Israel, once people have gone through the experience in the army, they are a bit more rounded, because they're not only kids that lived at home and then went to school and lived in a dorm. They did other things and confronted more complex situations and so on. So I was a TA, and I loved it; I loved the teaching, I really enjoyed that. While I was recuperating, I had a visit from the department administrator for EE, the exec—how should I call her?—the person that makes a department work. At the Technion her name was Susie, and she ran everything on the academic side of this large department, almost ten times larger than the one here.

ASPATURIAN: An academic administrator.

BRUCK: Yes. She managed everything with grace—a very nice person.

ASPATURIAN: First name Susie; last name do you recall?

BRUCK: No. I know she's not with us anymore. In any case, she came to visit me at home quite often, as well as other people, and she helped us a lot. She said, "What are you planning to do after you graduate?" I said, "I don't know." And she said, "How about if you come back and be a TA again? And maybe you can enroll for the master's degree." And I said, "I cannot be a TA because of the recitation"; I was still using a cane, so I felt it would be a bit awkward. And she said, "Well, you were such a great TA that you will be the head TA and you don't need to

give recitations." So basically, in her very gracious way, she put me back on track.

There were six TAs, and as the head TA, I took care of all the planning. It was a big class. The professor just gives the lecture in a huge lecture hall, and the head TA does everything else. It's like a big zoo. I really enjoyed that, and I decided to do a master's degree. At the Technion you do a master's with a thesis, and sometimes a thesis has a lot of ideas like a PhD thesis almost.

Work with J. Raviv & the IBM Israel Scientific Center

And then I think at the end of '82 I took a class—maybe it was part of the master's requirement—and the person teaching it really impressed me. His name was Joe [Josef] Raviv; he was a Stanford and Berkeley graduate. He had been working as a researcher for IBM in New York, and he wanted to go back to Israel. He's a very talented person, and IBM told him "Wait, don't leave IBM; how about if we have you go and start a small research center in Israel?" So that was the beginning also of CS in Israel. He started IBM Research in Israel [originally IBM Israel Scientific Center]; it was housed on one floor in a small building on the Technion campus. There were about twenty people there. The course he was teaching was on pattern recognition—neural network type things. First, I was really impressed by him, and second, I loved the material and did well. I'm not sure how it happened, but he talked to me about wheth-

er I'm looking for a job. I ended up joining the IBM Research lab in the Technion in '82.

Aspaturian: Now was this a private IBM operation, or was it an academic collaboration?

Bruck: No, it was private.

Aspaturian: Private but within the Technion

Bruck: Yes. At that time IBM had what they called scientific centers; I don't think they exist anymore. The idea was that the center does research that benefits the country where they are located. In a way, this was because of monopoly issues, where these other nations said, "Well you cannot just be the only company that sells this type of product." So IBM said, "Okay, we will give something back to society." So they established these IBM science centers in many places and had projects that helped with medicine and water and other things.

But at the time I joined, we also started working on projects for IBM in the U.S. So it was both a science center and an R&D center. Yes, definitely, he was a fantastic influence on me. He visited me later on in every place where we were. Here too; we had lunch at Caltech. He always believed that I would come back to Israel. So when I joined the IBM science center there were about twenty people there. Now there are more than a thousand.

Aspaturian: That doesn't surprise me.

Bruck: Raviv unfortunately died in a car accident in New Zealand with his wife while they were there on vacation. He was a really special guy. There is a very prestigious worldwide postdoctoral fellowship named after him that is sponsored by IBM. So basically, '82 to '85, I worked for IBM and did a master's degree in the Technion. At that time there was a construction of a new building of electrical engineering, and when it's completed IBM had half a floor in this new building.

Aspaturian: Half a floor.

Bruck: Half a floor, not a whole floor. There is a door, and half a floor is there. It's not there anymore. IBM now has its own building somewhere with 1,000 people. But I did my thesis research in the same building.

Aspaturian: Was your research connected to what you were doing for IBM?

Bruck: No, it was separate. Conceptually there were relationships, because at that time I worked in signal processing and image processing—research like what Professor [Pietro] Perona [Puckett Professor of Electrical Engineering] is doing. Both image analysis and image compression. I'll tell you more maybe next week. Now when I think about it, it was a fascinating time.

Aspaturian: You must have been very much on the ground floor of all of this. The field was brand new.

Bruck: Yes, everything was. It was impossible to do image work, especially video, because there was no storage space to store it, and there was no computing power to process it in real time.

Comments on dichotomy between academic & industrial R&D & need to overcome artificial disciplinary boundaries

Aspaturian: Where was the intellectual impetus for this work coming from? Was it scattered in various places across the world, or were there one or two academic or commercial centers that basically set out an agenda for what you were working on

Bruck: So, you know, there is a very important point here. In engineering, a lot of the new ideas emerge in industry, not in academia. If you look at the invention of the transistor, for example, it happened in Bell Labs. If you look at the invention of the hard drive, which happened the year I was born, in 1956, it was done at IBM in San Jose. There are many other examples like this. Unfortunately I think we have now lost some of it, although you have organizations like Google inventing things that no one in academia has gotten close to. But definitely in the start-ups that I was part of [*Session Eight*], we did things that were ahead of research in academia.

I think this is a dilemma that is not yet well understood: How do you make academia and industry work better together? Right now, the only link is start-ups, and it's typically more one-directional, that is, knowledge goes from academia to industry. Because industry by nature is very secretive, so you don't know much about what's going on there.

ASPATURIAN: This is something you were trying to deal with or transcend with regard to establishing IST [Information Science and Technology program] here, I think.

BRUCK: Yes.

ASPATURIAN: So that's a topic we'll get into [*Session Seven*].

BRUCK: In general, what I am struggling with here is the notion of interdisciplinary. I think life has no disciplines, so there is no meaning to the notion of interdisciplinary. I think we invented it. We did it so we can have a structure where we can develop expertise and train the next generation and all of that, but reality has no disciplines, and I think disciplines appear more in academia than in industry. Industry doesn't have disciplines. Again, I don't know Google very well, but they have many interesting and novel activities. The challenge is when we get this type of research dynamics in industry, it's not clear how to align it with the training of the next generation, and how to create a productive flow and evolution of ideas going forward. Is the driving force always economics, and is that the right driving force?

Aspaturian: Is profit the right—

Bruck: Exactly. So how do we integrate that into educational programs? For me the two most important aspects of life here are health and education, and I know that these days you have to also talk about global warming, but I think that if we have good education, the other parts will work out. Especially if we educate people about that and how to conserve the planet. But global warming is maybe an example of this dichotomy between industry and education.

Aspaturian: That may be so.

Bruck: Maybe it is. I never thought about it before. But there are activities that are driven by economics and are short-term, and activities that are driven by long-term objectives, which is more what we do here at Caltech. I think that with the demise of Bell Labs, and IBM Research, we have created more of this dichotomy. But it was very good while it lasted—people from IBM Research won Nobel Prizes and same thing with Bell Labs. But now I think the day in which someone from IBM or Bell Labs or anywhere in industrial research will win a Nobel Prize will be very far off.

Session 3, October 24, 2016

"I learned a very important life lesson from my father: We should continue our life with who we have and what we have"

Aspaturian: I want to ask you a question that occurred to me after last week's interview. You describe yourself frequently as an optimist and say your outlook on life is a positive one. How did growing up in a country that in a sense was continually under siege for about the first twenty years of your life affect your thinking and feeling with regard to your generally optimistic outlook?

Bruck: That's a good question. [Laughter] It's a very interesting question for me because my degree of optimism increased when there was more hardship, and I survived it. You know, I talk to my mom almost every day on the phone; I just talked to her today. The key is, what is your reference point? And I think for people like my mother who survived a traumatic event like a war or the Holocaust, typically they discover which external issues are meaningful and which aren't and then it helps them refine what are truly the important issues. I learned a very important life lesson from my father, who had a difficult Holocaust experience [*See Preamble*]; he claimed that *one should never feel that he is a victim*. This lesson became a guiding prin-

ciple for me. Bad or even terrible events happen: *We should continue our life with who we have and what we have.*

In the end, the question is what is important for you and what makes you happy, and what do you to tie your mood to, because optimism is about happiness and not about being correct about the future. I grew up in a family for whom the most important part of life is the family. Then, after I was wounded in a war, I thought that health is very important, because as a young person you never—at least I, didn't—imagine not being healthy and being unable to run around; that's the beauty of being young. But then suddenly, as a young person, I lost mobility for a few months.

So then I realized that if I am able to wake up in the morning and go about whatever it is I like to do, that already is a wonderful day. I still feel this way, and it really helped me that this realization happened early in life, when I was twenty-six. When I walk around here on campus, and people ask me, "How are you doing?" I say "Excellent." Some people already know what I'm going to say, and they say to me, "Excellent again!? What's so wonderful today?" And I say, "Well, we are here and we're doing what we enjoy, and we are being paid to do it, so it's a fantastic day." There is this saying by Socrates that, "People that are not happy with what they have will not be happy with what they want to have."

That's what he said. [Laughter] I didn't invent it. But at the end of the day, we live in a very materialistic society, and we

measure people all the time, and today more than ever. We give kids grades from a very early age, and they compete on a very linear scale, and then their optimism is affected by their grades, which is the wrong thing to worry about. So I think that's a problem. You see it here with undergrads that come to Caltech. They're all superstars in their town, and once they are here, they suddenly discover that everyone has these gifts. And some of them become very discouraged and sometimes depressed because of that.

I also think that the way every competitive kind of discipline is working, whether it's sports, science, or engineering, we put too much emphasis on external validation, which is similar to grades. And if you're in, say, biology, chemistry, or physics and don't win a Nobel Prize, then you maybe feel like a failure. Is the immediate external recognition really an issue?

It all ties into optimism. Sometimes it's not clear whether some work or achievement is going to be recognized during the lifetime of the person, and there are many examples where that's actually the case. And it's not like people wake up in the morning and say, "Let's look at the list of Nobel prizewinners again!" Life doesn't work this way. I think it's important to recognize achievement, but at the same time people who maybe are not recognized at the level they expected shouldn't feel that they're failures.

Aspaturian: Do you feel that Israel at the time you were growing up was not a materialistic society?

Bruck: There was no material. [Laughter] I think it was probably materialistic in some neighborhoods and in some circles, but where I grew up we all had very basic stuff. I think it was very rare, very unusual, to own a car; we all used public transportation. We didn't have a phone or TV at home. We all had food; and there were no restaurants where I grew up. We were very happy. Since there was no material, then it's not a materialistic society. Of course now it's very different. I think it's very similar to the Western world.

Master's research & early IBM work leads to development of innovative signal & image processing algorithms

Aspaturian: When we left off last time, I think you were finishing up your master's degree and reapplying to Stanford.

Bruck: Yes. There were three years there that I worked full time at IBM-Israel, and I did my master's.

Aspaturian: And you were also the chief teaching assistant

Bruck: Yes. The first time I did research, actually, is during those three years. And I learned a lot.

Aspaturian: Did you do the research mostly for your master's or for the job at IBM as well? I know you said they didn't really converge a great deal.

Bruck: Both. They had one thing in common: they both were related to signal processing and specifically to image processing.

Aspaturian: Which was new, I think, at that time.

Bruck: Yes, it was new because at that time you couldn't store an image. And for my master's thesis I worked on techniques to compress still images.

Aspaturian: Like a standard photograph or illustration?

Bruck: Yes, a photograph. When we look at an image, the image is represented by bits, and each point in the image is called a pixel. When you make some compression, then maybe you lose the regional content, but from the subjective point of view, the image still looks good and you cannot tell the difference. So at that time there was a lot of work—and there still is—about this topic, and since this was my master's thesis I became an expert in signal processing and image-processing. In fact I liked the mathematical part more than the application aspect, because at the end you come up with some idea, and since the test is subjective it was not a clean solution. Then, at IBM, I worked on a project that dealt with using a computer to visually inspect printed circuit boards. At that time, in the early '80s, IBM built printed circuit boards that people inspected by eye. The idea was that perhaps a computer could help with this. Of course, today it's standard, but at that time it was not.

Aspaturian: You wrote the software?

Bruck: Yes, I came up with algorithms to inspect printed circuits boards, and I wrote the software that implemented these algorithms. In fact, this work at IBM on computer-based inspection of printed circuit boards resulted in my first issued patent.

Aspaturian: So it worked.

Bruck: It worked well. And I still remember the day I figured out how to have an extremely efficient algorithm to do it, and on that day, like every other day, my wife picked me up—we had only the one car. When I got into the car I told her, "Today I made the most amazing invention. It's so clean, it's so perfect; and I don't think I will ever reach this level in my career again." I felt so excited about it. It was the first time I felt I'd discovered something. It's an amazing feeling. And my wife didn't even look at me because she was driving. She said, "I'm sure you'll make many more discoveries even more amazing than that." However, at that time I really felt this way. I felt, this solution is so perfect, "how did I discover it?" You know, I was so amazed by that, because when you start working in research, then you look at what has already been accomplished, and you say to yourself—and I see this with my students— "How can I ever contribute? All of those smart people." It takes a while to understand what they did, and you're amazed by their creativity, and you say, "How am I going to fit in? What am I going to do here? They did everything. They knew more than I do." It looks like a very tall mountain. So it was a great feeling

suddenly to be able to come up with some clean idea that is very useful.

Aspaturian: When you say an efficient algorithm, do you mean one that could handle a great deal with a minimum of parts?

Bruck: Yes. That's a very good point. At that time, one of the key challenges was that you couldn't store images in the computer. The only thing you could do was what people call a scan-line algorithm. Imagine that you look at the printed circuit and you can only see a few lines. And you cannot remember the lines that came before, and there is no way to see the whole thing at once. And just by moving this limited window you have to make a decision if there is a fault in the circuit or not. You can remember only very limited information from previous lines and based on that decide whether the circuit has any problems. Because we couldn't store much. Computers didn't have much memory, and they worked very slowly, so the challenge was how to make the computer usefully do things that humans do. We knew how we would do it if we had unlimited computational resources but we didn't have them.

And interestingly enough, today we are at the point where we have in a sense unlimited resources, but we don't have ideas about how to use them. If you look at where we are now, at the companies that are doing well, like say Facebook or Twitter, there is limited innovation in technology. People invent more and more apps, but basically they don't know how to use the wealth of resources we have. In the early '80s it was the

opposite because humans were much better than computers, and the question was, how do we use computers to help humans a little bit? So this was the first project at IBM.

Aspaturian: Was your algorithm one that could handle a scan globally?

Bruck: Yes.

Aspaturian: It didn't take things piecemeal and try to accurately assess the whole.

Bruck: Yes, it could get the whole thing.

Aspaturian: No wonder you were so excited.

Visits North Carolina's Research Triangle Park on first trip to US; IBM R&D work on video compression

Bruck: Yes. And it's the first time I went to the U.S.

Aspaturian: While you were still in graduate school at the Technion?

Bruck: Yes, but I went there as part of the IBM job

Aspaturian: Where did you go?

Bruck: I went to Raleigh, North Carolina. Research Triangle Park. And my first visit to the U.S. was pretty impressive.

Aspaturian: It must have been around, what, 1984?

Bruck: '83.

Aspaturian: Okay.

Bruck: My English was a disaster.

Aspaturian: Well, you were in the South, too.

Bruck: I was in the South. I couldn't understand what they're telling me, and they didn't understand what I'm saying. I went to talk about the IBM project I worked on; the goal was to raise funding to renew and expand the project. It went well; the new funding came through. It was the first time I gave a presentation in English, and the first time I was trying to raise funding for a project. At that time there was no PowerPoint, just plastics; I still have many plastics here. Plastics? Foils, they're called?

Aspaturian: Transparencies.

Bruck: Transparencies, yes. And I wrote on them with marker, and I still remember that I didn't sleep much the night before giving the presentation. I basically rehearsed the talk most of the night, and then finally I fell asleep. So I was very tired, and I remember when I came to give the talk, the host, who was very nice, said, "Perhaps you want to drink something?" So we went to a vending machine, which was unlike anything I'd ever seen.

Aspaturian: You'd never seen one before?

Bruck: Well, not at this complex level. And I still remember—I picked a hot chocolate, and of course on the way from the vending machine to the seminar room, I lost control over the hot chocolate and it spilt all over my pants. Now you have to understand: I didn't have those nice pants before going to visit the United States. My wife and I went and got some new clothes, and I was wearing these light-colored corduroy pants. I still remember this from thirty-three years ago.

Aspaturian: This must have been the fall. Hot chocolate, corduroy.

Bruck: Yes, I think so. I had the color brown on one side of the light corduroy, and the other side was kind of white. So this was the beginning of my presentation career. [Laughter] I felt that the talk didn't go very well, but afterward we had a discussion about the project where I used the whiteboard, and they had many questions and that went very well, and they gave us the funding. I felt a sense of achievement; it was the first time I raised funding. [Laughter]

Aspaturian: And your first exposure to America, also.

Bruck: Yes. So this was the first project. The second one was related to compression of video.

Aspaturian: That early?

Bruck: That early. And it seemed like an impossible project because technically, you know, video consists of frames, and

there is some number of frames per second. The video is stored as frames, and when you play it you need to show the frames at, say, fifty per second or twenty-five, whatever the rate is. The problem is that when you do compression, you treat each frame separately, so you need to store the frames and then show each one. There was no device, not anything, where you could store frame by frame, and even if you could, how would you show them at this very fast speed of video?

So we purchased a used device, about the size of a refrigerator, that had what they called an analog disc; it was like an LP. And you write those frames on that disc and then read it. You could store forty seconds of video that way. The cost was close to a million dollars for this device. It took a while, but finally it arrived and came through customs, and we could start using it. I learned a lot from this; it was an amazing year. So you see that many of the things I did at the beginning brought together conceptual work and mathematical theory as well as implementation. At that time I did a lot of application work and implementation.

Awarded Rothschild Fellowship for PhD study at Stanford; relocates to Bay Area

So while doing all of that, I decided to reapply to Stanford for my PhD, and I got very good recommendation letters from my master's advisor, from the people that advised me at Eindhoven, from the people at the bioengineering department in

Israel that I built the system for, and of course IBM people. So overall, I had pretty good support from everyone, and I had good grades. So I got accepted again.

Aspaturian: Did you get a fellowship of some sort, I assume? How were you funded to do this?

Bruck: That's a very good question. I got a fellowship from Stanford; it was like $700, maybe $720 a month. Now this was the normal fellowship. But I was married, and our son was born, and the rent, because we were a family already, would be about $500. So it seemed like a bit of a challenge to start the month with a balance of $200. We had some savings because both of us worked during those three years, but not enough. So I had the tuition and a stipend from Stanford, but we needed additional income.

Aspaturian: Sure, you needed some money to live on.

Bruck: In Israel there is a very prestigious fellowship named after Rothschild. Today they give it just to postdocs, but at that time they also gave it to a few grad students selected from all over the country. Every university in Israel—Weizmann, Tel Aviv, Hebrew University, Technion—nominated people from all areas, not just science and engineering. So I was nominated and eventually got to the final stage, which was an interview in the Jerusalem headquarters of this foundation. I think about half of the interviewing panel was actually from the U.S. or

Europe. I remember one impressive guy there, Berlin—he's a philosopher.

Aspaturian: Isaiah Berlin?

Bruck: Yes.

Aspaturian: He was on the Rothschild committee? That's interesting.

Bruck: Not the composer.

Aspaturian: No, the hedgehog or the fox guy.

Bruck: Exactly. Of course, again, it was all in English, and I tried to connect to my "English" personality. [Laughter]. It was hard to know what to think, because it's very competitive, but after a few days, they were supposed to let us know. They told us, "Don't call, we will call you." As it turns out my mom had to go in for surgery later that week, and I asked the secretary of the foundation if she would call the IBM office and tell the secretary there if I got a fellowship, since I would not be there. And they were very nice. She said, "If we don't call, it means you didn't get it. If you get it, we will call." And on the day they were supposed to call, I was with my family at the hospital.

Every time I had an opportunity I called the IBM office from a payphone, and the IBM secretary said, "No, I didn't get any call." Everything worked out well at the hospital; my mom is still with us. [Laughter] And then it was night, and I told my

wife, Anat, "You know what"—because we felt that if we don't get the Rothschild, we will not go to the US, because we will not have the funds to support ourselves—"I'm going to drive to the IBM office. I must see if the secretary put a note on my desk." I drove to my office and my desk was empty. So I went home.

The next day I went to work and asked the secretary, "Did anyone call?" And she said, "No. I'm sorry about that." I am an optimist, right? I said, "Maybe I will call the office that coordinated the fellowship at the Technion, to ask them if they know anything." Because I really wanted to get some closure on that. I called there, and the first thing I heard was "Congratulations!" I couldn't speak; I was speechless. She said, "They called yesterday and informed me that you won the fellowship." I was delighted. The fellowship people somehow got confused and called that office instead. And Stanford was very nice, given that I had already a child and was married. They allowed me to use both the stipend and the fellowship. It looks like small things today, but the fact that I remember it so clearly means that it was very critical at the time.

Aspaturian: How many of these Rothschild Fellowships were awarded annually; do you remember? Was it a dozen?

Bruck: Maybe. I don't know

Aspaturian: Sounds like it was very competitive.

Bruck: Very competitive. I just wrote a recommendation letter for a grad student in Israel who wants to do his postdoc in my lab, and he applied to Rothschild because they provide generous funding for postdocs. When I write these recommendations to the foundation, I always thank them for the support they gave me.

Aspaturian: Were there particular people at Stanford whom you wanted to work with at the time you applied?

Bruck: Your questions today are excellent!

Aspaturian: You mean they weren't good last time?

Bruck: They are always good! However, now you sound like a Jewish mom. You know when you tell a Jewish mom, "This is a great meal that you prepared," she says, "What was wrong with the meal last time?" I am used to it. [Laughter]

It was interesting because when I applied the second time, I looked at all the professors at Stanford, and I also talked to some friends. One of them had actually come back after doing his PhD at Stanford to work for IBM in Israel. He had worked with one professor who seemed very interesting: Martin Hellman. In fact he just won a Turing award [2015]. He invented public key cryptography many years ago. It's a way to send encrypted information in such a way that no one can tell what I'm sending you, but I do it without coordinating anything with you. Conceptually it feels like it's impossible, but practically, if

it is possible, then it's extremely useful, which it is. Professor Hellman came up with this idea, together with his student [Whitfield] Diffie. My friend worked with him, and I thought, "That's a cool topic, cryptography," very mathematical and so on. Other than that, I didn't have enough information and guidance.

The way it works in EE at Stanford, similar to EE here at Caltech, is that a professor accepts you, so you know whose group you are joining. The professor that accepted me, Professor [Bernard] Widrow, is an expert in signal processing. I think he accepted me because I'd worked in this area for three years—but I didn't want to continue in it.

Aspaturian: Was the CS department embedded within electrical engineering?

Bruck: At Stanford? No, it was separate.

Aspaturian: But you applied for the PhD in electrical engineering. Why is that?

Bruck: Yes. It was very hard to get into CS at that time if your background is EE and vice versa. That's what I was told. And I felt that in some sense it doesn't matter, and so I applied to EE. At Stanford there are two components to entering the PhD program. One is that the advisor accepts the student. The second is that there is a qualifying exam during the first year. The qualifying exam is a weeding out, to be blunt, because I

don't feel like a weed. Half the entering class passes, and the other half fails. The top third—they do some complicated ranking—passes, the bottom third fails, and there is a discussion about each student in the middle third. It's a very scary event, especially for someone who comes to the US with a wife and a baby.

Aspaturian: Did you know about this when you applied?

Bruck: Yes. Some people, even today, feel a bit worried about it, to say the least. And that's one of our benefits here at Caltech: We do have a qualifying-like exam, but we tell the students, and it's true, that the goal of the exam is to test each one of them individually to assess if they have the right background, but we don't use it as part of the admissions process for the PhD. So in a given year, out of, say, twenty students, maybe all of them will pass, or maybe one or two will fail, and they can take it again; but most of the time we just say, "You passed. But perhaps you should take this class to strengthen your background." It is more part of the academic process than part of the admissions.

Shifts focus research from EE to CS; experiences funding crisis; meets future thesis advisor J. Goodman

So the first year in Stanford was very difficult for me. I think it was the combination of the language, being in a new country, the fact that we had a very young child—our first child—with

all the complexities around it, and just the adjustment to studying and helping my wife with the new family responsibilities. I was twenty-nine.

ASPATURIAN: I was going to say, given your service in the IDF [Israel Defense Forces], you must have been older than a number of graduate students.

BRUCK: Yes, most students there were twenty-two or twenty-three. And they were at a different stage in life. I was older because I served in the army; it's also an advantage, right? At least that's what I found. So the first year was a challenge. I wanted to change my advisor, which was not easy. Today when students come and talk with me about changing their advisor here or elsewhere—somehow they consult with me—I always tell them, "If you don't feel excited about working with the advisor you have, you have to make the change." Because you do a PhD only once, and it's a very critical decision, who will be your advisor. Now most people will not take the risk, because it might happen that you don't have a backup or an alternative. You might end up not having any advisor.

ASPATURIAN: So what happened in your case?

BRUCK: Because the Technion had a very, very strong undergrad EE program and I had also done a master's degree, there were not too many graduate classes in EE at Stanford that I was interested in taking. I knew this material; I had already studied it. So I mainly took classes in CS and statistics and mathemat-

ics, and I started looking around for a new advisor from CS. I did very well in the CS classes; however, you know how it works, it's a combination of the competition for the few slots and the funding that certain people have; and typically if you start the program with a certain advisor, it's likely that all the other advisors have already committed their funding for that year.

The other thing that happened, just to make things even more interesting: During my first year at Stanford, Professor Widrow, the advisor who accepted me to Stanford ran out of funding.

Aspaturian: What happened?

Bruck: I got a letter in the mail; I still remember that day. We lived in married student housing in Escondido Village, a fantastic environment. I get a letter in the mail; it comes through the slot in the door. I remember this; you know, suddenly you see something lying on the floor. Probably I still have this letter somewhere. The letter was very short. It said that one of the agencies that is funding my advisor decided to stop the funding, and as a result my funding will end at the end of the spring term.

Aspaturian: I didn't realize this sort of thing would happen at Stanford.

Bruck: Yes, well, it did, to me. My advisor had to cut funding for many people in his group. So now I'm in a position where

I'm here, not a US citizen and all of that, and the advisor I thought I had says he doesn't have funding. So definitely an interesting day for us. You know, it's one of those days that you want to urgently act, *do something*; however, you don't know what to do. That's why I tell students that they earn a very important benefit for their studies at Caltech if they pick the IST4 class in their freshman year, because if they ever get to a point during their lifetime at Caltech where they need to talk to someone, and they have no idea whom they can talk to, and it seems like a serious issue, they can always come and talk to me. [IST4: Information Science and Technology, taught by Shuki. – *Ed.*]

Aspaturian: Because you understand what it meant to be cut adrift like this.

Bruck: I understand what it means suddenly to be in limbo. And some of the students do. They send me an email; they come and say, "I took IST4, and I remember you said I can come at any point to talk to you about anything." I say, "Welcome, have a seat." At Stanford, I didn't have anyone to talk to like that. So one of the professors who really impressed me, when I took his class—he's probably one of the best teachers I ever met in my career—was Professor Joe [Joseph] Goodman. He taught a class about signal processing and optics.

Aspaturian: Was he in EE or CS?

Bruck: In EE. A very nice person, very kind, and a great scientist. So his area of research is optics—like the work of Professor Yariv and Professor [Ahmed] Zewail [Pauling Professor of Chemical Physics; 1999 Nobel laureate in chemistry; d. 2016]; it's all related to light. In fact, he wrote the bible on optics in 1968. I was not interested in optics, but I went and talked to him. And he told me that he doesn't have any funding.

J. Hopfield talk on neural networks & summer IBM job "intellectual highlights of my first year at Stanford"

Okay. So let me tell you two very wonderful things that happened during that time. First I heard a talk by a person called John Hopfield.

Aspaturian: He was at Caltech at that time?

Bruck: He was. I think John Hopfield and Carver Mead [Moore Professor of Engineering and Applied Science, Emeritus] started CNS [computation and neural systems]. I didn't know about that at the time. But Professor Hopfield came to campus, and he gave a talk about his work, and this was one of the intellectual highlights of my first year at Stanford. I said, "This is amazing. To try and think about the brain in the language of computer science."

Aspaturian: Was this the first time you had heard any of this?

Bruck: Well, it's the second time. Remember Joe Raviv, who was the head of IBM– Israel—he taught a class on pattern recognition, which had a small part related to perceptrons, also known as artificial neural networks. I got excited about it then, but no one at Stanford was really doing anything with that. So then Professor Hopfield came, and he talked about networks of perceptrons and their different properties. Now given all the CS background I had, immediately I had many different ideas of how to think about these computational structures.

A few years ago, as part of the molecular programing project, we had Professor Hopfield give the plenary talk, and Eric Winfree [professor of computer science, computation and neural systems, and bioengineering], who is the PI on the project, asked me to introduce John Hopfield. John was sitting there with his wife, ready for his talk, and I said something like, "Thirty years ago, there was a child sitting in the audience, and Professor Hopfield gave a talk about his work. And as a result this child started working on those topics and really enjoyed it and in fact ended up as a professor at Caltech"—and I said, "This child is me." [Laughter] He was so moved by that, and said he's happy that his wife was there, so she could hear that he made an impact on the next generation.

In any case, to hear him at Stanford was very exciting, but I didn't know whom I can work with on that. But I was lucky because I went back and talked to Professor Goodman, and he said, "You know, I got some initial funding for work on neural

networks; it's not clear if any more will materialize." I think it was from the air force. He said, "How about if I give you some papers to read, and we'll talk about it." I said, "What about the summer?" because I needed funding. He said, "I don't have funding through the summer. But maybe in the fall." He gave me those papers, and I had a lot of fun working through them, thinking about those problems, and fairly quickly I had many interesting new ideas and research results.

I still needed to find a summer job, so I would have support for the summer. I reached out to a person who used to be a grad student at Stanford and was now working at IBM Almaden in San Jose. He said, "There are always summer openings for grad students; how about if you apply?" I applied and was invited for an interview.

So there were these two highlights. One was Hopfield. The second was that I went to IBM, and suddenly I felt that I'm treated like a person. Because when you take classes and they cut your funding and you have to take the qualifying exams, you tend to feel a bit like a number. I went to IBM, and they hosted me and had me talk to many people about the work I did in Israel for my master's degree, and they made me an offer.

That was progress! Now I had a summer job, and I started doing work on what I loved, because I really liked this whole area of neural networks. Caltech was actually leading this wave in the '80s with the CNS program and the work of Hopfield and

Carver Mead. I think during those years they also hired Christof, in 1986.

Aspaturian: Christof Koch.

Bruck: Yes. Christof Koch. Also, there was a wonderful paper by Bob [Robert] McEliece [Puckett Professor and professor of electrical engineering; d. 2019] on the capacity of neural networks, so most of the interesting work in this field came from Caltech. Of course there was no internet, so I somehow figured out a way to get recent results and papers from here, and I became friends with two Caltech graduate students, Pierre Baldi and Santosh Venkatesh. Pierre worked in mathematics, and Santosh was in EE with McEliece and someone else. Pierre is now a professor in UCI [UC Irvine], and Santosh is a professor at Penn [University of Pennsylvania]. I am still in touch with them. They sent me some material from their recent work here. The summer of '86 was really a very important turning point in my career. The summer I worked for IBM, I wrote a very extensive paper exploring the connections between CS and the new area of neural networks.

Aspaturian: You wrote this for IBM?

Bruck: IBM Research at that time was like a university.

Aspaturian: They were interested in this field.

Bruck: Yes. So I wrote it as a tech report and later it became a journal paper ["A Study on Neural Networks," *IBM Tech Report RJ 5403*, 1986; *International Journal of Intelligent Systems,* 1988].

Neural network & error-correcting code work at Stanford & IBM yields "a wealth of new research results"; mentor influences during grad student years

Aspaturian: So both Caltech and IBM Research were ahead of Stanford in this area? They were pioneering neural networks, and Stanford was not?

Bruck: At Stanford there was work, I think, in the psychology department. A professor there, [David E.] Rumelhart, together with Geoff Hinton, invented backpropagation [an error-correcting algorithm designed to help train neural networks]. Hinton won the Turing award in 2018 for his work on deep neural networks. I was never able to get in touch with Rumelhart. There was work at Stanford but not—

Aspaturian: It was not concentrated anywhere.

Bruck: Yes, it was not concentrated. Also at IBM I really loved the environment. It was an environment where many senior people are available, because they don't need to do anything but their research. I remember walking in the corridors there and seeing names I recognized as people who had made really very important contributions, and suddenly I see them sitting right there.

Aspaturian: Did you feel more like a peer there than a graduate student?

Bruck: Yes.

Aspaturian: The hierarchy was not the same.

Bruck: Yes, and also, they were very kind.

Aspaturian: And accessible, it sounds like.

Bruck: And accessible. I learned a lot during those years. So what happened—just to accelerate it—I was exposed to other ideas. For example, during this time, I met Mario Blaum, who became a close friend of mine. He still works for IBM. He got his PhD at Caltech in mathematics—his advisor was Professor McEliece—and he is an expert in coding theory, error-correcting codes. So I started learning about error-correcting codes, even though it was not part of what I did for my thesis, just through my interactions with him. At that time, IBM had probably the strongest group in those areas that relate to dealing with errors in storage systems, and that became an area that I got interested in later on. But that's how it began, in '86.

Aspaturian: Whom did you wind up with as an advisor, and what was your dissertation about?

Bruck: Luckily, my advisor was Professor Goodman.

Aspaturian: So he did take you on as a student?

Bruck: Yes. Because, number one, he got the funding. And number two, after he gave me all those papers to read, I had a wealth of new research results within a very short time. And he was very happy about it. And because it was such a hot area at that time, and somehow because I had unusual types of results in terms of the connection between CS and computation, I received visibility way beyond what a grad student normally receives. For example in 1987, Yaser Abu-Mostafa [professor of computer science and electrical engineering] organized the first NIPS conference—Neural Information Processing Systems—which is still a very competitive conference. [*SB subsequently added:* In fact, currently (2024) it is the top conference in the exploding area of neural networks, with more than ten thousand attendees.] I had a paper, with a real presentation, for that first conference [*See also Session Four*].

Aspaturian: As a graduate student.

Bruck: As a graduate student. Then I was invited to give talks, invited to workshops, and I did a lot of things that typically grad students don't get to do. And my advisor gave me a lot of freedom in the sense that I did most of the work on my own.

Aspaturian: What was the title of your dissertation?

Bruck: "Computing with Networks of Threshold Elements."

Aspaturian: In layperson's terms, what does that mean?

Bruck: Computing with neural networks. [Laughter] I don't know which one is simpler. So it was fun. I kind of had all the material for the thesis after a year and a half. Typically a thesis takes more like four or five years to complete. I think the key was that I really enjoyed that.

Aspaturian: Was your dissertation basically mathematical in nature?

Bruck: Yes, the whole of it was mathematical. I really loved doing it, and I also think that because I had done research before at IBM and for my master's, I already knew how to manage myself in terms of research.

"The most important period of my career was really those Stanford years where I built the foundation of my knowledge"

Aspaturian: How was your assimilation to the United States? Was there an element of culture shock at all? Did you feel comfortable?

Bruck: I felt pretty comfortable. Of course I never gave up my accent, but I felt comfortable. I felt that I fit very well, because the culture here—and I have always felt this way—is that if you do good work, there is no limit to where you can get to. And I think the difficulty I had at the beginning was that I didn't have the opportunity to excel. I think that once I figured out the funding, and got an advisor who allowed me to work on

whatever I wanted, I just took off. And I didn't stop since then. It's the only time since coming here that I felt blocked, and it was the last time. At the end it worked out, and I'm glad that I drove this change. I'm very happy I worked with Professor Goodman, and I'm very happy I got to work with IBM Research. I worked with IBM full-time every summer during graduate school, and after that first summer IBM offered me to work there one day a week.

Aspaturian: You commuted to San Jose and back?

Bruck: Yes, it was 30 miles between there and Palo Alto.

Aspaturian: I imagine traffic wasn't as bad then as it is now.

Bruck: No. Financially those jobs helped a lot, and also Anat was able to get a teaching job at the JCC [Jewish Community Center] in Palo Alto. After the first year, we were stabilizing our life. I think we'll need to stop soon.

Aspaturian: I have one quick question.

Bruck: Please go ahead.

Aspaturian: Do you think the fact that you had spent several years in the military, which I think was an experience that probably very few of your peers had—unless they were fellow Israelis—affected your approach and your attitude? Your age aside, did you feel more mature?

Bruck: Much more.

Aspaturian: I would think even perhaps more than some of the junior faculty.

Bruck: Yes, some of the junior faculty didn't have a family, and maybe they were about my age or a bit younger.

Aspaturian: They hadn't had your experience, either.

Bruck: I think resiliency is something that you need to develop through experience. Of course there is a basis in the personality for this—some people have it naturally, some people don't. I have it from experience, but I also felt that I had the resiliency inside. I grew up in a family that went through a lot, so I think that's something we both have, my wife and I, and life here was not hard. It sounds like hard, but we had a lot of fun.

Aspaturian: I would think in some respects life in America must have seemed softer than what you were used to.

Bruck: It's much easier. Firstly, I tell people that in America it's a society with no friction, because all the routine is very easy to manage. Very easy. The only thing you need to do is your job, and to do it well. And there are no distractions—there is no sudden war; you're not called to the reserves; you don't spend two months a year in the military. I was so used to being highly efficient and always focused, and suddenly life becomes extremely simple. As I said, this is very easy.

I remember that at Stanford, we were four grad students sharing an office. And I would come in the morning; I had my lunch that I'd prepared at home, and I will sit there the whole day. I will only go to the restroom. And they would do this and that, and played tennis, and they always asked me, "How come you can work the whole day?" I said, "I love it. It's an opportunity; I'm really enjoying it. I'm not going to waste my time doing anything else." The most important period of my career was really those years at Stanford where I built the foundation of my knowledge and also understood how I can manage myself, my brain, when I try to think about new problems.

Aspaturian: It sounds like in some sense you advanced exponentially during that period of time.

Bruck: Yes. Definitely.

Session 4, November 8, 2016

Intellectual & historical foundations of CS & information theory; working with field's leaders at Stanford

Aspaturian: This is November 8, 2016, Election Day in America. I have a couple of questions, but I'm not sure in what order you'd like to answer them. The first one is that most young people going into the sciences go into a fully-fledged field, with

a rich history and intellectual tradition—some heroes of the discipline and that kind of thing—whereas computer science, when you went into it, did not have, it seems to me, these very deep roots. I guess you had Alan Turing and Claude Shannon and other people who I've never heard of, but it's not something that went back, as far as I know, many dozens of years. So it struck me that in terms of the intellectual background and culture, it was something you were building from the ground up. And I wondered how that affected your thinking, if it did, and what kinds of challenges and opportunities it gave you?

My second question is that I'd like to know more about your PhD thesis. Since you were hired at Caltech four years later, I'm sure it was on something pretty significant. We didn't talk about that last time.

Bruck: Yes, those are really good questions. You see, I think there is a rich history, and I was just very ignorant about it. What I discovered is that I was not special in my ignorance because people are still very ignorant about the history of information, and this was the reason I created the class IST4 [*Session Twelve*]. There are some very deep ideas related to information that people have worked on for thousands of years; and today when we look at smart phones and all the computing powers and the fact that we can communicate so efficiently and reliably, we are seeing the artifacts that resulted from those ideas. But I never heard about these concepts in school. I had

probably only heard about Turing and [John] von Neumann, and I didn't know much about what came before them.

So for me at Stanford it was all like a "wow!" experience, because suddenly I take a class with Tom [Thomas M.] Cover. He was teaching information theory. He died a couple of years ago. And he really was very inspiring to me, because I could see that he really understands this material very deeply. He is someone who met Claude Shannon—who unfortunately I never met—and he has contributed to the area of information theory from the beginning. So I could get a sense of context and the bigger picture taking his class. So that really influenced me. The TA of this class was Joy Thomas, and he and Tom actually ended up writing a book [*Elements of Information Theory*, 1991]. It is the best book in information theory, and everyone is using it. And when they were done writing it, Tom sent me a copy. He was my associate PhD advisor at Stanford, and I used to go and talk to him. So that's on the information theory side.

And then I took classes with two people in computer science: Christos Papadimitriou, who's now a professor at Berkeley, and Andy [Andrew] Yao. And they were both in at the beginning of computer science. I also took a class with Jeff [Jeffrey D.] Ullman and a class with Don [Donald] Knuth, who was actually a Caltech graduate; he, Yao, and Ullman won the Turing award in later years. So suddenly I saw the people who created the field and really understood the area very deeply. It's a very

different experience than in Israel where I learned from people who knew the material extremely well but typically were not as involved in the creation of the ideas.

ASPATURIAN: So at Stanford you were taking classes from people who were inventing the field.

BRUCK: Yes. It's very hard to describe verbally what it means. But basically it's not the content that matters when you take a class with someone like that, it's more the context—how to think about a whole topic. You feel that it's part of you, somehow, and it's not just the syntax.

ASPATURIAN: Kind of an intellectual osmosis for you.

BRUCK: Exactly. I really enjoyed that. I felt that there was both a very, very deep foundation there, but also many opportunities to study new topics. So I'm not sure where I got it, but my research style was, and still is, that I don't identify myself with any given area. At a given time, I'm interested in a specific topic, but in general I have worked in quite a few topics and I have enjoyed that. I don't see these as separate topics. You know, disciplines were invented by people; they do not exist independently in the real world.

ASPATURIAN: Yes, we've talked about this [*Session Two*].

BRUCK: And of course, Caltech is very special in this sense. When students study here, I think most of them understand that while they have a major in EE or CS or physics, or

whatever, there is a whole spectrum of study, and there are no boundaries. It's not clear how to teach students to understand that disciplines are an invention and that we keep changing the disciplines, but it is easier to see that at Caltech. If you go to a big university, you say, "Well, I have no clue what they are doing on the other side of campus." Here you get to meet people from all over the campus whether you are faculty or a student.

So my background is in electrical engineering, computer science, and mathematics. I love the depth of it, and I think the opportunity that I saw when Hopfield gave his talk at Stanford was that I understood that he's talking about a computational structure—what is known as the Hopfield model. But the tools he and most other people were using—he was trained as a physicist—were not tools that are taken from information theory or computer science. They were using different tools and asking different kind of questions. So suddenly I started asking questions related to those brain-like structures, using tools that are very different from the ones Hopfield and his scientific community were using. I got those ideas by being at Stanford. I felt like I'm in a green field, and I basically can run and play with that as much as I want.

So I felt extremely productive, and I also learned a lot. At that time there was no internet, so every week I spent at least a day at the Stanford mathematics and computer science library. Typically it started by deciding that I'll spend a few hours in the

library to go over a few things that I want to read about—some new papers and all of that. We actually had to copy the papers, and there were those big books with references, so you keep looking for citations and so on. But I ended up staying there until the evening. I couldn't leave the library once I went in. [Laughter] So I learned a lot. A lot of my basic knowledge comes from those very long days at the Stanford library.

Extends Hopfield network model to formulate unified convergence theorem as part of thesis

Aspaturian: So your thesis, what was it about? You said computing with neural networks, but what was the central premise of it, in layperson's language?

Bruck: There are different aspects; I'll give you maybe a taste for them. Hopfield's paper from 1982 discussed a structure in which you have a graph with nodes, and edges connecting those nodes, so it looks like a network, right? You can think about each one of those nodes as a single neuron that computes, and that the computation is done locally. Think about people: Today we talk about social networks where each person communicates with a few people. And then from these local interactions, you get some global behavior. Maybe the global behavior is the mood of the nation. But it's not like everyone talks to everyone else. We kind of talk to each other, and somehow there is something that emerges out of that.

Aspaturian: I was going to ask about emergent properties, which you do not necessarily expect to see from the local behavior but which inevitably emerge globally. Was this part of what Hopfield was dealing with?

Bruck: Yes.

Aspaturian: I can see that would have been very exciting.

Bruck: His idea came from physics where you think about, say, the phase transition. You have a liquid and then you change the temperature and somehow, suddenly, there is an emergent property, which is the liquid turning into a solid, but it's not like you need to tell each one of the atoms what to do.

The models that Hopfield was looking at had properties that under some conditions will—it's like the brain—wander around. But then these always get stuck in a stable state. And if you think about the brain, it's not like there is, as far as we know, some central point that's controlling it. Instead there is a lot of flow of stuff. And then somehow reasonable things happen. And that's something we still don't understand.

Aspaturian: Yes, I know exactly what you're talking about.

Bruck: It's like, say, when you look at a person, and maybe it's been five years or ten years since you've seen them, and suddenly it comes back to you who they are. It's all in pieces, and it converges—fascinating. We still don't know what the heck is going on. So I was really fascinated by that, and Hopfield had a

beautiful paper where he showed that the mathematical model of neural networks with local interactions, starting from any state, will always get stuck somewhere; metaphorically speaking, it always converges to a conclusion.

ASPATURIAN: He was able to put this into mathematics that you could follow as well?

BRUCK: Yes, he was able to prove that we are not going to go in circles, but you go and get stuck, because the other option is maybe you go and come back.

ASPATURIAN: An endless loop?

BRUCK: Yes. It happens to all of us. We think about a topic; we think we make progress; and then we come back to the beginning. But those models had this fascinating property. So I was very fascinated by that. I said, "Okay, this is a proof, but what is actually going on?" And so I was trying to look deeper into this behavior and at that time there was a grad student here at Caltech, Pierre Baldi, whom I interacted with.

ASPATURIAN: That's right, you mentioned him [*Session Three*]. He was a mathematician, I think you said?

BRUCK: Yes. He's now in computer science at UC Irvine. He told me that under some conditions there is a result where instead of getting stuck in one point in this big space, you actually get stuck in two points and you oscillate between them. I said, "That's amazing!" So I asked him, "What is the proof for

that?" and he said, "I don't know; I don't remember where I saw it." And at that time, it was hard to find papers. So that night, after he told me that, I was trying to see how to prove it; and what I discovered is that those two properties—the one that gets stuck in one point and the other that oscillates between two—are actually from a mathematical perspective identical.

ASPATURIAN: Is it anything like the wave-particle duality?

BRUCK: I don't know.

ASPATURIAN: It's the one, but it's also the other?

BRUCK: I think this one is much simpler. [Laughter]

ASPATURIAN: Ah, I see, so they were equivalent.

BRUCK: Yes. So I found another behavior that is very, very simple and easy to prove. And that from that you can derive both Hopfield's result, and the result Baldi told me about. I felt that I finally understood that. And it turns out that no one had observed this general result before. I did because I tried to understand it. Then I found another paper describing how under some conditions the system actually always goes to a situation where it is oscillating in a circle between four states instead of two, and always exactly four. And of course I was able to prove that also as a consequence of this simple framework that I had. So I wrote a paper unifying those results. ["A Generalized Convergence Theorem for Neural Networks," *IEEE Transactions on Information Theory* 34, 1988], See also "On

the convergence properties of the Hopfield model", *Proceedings of the IEEE* 78, 1990)]

This was in the 1980s, and I believe this was my first paper in the *IEEE Transactions* on information theory. I didn't feel that there is much innovation there, but I kind of went deep and connected all of what was known.

ASPATURIAN: Yes, you synthesized a lot of things.

BRUCK: It made a positive impression, because now everyone understood it and could appreciate the unified convergence model. I gave talks in different places, and I was invited to teach it even though I was still a graduate student. This was fun, you know. I actually sometimes teach this result in my class because I talk about neural networks, and I like to present that.

Thesis research demonstrates computational advantages of neural gates over logic gates

So that's, I would say, the first result that I had in my thesis. And then I did something a bit different. In neural networks, the elements that compute are different than the elements that we compute with in normal circuits. In normal circuits we use very simple computational Boolean logic elements. They're AND, OR and NOT gates, so the logic gates, and the neural gates are a bit different.

ASPATURIAN: They're more complicated?

Bruck: They're a bit more complex. I was trying to understand how we can compare the efficiency of computing with one versus the other. This topic is very, very important, because you ask yourself how come we converged to this type of computation in the brain.

Aspaturian: How did biology choose this.

Bruck: Yes. I was trying to understand what the benefits are of using this special computational element. And so there is an area in computer science called circuit complexity—the complexity of circuits, and specifically logic circuits. And I fell in love with this area.

Aspaturian: Which must have been in its infancy.

Bruck: Yes. So suddenly I was contributing to circuit complexity as well as to neural networks. And there were not too many people that knew much about both. And the beautiful thing about circuit complexity is that it's very difficult to make progress there, so for many years they kept inviting me to workshops, and when I went to one of these workshops I always said jokingly that even though I've stopped working in this area, it takes me no more than five minutes to catch up because the progress is so slow. [Laughter]

Aspaturian: Is this because biology is inherently kind of messy?

Bruck: Exactly. So what I was able to prove is that the big benefit of using neural type elements instead of logic gates is that you can compute things in a relatively very shallow network. So things that take a long time to compute with a very deep network of logic gates take maybe two hops to compute with neural gates. So that's something I was able to prove.

Aspaturian: I see. That must have been considered something of a breakthrough at the time.

Bruck: Yes, I think it was, but there are still many things that we don't understand. But if you think about it, if you are an early human who can't make a decision fast, you would probably be eaten by a lion, so there is an advantage to making decisions quickly. And of course there are different tradeoffs. My first EE student here, in collaboration with a student of Carver Mead, designed a chip based on those ideas that computed those interesting functions, and this student ended up starting companies doing those kinds of things.

Aspaturian: Were you working in what we would today think of as fuzzy logic? Was that to some degree related to this?

Bruck: No. I know what fuzzy logic is, and I met with its inventor, Professor Lofti Zadeh, at Berkeley, but this is a bit different. Fuzzy logic is using probabilities. Later on, motivated by DNA computing, I did work on circuits that generated probabilities. Studying circuits with neural gates was a major piece of the work in my thesis. In electrical engineering, it's very

common to use a mathematical tool called Fourier analysis, where basically instead of looking at amplitudes, you look at the frequencies, so it's just a different representation of the same thing. There's no magic there; it's just trying, again, to look at things from a different angle. And I discovered that with those neural gates, it's very useful to use Fourier analysis.

So that evolved into a very interesting set of papers and was a key tool to proving all of those results. And actually this part still is making an impact today. For example, there was a student, Jeffrey Jackson, at CMU in the early 1990s who started using the results I had in my thesis to prove a very nice result in computational learning theory. It is interesting how I learned about his work. At the time, I thought, maybe I will go and participate in a conference on computational learning, because I wanted to teach computational learning as part of a graduate class that I was teaching then at Caltech. I do it sometimes: I go to a conference not in my field, where I don't know anyone, and it's fascinating to attend the talks because the learning curve is very steep. So I went to this conference, and suddenly I noticed that quite a few people there referred to my work. It was a surprise. I went to talk to Jeffrey Jackson, and he was very excited to meet me.

ASPATURIAN: He didn't know you were at his own conference?

BRUCK: That's right. [Laughter] So it was fun. I ended up learning more about the work, which is beautiful, and teaching it, because then I connected it to other topics. At the time I was

also collaborating with some people from Berkeley, and this line of work continued after my thesis as well.

Publishes pioneering paper demonstrating intrinsic limitations of Hopfield model in solving complex neural network optimization problems

There are a number of theoretical research results in my thesis; let me just mention one more. Hopfield and [David W.] Tank wrote a paper about solving difficult optimization problems with neural network ["'Neural' computation of decisions in optimization problems," Biological Cybernetics, 1985] They addressed, as an example, the so-called Traveling Salesman Problem [TSP]. [SB subsequently added: TSP is defined as follows: Given a set of cities and the distances between each pair of cities, the objective is to find the shortest possible route that starts at one city, visits every other city exactly once and returns to the starting city. TSP is classified in complexity theory as an NP-hard optimization problem, meaning that there is no known algorithm that can solve it efficiently for large numbers of cities and it is conjectured, and likely true, that efficient algorithms do not exist.]

This paper had a lot of visibility from about 1985 on. Clearly, the theory of NP-hard holds for Hopfield networks, so to solve TSP it must compute for a very long time. I was fascinated by this and then I spent time thinking about it one weekend when I asked, "Can the Hopfield network solve the Traveling Sales-

man Problem even if it computes for a very long time?" I ended up showing that you cannot get good results with Hopfield networks for optimization problems, even if you let the network run for a very long time. In fact, the solution you get might be very far from the optimal solution "On the Power of Neural Networks for Solving Hard Problems," *Neural Information Processing Systems*, 1987.

ASPATURIAN: Is that intrinsic to the structure, or simply because the structures weren't sophisticated enough?

BRUCK: It's intrinsic. You're going deep; I'm impressed.

ASPATURIAN: You explain it well, so I'm following you.

BRUCK: It's intrinsic to the fact that those structures can only perform a local search. What is local search? Say, you are walking somewhere in the mountains and you want to find the highest point, but the best you can do is to just look very closely around you and walk in the direction that leads to a higher point—that's called local search. I was able to prove that because this structure is leading to local search, then it has a limited ability to solve problems optimally.

ASPATURIAN: In other words, it's self-limiting in some sense.

BRUCK: Yes. I remember talking to a friend about it and saying, "You know, I have this result, but I didn't think it's worth sending to a conference." And he said, "Why? It's very interesting. You should do it." So I wrote a paper in a few hours and

sent it to what is called the NIPS conference. It was the first year of the conference, which has now become very prestigious, arguably, the most prestigious conference in the exploding area of machine learning. The program chair that year was our own Professor Yaser Abu-Mostafa, and it was held in Denver.

ASPATURIAN: Yes, you mentioned this last time [*Session Three*].

BRUCK: So this was in '87. And the paper was not only accepted, it was accepted for oral presentation in the main track. I went there and gave the talk, and I think that's the first time that Yaser and other Caltech people noticed that here is a guy who came from nowhere, and he has all of those interesting results.

ASPATURIAN: A couple of years before you got your doctoral degree.

BRUCK: Yes. The PhD research itself took about a year and a half. I started my research with Professor Goodman in the fall of '86, and I made good progress. In 1988 I was working on what I thought were some difficult research problems—and I still think they're difficult problems—for a few months, and I remember that during spring break in 1988, I went with Anat and Or, our son, who was about three years old, to Yosemite. At that time Anat was pregnant and Gal, our daughter, was born in July of '88. During the evenings there, I was working on this problem, and I solved it in Yosemite, and I told Anat, "I'm done

with the thesis! I just solved the problem that was the missing piece for completion."

Aspaturian: Do you call it the Yosemite Solution?

Bruck: [Laughter] The funny thing is, I was looking for a function that has some properties, and I didn't know if it existed, but I knew that if I found it, with that I could solve the problem. I was able to find it. And then a few years later someone wrote a paper and showed that actually there is only one function like this. So I was looking for a function with certain properties out of many, many functions called Boolean functions, and I still consider it good luck that I found it, because I am not sure how I would have proven this result without the existence of this function, and there is just the one.

Aspaturian: And you plucked that one out while you were in Yosemite!

Bruck: [Laughter] I must say I was lucky in life.

Stanford graduation 1989, with PhD advisor Joe Goodman affixing the hood (left) and with Anat, daughter Gal, son Or, and balloon. *Photos courtesy of Shuki Bruck*

Visits Caltech for job interview; initial meetings with EE/CS faculty & memorable encounter with J. Hopfield

Aspaturian: So after you finished your work at Stanford, did you think about an academic job immediately? I note that you stayed on at IBM for a few years.

Bruck: Yes, I'm not sure what was going through my mind. I was not very sophisticated.

Aspaturian: Not too career-oriented at that time?

Bruck: Yes. I really enjoyed being at Stanford, and then in 1988, I came for an interview at Caltech. In '86 Caltech had started a CNS program.

Aspaturian: I remember that; I remember writing about it.

Bruck: And in '88 there was a search for a new CNS faulty member. Yaser was the chair of the search committee and he invited me to apply.

Aspaturian: You had not yet gotten your PhD.

Bruck: No. I may have already scheduled my defense for November of '88, and I was also writing papers throughout this time. So I came to interview here, and IBM Almaden, where I was working part-time, also asked me if I was willing to interview there, for—call it a permanent position. At that time IBM jobs were kind of lifetime jobs.

Aspaturian: Yes, it was like Murray Hill [New Jersey], I suppose —Bell Labs.

Bruck: Yes, it's not true today but at that time it was equivalent to having a job at a top university. And I really loved IBM as well. So I interviewed at IBM and I interviewed here.

Aspaturian: How do you remember your first visit to Caltech?

Bruck: I came here, and I gave a talk, and it went very well because I had many interesting results.

Aspaturian: You spoke within the Division of Engineering and Applied Science [EAS] or was it a campus-wide talk?

Bruck: I remember there were many people at my talk—many faculty members and the search committee. And I met with people one-on-one. I showed all of these very elegant results, and Caltech was the pinnacle of neurocomputation at that time: Suddenly here comes this guy from Stanford presenting all these new ideas. I received really good and kind feedback from many people who were here, like Bob McEliece and [Edward] Posner and Yaser Abu-Mostafa, and Demetri Psaltis, and Christof Koch.

I had actually met Bob McEliece in Almaden because my collaborator there, Mario Blaum, got his PhD at Caltech, and Bob was his adviser. So I had a good degree of familiarity. I was really impressed by Caltech, very impressed. There was one incident that for the sake of history I will disclose, but it's not a nice story. I went to interview with my hero—with John Hopfield. John is a great guy and is obviously very deep and knowledgeable. I'm not sure what happened, I speculate that perhaps the way I was presenting ideas in my talk triggered some negative feelings in him, and it came about in the interview: I entered his office and was of course very respectful—you know, I was thirty-two years old—and then, a surprise! He pulled out a resistor from the drawer of his desk!

You know what a resistor is—it's an electrical component that current goes through, and they have different values of resistance. And the way to mark the resistance is with color-coding; there are those circles in different colors. So you look at a resistor and you can tell what the resistance is, based on the color-coding.

I was sitting across the desk from John Hopfield, and he pulled a resistor out of his drawer, and he threw it across the desk to me. So I caught it. And he said, "You are saying that you are an electrical engineer in your background." I said, "Yes." He said, "What is the resistance of this resistor? So what I did is, I rolled it back to him and said,"I don't know, and I don't care. I know that there is a color code, and if I need to figure it out I'll just look at the book with color codes, but right now I don't remember what each color stands for." I think that created a delay of five years in my hiring. [Laughter]

Aspaturian: Really?

Bruck: Well, that's one option, maybe not.

Aspaturian: Why do you think he did that? I mean, Hopfield was not an electrical engineer either.

Bruck: He was a physicist.

Aspaturian: He was a biophysicist.

Bruck: I don't know, I never talked to him about it and of course I already mentioned to you how I introduced him years later when he gave a talk at Caltech [*Session Three*].

He inspired me to work on my ideas so of course I had a deep respect and admiration for him. But I learned something from that. Mainly in the way I treat other people.

Aspaturian: Do you think he vetoed your hiring as a result of that?

Bruck: I'm not sure. I never really checked. But I was hired while he was still here a few years later. So maybe my interpretation had nothing to do with the decision.

Aspaturian: That's so true. We don't always know what's going on.

Bruck: Yes. But this was an experience that I still remember because I felt unhappy with how I reacted. And probably I will react the same way today. It got me in trouble, this behavior, but somehow I'm here. [Laughter]

Accepts offer from IBM Almaden to initiate project in massively parallel computing: "I couldn't believe the names of the people on the doors"

Aspaturian: Here you are. So Caltech did not make you an offer but Almaden Research Labs did; is that what happened?

Bruck: Yes. Well, it's not that Caltech didn't make an offer: What I heard is that they need more time, and that I'm still one of the top candidates, but, you know at that time our daughter was a few months old, and our son was about three and a half. Anat was working at the JCC in Palo Alto, and she was very happy there, and the kids were happy with the arrangements they had, so I told Caltech, "Listen. I'm going to take the IBM job. This is the situation with my family. We love Palo Alto and we'll stay there, and we'll keep being in touch." And that's what we did. So I stayed in Almaden. I started in Almaden, and while being in Almaden I had an adjunct position in Stanford.

Aspaturian: You taught at Stanford?

Bruck: Not very often, but I had grad students. So typically on Thursday I will be in my Stanford office. I had two PhD students over those years; I used to meet with them on Thursdays. Also they typically spent the summer in Almaden. It was a very nice arrangement, because I lived next to campus, and on Thursday I didn't commute to San Jose but I worked on campus. It was a fantastic time.

Aspaturian: I was going to ask for an overview of what you did at Almaden, and maybe we can end with that.

Bruck: It was very interesting in Almaden. Again, at the time Almaden CS was probably one of the best computer science departments in the world. I would be walking there in the

corridor, and I couldn't believe the names of the people on the doors. It was very inspiring for me.

Aspaturian: What were some of these names?

Bruck: Well, John Backus, who invented the programming language Fortran. Suddenly you see him and you talk to him —"John, how are you?"—and he was a very nice guy. And then the people that invented the first relational database were there. [*SB subsequently added:* And then in theoretical computer science, there were people like: Mickey [Miklos] Ajtai, Nick [Nicholas] Pippenger, Maria Klawe, Nimord Megiddo, Larry Stockmeyer, and Cynthia Dwork, to name a few.]

Aspaturian: All these pioneers in the field were all together.

Bruck: Yes. And then I'd get an office in between those guys. So it was very, very inspiring for me as a young person. And since students are only there in the summers, you end up working with peers a lot. I was in CS, and then the coding and information theory group was in a different wing of the building. That's where Mario Blaum and Paul Siegel and others were. By the way, many of those people ended up in top universities when IBM Research fell apart in a sense.

So I was in an interesting position. While doing the PhD I worked in coding theory—error-correcting codes—which was not part of my thesis. I developed a separate career in information theory and coding theory. Hence, the two areas that I

knew: the neural networks circuit complexity from my thesis, and coding theory from the part-time job with IBM. And Almaden said, "We want to hire you to CS. We want to start an activity in massively parallel computing, and you are the first hire. What do you know about this topic?" I said: "Nothing." They said, "It's a new project. IBM doesn't have a parallel computer, and we think if you spend enough time on that, then you'll do well. Are you interested?" I said, "Yes. I love new challenges."

So here I was, studying a new area again. We started interviewing people to build a group, and after a few months they asked me to be the manager of this group. I didn't want to do it, but there were not too many other options, and in the end I decided to do it. We interviewed and hired some really fantastic people. I built a group with like ten people or more, most of them PhDs. And in some areas we had, again, probably the best group in the world.

Aspaturian: Was this the first massively parallel computer?

Bruck: Well we didn't build anything yet. That happens a few years later.

Aspaturian: Was this the first group to do it?

Bruck: No. At that time there were a few activities. There was Thinking Machine from Danny Hillis, out of MIT. Another

place with relevant activity was here at Caltech with Geoffrey Fox.

Aspaturian: Oh yes. The Cosmic Cube.

Bruck: And Chuck [Charles L.] Seitz. So those collaborations. In fact, when I was managing this group at IBM, I had a collaboration here with Paul Messina [director of Caltech's Center for Advanced Computing Research and assistant VP for scientific computing, 1987–2002]. And I gave Caltech some funding for two of my group members to collaborate with Paul. I didn't participate in that.

Aspaturian: You were giving away money at that point rather than looking for it?

"Now active in three communities": coding theory, neural networks & parallel computing

Bruck: Yes. But what happened is that while doing all of that in this new area, I still collaborated with storage people and on information and coding theory, and I still worked on topics related to my thesis.

Aspaturian: Neural networks.

Bruck: Yes. So I was active in three communities. And I remember that in the beginning of the '90s I went to an information theory conference—my first one was in '88 and I tried to

go every year. I talked to someone there, and he said, "You know, I notice that there is another guy here with exactly your name who works in parallel computing; do you know him?" And I said, "It's me." [Laughter] This is the story of my life!

But the great thing that happened, and I still remember that, it was over Christmas break 1991, I got a phone call from my manager. At the time IBM didn't have a parallel machine, so there were many discussions about whether they should acquire an existing technology or company or build one themselves. My manager calls, and he tells me, "Listen, you need to go to New York immediately, first week of the new year." I said, "What happened?" He said, "The top management in IBM has decided to build a parallel computer, and they want to aggregate the pieces that we have inside the company and to pool all the people who lead those activities into one room and decide how to pursue that." So here I am. I went to Kingston, New York, in the winter of '92. You know, it's pretty cold there.

Aspaturian: That must have been an experience for you.

Bruck: Yes. It's very cold and white. We were sitting in one room, this really tremendous IBM Research talent from all over the company. I was there, I think, for a week or two weeks. We made a plan, and everyone was supposed to deliver something. And the goal was to show a prototype of the first IBM parallel machine ten months later in a supercomputing conference that November, in Portland, Oregon. Ten months! This is like—impossible. And we did it; we achieved that, and my group built a

very important part of that computer. It was really like a startup experience for me to do it. That's kind of an appetizer for the IBM story.

ASPATURIAN: Okay. We will get back to it next time.

At IBM Almaden Research Center in 1991. *Photo courtesy of Shuki Bruck*

Session 5, November 21, 2016

Oversees development of IBM software for efficient communication across parallel processor

Aspaturian: Today is November 21, 2016, Election Day is over. . . . Last time we were talking about your work on massively parallel computing. At the time you were working on this at IBM, there were also huge developments in personal computing: Bill Gates with Microsoft, Steve Jobs at Apple. But you were in a rather different area. You were working with the mainframes?

Bruck: Yes, one of the original ones. So a mainframe is one big machine and has a very strong processor, or maybe a few, and a lot of memory and so on. The idea in parallel computing is the realization that it's much easier to get better performance by putting many, many machines together rather than to keep improving the speed of a single machine. The challenge, and it's still a challenge, was how do you write programs that run on, say, a thousand machines? The whole programming "model," as they say, is more difficult. Imagine that you have just one person whom you need to tell what to do: You tell them what to do. But suddenly, you have a big task, and you have a thousand people that you are telling what to do. And you want to make sure they don't argue all the time and that the work gets

done much faster than if you tell it to one person, which might not happen of course. Then it becomes a bit more complicated.

Of course today, if you look at Google or Facebook, what they do is they compute things in parallel—all the search engines, everything. They build huge clusters of machines, and they compute on those. And they build their own; they don't buy from the outside. So this technology became mainstream, in a sense.

Aspaturian: What was your role in all this? Were you designing mostly software, or did you also work on the hardware, or was it the integration of both that you were—?

Bruck: The people in New York had responsibility for the hardware. IBM built its own processor. This was at the IBM Watson Research Lab—it's the same person that our applied physics laboratory is named after, T. [Thomas] J. Watson. They had also the building blocks to build the network connecting all the processors. And what my group did was create a communication library, which is software that allows you to communicate very efficiently between the different known software systems—between the different processors. So if you want to broadcast a piece of data to all the other machines, then you just say, "Broadcast this thing," and it gets everywhere.

Aspaturian: Were you to some extent basing this on your neural nets research?

Bruck: No, it was separate. And all of this functionality was visible to whoever was writing the software. And what we were doing led to an industry standard, which is actually still the standard. It's called MPI—Message Passing Interface. We actually developed the first version of that, and we called the software we created CCL—Collective Communication Library. And the CCL became the MPI of IBM. I was able to say three acronyms in one sentence. [Laughter]

Aspaturian: Did this computer have a name?

Bruck: It was called the SP2.

Aspaturian: [Laughter] Okay.

Bruck: I remember going to meetings during that first period at IBM, and everyone was using acronyms. And I used to come out with a kind of vague idea what people meant. It took me a while to understand that. And then I discovered that suddenly I was using the same language, which a few months ago was completely not comprehensible. I think that the codename for this project inside IBM was Trailblazer. I think there was an SP1 version, which maybe was the version we had demonstrated in the conference in November '92. But I think the real machine that came out was called SP2.

Aspaturian: Did you have an international team of people working on this?

Bruck: Actually everyone was in the US. And also the standard group, which included people from universities all over and other companies, had regular meetings; and two members of my team attended those. So it was a very interesting time because we were creating the standard while we were developing the software. In fact I think the document that my group wrote describing what the standard should be became, with very small changes, the industry standard. I was very happy when it all worked out well. It was probably the first meaningful experience I had doing something like a startup—but within IBM. I learned a lot from that, from this whole process.

Comments on concurrent evolution of personal computing: "green machines" to color monitors

Aspaturian: Did you keep abreast of developments in computing elsewhere? There was a tremendous explosion, I think, in the field at this time.

Bruck: Well I started working with computers in the 1970s, and I always followed what's going on, even today. You know, if you look at what was going on in the early 1990s, you will be surprised by the discussions at that time. People were talking about which operating system will take over, whether it's Windows—remember Windows 95?—or the Mac OS. Or a third one, the OS2 of IBM. You probably don't remember.

Aspaturian: I do not know that one.

Bruck: So the discussion was about these three, and then people were discussing which processor will be the leading one: Is it Power PC—that was a collaboration between IBM and other companies—or is it Intel microprocessor? There was also a company called DEC [Digital Equipment Corporation]. They disappeared—they were acquired by Compaq, and then Compaq was acquired by HP [Hewlett Packard]. So DEC was eaten by two whales. But at that time it was extremely innovative. It had VAX machines and a processor called Alpha. So if you look at what was going on then, it was all about which processor will be the leading one? Which operating system will take over? And suddenly all of those things became secondary because of the emergence of the internet, which at the time no one could imagine would make such a huge impact.

Aspaturian: I see. That takes us a few years into the future.

Bruck: Well, it started around that time, in '92, '93.

Aspaturian: I guess you became aware of it early.

Bruck: Yes, of course. I heard about it. At that time there was this Mosaic web browser, but there was no way with it to know where things are. I had had email since the '70s; it was not a new thing for me. Within IBM and at the Technion and also of course at Stanford, we had email. But suddenly comes the internet and typically someone will say, "There is this URL. You should take a look at it." And then you click on that link, then

you go and have lunch, and you hope the site has showed up by the time you come back.

Aspaturian: You hope the page has loaded by then. I guess I first became aware of the internet and its potential in 1994, '95. It was still quite slow and a little cumbersome, but it was obviously something very new.

Bruck: When I came to Caltech in '94 I created my own web-site, and I put my picture there. And I remember someone from the faculty telling me, "I hear you have your own personal website with a colored picture." This was twenty-two years ago.

Aspaturian: Like color television.

Bruck: Exactly. When I was in IBM, during those early years, we didn't have graphic monitors, right? It was the era of the green machines, as I called them. You just had a screen with green characters, so it was impossible to visualize an image. I think the first time I could see color images on the screen, it was like, "Wow!" Remember the first laptops that had colored screens? Because at IBM when I worked over the weekend, I used — it was not a laptop, it was more a "back top", because it came with a big carrying case, like a backpack. You put the machine inside, and you carried it home and you put it all together. It had a box, which is the processor, and had a screen. So this was a portable computer, and it was very exciting to have that, because before that you could not take it with you to work elsewhere.

Aspaturian: That's right, you were wedded to wherever the monitor was.

Bruck: Yes, and suddenly you can put it in a backpack and walk with it. When I came to Caltech, my first laptop was a Toshiba. It was small and had a colored screen, which was very unusual in '94. I remember I used my startup funds to buy it, and it cost more than $6,000.

Caltech renews job offer as IBM "restructuring" takes heavy toll on Almaden research culture

Aspaturian: How you did come to Caltech finally?

Bruck: I got the second offer in '93. I was working long hours at IBM on the SP2 project, as well as continuing my independent research. I recruited people. We had between ten and fifteen people in my group, and being a manager in industry is a lot of work. I was taking many trips, and because I also wanted to continue my research, I would typically do my day job until 4:00 or 5:00 pm and then stay there until midnight to do research or write papers. I was a bit younger, so I could work for many hours. I did both all the time, which was a good idea, not only because I enjoyed it, but because I think without it I wouldn't have been able to move from industry back to academia.

In any case, during those years at IBM, I used to come down to Caltech and teach a couple of lectures in a class taught by

Demetri Psaltis and Yaser Abu-Mostafa. And they invited me to lecture about some of the results I had in my PhD thesis. Even today, I meet many students and others who tell me, "I remember taking the class in '92 when you were giving these invited lectures." Of course it's now twenty-four years ago. I had very good relationships with some of the people here in CNS, and then one day, I think in early '93, Yaser Abu-Mostafa called me. It's not something unusual; we were in touch because of my visits here. And he said to me, "You remember your interview in 1988?" I said, "Of course I do." He said, "Well, we still haven't hired anyone." So that's almost five years later. "And we already interviewed thirty-eight people."

Aspaturian: He had that number down, thirty-eight.

Bruck: I still remember it, because I remember numbers. And I said, "Okay." He said, "We had this soul-searching meeting of the search committee and tried to see how we can make progress. We went through all the people that we interviewed, and we realized that there is only one person that we all agree that is a good candidate. And that's you."

Aspaturian: Were you one of the thirty-eight or were you the thirty-ninth?

Bruck: No, I was very early in the process. I was in the first year, and maybe they interviewed five or ten that year. So I said, "Yaser, what do you suggest?" and he said, "Are you interested in coming back to Caltech for an interview?" And I told him,

"Let me call my wife and see what she thinks." I called Anat and she said, "Listen, go and interview." She knew that I am very interested in an academic position at that point. I called Yaser and told him that I'd be happy to come and interview here. So that was it, more or less.

I'll give you some context that also made me feel a bit stronger about interviewing here. In '92, IBM went through very difficult times. Originally when I interviewed people who had a PhD to join my group, I would tell them, "Listen, coming here to work in Almaden is like getting into a top university with tenure, because we don't lay off people here." And I think all of that was true at the time that I said it. But in '92, IBM went through very difficult times.

Aspaturian: Did it go through a restructuring?

Bruck: That's an understatement.

Aspaturian: Okay.

Bruck: It's the most amazing turnaround I have seen in my lifetime. What happened is that with the transition to small machines, and the fact that a lot of the revenue came from software, IBM was basically left out of this celebration of Intel and Microsoft. There were a few other issues, but suddenly the stock—

Aspaturian: Plummeted?

Bruck: Yes, very strongly. And the IBM management left. Or was let go. There were discussions—maybe IBM will be split into different independent companies. The money people suddenly became very prominent. They said, "Okay, let's cut it this way or this way." And the good thing that happened is that they found an amazing CEO, Lou [Louis] Gerstner. He was the CEO of Nabisco, but he was an amazing manager, and this was not his area at all. He came in and visited many of the locations of the company, and what he was saying is, "Listen. We will cut the company by half. We will refocus, rearrange the priorities, and then we'll grow it back." Of course this is scary. There were 400,000 people working there. And in fact, IBM did cut; Gerstner wrote a book about that. In the end there were many books about it; people teach it in business school. I was inside the boat when they cut it from 400,000 to 200,000. And we were not sure if Almaden would survive.

Aspaturian: Almaden was of course the key research center. With the other one in New York.

Bruck: Yes. In the US, the key ones are New York and Almaden. And if you want to cut staff by half, there are different ways of doing it. One way is geographic, where you say. "Where is this? San Jose? Okay, let's close it." At the time, we had two young kids. My wife was a teacher. We had a large mortgage on a house in Palo Alto. Very scary stuff; it still happens to many young people that they see how the earth is moving sometimes. But I never felt when I was there that I am

in any danger because this SP2 project was so visible, and so strategic for IBM, that every time the top management talked, I brought that up as an example of how we should do business and how research should be involved in helping grow the company.

In fact, when they let go of people in Almaden, which was unheard of—people who do research being laid off—it was a very bad feeling, in general, to deal with layoffs. For some people that were part of the layoffs, the top management asked me, "Can you take them to your group?" They were trying to reassign people. This was the climate, and when you sit at home and you think about this long-term, you realize that probably it's a better idea to be in academia than in a research organization in a big company.

Recalls Caltech's hiring process & motivations for leaving industry for academia

ASPATURIAN: Was that your only motivation?

BRUCK: No, no; I wanted to be in academia from day one. However, from the stability point of view, it's very unusual to see people who are older than fifty working in hi-tech companies as individual contributors. They may be in top management, but most people, before they reach that age, somehow they evaporate. I noticed it when I was young, and I always like to see more than one or two generations in my work environment. In our

business—information science—there are two ways to stabilize your life. One is to do startups, to stabilize your life financially. The other is to go to academia. It depends what you enjoy, right? If you want to mentor students and teach and do research, then you go to academia. If you want to impact the world and create new products, then probably long-term, it's better to be in startups.

I wanted to teach: I had a really good experience mentoring students at Stanford, and I enjoyed teaching. At least I wanted to try it. When I came for an interview, I was not sure, one, if I would get an offer, and two, if I would take it. [Laughter] I don't actually remember much of the second interview. I remember it was very positive. By that time I knew many people at Caltech, and I had had more experience in terms of giving talks and meeting one-on-one with people.

Aspaturian: If out of thirty-eight candidates, you were the only one, why did you even have to go through an interview process again? Was it just pro forma?

Bruck: No, I think, you know—the way we make decisions here, and by here I mean in academia in general, not just Caltech, is to treat it as if we are trying to prove a theorem by conducting a very sophisticated experiment. That's the style. Everyone is a scientist, so we over-analyze everything. Of course, everyone looks good before they come for an interview, and they have really good scientific results and papers, so the analytical basis is there. But at the end of the day, the decision

whether to hire someone or not—it's a gut feeling. And then you justify your gut feeling. The reason why we're so careful is that typically people stay here for their career, for life.

ASPATURIAN: And it's small. What I keep hearing over and over is, "We can't afford to make a mistake."

BRUCK: And, you know, of course we have to take the risk that we will make mistakes; otherwise we will have a bunch of very boring people.

ASPATURIAN: There's also that.

BRUCK: Because we can always be safe, but that's not the idea. But again, it's personal style. I think we should always take some risk. Caltech, again, is very special in the sense that we treat junior faculty as faculty, and we treat senior faculty as faculty and we treat everyone well. Culturally we don't have a faculty hierarchy, and that's the beauty here.

I love this place. You come in, and you sit in a meeting and there are people there who are thirty years after their PhD, and people who just graduated, and you don't have a feeling that anyone is talking down to anyone else. Also in terms of how we structure the startup packages—the freedom of people to teach or do research in any way. It's not like in a bigger school where someone comes in, and they're told, "There are those older guys, and you should collaborate with them." We don't do it here. You come in, and you do whatever you want. You don't

need to be in any group. You need to develop your own gravitational field and enjoy it. And that's why we are so careful. Because we don't have this hierarchical structure that other places have. So I had a great time interviewing here. And it went really well, also, I think from the Caltech side.

"You know how many universities I interviewed with in my lifetime? One. Caltech"

Aspaturian: Did you consider offers from anywhere else?

Bruck: I didn't interview in any other place. You know how many universities I interviewed with in my lifetime? One. Caltech. I interviewed only here in '88 and again in '93. And since I came here, I have never gone for an interview anywhere else. I never got an outside offer to bargain to get some improvement in whatever; that's not my style. If I decide to interview, I'll probably leave and go there. I'm not sure that it was a wise idea that I didn't interview in other places, but it was the right idea for me.

Aspaturian: Were you one of the relatively few faculty to be hired here from industry? I think I know offhand of one or two others. It's not very common, I don't believe.

Bruck: Not after so many years in industry. I think we have a few faculty members who came from industry, but typically it's after a year or two, not after five years like in my case. At that time I think Axel Scherer [Neches Professor of Electrical En-

gineering, Physics, and Applied Physics] was hired, and he was hired out of Bell Labs.

Aspaturian: Did IBM counter?

Bruck: I don't like the idea of countering an offer, because I never did it in my life. When I got the offer I decided basically to take it, but I was not sure, so I went and talked to IBM. I did well at IBM, and I really enjoyed my time there and the part-time faculty position that I had at Stanford, and the family was fully installed in Palo Alto. It's not like I was completely confident about the fact that, "Okay, we will move from Palo Alto to LA." And at that time at IBM—I don't know if they do it today—they marked you as someone on an executive track, and you cannot just leave without some top manager needing to understand how come this guy left. So apparently I was on this track, and the day after I told IBM that I had gotten an offer from Caltech, they raised my salary by 35 percent, without even saying they were going to do it. It just happened the next day. I came home, and I told Anat, "I am very unhappy because how come they didn't do it before?" [Laughter] You see getting a raise because of an outside offer; never happened to me again in my life.

Aspaturian: Did it make it harder to decide?

Bruck: No. You have to understand that I took a major salary cut coming here, which was not easy because I'm the main pro-

vider. My wife is a teacher. She stopped working when we came here. And I was paid much less than what I was paid at IBM.

ASPATURIAN: Did you come in as an associate professor?

BRUCK: Yes. I came in as an associate professor without tenure.

ASPATURIAN: You did take quite a risk.

BRUCK: No, I didn't take a risk. I'll explain to you why. When I talked to IBM about going to Caltech, I had a large group of people working there with me. And I also had a commitment to deliver things for in IBM. It was not just me sitting next to a desk and writing papers. IBM asked me not to leave during the academic year '93–'94, and I agreed to that. That's my style. I am always committed to the people, number one, and to the place, and I like to do things in a way that is complete and responsible. That's my upbringing. So in fact I stayed in IBM during the academic year '93–'94 and joined Caltech in June '94. Not only that, but IBM told me that they would give me a leave of absence for two years, and that if I wanted to come back at any point during those two years I just needed to make a phone call and I would be reinstated the next day on the payroll.

So I didn't take a risk. The risk was just moving everyone in my family here. I was hoping to get tenure right away, and I think at least at that time it was very unusual for people to get tenure if they came from industry after the length of time that I was there. But the agreement was that my tenure case would be con-

sidered after I was here for a year. During that year, of course, I didn't do too many new pieces of research, so it was more to see if I am well behaving, and if I like the place. That was my understanding.

So I ended up getting tenure about a year after I came here. During '93–'94 when I was still working at IBM, I also came here every month or two for a few days. This building [Gordon and Betty Moore Laboratory of Engineering] didn't exist.

Aspaturian: No, that's right. Where were you?

Bruck: In the Steele building [Harry G. Steele Laboratory of Electrical Sciences]. I had an office there, and when I came for short visits to Caltech, for example, I reviewed the folders of graduate student applicants. I wanted to make offers, so that by the time I started on the faculty I would already have graduate students. Also, when I was visiting during this time, there were students knocking on my door looking for an advisor. I ended up actually hiring one of them—my first Caltech student, Vasken Bohossian—and I started mentoring him during this time. Also something Caltech did that was very nice was to nominate me for the NSF [National Science Foundation] Young Investigator Award. And to qualify for that, I needed to be part of Caltech. So in January '94 I officially joined Caltech and immediately went on leave until I left IBM in June. But that allowed Caltech to nominate me for the award, which was both prestigious and provided funding for five years or so.

Aspaturian: I do remember that one of my first press releases here in 1984 was to write about eight faculty who had all won the award in that same year.

Bruck: I think I was also nominated at that time for a Sloan Foundation Fellowship. So in addition to working at IBM and coming here back and forth, I wrote all of those proposals and packages, and I got both of these awards. So I kind of felt, "Okay. Maybe I am doing something right here."

"Like going from driving a car to riding a bike": adjusting to Caltech's culture after IBM Almaden

Aspaturian: How did working at Caltech, which is one of the leading academic research institutions in the world, compare to being at IBM Almaden, which was one of the leading corporate research organizations?

Bruck: It was very depressing at first to come here.

Aspaturian: Really, how so?

Bruck: You don't know that your questions are unbelievably good and not always do you know why. [Laughter] I felt that when I came here, suddenly I kind of went from driving a car to riding a bike. Part of it was that at IBM I had been doing research in collaboration—it's a social environment, right?

Aspaturian: Yes it is.

Bruck: So of course, at Almaden, where I knew so many people, I could walk down the corridor and meet someone, and we then would go and have lunch together, and then we would stay after lunch and argue about some ideas, and then we would keep arguing at a conference room in the afternoon, and then the next day we were writing a research paper. That was my life there: I wrote many very interesting papers and learned a lot, and it really gave me a tremendous foundation.

Aspaturian: Everything sort of grew out of this collegiality that you all had.

Bruck: Exactly. We didn't have students, but there were many experienced researchers that you regularly interacted with. Now I came here—and when I came I had one grad student who had moved here with me from Stanford. He was only a year away from graduation, and so with him things were pretty effective. But the other three were new. Two of them were still taking classes and getting ready for the oral exams, and they didn't know much about research. It was in a sense frustrating for me. I dealt with it in a few ways. One was that I went back to Almaden once a month for a few days, so I kept collaborating with the people there, because we had still activities in the pipeline. When I created my website here in '94, one of the areas on it was electronic technical reports, ETR.

Aspaturian: Another acronym.

Bruck: Yes. Well, I had just came from IBM. [Laughter] So if you look at the first few reports there—and I just looked back at them today—they were written with people from IBM. And in the first year, and even the second, most of what I published was work that I was doing with people at Almaden.

So that was one approach. The other one was that at that time, I would eat lunch in the Rathskeller in the Athenaeum [gastropub venue in the basement of the Caltech Athenaeum faculty club]. Which I no longer do. But I was very isolated, and my wife, who had left her job in the Bay Area, didn't get a new one because she wanted to support the kids when they moved to a new school. And we had to look for a house and all of that, so we had quite a few things on our plate. Anat took art classes at PCC; she's very artistic. So we used to have lunch a couple of times a week at the Rathskeller, and I remember walking back after one of those lunches and telling myself, "Relax. Your main goal is educational. It's okay if you do less research. It will pay off in the way you mentor and educate the next generation." I kept telling myself, "That's why I'm here." Basically, it's like you've played in the NBA, and suddenly you are a coach in high school or college. I didn't like sitting on the bench and trying to train people; I just wanted to run with people like me.

Aspaturian: Did that come as a shock to you because you had been looking so forward to teaching and mentoring?

Bruck: Yes, to some degree. I love mentoring, but initially there was a void in the ability to collaborate with senior researchers.

Also, on a personal level, the first two years were very difficult for us, especially in the beginning because my father-in-law was very sick. He had cancer, and he died in September '94.

Aspaturian: This was in Israel?

Bruck: Yes. And my wife and the kids were in Israel during that summer when I was here; and then immediately after they came back and started school he died, and Anat went back to Israel. So this whole first year was challenging. Also socially, we had had so many friends in the Bay Area. When we left, we had a huge party in one of the parks there, and they all felt very sorry for us because we are moving from Palo Alto to the worst place in the world, LA. By the way, I prefer living here to Palo Alto. I really love this area. But of course when you live in Palo Alto, you hear about LA—that there's crime and smog and all that.

Aspaturian: "It's the pit of the Universe."

Bruck: Yes. But this is a great place; it's just that we didn't know anyone, and we are very social, especially Anat. So I remember the first few Fridays. Typically on Fridays, we had many people who came over and we had dinner together. After we moved, the kids would ask on Fridays, "Who is coming tonight?" and we said, "No one, it's just the four of us." [Laughter] You know, when you move to a new place, there is a kind of a social startup to take care of.

"I was not lost because I had enough experience & momentum & ideas about what to do when I came"

Aspaturian: You had a standing offer to go back to Almaden. Were you ever tempted?

Bruck: No. I feel that, you know, I love Caltech and I fell more deeply in love over the years. I was never tempted to go back. So there is a strange tradeoff here, and I try, when I can, to help young faculty. And it's not so simple, because, as we talked about, at Caltech you treat everyone as equal. We are so careful here in terms of making sure that they have their space that we overdo it sometimes. Some people need a hug. Some people need a hand. Some people need someone to talk to. It's not clear what the balance is here, and we have many discussions about it. I've seen faculty who come here, and they seem lost. I was not lost because I had enough experience and momentum and ideas about what to do when I came.

Aspaturian: The environment is designed to give everyone maximum intellectual freedom.

Bruck: Yes. So then it worked out. I'd say the first two years, especially the first year, were more challenging. Also, suddenly you go to academic meetings and you're not sure what you're supposed to do there. I'm used to industry, and here you participate in defense exams, and candidacy exams, and are supposed to ask questions. So you do everything for the first time.

Like when you want to go to the restroom for the first time, and you need to figure out where it is. And, you know, teaching took a huge amount of work for me.

Caltech office, c. 2000. *Caltech photo by Robert Paz*

Aspaturian: Do we have time for one more question?

Bruck: Sure.

Aspaturian: I think you were the first professor to come in with the title of computation and neural systems. Did you devise that title yourself? Did somebody create it for you?

Bruck: I think there was one before me, Christof Koch.

Aspaturian: Christof was in biology, I think.

Bruck: I had a joint appointment in CNS and EE from day one, but the slot that I was hired into was a CNS slot—that's what the thirty-eight people interviewed for. I don't think Caltech has hired too many people with this designation—I think the last one was Thanos [Athanassios] Siapas [professor of computation and neural systems]. And I'm not sure who was between Thanos and myself. Definitely we don't do searches very often for CNS. So I was lucky. And of course at the time that they interviewed me, I had a very good fit with EE because I worked in coding and information theory. Also, I had a good fit with CS because I worked in distributed and parallel computing. But I wanted to be in at most two departments, so I ended up being in CNS and EE.

Aspaturian: We'll talk more about that next time.

Session 6, November 29, 2016

Early impressions of Caltech's engineering & applied science (EAS) division & campus environment

Bruck: We were just talking about the faculty meeting I went to, and I said that I believe that it's my duty to attend them. If you look at attendance at faculty meetings, it's very, very low, and it's inversely proportional to the size of the group it represents. So if it's an Institute-wide faculty meeting, then you get thirty people out of 300. If it's a division [EAS] meeting, out of eighty people, you get about twenty. If it's a department of electrical engineering meeting, then almost everyone in the department shows up.

Aspaturian: To what do you attribute these disparate ratios?

Bruck: I think people come because they feel they belong. I always try to go especially to the Institute-wide meetings that happen once every quarter. I see it as my duty, so not going is not even something I consider. I think that's an interesting topic because, you know, we have academic freedom here and the question is, what is the meaning of academic freedom? For me, the freedom is mainly in the research and the ideas and the concepts we pursue, and the things that we want to teach. I think that doing a fantastic job in teaching is a duty; not a matter of freedom. You cannot say, "Well, you know, I can be

late for class" or "I don't prepare my classes." Or "I just thought about some really brilliant ideas in my research, and I forgot about class." If you do, you're not doing your job.

ASPATURIAN: Does that happen with some of your colleagues?

BRUCK: I don't know, but I think people here don't take teaching as seriously as they take research. And it's the same thing with the faculty meeting. I put it on my calendar, and I know I have to be there. That's been my approach. Sometimes I have a conflict, and I will not show up, but if I can be there, I am. And that's definitely not the case for a number of my colleagues. However, I believe that we must accept different personalities on campus and try to optimize on the key goals. Our approach, that I strongly support, is that we prioritize the creativity and passion of people for research.

ASPATURIAN: That actually brings up a question I was planning to ask you. In your first few years here, what was your sense of the culture of the Division of Engineering and Applied Science?

BRUCK: I'll tell you first one thing about the culture at Caltech. When I came here with my wife to look at the campus, we went for lunch at the Athenaeum, just the two of us, and as we were sitting there, I was looking at the Round Tables, right? And the average age at the Round Tables never changes. It's always somewhere between eighty and ninety.

Aspaturian: That's a little harsh, but okay. [Laughter]

Bruck: No, no, it's good. I love the people there, and I still see some of them there today. But at that time, in this lunch, I didn't know anyone. But I could tell that the average age is eighty. And I told Anat, "You know what, I am going to accept the offer from Caltech. And the reason is that a place that treats their elderly well, where they feel comfortable coming back over for lunch and sitting there, it's the right place."

Aspaturian: That was really your determining point?

Bruck: Yes. I'm a strange guy. You know, obviously I was in my thirties then, but I thought, "I hope one day to sit there and eat lunch and hopefully to have inspired someone else to come to Caltech."

Aspaturian: You hope one day to age into the Round Table?

Bruck: Well, they are inviting me. You know, there are two Round Tables. There is one where it's more like seventy, I would say.

Aspaturian: A youthful crowd.

Bruck: So when they see me they say, "How come you are not joining this table?" And I feel that I'm still too young. [Laughter] I hope that one day I will graduate to being able to attend that table. [Francis] Clauser [Millikan Professor of Engineering, Emeritus; d. 2013] used to sit there, and I really

loved Clauser; he was a fantastic guy. I really had a great relationship with him.

ASPATURIAN: He was kind of a leader of his Round Table, that's what I understand.

BRUCK: Yes. I went to his memorial with my son—I think their birth dates are identical. He died at ninety-nine, and the memorial was on his hundredth birthday. It was a fantastic memorial, and people disclosed that in moderating the Round Table topics Clauser didn't just show up for lunch every day. He was really doing a lot of research beforehand. So everyone thought that he knows everything. [Laughter]

ASPATURIAN: He prepped for the Round Table? That's funny.

BRUCK: Yes. He prepped for the lunch. [Laughter] It was great.

So about the culture. I was used to industry, where it's a very different structure—very hierarchical and very clear who is saying what, and very clear as to why we need to do something, and all that. Definitely Caltech is a bit more fluid. [Laughter] And of course as a young faculty member, you go to faculty meetings and you mainly listen, because you want to understand; you absorb, right? And of course now I talk in every faculty meeting. In fact I feel I talk too much in faculty meetings, so before every faculty meeting I try to convince myself and promise myself that I will not say a word in this one. And so far I always failed; I end up talking too much. So we'll

see if I can once, even once, be able to shut up. [Laughter] But I was very quiet the first few years, and John Seinfeld [Nohl Professor and professor of chemical engineering] was the division chair at that time. Bob McEliece was the chair of the EE department. And [Thomas E.] Everhart was the president [1987–1997]. I think I told you when we talked last time, that in the beginning I felt extremely lonely here.

Aspaturian: You said it was a little isolating at first.

Bruck: Yes. It is a tricky issue; how do you provide freedom and space without isolating someone?

Aspaturian: Yes, you were saying that it was very tricky to strike the right balance.

Bruck: Yes. I'm not sure what the answer is, I think it's very hard for young faculty when they come to Caltech because of our style. Because if you go to a big school, typically as a young professor you are part of some group that is defined by the topics they work on. But here the whole idea is that we don't have too many people who do the same kind of work. You are hired because you are bringing some new way of covering the landscape, and there is a bit more intellectual space between what you and your colleagues are doing. In other schools you come in and write proposals with more senior professors in your field and get mentored by them, so it's a very different experience than here.

Recalls friendship with Caltech president T.E. Everhart & Doris Everhart

The reason I thought about this point again in the context of Everhart is that one person who really helped us as a family to feel welcome here was Everhart.

Aspaturian: Can you say some more about that?

Bruck: Yes. At that time we didn't have socially many friends. We were with young kids, so we used to go with them to different shows in the Beckman Auditorium. And Everhart, whenever he saw us, would come and talk to me, to the kids, to my wife; and he and his wife, Doris, always invited us to different events at their home. We were in a very close relationship with them and still are. In fact a few months ago Anat and I drove to Santa Barbara and spent a day with Doris and Tom, and it was fantastic. We had lunch, we were at their home, we talked about different ideas. He has a gift of on the one hand being able to be the president, and on the other hand to be able to relate to people on a more personal level.

Aspaturian: Most of the people I've talked to about Everhart speak about him in his professional capacity as Caltech's president. What did you see of his personal qualities since you formed a friendship with him and his family?

Bruck: I think he really appreciates the value of the family, which is a very important value for us. So it was not at the level

that he sees me and he says, "Tell me something about some research you just did." He would ask me how Anat is doing, how are the kids, and all of that

Aspaturian: I think it's really interesting that you say that, because I think one of his most successful legacies was establishing a stronger sense of community at Caltech. That was my impression of how things evolved once he came to campus.

Bruck: Yes. You know, he always walked around, and he always showed up in different events—big or small—and he always talked to everyone. And he was very approachable, and he loved the interaction with people, no matter who they are. I know that some of my colleagues don't have the gift that Everhart has. You know, the gift of a Caltech professor is not in engaging in small talk. Some of them feel very awkward to do it or to discuss topics that have an emotional component. This is also very difficult for people that do science and engineering. Of course I'm over-generalizing here.

Aspaturian: It's true, though, of some individuals.

Bruck: So I think Everhart is definitely someone that is well-balanced and appreciates this type of connection. I think the reason I'm saying all of this is that it worked really well for me and for my family, but maybe there were some people who felt very awkward interacting with him. Maybe they thought he's not as smart as a Caltech president should be. And that's going back to what we discussed before, not on tape. I believe that

everyone is smart in a different way. Everyone has a gift! Smart is not about being just on one wavelength, like a physicist who cannot talk about anything but physics. I think it's important to teach people to talk about topics that they don't know much about. And also to be able to talk some nonsense. I think it's all good. One way to learn is to interact with people and on topics that you don't know much about. So you don't know much about it, what's the big deal? If you're interested in it, you'll figure it out.

Rebuilding Caltech's CS program & articulating & implementing a new vision for recruiting CS faculty

Getting back to your question about the engineering [EAS] division, it's really big.

ASPATURIAN: It is very big, and I wondered how you, with your specialization in computation and neural systems, fit into it.

BRUCK: So that goes back to when I got an offer from Caltech, and some people said, "Caltech? Wow, wonderful!" And some people said, "Caltech? They don't even have a CS department."

ASPATURIAN: You were going to *be* the CS department, or at least a large part of it, yes?

BRUCK: I was never formally in CS. In fact, there were excellent people in CS at that time, but it was a very small group. During

those first few years I noticed that there was not much activity in CS and also people left.

Aspaturian: Good people?

Bruck: Good people left. I think Chuck Seitz left. And then there was a mishap with one of the professors who committed suicide.

Aspaturian: Was that Jan van de Snepscheut?

Bruck: Exactly.

Aspaturian: I was teaching Advanced Conversational English for the Women's Club in the early 1990s, and his wife was in the class. She was a lovely person. And this happened a year or two later. It was very sad.

Bruck: It actually happened, I think, somewhere around January '94, because the evening after it happened, I was at the faculty records office doing all the paperwork to join Caltech, and I could see that people are concerned, and the provost came in, so something was going on. I said, "What is happening?" And they said, "Well, that's what happened." So I think CS went through a very difficult period, and they were not able to hire faculty, because it's very helpful to have a vibrant community when you want to hire someone. You want to be able to say, "We have ten people here in the department; it's a very energetic group, with people from different generations." You get people excited about joining the activities and all of

that. But there were not too many people in CS, and they were not in a good mood. So they failed year after year to hire people.

Aspaturian: This was in your first years here?

Bruck: The first few years. And then Seinfeld one day asked to meet with me.

Aspaturian: Not long after you'd arrived?

Bruck: It was about three years after.

Aspaturian: OK, so '97.

Bruck: Yes. And he said, "I need your help, okay?" He said, "We are failing in our efforts to recruit faculty."

Aspaturian: In computer science?

Bruck: In computer science. Now I was in electrical engineering and CNS. I was not part of any recruiting effort in CS. But Seinfeld said, "I need your help, if you can chair a committee to hire new faculty in CS." And I said, "How many do we need to hire?" He said, "Five." It was like doubling the size of the department.

Aspaturian: Who else was in CS at that time?

Bruck: The core group consisted of Mani [Kanianthra] Chandy [Ramo Professor of Computer Science, Emeritus]. Alain Martin

[professor of computer science, emeritus]. Al [Alan] Barr [professor of computer science], Peter Schroeder [Hanisch Professor of Computer Science and Applied and Computational Mathematics] and Jim Arvo. Jim didn't get tenure. He moved to UC Irvine, and he committed suicide. It's a terrible story. And the CS building at that time also was depressing.

Aspaturian: What was it, Jorgensen?

Bruck: Yes.

Aspaturian: Oh yes. Like something from *The Matrix*.

Bruck: I didn't see *The Matrix*.

Aspaturian: Honeycombs.

Bruck: In any case, something didn't work there. So I thought about it, and I told John that I thought one way to make progress is to engage all of Caltech in recruiting people to CS.

Aspaturian: How did he feel about that?

Bruck: He was very supportive.

Aspaturian: So what did you do?

Bruck: I don't remember the exact number, but we had probably fifteen faculty members on my committee. And basically my model was very simple. Typically, when someone comes here for a job interview and a visit, they give a talk, they go for

dinner, and they usually meet one-on-one with faculty. I thought that first we needed to make sure that when they meet many people, those people are happy and productive. Number two, I said, on the second day we will take the candidate for lunch, with like ten or fifteen people around the table, and they all eat sandwiches and smile. Namely, a lunch gathering where all the participants are genuinely relaxed, sociable, and cheerful. I thought if that happens, we will be able to recruit. So we put together a committee from all over the Institute.

Aspaturian: It's interesting to me that you were looking more at social incentives.

Bruck: Of course.

Aspaturian: Was that an unusual approach for Caltech at that time?

Bruck: It may be. It's easy to recruit people that don't have other options. It's hard to recruit people that have many other options. But they want to feel a sense of joy and a sense of optimism when they're being recruited, and it's very hard to project that if you have five people in a department that has not been able to recruit new members for a few years. So I thought, "There must be a way; we have to break the mold." The other thing I told Seinfeld is that I'm going to take more risk. Typically at Caltech we hire people where it is extremely likely they'll get tenure.

Aspaturian: Yes, that's right.

Bruck: Of course there are many cases where people didn't get tenure, but what I told John Seinfeld is, "I think we have create a critical mass and then optimize. Maybe we will have a bigger variance in the quality," meaning that down the road some of the people we hire may not get tenure. "So I'm going to take more risk, and more specifically, if everything goes well, try to recruit five people in two years." Which is really a lot for Caltech.

Aspaturian: Yes, that's over a short time–frame, too.

Bruck: Yes. But we had to create this momentum, and there were many people from all over campus that participated, not just EE. I divided it into four subcommittees according to different areas. And at that time, we still used a paper-based system. But I felt that maybe we should have an online system for recruiting, and I worked with Jeri [Chittum], the department administrator from CS. And I needed someone to help with creating this online system. And guess who did that? It was Marionne, who now is the [EAS] division administrator.

Aspaturian: Marionne Epalle.

Bruck: Yes. I think one of her first jobs at Caltech was working with me on the big CS search, and her job was to create the online system that you can interact with as an applicant. You can submit your application, and the references can submit

their letters online. In fact I think that for many years after that, this was the system that was used in our searches.

Aspaturian: Did you have a vision for how you wanted the discipline to evolve that you were guided by in your recruiting and hiring choices?

Bruck: Well, it's not my vision.

Aspaturian: It's a collective vision?

Bruck: It's a collective vision, and one nice thing that happened as a result of this activity is that I got to know many people, with different backgrounds, on campus. So we realized that we should recruit someone more on the physics side and perhaps someone more on the biology side, and someone with more of a networking background. Because we had no faulty like this. Also someone doing more theoretical computer science or someone more on the mathematics side. We ended up hiring five people. Three of them are still here.

Aspaturian: Who were these?

Bruck: Leonard Schulman [professor of computer science], Steven Low [professor of computer science and electrical engineering], and Eric Winfree. Two out of the five didn't get tenure. I think one case was pretty clear; in the other case, I voted for the person to get tenure. In fact, this person is currently a professor in an extremely good university and doing extremely well there. Looking to the future, this search process

led to forming my vision of IST, because through doing it, I learned, one, to look at CS from a more holistic perspective, and two, that there are many people on campus who also believe that an activity centered around the notion of information is something that will be able to connect the intellectual views of people from all over campus.

Aspaturian: So these were the germs of the IST initiative, within this committee and this recruiting effort?

Bruck: Yes. The recruiting effort and the involvement of people from all over campus. You see, life is interesting. I wanted to have this lunch I mentioned, and the question was, who is going to sit around the table.

Aspaturian: You wanted happy faces at the lunch.

Bruck: Yes. But once we had people from all over campus sitting around the table, then I said, "Oh, this is interesting."

Aspaturian: Aha.

Dot-com bubble impacts CS recruitment & retention; establishment of the Lee Center for Advanced Networking

Bruck: So this is the heritage of the IST idea. There was another activity related to this. I don't remember exactly which year it was, but around the same time, David Rutledge [Tomiy-

asu Professor of Engineering] came and talked to me and said, "You know, over Christmas I met someone in our circle of friends." You know how Christmas time works, you get to meet some new people.

Aspaturian: Yes, it's very convivial.

Bruck: "And his name is David Lee." He's now the chairman of the Board of Trustees. [Lee stepped down as chair in 2021. *–Ed.*] He had been a graduate student here in physics, but at that time he was not involved with Caltech. I just want to mention that in parallel to what we were doing on the CS, there was an unbelievable bubble related to the internet. This is one reason it was hard to hire people. It was to the point that people left academia. Professors left tenured positions and went to industry. Graduate students stopped their studies and went to industry.

Aspaturian: I remember that period. This is the late 1990s.

Bruck: Yes, it's about the same time. It was very hard to recruit, not just at Caltech but in general. It's not because other universities recruited our candidates; it's because no one wanted to be in a university.

Aspaturian: They wanted to go into business and make lots of money.

Bruck: Yes, because at that time, if you come up with a domain name that is not taken, you are already a millionaire.

Aspaturian: That's a bit of an exaggeration.

Bruck: No, it's not. I know some people that became very affluent because they had the idea. They took every word in the English dictionary and then they start selling it. So it's like the Wild West, you know. You take a hill, and the next thing that happens is this hill becomes Palo Alto, and you sell the real estate that was never yours. So it was an amazing time.

Aspaturian: It was a wild and woolly time.

Bruck: So David Lee had started a company called Global Crossing.

Aspaturian: I know the name.

Bruck: And this company laid cable connections between continents. And he did well.

Aspaturian: To say the least.

Bruck: And it was Christmas time. And he felt, "Okay, I did well." I think his PhD advisor was [Thomas A.] Tombrello [Goddard Professor of Physics, d. 2014], but I'm not sure.

Aspaturian: Yes, I knew Tom.

Bruck: Yes, I loved Tom. So David Lee talked to David Rutledge, and he said, "I want to give something to Caltech, but I want to give it for activities in research, and specifically research in networking. So how about if you talk to your col-

leagues and come back to me with some ideas?" So of course through the search and all of that, I got to meet many people, including David [Rutledge], and he was a very, very good partner for me, in many ways. In fact, I asked him to serve as my deputy director for IST.

A lot of the initiative to start the undergrad program in CS is due to David. At the time there was only a graduate program. I would say it probably happened when he was the EE department chair, and he started a joint undergraduate program in computer engineering that then became CS. So it's fairly recent. And from zero, it first became bigger than EE, and now it's got one third of the undergrads.

Aspaturian: It's the biggest major on campus. That's right, yes.

Bruck: Which we predicted with the IST vision—that about one third of the students would be in this domain.

Aspaturian: You were right.

Bruck: In any case, David Rutledge came and talked to me and Mani Chandy. And the three of us wrote something like a two-page document with feedback from some other faculty members, and we proposed to David Lee the Lee Center for Advanced Networking. And the beautiful thing is he gave us directly $10 million. There was no overhead, and the money was not going to the endowment, so we could use it right away for

funding. And of course we got the administration involved only when it was too late for them change those terms.

Aspaturian: You were able to do that?

Bruck: Yes. Well, now you would not be able to do it because David Lee is the chairman of the board. [Laughter] But we were successful in doing it, and the idea was to include people from many different divisions and disciplines. We wanted to involve people not only from EE and CS, but also from biology, to study biological networks. And from social science and economics, to study social networks.

Aspaturian: Who came up with this integrated concept?

Bruck: I believe that David, Mani and myself.

Aspaturian: You were just working collectively, and it emerged as an idea.

Bruck: Yes. So it was all around the concept of networks.

Aspaturian: I'm asking partially because I remember writing about the Lee Center and thinking this was a new departure for Caltech, the integration of the social sciences with biology in this way.

From neural networks to nematodes: exploring & modeling gene regulatory systems within cells

Bruck: On a personal level, in 1995, I went and talked to people in biology and at that time I had a student named Mike [Michael] Gibson. He was a CNS student who was interested in the interface between biology and computer science. And I said, "Go and talk to anyone in biology about anything, because I don't know many people there." He did that, and we used to meet once a week and he would tell me about his meetings, and then he told me about Paul Sternberg [Bren Professor of Biology].

Aspaturian: Oh yes, of course, with the nematode research.

Bruck: Yes. And somehow I got the feeling that Paul is someone, again on the personal level, whom I will be very happy to talk to. And so I arranged a meeting with Paul, and the rest is history because it started a really very long collaboration. I wrote a proposal with him to ONR [Office of Naval Research] about the logic of gene regulatory networks. This was before the days of systems biology. And in fact we got funded.

Aspaturian: The ONR funded this?

Bruck: Well, this is before 9/11. The people on this ONR program were the seed that started systems biology in some sense. Adam Arkin was a postdoc at Stanford; now he's a very successful professor at UC Berkeley, and Drew Endy was fun-

ded by this program when he was a postdoc in Texas, and he's now a successful professor at Stanford, and before that he was at MIT. It was a lot of fun working with Paul on gene regulatory networks, and doing so I had the insight that biology is not just neural networks of connected cells, but that within the cell itself you can think about the control mechanisms as a network of chemical reactions. And for me this was a very important insight.

ASPATURIAN: So an intra-neural network in some sense as well as an inter-neural network?

BRUCK: Right. It's not physical; in structure it doesn't look like a network, but logically the interactions—

ASPATURIAN: The interactions mimic the functioning of a network?

BRUCK: Yes. So I felt that the brain is hopeless for us to understand, but maybe it makes more sense to understand the logic of a single cell.

ASPATURIAN: You could use that as a model system for investigating some of these questions.

BRUCK: Yes. And I was very impressed by one poster Paul showed me of the nematode and it showed that it has exactly 959 cells. So I asked him, "Is that approximate?" "No, it's exact." Every nematode has this number. So I was really impressed how biology can be so precise. It's not necessary for it to have

this precision, but obviously it can have it, and this was very inspiring for me.

ASPATURIAN: Was this a new idea, a new concept for you?

BRUCK: Yes. Definitely. So I started collaborating with Paul. We did many different things. I think one of the papers I wrote with Mike Gibson became probably my most cited paper ["Efficient Exact Stochastic Simulation of Chemical Systems with Many Species and Many Channels," *The Journal of Physical Chemistry*, March 2003]]. It's about a way, I would say, to analyze gene regulatory networks. We invented an algorithm to do it efficiently, and it became the standard fairly shortly after that.

ASPATURIAN: I have a question. Is it scalable across all types of genomes, for all types of organisms?

BRUCK: Well, it's more general than the genome. If you are given a set of chemical reactions, you can use what's known as kind of a stochastic simulation or Monte Carlo simulation to get predictions about what this set of reactions will do. So there was an algorithm to do it called a Gillespie algorithm. And I know [Daniel] Gillespie; I met him after I coauthored the article. But what Mike Gibson did is greatly improve it.

Gillespie was not a computer scientist, so he addressed the problem more from the chemistry point of view, and we turned it into a very efficient algorithm. So that's just one example. We didn't plan on doing it, but we studied the tools that existed,

and I remember Mike was here in my office explaining the Gillespie algorithm, and as we understood it we could see that we could do much better than that.

That's the beauty of going into new disciplines—sometimes it's easy to help and improve the existing knowledge. So the work with Paul was a way for me to think about biology and that kind of a network vision.

Fostering multidisciplinary synergy & innovation across research & startups at Caltech

Also that was a natural connection to the Lee Center. The Lee Center was also great because we had this mechanism of having a lunch every month where one of the faculty members would give a presentation. It was the first time for me at Caltech that I had the opportunity to sit around a table with colleagues and learn about their research.

Aspaturian: Really?

Bruck: Yes. Typically in faculty meetings you talk about bureaucratic stuff and about administration. So this was a great mechanism. The other thing is that once a year we had a workshop in a local hotel for just one or two days, and typically we invited Center faculty and students as well as outside visitors. David Lee also attended. So again it was a bigger version of the lunch, and typically students also gave talks and presented posters. What I started doing was to invite all my alumni, both

students and postdocs, to the Lee Center workshops. The Lee Center had a tenure of ten years, so on average we spent about one million dollars a year. My alumni came from all over the US for the workshop. And then immediately before or after, I organized a Paradise workshop—"Paradise" is the name of my group—where the alumni would give presentations about what they were working on.

ASPATURIAN: Was this a fairly new model for the division or even for the campus at large, this kind of interdisciplinary synergy?

BRUCK: Yes, I think so. Definitely the Lee Center and the generosity of David Lee was key there. We need to have activities that are not funded in a structured way—I call this type of support the oil. We extended this concept, of course, in IST—it's not the gas, it's not the fuel—it's the oil. You need to oil the system, and then maybe some collaborations will emerge. Or even if there are no collaborations, at least there is some mutual inspiration and fruition.

Past and present students and postdocs join Shuki for a Paradise Workshop group photo in front of the Moore Laboratory on the Caltech campus, c. 2015. *Photo courtesy of Shuki Bruck*

So this was very, very helpful. I don't think it's something you can expect from external funding. You cannot write a proposal to the NSF saying, "Here is what we're doing and it involves fifteen faculty members and everyone is involved to the level they want." They will ask, "Who is managing that? What are the goals?" I don't know what are the goals, but I know it's to talk to each other. So it was extremely helpful, the activity of the Lee Center. And I think between the CS search and the Lee Center activity, it was really natural to think about the IST.

Aspaturian: Maybe we will talk about that next time. I did want to ask a question if you have another minute?

Bruck: Yes, sure.

Aspaturian: During the go-go years of the dotcom boom, was it hard to hold onto graduate students and postdocs? Did they keep peeling off?

Bruck: I didn't lose anyone. We didn't talk about what research I did during this time.

Aspaturian: Not yet. We didn't talk about Rainfinity yet.

Bruck: So I had a couple of projects after I came to Caltech. One of them was called RAIN. And then in '98 we started Rainfinity [*Session Eight*], so in a sense we were part of the

dotcom thing. So my students who were interested in working for a startup, they had an outlet.

Aspaturian: You kept them close by giving them a company to run.

Bruck: Exactly. I personally didn't have this issue, but it was a busy time as you can see. Many things were going on. In fact, last night, I don't know if you saw this email, but Larry Gilbert —

Aspaturian: I know who Larry Gilbert is. [Larry Gilbert was the founding director of Caltech's Office of Technology Transfer. –*Ed.*]

Bruck: He died a couple of days ago.

Aspaturian: Oh, I'm so sorry.

Bruck: Yes, he had a massive stroke.

Aspaturian: He was a Caltech legend.

Bruck: He came to Caltech, I think in '95.

Aspaturian: Yes, David Goodstein [Gilloon Distinguished Teaching and Service Professor, Emeritus; professor of physics and applied physics, emeritus; d. 2024] recruited him when he was vice provost. I remember.

Bruck: And he was extremely helpful with Rainfinity. When I came to Caltech, a startup was a guilty secret. But with Larry's presence, a startup was more like a cause for pride.

Aspaturian: That's something else to talk about, the change in climate with regard to entrepreneurship, which occurred, I think, in the space of maybe half a dozen years. It was quite a remarkable explosion of interest.

Bruck: I feel lucky that when I had the desire to start Rainfinity, that there was someone here at Caltech that I could talk to about this.

Session 7, December 5, 2016

Genesis of IST (Information Science & Technology) initiative: setting the stage

Aspaturian: We're going to start today by talking about the genesis and the evolution of the IST program, including the Annenberg building, and what developed after that. Last time you talked about how your effort to reconstitute CS at Caltech was essentially the germ of the IST initiative [*Session Six*], and I think we left off around 2000. You've just shown me a document that suggests that planning for this began in 2002. So what happened between 2000 and 2002 to lead you here?

Bruck: Well, I think we talked about how the Lee Center was the activity that helped us make connections between engineering and the rest of the campus [*Session Six*]. Also in 2000, we had a new division chair.

Aspaturian: Is that Richard Murray [Everhart Professor of Control and Dynamical Systems and Bioengineering]?

Bruck: Richard Murray. He replaced John Seinfeld.

Aspaturian: Who'd been in the job for ten years, I believe.

Bruck: Yes. And in fact I was on the division chair search committee that chose Richard, and it was a great committee. Typically the process is that the provost suggests some names, and the charge to the committee is to come back with a couple of names in some kind of order, prioritizing it. And the interesting thing is that at the time Richard was an associate professor.

Aspaturian: Was he tenured?

Bruck: Yes. And the committee felt that he's the right person.

Aspaturian: Why?

Bruck: You know, when we hire people here, we don't look at their potential to be leaders in academia. Typically they are young, and we want to optimize their research promise. That's why it's not always easy to find people to lead activities on

campus. Richard's a very gifted researcher and teacher, but it was very obvious to the committee that he also has natural leadership skills. We did something unusual in selecting a relatively young person and promoting him to be a full professor while asking him to be the chair of the division.

My engagement in administration at Caltech started when Seinfeld asked me to lead the big CS search [*Session Six*] and continued with Richard. I worked very closely with Richard and was really involved in many decisions in the division during those years. Also, I felt very excited to collaborate with [David] Baltimore [Caltech president, 1997–2006] and [Steven E.] Koonin [Caltech provost, 1995–2004] and very motivated to contribute at this level to Caltech. When Richard started his position he was looking for ideas about what to do, and I remember we had lunch at Avery House. At that time there was a restaurant there.

ASPATURIAN: Citrus. That was a lovely venue.

BRUCK: It was the best informal meeting place that Caltech had to offer at that time. I ate there very often. It definitely affected the morale in a positive way. So I remember we met there.

ASPATURIAN: You and Richard.

BRUCK: Yes, for lunch. Probably in late 2001.

ASPATURIAN: Right after 9/11.

Bruck: Yes, around that time. I thought about it beforehand, even prepared a couple of slides for the lunch, and I told him I thought there was a huge opportunity for us to start a program that will be centered around the notion of information. And I remember that at first he said, "You mean computer science or —?" and I said, "No, information." And I started to try and explain what I meant—that it includes physics, the social sciences and economics, mathematics, biology, CS and EE and so on. And he got really excited. At that time also there was an opportunity to submit proposals to the Moore Foundation.

Aspaturian: They were gearing up for the big gift.

Bruck: I think this was after they committed. I think Gordon Moore committed $600 million. I'm not sure what was the date.

Aspaturian: We [Caltech Office of Public Relations] publicized it in 2002. You may have known about it sooner.

Bruck: I'm not sure what the timing was, but there was an opportunity to get funding to try some new ideas. Actually, for me 2002 was one of the most challenging years in my career. There were many things that were going on. I had started Rainfinity in '98—we haven't talked much about that yet.

Aspaturian: We'll do that in a subsequent session [*Session Eight*].

Bruck: We had raised a lot of funding for it. When 9/11 happened, we had 110 people in the company [i.e. Rainfinity],

most of them in San Jose. And we had also offices here in Pasadena, and sales offices in Europe, Japan, Brazil, many places. When 9/11 happened, the stock market, and especially the tech market all collapsed, and many companies closed. It was more dramatic for tech companies by far than the 2008 downturn. Our sales went down dramatically because no one was buying anything, and we had to let go half of the company in January 2002.

ASPATURIAN: You had to downsize that dramatically.

BRUCK: Yes. Because, you know, it's simple arithmetic to see that if we don't do it, then we need to close the activity.

ASPATURIAN: That must have been hard.

BRUCK: It was probably the most difficult decision that I was part of in my entire professional career.

ASPATURIAN: That must have brought back to you what happened with IBM research when they were faced with a similar situation [*Session Five*].

BRUCK: Yes, the company went from 400,000 to 200,000. So ten years later I was part of similar downsizing activity. On a personal level, my father was sick—it's a complex story, but he had Alzheimer's disease. Anat, my wife, had some health issues and went through surgery later in that year. And on the business side, in August 2002, after we did the downsizing in January, the CEO of Rainfinity decided to leave, without

warning me that he's doing it. And of course there are still fifty or sixty people in the company.

IST vision of "information as a unifying scientific concept" gains momentum & support while raising key questions of scope & implementation

So, getting back to IST, you can see in these documents all the meetings that we had—eighteen meetings in 2002.

Aspaturian: What we're referring to here for the record was the final report from the IST planning committee: "Information Science and Technology Faculty Planning Committee Report," dated January 8, 2003.

Bruck: Now, the interesting part is that the first meeting of the planning committee was on Friday, May 17, 2002. You might be surprised how come I remember this date. It was the day my father died. We had the meeting here in the Moore building, in Room 239. You know it's hard to find a time to get this many faculty together, so we figured out a time, everyone showed up, and we planned for the next meetings and all of that. Then, after the meeting as I was getting organized, collecting my stuff, and getting ready to leave, my brother called me. I still remember that it was already Saturday morning in Israel, and I had an old-fashioned cell phone, because this was 2002, and he said that our father had just died in the hospital.

I bought a ticket to fly to Israel the next morning because they were waiting for me with the funeral. [*See "Preamble" to this oral history for the story of Shuki's parents*] I went to Israel—you know we sit Shiva, the customary Jewish way of mourning. After that I came back here to lead the second IST committee meeting in May, and then we went through the schedule, where we had every month two or three meetings.

ASPATURIAN: Who was on your committee, and how did you determine what the composition would be? I assume you worked with Richard Murray on this?

BRUCK: Well, not only Richard. The committee was appointed by the president, as far as I remember. I have all the documents.

So in addition to myself, we have Yaser Abu-Mostafa who is in CS and EE, Emmanuel Candes in ACM—applied and computational math—who is now a professor at Stanford, and Mani Chandy in CS; he's retired now; Michelle Effros [Van Osdol Professor of Electrical Engineering] in EE; John Ledyard [Davis Professor of Economics and Social Sciences, Emeritus] and Tom [Thomas] Palfrey [Flintridge Foundation Professor of Economics and Political Science] in HSS [Division of Humanities and Social Science]. Pietro Perona is in EE, Niles Pierce [professor of applied and computational mathematics and bioengineering] is in ACM; John Preskill [Feynman Professor of Theoretical Physics] is in physics; Tom Prince is in physics; David Rutledge is in electrical engineering; Paul Sternberg is in biology; Kerry Vahala [Jenkins Professor of Information Sci-

ence and Technology] is in applied physics; Eric Winfree is in CS and also bioengineering now; and Barbara Wold [Bren Professor of Molecular Biology] is in biology.

ASPATURIAN: And I think at the time she had just succeeded Harry Gray as the director of the Beckman Institute, so she brought in a chemistry component as well with her.

BRUCK: Yes. So those were the people, and since the idea was to create an activity that is broader than engineering, they actually worked very closely with the division chairs across campus. You need to get their blessing to ask someone to serve on a committee, so the idea was to create an activity that is broader than engineering. I met with Tom Tombrello many times to discuss it and with Elliot Meyerowitz [Beadle Professor of Biology], who was the division chair in biology. And I think John Ledyard was—no, what's the name of the division chair who came after him, a woman?

ASPATURIAN: Jean Ensminger [Wasserman Professor of Social Sciences].

BRUCK: Exactly. So I met with her. Maybe John was the division chair earlier in the process. In any case we had a great team. And those years, I would say 2000 to 2005, were extremely active for me. Very active; everything was integrated. It's always active. I was also working with Rainfinity [*Session Eight*] and the voting technology project [*Session Eleven*]. So the context switching was a bit more brutal than usual.

Aspaturian: I know what you mean, I think. Everyone has a period like that at some point in their life.

Bruck: If they are lucky.

Aspaturian: Although at the time you don't necessarily feel terribly lucky, you might just feel overwhelmed.

Bruck: No, I was very happy. All of those were good opportunities. Also, I was very organized with those IST planning meetings. It's not here in this document, but I had a handout for each meeting, where we had a schedule and a list of topics that we discussed, and I think we had the minutes for each meeting, and we addressed many topics.

So you see, the question was, What is the right mechanism? And here is the content part, which is, "What are the topics that encompass information?"

And beyond the content, there is the question of mechanism, like "Okay, you want to do something in biology and engineering; how do you do it? What is the exact mechanism for that?" And I remember that we had a presentation on the mechanistic part: Would IST be something like the Lee Center or something like the Beckman Institute, or this and that? How exclusive will it be? So we had all of those discussions because there is a budget, and the question was, how are we going to manage all of this?

"I told the head of Development that I don't need the IST building to be on his list; I just need it to be on the ground"

Aspaturian: At what point did it become clear that this would all be folded into the [2003–2008] capital campaign that was gearing up? I'm looking at the page here in the report where you talk about the operating funds and the capital campaign, and obviously the two were put together at some point. Did you know from the outset that this was how it would work?

Bruck: I didn't know that it would be part of the campaign. And I didn't have a good experience working with Development on the campaign. I wanted to fundraise between $100 million and $120 million. I also thought that if we were to create a separate IST division, then probably we can raise about $200 million just for the new division, maybe through a naming opportunity or doing some big effort around that. But I think this early report had more modest goals. The top priority at the time was the building.

Aspaturian: Did you have buy-in from the administration on this from the very beginning—the prospect of building a new structure to house this program? Were Baltimore and Koonin enthusiastic?

Bruck: I think the president and provost were supportive of that. I think that the problem was with the head of Develop-

ment, and Development in general. I went to have a chat with the head of Development, Gary Dicovitsky. A very nice guy. He likes basketball, and I also like basketball. But I talked to him about IST and specifically about the building, and he told me that he can work on one or maybe two building projects at the time as part of the campaign, and that my building is not on his list. And I told him that I don't need the building to be on his list; I just need it to be on the ground.

ASPATURIAN: How did he react to that?

BRUCK: He got used to my sense of humor. But I told him, "You know, honestly I don't worry about the list, but we will get this building." At the end, we didn't get it through Development.

ASPATURIAN: I looked into this. Three buildings came out of the capital campaign. There was Cahill [Cahill Center for Astronomy and Astrophysics], there was Schlinger [Warren and Katharine Schlinger Laboratory for Chemistry and Chemical Engineering], and there was Annenberg [Annenberg Center for Information Science and Technology].

BRUCK: So it's consistent, because he worked on one and two. And not on the IST building.

ASPATURIAN: So what did you do once you realized that there was not going to be much assistance from Development?

BRUCK: I decided to connect with friends of Caltech.

ASPATURIAN: You did this independently.

BRUCK: We did it independently. So at the time Bob Carroll worked with me. I hired him as a managing director for IST, and I also was very lucky to hire Mary Sikora. And they were a great team. A fantastic team! The way I got to know Mary is because she was running the administrative part of the voting technology project [*Session Eleven*], and when we started IST she was ready for some change, so I hired her to help me. Bob and Mary had two offices on this floor, and so we had a little operation here. They were very instrumental in figuring out whom we can approach and how to reach out to them. They got a lot of data from Development with regard to potential people.

ASPATURIAN: So Development was helpful indirectly? They provided information?

BRUCK: Yes. I think the problem was more an incompetence problem. They wanted to do the work, but they didn't know what to do, and I think there is an art of being in Development in universities, and I think some schools do it better than other schools. Just to be politically correct. [Laughter]

ASPATURIAN: Very diplomatic.

BRUCK: Yes. I think an interesting milestone with IST was that I was invited to give a presentation about the IST proposal at the annual retreat of the Board of Trustees.

ASPATURIAN: This is at Smoke Tree?

Bruck: It was somewhere around Palm Springs [Smoke Tree Ranch]. And it was very well-received by the trustees, and that created tremendous momentum.

Aspaturian: Who invited you to do that? I assume it was the president or provost.

Bruck: Yes. At that time the provost was already Paul Jennings. I'm not sure what the dates are that we received the gift or the promise for the building. Probably 2004.

Securing donor funding for the Annenberg IST Center; selecting successive architects; establishing the building committee

Aspaturian: Yes. I don't have the month in my notes, but I have the year. The Moore Foundation pledged $22 million, from what I have here, and the Annenberg Foundation pledged $25 million. So what brought you to the Annenberg Foundation and how did that go? I don't think they'd ever given money for something like this. Mrs. Annenberg said as much in her remarks at the groundbreaking—that this was an absolutely new departure for them.

Bruck: So there were two people that helped. One was Si [Simon] Ramo. He was the chairman of TRW and a Caltech trustee, and he was the person who reached out to the Annenbergs.

Aspaturian: After you made this presentation to the trustees, I assume.

Bruck: Yes. Si knew the mother of—I forgot the name.

Aspaturian: Wallis?

Bruck: What's the name of Wallis's mother?

Aspaturian: Oh, that I don't know. Although actually I read it yesterday. Wait. Leonore Annenberg.

Bruck: Yes. So Si talked to her. I did research on the Annenbergs, and I discovered that the grandparents of Wallis, their names were Moshe and Sara, like my parents. So I told her that. They were from Chicago, dealing with newspapers and other businesses. In any case, Si talked to Leonore, and she was ready to pledge $10 million.

Aspaturian: Just on the basis of what he told her.

Bruck: Yes. Because at that time we were also offering naming opportunities for the four IST centers. And then there was the building, which was the biggest donation opportunity

Aspaturian: A mega-naming opportunity.

Bruck: I think at first she said, "I'll give $10 million dollars for one of the centers." And then I think the person that made the big impact is Richard Rosenberg, who was also on the Board of Trustees. He was, I think, chairman of Bank of America. He

lived in San Francisco. He met with Leonore Annenberg, and what he told me afterwards is that he told her, "Listen, if you're already willing to give $10 million dollars for a center, then, it makes sense to do something even more meaningful and do the building."

ASPATURIAN: And then you'll get your name on it.

BRUCK: Yes. So the name on the building, I think, includes the names of Leonore and her husband [Walter and Leonore Annenberg Center for Information Science and Technology].

ASPATURIAN: Walter.

BRUCK: Walter, right. And this was a very short discussion, based on what Richard told me.

ASPATURIAN: Were you even aware that it was going on?

BRUCK: I knew that something is going on. I didn't know that there was this jump between $10 million and $25 million. I knew that the meeting with Si went well. But then immediately after the upgrade from 10 to 25, I heard the news right away.

ASPATURIAN: From whom?

BRUCK: I think the person that told me that is Sandra Ell. She was at that time the Caltech treasurer. She was part of the management team, and I had a good relationship with her. And she was helping me a lot by giving me names of people that I

should talk to, because some of those trustees—I hope I don't get her into trouble because she did fantastic service to Caltech —were members of the investment committee, so she knew them. Specifically Richard Rosenberg. And after it happened, I told Sandra, "You know what? Let's go and say 'Thank you' to Richard Rosenberg." So we flew to San Francisco, myself and Sandra, and we met with Richard in the Bank of America building in San Francisco, where he had a nice office, and we had a nice lunch with him, and I made sure to thank him. Then I also organized a lunch with Si Ramo. And he invited me for lunch at the California Club in downtown LA.

Aspaturian: Oh yes. Which used to be restricted, we will just note for the record.

Bruck: In what sense?

Aspaturian: No African Americans, no Jews, no— This was a while ago though.

Bruck: I think Si Ramo is Jewish.

Aspaturian: Well, things change.

Bruck: In any case, they let me in [laughter], and we had a nice lunch there. He's a very impressive gentleman. We just exchanged emails after that point, but he actually died in 2016.

Aspaturian: He was in his nineties, I believe. He had a very long and interesting life.

Bruck: He was a very, very sharp guy. He was an alum of Caltech, as you know, and I think Ramo Auditorium is named after him.

Aspaturian: Yes. That was his gift. Had you met any of the Annenbergs at this point? Mother or daughter?

Bruck: No. The first time I met the Annenbergs was when we had the groundbreaking here.

Aspaturian: So they bought in on this largely on the say-so of Si Ramo and Richard Rosenberg?

Bruck: Exactly.

Aspaturian: Did you have a hand in drawing up the kinds of persuasions that were used?

Bruck: Yes. I had an exchange of email between Baltimore, myself, and Si Ramo where we tried to write down the idea of IST and somehow pitch it so that Si can talk to the Annenbergs. We worked on some of the texts that would be presented to them. We also discussed the name, and I came up with the name of IST. The question was whether it will be on the building or not. It *is* on the building.

Aspaturian: I understand, or am I wrong about this, that there were a couple of architects? One firm was commissioned and then another took over. Is that right, or am I thinking of a different building on campus?

Bruck: No, no, this is the building. There was a very famous architect that I think did the library in Seattle.

Aspaturian: Who is this? Is that Rem Koolhaas, something like that?

Bruck: Yes.

Aspaturian: Okay. So that didn't work out.

Bruck: Well, I think there is always a trade-off between creativity and budget. And I think what happened is that the creativity part created a budget that we cannot sustain.

So we had to identify someone to lead the building committee. You know, first you write in a building in the IST proposal, and you're not sure if it will happen. And then it's actually happening after many meetings, many presentations, and many jokes. Now there is a building in the plan, so someone needs to work with the architect and to do all the detailed work. Obviously, I'm not the right person for that. So we asked Peter Schroeder from CS. He's a very creative person.

Aspaturian: Yes and very visual; he's involved in all this modeling research.

Bruck: Exactly. And Peter did an outstanding job.

Aspaturian: So he was the liaison with the architects.

Bruck: Yes, he was the head of the building committee. I also worked with him, and of course there's always something to worry about. So we started with the famous and creative architect, but then we had to fold it and restart it with a new architect, who I think did a great job.

Aspaturian: I think it's a beautiful building, personally.

Bruck: Yes. And really, you could see the mood of the people in CS changing as the building was built.

Tensions arise within EAS over proposed creation of new IST division

Aspaturian: What was the reaction on campus and within the division as a whole to the idea of having this brand-new building with this new emphasis?

Bruck: There is a notion of north and south in the engineering division. The north is CS and EE and applied physics. The south is more the physical side—more focused on matter and energy. Aeronautics and mechanical engineering and so on. Also materials science. If you look at the report, the vision we had is that on the north side there would be an information triangle. We will have applied physics in the Watson Lab, CS and EE in Moore Lab, and the new Annenberg Center. We even thought about opening some pathway in Watson such that you can walk into Watson from the north. And my vision

was to create a division right here with the division office in one of those three buildings.

ASPATURIAN: You would have kind of an IST park, basically.

BRUCK: Exactly. Because there were discussions also about where the new building would be. There used to be a parking lot where the IST building is now. In fact I parked there. And when I gave presentations on IST, I showed my car using Google Earth, and I said I hope that there will be a building here and I will lose my parking spot.

So this was the vision, to have this IST triangle and to have this concentrated activity. This created tension within the division. I believe the president—Baltimore—and Paul Jennings, the provost, were extremely supportive of creating a new division. The reason a new division was not created is because there was opposition mainly from the south side of engineering. You will always hear different interpretations about why there were objections, right? I felt, and I still feel, that Caltech is primarily a science school. It has technology in the name, but it's still a science school. Engineering is nice to have here, but it's definitely a second citizen.

That's why I felt that it's critical that we split engineering into two divisions. That's the only way to create more focus on engineering at Caltech. If it's just one division out of six, and there is only one person out of six representing all of Caltech engineering at the IACC [Institute Academic Council], then

we are not going to get anywhere. It's still the situation right now. Beyond this internal political issue, the key was our vision —that information is a unifying scientific concept, like physics was many years ago. Of course, I believe it is more obvious now, but fourteen years ago there was no iPhone and no smartphones, and it was very different at that time than it is today.

"Caltech is not about disciplines; it's about intellectual centers that interact with no boundaries"

ASPATURIAN: You felt that it was not a good idea to continue to have information science kind of bottled up inside engineering?

BRUCK: Exactly. Because you want to make connections between, say, people from HSS and physics, and we have that now in the Annenberg building. The whole idea was to create those types of opportunities, and this part was successful. Caltech, as we talked before [*Session Four*], is not about disciplines; it's about centers. Intellectual centers that interact with no boundaries. The centers address different concepts in information, physics, biology, social sciences and electrical engineering and computer science. The interesting creative dynamics happen in between those centers.

ASPATURIAN: You saw information as becoming the common denominator among all of these disciplines?

BRUCK: Yes. And also, if you look at the report, we forecasted that the largest group of undergrads will be interested in in-

formation. Of course at that time there were maybe ten undergrads in CS. Now there are eighty.

Aspaturian: Were you believed when you said this?

Bruck: No. Of course, now everyone wants to be in this area. If we could offer a degree, undergrad or grad, in IST, then we would be unique, even today, and very attractive to the best students and faculty in the world.

Aspaturian: While Caltech rejected this model to the extent that you wanted to implement it, did other schools run with it?

Bruck: At that time no one was doing it.

Aspaturian: But since that time?

Bruck: Since that time, many schools have started programs that kind of connect up different parts of campus, but because they're bigger schools, it cannot be as effective as here.

Aspaturian: The synergy would not be the same as could have happened here.

Bruck: Exactly. So I still think that it makes sense to do it. You see, from every angle that I looked at it, including organizationally, at the end the question that we always tried to answer was, "What is the best mechanism to bring the best people in the world to Caltech at any given time?" Whether they're undergrads, grad students, postdocs, or faculty members, if we are

able to get the best people in the world, we've achieved our goal. And I think that a program like this would be a very, very attractive draw for Caltech. We cannot compete with the big schools by having yet another EE or CS department, because in schools like CMU, there are probably more than a hundred faculty members in CS. Here we don't have one hundred faculty members in engineering as a whole. Same situation at Stanford—we cannot compete with that.

We cannot cover all of CS, so if I am an undergrad who wants to study CS, of course I'll prefer CMU or Stanford or MIT. Why should I go to Caltech? Well, suppose Caltech has a very interesting information science and technology program. I get to study, not CS in the old-fashioned way, but to learn about information in a way that that includes EE and CS and biology and economics and quantum physics, and this sounds very exciting because if I want to go to grad school or even to work in industry it will give me a much better preparation. It will help me figure out what I'm excited about, and students, when you talk to them, are very excited about this.

EAS vote to create IST division falls short of a supermajority & Caltech remains a 6-division institution

The reason it was blocked is because the south part of campus —

Aspaturian: That is, the south part within EAS.

Bruck: Yes. They felt that if we create the IST division, then they will lose something. That's a generalization, but I would say that was the majority of objections—that they will lose resources, because they said, "You're running away with all the exciting stuff in engineering." I told them, "Listen we are here at Caltech. The idea at Caltech, and at every other good school, is that you always feel that what you do *is* the most exciting thing in science at this point. Why? Because that's why you're doing it."

Aspaturian: Who led the objections, do you recall? Where did the impetus for this come from?

Bruck: I would say from aero/mechanical engineering and materials science. Those groups. And a few people from EE also. Because people said, "Okay, where will applied physics be from now on? Will it be here or there? And how come you got so much money for postdocs?"—because we had a lot of funding —"and we didn't get so much. And you have this new building."

Aspaturian: They thought that IST was going to turn their areas into dinosaurs in a way?

Bruck: Yes.

Aspaturian: Did you think it was a misconception that this was kind of how they felt?

Bruck: What I felt was that if we create two divisions, it means that the sum of the resources we have will be bigger than if it's a single division. I still believe it was the biggest mistake of engineering here in the last fifty years.

Aspaturian: To not take advantage of this opportunity.

Bruck: Yes, it's fourteen years since then.

Aspaturian: Where did Richard Murray stand on this?

Bruck: He was very supportive.

Aspaturian: Because I noticed in the *Caltech Catalog* for two years in the division listings [2004, 2005], he is first as chair of the division and you're next as head of the IST program. So it was obvious that the two of you were working very closely together.

Bruck: Yes, he was my partner. He was extremely supportive from Day One. I told him, "If there is a new division I'll be happy to lead the formation of this division and serve as the chair for a few years. However if it's not happening, then I will step down from the IST directorship because I think that's the natural next step."

Aspaturian: How did this finally get negated? Was there a vote?

Bruck: Yes. At that time there was a division steering committee that I served on, as well as other people who led different activities and departments, so we had many discussions about how to make the decision. A number of people were against the split of the division. Richard felt that we had to come up with a scheme, and what we converged on—and again I can dig out all the documents—was that in order to approve it we need support of at least two-thirds of the division voting faculty and in order to negate it we need one-quarter of division voting faculty.

Aspaturian: Two thirds!?

Bruck: Yes.

Aspaturian: How did you feel about that?

Bruck: There was no way to get agreement on the steering committee for a different formula.

Aspaturian: So a simple majority they just would not agree to.

Bruck: Yes. A majority within the division actually supported the split.

Aspaturian: I did not know that. That must have been very hard for you.

Bruck: Yes. [*SB subsequently added:* The outcome of the vote that happened on June 2005 was as follows: We had a total of 69

faculty (80 percent of the division) give their opinion on the proposal. A total of 40 faculty (47 percent of the division) voted in favor of the proposal and 25 faculty (29 percent of the division) were opposed. This fell short of the two-thirds vote required to approve the proposal and exceeded the one-quarter vote required to turn down the proposal. I took the data from my records.]

ASPATURIAN: Did you expect this result, or did you think it would be successful?

BRUCK: No, I knew it would not be successful the second we agreed on the two-thirds/ one-quarter formula.

ASPATURIAN: I see.

BRUCK: And I didn't do anything at the level of talking to people separately to change this verdict.

ASPATURIAN: Could this decision have been overruled by the president or the provost?

BRUCK: I think another approach that some administrators do take, especially at universities, is to say, "You know what, I'm not asking anyone; let's do it." Because for professors, who are overanalyzing everything—I do the same—it's impossible to agree on any change. I think the reason we made the progress we did with IST is because of the composition of the committee. We were all people who were very motivated to get some-

thing done and to close in on some decisions. To the best of my abilities, I was focused on driving the process.

ASPATURIAN: Were the negative votes cast mostly by older faculty? Was it a generational as well as a disciplinary split?

BRUCK: I don't recall that, and I'm not sure if that's the case. I'm not also sure where the boundary is between young and old.

ASPATURIAN: I'd say maybe fifty. I'm insulting both of us!

BRUCK: I'm kind of strange in this way; I don't get insulted by weight or age. Because now, with my health project, they ask me for my weight, and I typically round up: "It's this, but write that." They say, "How come you are willing to accept a larger weight?" I said, "I don't care."

ASPATURIAN: I actually meant it in the sense that people over fifty are not always as capable of appreciating change, which I don't think is true of either of us. But that's roughly where I put the dividing line.

BRUCK: Well academia is more conservative than the church or the synagogue. Extremely conservative. *Extremely* conservative. I served on the task force for revising the core [curriculum] a few years ago. And after two years of arguing, we made very minor changes.

ASPATURIAN: That's generally been the story with the core curriculum here.

Independent IST centers across campus "flourished in a fantastic way"

Bruck: Exactly. I'll dig out some material on that. So in terms of the content, you cannot beat ideas. Ideas, they fly. And all of the four centers we started flourished in a fantastic way.

Aspaturian: Which just for the record were in mathematics, biology, physics, and the social sciences.

Bruck: Yes. And social science is very, very active; there are many collaborations. They got a lot of funding from outside.

Aspaturian: Yes, this was a novel concept for the social sciences.

Bruck: In 2008, we applied to a new NSF program called Expeditions in Computing, a molecular programming project with Eric Winfree in the lead, and this was a natural progression from the IST Center for Biological Circuit Design. And in fact the first five years were so successful that we are the only Expeditions program that NSF suggested should apply for a second five years. This is a program for which they allocate only two awards a year, and we also got funding the second time. So that's biology. And then in physics, of course, the whole area of quantum information, with the leadership of John Preskill, is doing extremely well, and they have probably one of the best centers in the world, if not the best.

Aspaturian: IQIM [Institute for Quantum Information and Matter], yes.

Bruck: And again, just on the micro level. When we made the decision in 2002, 2003, that the physics of information will be mainly centered on quantum information, many people were very upset with me. They felt that it's not fair that their area is not covered in the center. And also in biology, when we made a decision to focus on a Center of Biological Circuit Design, this was before systems biology really took off, with CRISPR and all the things that we have today. Some of the people who do other things in neuroscience and so on got upset. But I didn't make those decisions; we had a committee, and we had very deep discussions about that.

Aspaturian: And if the idea of the new division had taken off, there would be potential for incorporating some of these other areas down the line.

Bruck: Well we could have created classes in them. Or a program and labs for students to experiment with things. We didn't do that.

Aspaturian: How did you feel, realizing that you had spent three or four years working on this—developing it, having a building, and proposing a visionary program—and then it was not accepted. You are the eternal optimist. How did you feel about that?

Bruck: I love Caltech.

Aspaturian: Yes.

Bruck: I feel that this had been good service for Caltech, and I said, "Now I'm going to focus on my class and on research."

Aspaturian: I notice you're not in the beautiful building that you brought to campus.

Bruck: Yes. Some people thought that I would have a suite there. They kept asking me, "Where is your large corner office?" And I would say, "I'm not going there; I already have a nice office."

"My experience is if you do anything of any use, you'll get this portfolio of feelings"

Aspaturian: Do you think Caltech made a mistake?

Bruck: Huge mistake. You know, I told you before that given my background and my parents' background, I never feel like a victim—never in my life. And it's the same thing here. I don't take it personally. I feel lucky that I was able to do that, and I think in the process some people—quite a few people—felt that I did a good service. Other people were envious. Other people created some kind of negative feelings against me. And my experience is that if you do anything of any use, you'll get this portfolio of feelings. I felt that I was pushed to the side at the Institute after I stepped down from the IST position. I'll give

you an example, and then I'll go to my faculty meeting. We had a ceremony to cut the ribbon to open the building. Were you there?

ASPATURIAN: I remember being at the groundbreaking; '07, was it? It was a rainy day. You were all there with shovels. I think I was at the opening ceremony, too, which I don't remember, however.

Annenberg IST Center groundbreaking in December 2007. From left to right: Shuki Bruck, Wallis Annenberg, architect Frederick Fisher, and Caltech's then-president Jean-Lou Chameau. Behind Shuki at podium (right) is Avery House, where he and Anat were then living as faculty residents—"my shortest commute ever." *Caltech photos by Robert Paz*

BRUCK: So you know where Richard and I were at ribbon-cutting ceremony? We were standing in the back. You know who was standing next to us? Tom Everhart. And he asked me, "Shuki, how come you are not up there?" I wasn't there because they didn't arrange for me to sit there. They didn't ask me to cut

the ribbon. The person who was up there was [Ares] Rosakis [Von Kármán Professor of Aeronautics and Mechanical Engineering].

Aspaturian: The chair of the division at that time.

Bruck: The chair of the division. And Mathieu Desbrun [Braun Professor of Computing and Mathematical Science]. And I was not there. Richard was not there. I asked Development if I can get the scissors that cut the ribbon. And I actually got them; no one knows I have them at home.

Aspaturian: We'll take a picture and put it in the—

Bruck: [Laughter] And they produced another set of scissors, so no one will know that. Because the head of Development—Bob, what's his name, who left—

Aspaturian: Bob McQuinn; he went to Northwestern University.

Bruck: He knew about all the work that I did, because I had traveled all over the U.S. I gave lectures; I did events with people and alumni. I did a lot of Development work for this, and we had a really good relationship. He didn't feel it was right that I was pushed to the side this way, so he came the next day to my office and he brought me the scissors. [Laughter]

Session 8, December 12, 2016

Laying the groundwork for RAIN—a reliable & distributed storage system

Aspaturian: Today I thought we'd focus on what I think of as your adventures in entrepreneurism here at Caltech. That will take us back, I believe, to around 1994 and the start of the project that eventually became Rainfinity. Is that correct?

Bruck: Yes.

Aspaturian: You got involved with it through working with a colleague at JPL, I believe.

Bruck: Yes. There are many stories about how it happened because at that time anything involving the internet attracted publicity. There was coverage from CNN and in Forbes and many places. Typically I don't appreciate this type of exposure, but it was kind of the style in those days, because it was the beginning of the internet.

Aspaturian: That's right. It was a fairly new area.

Bruck: Yes. So, I came from IBM, where I had worked, as we discussed before [*Session Four*], on parallel computing, and I also worked on storage systems. Just for the sake of historical completeness, the first disk drive was invented by IBM in San Jose

in the same year that I was born, 1956. I think it's an interesting story so I mention it here. A guy called Reynold Johnson, who was a high-school teacher in Minnesota, actually created a machine to do automatic reading of tests. This is before there were computers. And IBM acquired his startup. So we're talking about startups.

Aspaturian: Very early.

Bruck: Very early. So IBM sent him to San Jose to build a team and to build a disk drive, and they created a disk drive that was called RAMAC [IBM 305 RAMAC]. Of course, that was an IBM type name, some kind of long acronym that only a few people are privileged to know.

Aspaturian: Not some ancient Aztec god, although that's what it sounds like.

Bruck: Yes. [Laughter] It was 5 meg [megabytes], and it weighed one ton. But it was a very important beginning. So in fact San Jose was the site both for manufacturing disks and for all the technology related to disk drives in terms of error-correcting codes and signal processing and the physics around them and so on. It was a really fantastic place. It's not the case anymore, because most of it was sold, and the manufacturing is no longer in the US.

Aspaturian: That's for sure.

Bruck: And, you know, maybe it will come back now with Trump. But we don't need hard drives anymore. So I was exposed to storage because of Mario Blaum, whom I became close friends with as I worked there. He did his PhD here with Professor Bob McEliece.

Aspaturian: I think you mentioned him in a prior interview session [*Session Four*].

Bruck: Yes. So through this friendship I started getting interested in storage, even though what I did in my day job was not storage. The two of us did very interesting work that ended up in IBM products and in fact became kind of an industry standard, so that now there are many variations on the scheme that we developed to deal with the reliability of large storage systems. This scheme is called EVENODD ["EVENODD: An efficient scheme for tolerating double disk failures in RAID architectures," *Computers, IEEE Transactions on 44 (2), 192-202*]. So when I came here I had ideas about how to create a storage system that is not confined to one box but is a distributed system. Of course now that sounds very natural because today all the storage systems are distributed, and you have the Cloud and all of that.

The approach in IBM and in general in industry, was to address reliability in storage by adding redundancy, the so-called RAID —Reliable Array of Independent Disks. I worked on a RAID project at IBM; this was not a distributed storage system. When I came here, I changed the D to an N: Reliable Array of Inde-

pendent Nodes. And this was the RAIN project—a reliable and distributed storage system.

Adapting RAIN technology for space missions while navigating NASA/JPL culture

Aspaturian: I have here you hooked up with a fellow at JPL, Leon Alkalai?

Bruck: Yes.

Aspaturian: How did the two of you come to meet?

Bruck: I knew his brother from the Bay Area. So when we came here, we got to meet them socially, and Leon got really excited about what I had in mind, which was to build a system using commercial, off-the-shelf components.

Aspaturian: How had you become familiar with what JPL was using in its space missions?

Bruck: Because I talked to them.

Aspaturian: I see.

Bruck: JPL is always using—when it comes to computer technology, it's kind of a collector's item. It's typically twenty, thirty years older than state of the art. In fact, today I'm working again with JPL, and again it's about storage but now we're trying to

help them to use Flash memory, which is what we have in USB sticks.

ASPATURIAN: They're not using that on their space missions?

BRUCK: Very little because it isn't designed to resist radiation.

ASPATURIAN: Oh I see, of course.

BRUCK: So we've actually figured out a way to take existing Flash memory technology and make it reliable through mathematics and algorithms [*Session Nine*], and we've been running experiments in radiation environments at JPL.

ASPATURIAN: This is a recent project?

BRUCK: This is ongoing. In fact next week my postdoc and our JPL collaborator are going to Colorado Springs for a few days of experiments in radiation chambers. That's the second project I have had with JPL. The first one was the RAIN project.

ASPATURIAN: What gave you the idea that off-the-shelf components could be used to replace the customized devices JPL was using? That's my first question, and my second one is, why had no one else thought of this?

BRUCK: Yes. I think you can think about many things. The question is, can you do it? [Laughter]

ASPATURIAN: Yes, that's a good way to prioritize it.

Bruck: You see, the challenge with JPL is that there is zero margin of error.

Aspaturian: Once a mission is launched.

Bruck: Yes. And so even if it's unmanned, how do you make sure you don't lose a mission that you worked on for ten years and so on?

Aspaturian: When you started, was it around the time of that Mars Observer was lost, in 1992?

Bruck: Maybe, yes. This was before Galileo?

Aspaturian: Yes. It was a Mars mission. Almost a billion dollars. Apparently it didn't go into orbit around the planet; it went—zoom.

Bruck: Yes, I cannot take responsibility for that.

Aspaturian: No. But I think your timing was probably not long after that happened. I remember that. It was a major catastrophe.

Bruck: So one part is this zero margin of error. The other part is the financial part, because why would I innovate for anything related to outer space? It's a very small market, and also it's very hard to recruit people who do computer technology to NASA. Why would you work there?

Aspaturian: Is it because NASA doesn't pay enough that they don't go there?

Bruck: It's a lot of fun, but they don't pay a lot and you're locked into one project, and it's not clear that what you learn can be used anywhere else. Also, most of the people that we train for advanced degrees in that area are not US citizens, and so with all the regulatory frameworks, they cannot work there. So the whole NASA environment is in a sense older, and there is a certain level of stagnation in the culture there.

Aspaturian: Were you yourself a US citizen by this time?

Bruck: No. I became a citizen in '98.

Aspaturian: But you were nevertheless able to do this work.

Bruck: Well it was before 9/11, and I had a Green Card, but I think after 9/11 they changed many things. But by then I'm a US citizen. At JPL there is a fantastic group of people, very talented scientists. But again, when it comes to computer technology, it's very different from what you see in Silicon Valley in terms of how dynamic it is. So the RAIN project involved four students who worked on it full time.

Aspaturian: How about people at JPL? Or was it mostly based down here on campus?

Bruck: It was mostly based here. There were one or two people at the lab that we could deliver the prototype to.

Aspaturian: Was JPL supportive of the project?

Bruck: Well, it was a joint proposal that Leon and I wrote, and we had funding from DARPA [Defense Advanced Research Projects Agency, within the US Department of Defense] and NASA. Part of the funding went to support the JPL people.

Building the RAIN prototype: Creating "something very robust & flexible to deal with failures autonomously"

The fun part was building a prototype, which I rarely do at Caltech, but we had a lab, we had equipment, and we got many, many, machines both from Intel and IBM. Even the room here across from my office belonged to my lab at that time, and we had quite a few machines there with a lot of storage. And it was at that time one of the hottest demos on campus, because people would come and see many screens—I have pictures of this somewhere that I can look for. So you could see actual video, and the node that is displaying this video on a screen is getting the information from many places, and you can disconnect wires and see how it kind of reconfigures itself.

Aspaturian: Can you explain briefly what it was you set out to replace and what made your prototype superior to what existed at the time?

Bruck: Yes, so, when you want to can create something that is reliable, you have basically two ways to do it. One is to build something that will never fail.

Aspaturian: Which is what JPL had been trying to do originally.

Bruck: Right. And the other way is to build a few systems that collaborate and if one of them can take a nap every now and again, or even fail, so as long as you have something else that works, the system as a whole will keep working. So it's kind of a Borg type of behavior in that maybe you lose pieces but the system keeps working, and if you fix the pieces that are not working they will rejoin the system and it will be fine again. So that was the idea, is to create something that is very robust and very flexible in the sense that it will be able to deal with failures autonomously. And also able to deal autonomously with good news, not just bad news.

Aspaturian: Was this designed to fly as payload on space missions, or was this something that would remain on the ground?

Bruck: No, the idea is to put it in payload.

Aspaturian: Okay, you're going to put it in space

Bruck: Yes, as a way to store information. And I'm not sure what happened with that. So let me just jump forward. When we delivered the finished product to JPL they had a few companies bid to build a production-level version, and the Lock-

heed Martin facility in New Hampshire actually won the contract, and they built a similar system to it. I'm not sure where it went to—either DARPA or NASA, but I don't know.

Aspaturian: You don't know if it ever flew or if it went into military use?

Bruck: No.

Aspaturian: Really? You don't know what happened to it?

Bruck: You're not supposed to know, I think. But academically this work was very influential, and I think also in industry. I'm not sure what happened in NASA and DARPA. You see when it comes to introducing new computer technology, JPL does not build it. Typically when they understand how to do something well through a project like this, they will find someone else to build it.

Aspaturian: They subcontract it out.

Bruck: Yes. And it's not clear what happened to our prototype after that. It's not like in a startup where we take it from A to Z, and after a couple of years there is a product that is being sold and used in thousands of places around the world. But I think it was exciting to do it.

Aspaturian: Right, proof of concept and working prototype.

Bruck: Yes, and we also had patents. Those patents became very critical in the industry; I think there are thousands of citations on them. There were a couple of big lawsuits in the industry about those ideas, and the RAIN patent was used as a way to show prior art on all of those idea of distributed storage.

Aspaturian: Do you want to mention before I forget the names of the students who worked with you on this?

Bruck: Yes.

Aspaturian: It might be nice to get those into the record.

Bruck: So Lihao Xu, Vasken—we call him Vincent—Bohossian, Marc Riedel, Charles Fan, and Paul LeMahieu

Commercialization plans take RAIN & Caltech into new waters

So at the time, in '98, I thought about starting a company that will commercialize our work.

Aspaturian: Was that unusual for Caltech at this time?

Bruck: It was, at the beginning, unusual.

Aspaturian: But Larry Gilbert was already here.

Bruck: Yes, he arrived in '95.

Aspaturian: So your timing was very good.

BRUCK: Yes. In general he was an extremely helpful guy, and it was a lot of fun to work with him [*see also Session Six*]. So I think the Caltech part was easy in a sense. You know, when you start a company you typically get exclusive licensing to the intellectual property that belongs to Caltech—and this was a relatively easy process—and Caltech gets some percentage in return of the equity of the company.

Shuki and Rainfinity cofounders Charles Fan, Phil Love, Paul LeMahieu, Vincent Bohossian, and Gil Margalit. The RAIN prototype, c. 1997. *Photos courtesy of Shuki Bruck*

Aspaturian: What led you to think this had commercial potential? What did you envision it being used for?

Bruck: What I envisioned changed over time, I would say, and then at the end it was very close to my original concept. That's the nature of the startup. Sometimes you have a very crisp vision that you realize, and sometimes you have a crisp vision that you need to modify as you go forward. Because at the end of the day in a startup, your job is not to prove that you're smart or to have an unbelievable idea. That has no value.

Aspaturian: Do you think that's a mistake a lot of hopeful entrepreneurs make?

Bruck: Many people make this mistake. They think that they are measured by the depth of their idea. But that's not relevant at all. I always tell people, suppose you go and buy a car. Do you care about the idea behind the car's transmission? No, you don't. You are interested in other properties of the car: How quiet it is, what the gas consumption is, how reliable it is, how safe. You really cannot care less about everything else.

Aspaturian: Yes, all the back-end engineering doesn't really interest most people at all.

Bruck: Yes. And if someone says to you, "You will pay 20 percent more for this car, but it is based on an idea that is unbelievable, something that has never been done before, and it will save you 3 percent in the gas consumption," you will say, "I

don't care." Because you do the math, and it doesn't make sense.

Aspaturian: You're not paying for the quality of the idea.

Bruck: Right. So at the end, the key in a startup is to transform an innovation into a solution. People pay for solutions. They don't pay for innovations.

Aspaturian: So what solution were you addressing?

Bruck: It's a very interesting evolution, because what we had developed was a general way to connect many things such that even if some parts fail, the whole thing keeps working.

Aspaturian: You mean in general?

Bruck: In general for computers. Here we used it for storage: Each one of those entities was responsible for a piece of storage.

Aspaturian: Each of your nodes.

Bruck: Yes. Each of the nodes. And it kept working even if some of the nodes failed. But this mechanism that we created, this algorithm that we had, was more general than that. It had a piece that was specific to storage. And there was quite an interesting thing—You're puzzled?

Aspaturian: No, I'm just thinking, go on. I may be puzzled, too, but I think I'm thinking.

A "bitter lesson" learned from first attempt to license RAIN

Bruck: So we went and talked to different potential customers and companies. In fact I went to talk to Yahoo, which was a very young company then and met with one of the founders. I met with quite a few other companies. One of them was a very young Israeli company that deals with security, called Checkpoint.

Aspaturian: When you say "security," do you mean the secure transmission of information?

Bruck: Yes. Well, they designed firewalls, so it's a way to secure an organization. And Checkpoint's firewall was very good, and they actually did very well in the market. However, their firewall was a single node.

Aspaturian: And if that node were to fail?

Bruck: Yes. If this node is overloaded or it fails, then there is a problem. Actually, two problems. One is that it had a smaller potential bandwidth of going in and out, because it was just one node. And the other one was that it couldn't scale. It's like having just one entrance to the Rose Bowl.

Aspaturian: So its information-carrying capacity was somewhat limited, and there was no way to expand that.

Bruck: Exactly. And also, there was the risk of a single-point failure.

So the idea we had was to create a scalable gateway, using the same properties that we had designed for RAIN, and to do all the enforcement of security on this gateway. Now the tricky part is that Checkpoint already owned an application that was doing this work. So the question was, can we create that gateway without asking Checkpoint to collaborate with us very tightly. Can we find a way to separate between the two? I remember going to Checkpoint in June of '98 and meeting with their technical people.

Aspaturian: Where were they based?

Bruck: In Redwood Shores in the Bay Area. We explained what we thought we could do, and we showed them a demo of the RAIN project. We had imported our prototype to a bunch of laptops so we could demonstrate on them instead of needing the big machines, and we had a special carryon that we could travel with. It was a lot of fun. So they understood what we were trying to do, but they felt that it's probably impossible for us to do it unless they collaborate with us. So I told them that we would try to do it ourselves, and how about if we meet in three months and we will try to demonstrate it.

Aspaturian: So you were prepared to go it independently, even though they didn't think you could?

Bruck: Yes, well, a company is not going to let you just do it and give you unlimited access to things and so on. Like, Who are you? So they asked us, "What do you need?" And I said, "Just give us a box of your software, and we will try to do it, as if we are one of your clients that has your software and wants to expand it and buy one more license from you." We rented an office on Raymond [Raymond Avenue in Pasadena] above one of the restaurants there, and the team was really brilliant. We figured the technology out, and we had an amazing demo for Checkpoint in September '98.

So this was our first product, and my strategy was to have a deal with them. We will give them our product, and they will sell it and will give us royalties. This was the plan. In fact we had put together an agreement and already started selling when they decided to cancel everything and told us that they're going to build the same thing themselves. It won't be ready for two years, but they don't want an agreement with us. During those few months of negotiation they had had a version of our product in their labs, and they learned from it.

Aspaturian: Of course.

Bruck: Yes, this was a pretty bitter lesson for all of us. It happens.

Aspaturian: You had not expected this?

Bruck: I thought that it's possible, but I thought it's very unlikely.

Aspaturian: Was there legal recourse to something like this, or not?

Bruck: There was an option to go and do a lawsuit, and pay lawyers a lot of money and spend time, and I decided that I'm not going to do anything. It took them a while to build it. They tried to block us from the market, but in the meantime we were able to sell pretty well into the market.

Aspaturian: Again in the security context?

Bruck: Exactly this product. It was very successful.

Aspaturian: Regarding Checkpoint, were you disappointed because you thought that as an Israeli company they would deal with you in an honest fashion?

Bruck: [Laughter] There are two ways to look at it, right? It depends on your life philosophy, because you can say, "Well, maybe from my perspective, knowing some of the culture in Israel I shouldn't be surprised."

Aspaturian: I see, okay. [Laughter]

Bruck: I'm sorry that I'm cynical.

Aspaturian: It's not that, but I thought that on the other hand there might have been the expectation—

Bruck: Yes, I think it's not related to them being an Israeli company or myself being Israeli.

Aspaturian: I just wondered if you perhaps had more benign expectations of them.

Bruck: I know them, and I went and talked to their founders and CEO and so on, but that was the situation. So at that time Rainfinity was like five people.

Aspaturian: That's right, You and your students.

Bruck: And Checkpoint basically just said, "Okay we can do it ourselves; the Rainfinity team is nice, but let's kick their butt and move on." At the end, it worked out well for Rainfinity.

From setback to sales: Rainfinity finds its market

Aspaturian: I have a note here that the Chicago Board of Trade was your first paying customer.

Bruck: You did good research. Yes, they bought this product.

Aspaturian: After the disappointment with Checkpoint, they emerged as your first client?

Bruck: Yes, it all happened fast; we had many, many customers. Thousands of customers. In fact, that helped us from the financial point of view, because we got most of our funding from so-called angel investors—people who feel comfortable about in-

vesting in a company, and typically those amounts are not what they are in venture capital; it's more like a couple of million dollars.

ASPATURIAN: Were these people you knew through Caltech or through IBM or through other contacts?

BRUCK: I knew them through social connections, not through Caltech and not through IBM. And then in '99, we did two things. One, we opened an office in the Bay Area, because there was no way, at least at that time, to hire people and expand the operation here. And, two, we conducted a CEO search to bring someone to manage the company.

ASPATURIAN: You had been managing it until then?

BRUCK: No. I was always the chairman, but someone else was the president, and he managed the day-to-day operation. I wanted someone with a business background who is not one of my students. Because during the same time I was doing so many other things here. Like for example the CS search [*Session Six*].

ASPATURIAN: That's right; you said earlier that it went on simultaneously with this.

BRUCK: Yes, that I did starting 'in 98. I was just telling my son last night about this period between '98 and 2005, and the amount of stuff I did both here and outside of Caltech and also in the family. It was quite interesting.

Aspaturian: Yes. I think it's important to get that into the record, because we're deconstructing all these activities into chapters here, but from your perspective it was all happening at once.

Bruck: Yes, it all was happening. It was impossible for me to take a leave because I wanted to keep going with research in my group. I was teaching, and I also had commitments here on the administrative side. And then Rainfinity was happening. Back in '99, you know, no VC would invest in a company unless it had a strong management team, and it's very hard to recruit a management team unless you have enough funding. So the way I dealt with it was to say, "It's like the famous saying about the fork in the road. What you do when you have a fork in the road is to try to make progress on both branches at the same time." So we were able to raise VC funding, and more or less at the same time hire a CEO.

Aspaturian: Did you have this particular area to yourself? Did Rainfinity capture enough of the technology early enough that competitors were pretty much locked out?

Bruck: We had some competition in this security part, because it's just the beginning of the story. There was a Finnish company that had a product that was much more limited, but they were a competitor, and my philosophy is that it's good to have a competitor.

Aspaturian: It keeps you on your toes.

Bruck: It keeps you on your toes, but also it helps you to increase awareness, because it means there's also someone else telling the customer that it's a good idea to have this kind of product. So it's a good thing for Pepsi to have Coke, right? Because you buy either one of them, or you try one of them, but the key is that you drink Coke or Pepsi, so that's good for them. [Laughter] So we raised a relatively large amount during a VC round in '99—$15 million. And a year later, we raised $30 million.

Aspaturian: For the same company?

Bruck: Yes, for Rainfinity. This was the point where I started to worry because—it was a bubble, you know? I didn't think that we could sustain the valuations that we received. They were bigger than the $100 million that we received for Rainfinity later.

Rainfinity develops software to optimize large-scale data storage & is acquired for $100 million; campus reaction goes unrecorded

So I and one of the founders started a skunk project to figure out how can we do something related to storage with this technology. I went to talk to quite a few people in the storage industry. That happened, I would say, around the summer of 2000.

Aspaturian: Right before the dotcom bubble burst.

Bruck: Just before and just after 9/11. And what I discovered is that in fact enterprise storage systems [systems that can handle a large volume of data and many users] have a problem similar to what we addressed in the RAIN project and what we addressed in the scalable gateway project. Large companies buy something that looks like a refrigerator to store information. And then they buy another one because they run out of space to store their "ice cream." And then they buy another one. And those different refrigerators, they don't talk to each other. But still everything is okay because one project is on this refrigerator and another project on another refrigerator. The problem is that now comes the third guy, he needs space for his project and you want to move project A to be with B such that C will have more space. But because they don't know any way to communicate with each other, in order to do it you need to declare downtime. While you reorganize the projects, no one has access.

So we discovered a problem. A problem is very important, because a solution doesn't have the right to exist unless there is a problem. We went and talked to customers about this problem, and when you talk to a customer about a problem, the most important question for you to ask is, "What are you doing about this today?" I always give this story: Say that you have a pain in your shoulder. You go to the physician, and he says, "Tell me more about the problem." You say, "Well, the pain in the shoulder happens only on Tuesdays if I eat oatmeal on

Tuesday." That's not a problem, because on Tuesday you can decide not to eat oatmeal and eat a bagel instead.

However, if the physician says, "Tell me more, and you say,"Listen, it's tremendous pain; I cannot concentrate at work," he will ask you, "How do you deal with it?" You say, "Well, I bought this machine that gives me a massage. That's the only way I can concentrate. However this machine creates tremendous noise, and now they are going to lay me off because of the noise." Okay, now there is a problem. So we went to a few prospective customers, and I remember vividly one of the meetings where the company director said, "You see all the people in the meeting? They are all dealing with this problem. Because it's a very complex problem for us."

Aspaturian: How were they dealing with it, or were they just talking about their inability to deal with it?

Bruck: No, they had scheduled downtime, and they worked very hard at night to make sure to handle things in a way that is not disruptive.

Aspaturian: I understand. But it was a bit ad hoc.

Bruck: Yes. So we said, "What if we have a solution that means you will have zero downtime?" It's similar to the scalable gateway in that we can somehow miraculously move things around and you don't need downtime. In any case we were successful in doing that.

Aspaturian: You devised an algorithm that took care of it?

Bruck: Yes. And we built a product.

Aspaturian: You say "we." Was this you and your colleagues at Caltech again?

Bruck: I worked on it with Charles Fan, one of the founders already in Rainfinity. In any case, this solution is what created the value for Rainfinity.

Aspaturian: Was this never previously addressed because nobody had looked at it in quite the way you and Charles did? Or had people thought about it but couldn't figure out what to do?

Bruck: So the way people thought about approaching it is to say, "at some point, we as people that sell the refrigerators will figure out a way to make sure that the refrigerators talk to each other." This is something that the "refrigerator companies," metaphorically speaking, said they will deal with. But how to do it? It was not clear. When you build a refrigerator, you don't think about building something that will connect with more than one refrigerator, because you think "I'll be happy if every customer will buy just one." Okay, someone who buys two is not a big deal, but suddenly people are buying fifty. We offered a solution that can move things not only between Maytag refrigerators but also between a Maytag brand and something else. I

learned a lot from this project, and I learned also how to work with those data center people.

ASPATURIAN: I just want to make sure I understand. In your metaphor, the refrigerators are standing in for storage components, is that correct?

BRUCK: Exactly. It's a storage system.

ASPATURIAN: So if the number of units grew, the companies' ad hoc functional approach to optimizing storage got less and less efficient, or so I gather.

BRUCK: Yes.

ASPATURIAN: Okay. So you came in with something holistic.

BRUCK: Exactly. That's a good word. Actually, there were many other things we could do, which were really ahead of their time. And it was good, because after 9/11 things were very hard from the business perspective. We didn't have the storage solution yet; we just had the previous gateway product from working with Checkpoint, so we cut Rainfinity by half.

ASPATURIAN: Right. You talked about that last time.

BRUCK: We signed an OEM [Original Equipment Manufacturer] deal, like the one we had wanted to do with Checkpoint, with a company called Symantec, which is a competitor of Checkpoint, and they did very well with this product, and we

kept getting royalties. Because of the economic climate, we couldn't raise enough funding to continue the operation in Rainfinity, so we went to Symantec and we offered them an all-you-can-eat deal. So they gave us a one-time big payment, and then they could use our solution and not pay royalties. And that saved the company.

ASPATURIAN: Aha.

BRUCK: So life is pretty interesting. We used that funding to develop the storage solution that then led to the acquisition of Rainfinity.

ASPATURIAN: What did Rainfinity ultimately sell for?

BRUCK: A hundred million.

ASPATURIAN: What was the reaction of your colleagues on campus?

BRUCK: I don't remember.

ASPATURIAN: You don't remember?

BRUCK: I actually don't. You know, you typically don't get the whole hundred million, but you get enough that it gives you peace of mind.

ASPATURIAN: Yes, you and your students I think, also. They all had a share in this, as I recall.

Bruck: Right. And also Caltech.

Aspaturian: Yes, of course. Who bought Rainfinity?

Bruck: EMC.

Aspaturian: Which is?

Bruck: That's their name. It's the world largest data storage company and when EMC saw that we were selling our product to many different organizations, being the largest data storage company in the world, they said, "Hey, wait a second. If this is something that people are interested in, we want to sell it." [Reaches for an object on a shelf] So this is one outcome of selling a company; you get a plastic—

Aspaturian: You get a very nice standup plaque.

Bruck: Yes. I don't have awards in my office, as you noted. They are hidden in my garage at home. I only have one award in my office that I'm very proud of.

Aspaturian: Would this be the Feynman Teaching Award [awarded in 2009]?

Bruck: No. It's an award that my daughter received for promoting kindness in high school.

Aspaturian: Very nice.

Bruck: So actually both Rainfinity and XtremIO [*Session Nine*] were acquired by the same company.

Aspaturian: So in addition to a hundred million dollars, you, your team, and Caltech received these handsome plaques.

Bruck: Yes. [Laughter] And this one was for $450 million. That's why you see—

Aspaturian: That's right, it has a mobile component.

Bruck: [Laughter]

Aspaturian: And I suppose if it was for a billion, it would have a fiber optic feature on it as well.

Bruck: [Laughter]

Sounded out as possible candidate for Caltech provost; reflects on road not taken

Aspaturian: Were you ever tempted to sideline your academic career for a while and become more involved in entrepreneurial things?

Bruck: No. I love the teaching. Now if I was not here, I think dealing with startups is what I would do full-time. And I did do that from '98 until recently. But I think I found the right balance. I think from the financial point of view, if I would just

do startups, probably it would be better for my grandchildren. [Laughter]

ASPATURIAN: Did you ever look back during this very busy period? I should say, have you ever looked back and thought, "If I had not been so occupied as well with my entrepreneurial responsibilities I might have been able to get the IST divisional proposal through?" Do you think that that in any way affected your ability to—?

BRUCK: No, I don't think it was related because if you look at the timeline, when I focused on the discussions related to the creation of the IST division, I already knew that we have the EMC deal. My plan was to probably be chair of the new division, and I was very excited about it. So timing-wise it actually worked out well.

ASPATURIAN: So the two were not in conflict for you and your agenda.

BRUCK: This brings up a related timing issue. I was also during these busy times on the Institute search committee for a new provost. Koonin had stepped down.

ASPATURIAN: In '04, I believe.

BRUCK: Yes. And Ahmed Zewail was the chair of the search committee.

Aspaturian: Was it hard to persuade Paul Jennings [professor of civil engineering and applied mechanics, emeritus; Caltech provost, 1989–1995; 2004–2007] to come back?

Bruck: I think he's a fantastic servant of the Institute.

Aspaturian: Everyone says this, yes.

Bruck: This was not our preferred solution, but at some point we realized it was the only solution. So the reason I bring it up is that at some point Ahmed talked to me about being the leading candidate for the provost position. And the reason I decided not to do it was not because of Rainfinity; it's because I wanted to complete the work on IST. In fact, I recently found an email from Ahmed about that, where he said he has in mind some job that he wants to discuss with me.

Aspaturian: Would you like to talk about that?

Bruck: Yes. He was, you know, just a great guy. And I really shared his value system, and I think it was mutual. We felt that we have very similar backgrounds, and also similarities in the way we communicate, and the sense of humor and the optimism, so I felt very connected with him.

Aspaturian: Did the two of you ever stop and think—an Egyptian and an Israeli? In the United States it was easy.

Bruck: Yes. Well the person that recruited me to Caltech is Egyptian, Yaser Abu-Mostafa. So I was very lucky with Egyp-

tian professors at Caltech. [Laughter] Yes, so when I look back to that time, trying to see what associations are triggered by your question, in retrospect, if I had become the provost in 2004, 2005, there would have been an IST division. Because that's what I would have done as the provost: I would focus on that as a project and make sure it happens. You know, I felt that I wanted to complete the duties that I had, and that's what I did always, like when I moved from IBM to Caltech. When things were not working well at Rainfinity, I always tried to make sure that I was there and not jumping ship to anyplace else. But I think here, it was a mix, in the sense that I was maybe overly optimistic about the fact that the IST division will materialize.

And there was another consideration—at least I felt that—that if I become a provost, then it means that it will be very hard for me to continue doing research. So it was not an easy decision, and you already know what I decided. There were other times at Caltech that I was approached to consider opportunities related to division chair or vice president or dean—different positions—but when I looked at what I want to do, I really love the teaching and the working with students, and between that and entrepreneurship it doesn't leave much time.

Aspaturian: You felt you would have had to give all of that up.

Bruck: Yes, I would have to give it up. It's not something I would enjoy doing long- term, being an administrator, so if I did that, it would be only five years, but still I think it's a challenge to go back to other things after five years of adminis-

tration. Also, our style is that we talk about everything at home, so at this time, my kids told me, "Dad, you know what is your problem? You take every job too seriously. You already assume that you will need to put all your time into it, but maybe you shouldn't assume that." I said, "Well, I don't know how to do it without putting all my time into it." So I think that's the balance. I'm not saying that other people don't put in all their effort and time, but at least I felt that if I do that, I will not be able to do the research and teaching part.

ASPATURIAN: Looking back, do you regret the decision?

BRUCK: Here, sometimes. Because you asked me about other balance issues.

ASPATURIAN: Yes. This was a big one. A major choice.

BRUCK: Because I think that if I had taken a serious administrative job, it would have been impossible for me to start XtremIO, which I consider it to be the most impactful activity in industry that I did in my lifetime. It's really a miraculous activity and I'm very happy I was part of it. On the other hand, maybe if I had taken the provost's job I would have seen an IST division. So, it's okay; we make choices and we keep smiling and good things happen, and I'm always happy. So I don't have regrets, but I think there was definitely a dilemma there. A dilemma is like a bull, and it has two horns, and you just need to choose one. This is a negative aspect, right? You miss one but grab the other one. But you cannot escape the choice .

Aspaturian: I suppose another way of putting it is that even you could not distribute yourself among all of those nodes. You didn't have a personal algorithm for that. Somewhere you had to draw the line.

Bruck: Exactly.

Session 9, December 20, 2016

Internet's origins, evolution, & early use in academia, industry & scientific centers

Aspaturian: I have some follow-up questions from our last couple of interviews.

Bruck: Excellent. Just a word about the day. Today is my mom's birthday.

Aspaturian: Happy Birthday to your mother. How do we say that in Hebrew?

Bruck: *Yom huledet same'ach*. It's actually *Yom* is "day"*; huledet* is "birth." It's two words and *same'ach* is "happy." And she's eighty-eight.

Aspaturian: Wish her good health and a long life. [Sara Bruk passed away in June 2018. *–Ed.*]

Bruck: Thank you. So it's a good day.

Aspaturian: You were at the forefront of the field in computer science. When did you begin to realize that the internet was going to be the huge deal that it eventually became? Were you among the first to recognize this? Do you recall what the atmosphere was among your peers and colleagues? How did the realization come through, and when?

Bruck: I think it's a very good question. First of all, I want to say, I thought about our sessions, and it's much easier for me to talk about topics that are not self-promoting. Because that's not my style. I got an F in reputation management.

Aspaturian: Is that a course?

Bruck: [Laughter] I don't know. But I think with the internet, people got even more deeply into reputation management

Aspaturian: That's true, to say the least.

Bruck: So all the selfies. And Twitter and—

Aspaturian: Facebook postings.

Bruck: Yes. So you meet people, and they only want to give you their spiel about how they are so successful and all that. Sometimes I meet such people, and then I say to myself, "Wait a second. What did I do in the last forty years?" And then I discover I also did a few things: "How come I didn't tell them?"

But that's not my style. I don't do it. I prefer to focus on the future, and so what I've done before is not relevant really. The problem with the internet was that people in my generation, in some sense, didn't notice that it happened.

Aspaturian: Even you.

Bruck: Yes. Because we had it before it happened. As I said earlier, I had had email since the late 1970s, early '80s.

Aspaturian: Was this because it was something that had been developed as kind of an internal means of communication for CS?

Bruck: Yes. In IBM, anything that you think about today, they had it in the early 1980s. It was a company with hundreds of thousands of people, and every single person had email. The screens were green and could only hold characters, but we had email. And most of our communication was by email. Also we had Chat.

Aspaturian: In real time?

Bruck: Yes. You could also send a group chat, like sending a Tweet today. You could say, "Is anyone going for lunch?" And then whoever wants to go is coming out to the corridor, and we all go for lunch.

Aspaturian: But was this largely unique to a place like IBM, possibly Intel?

Bruck: Or other computer companies. It was also in academia.

Aspaturian: You were doing this at Stanford in the 1980s?

Bruck: Yes, of course. Not only that, at IBM, where I was a manager, I was signing the attendance report and the travel reports online. They had an application that did all of this without paper.

Aspaturian: This must have been the early '90s?

Bruck: No, actually the late '80s. Also IBM had a big server in Europe—it was, I think, in Holland—and we did searches for articles on it.

Aspaturian: I think that I first started using email at Caltech around 1991. There was some capacity for online searching.

Bruck: Yes. But definitely in grad school we had email. What we didn't have is all the document-processing software, so when I did my master's degree at the Technion, I actually wrote it with a pencil and paper and gave it to a typist and then we did all the cut and paste.

Aspaturian: Yes.

Bruck: You remember that?

Aspaturian: Yes, because I did that when we were putting out our Caltech publications in the late 1980s.

Bruck: Then Don Knuth—he's a former Caltech professor and a retired professor now at Stanford—created a system that is called Tex. Because he got tired of all this cutting and pasting. And that system is what I still use—what everyone is using to write papers. It evolved a lot. But thanks to Knuth I could write all my publications and my thesis at Stanford using this. There were also online news sites, and there was a command in UNIX called RN—"Read News"—where you would go and subscribe to different kinds of news. This was during the mid-'80s. What happened with the internet is that the connectivity improved, so that when you sent an email to someone, the internet would know how to route it and find this person. So we knew that, say, if we wanted to email someone, we should specify what intermediate number we should send it through. Because as you remember, there were a few sub networks like BIGNET, ARPANET.

Aspaturian: I do remember those, yes.

Bruck: But I think toward the late 1980s, this system started stabilizing. The internet really is more "interface" than "internet." What was introduced in the early 1990s was a language that made it possible to hypertext—to click on something. It was created, I think, at CERN, by Tim Berners-Lee—but the idea was to create a tool that would allow people to share data as part of a very big project in physics. But this mechanism that now we call the internet existed before that. The part that

didn't exist is that if you were not fluent with computer systems, you couldn't use it to do much of anything.

But suddenly in this physics project there is a brilliant system where you can see everything you need right there on the screen. Instead of saying, "Let's see what this file is; let's do the command to get this file," and so on, suddenly you click and the file comes to you. It's like having a store window where before you needed to go in and climb a few stairs and know some special directions through the store to get to it, and now you just reach into the window, and if you want something you just take it.

"For people who were fluent in it back then, it was not clear that the internet was going to be such a powerful thing"

I remember that in, like, '91 I had a friend who was studying business, and we had this discussion about whether it makes sense to buy airline tickets on the internet. And I told him it doesn't make sense: "Why would I buy an airline ticket on the internet?" I have a travel agent. I know him very well. Anything I need, I call him; I talk to him for maybe two minutes, and then I get the ticket. So why should I worry about doing it online?" Because you have to remember that when the internet started, the first commercial browser was Netscape, but before that there was one developed at the University of Illinois called Mosaic.

Aspaturian: Oh Mosaic. Yes.

Bruck: So while we could access the internet or those websites through an editor because we had text, we didn't have images. There were no search engines so we needed to know every URL to find something. Without a URL, how do I know where to look if I want, for example, an airline ticket? There is no street map or anything.

Aspaturian: It wasn't that user-friendly yet.

Bruck: Right. Now there are many ways to get to a website. Back then, nothing. So, say someone emails me a URL for a new website they'd like me to see. I will put it into Mosaic and click, and I could see a little search icon turning and turning. Then I'll go for lunch, and most of the time when I come back, the site was visible. But it always took a few hours. So when my friend asked me, "Do you think one day we will buy airline tickets on the internet? I said,"Of course not. Because, you know, you click and you go have lunch and come back and still __"

Aspaturian: Right. Who wants to do that?

Bruck: Right. Of course now it's instantaneous, everything, and I don't remember the last time I didn't buy an airline ticket on the internet. So it kind of sneaked in. You asked me when I realized it's actually happening. So when I came to Caltech, I created a website for my group.

Aspaturian: You mentioned that [*Session Five*]. And everyone was going, "Oooh" at that.

Bruck: Yes, I had pictures. And everyone was saying, "Ooh, wow." I took the domain name paradise.caltech.edu because that's how I felt when I came here. In any case, I was eating breakfast one day after I got here, and I noticed that on the box of the cereal there was a URL, whateveritis.com. And I said, "Oh wow, they have a website?"

Aspaturian: You picked this up from a box of cereal?

Bruck: Yes. And I said, "Okay, let me look at another food product." I checked that, it also has a URL. I said, "Okay, it's happening." [Laughter] Because, you know, back when the internet was becoming the Web, it was still only something that technical people and university people did. Functionality-wise, we had had the internet for a long time. So for people who were fluent in it back then, it was not clear at the beginning it was going to be such a powerful thing.

Aspaturian: Yes, or that it would become a cultural phenomenon, as it did.

Bruck: Honestly, I still don't understand this phenomenon. Because, say, someone would have come and talked to me about Facebook before it started. I will say, "That's a stupid idea. Why would you want to do this kind of stuff? Who has the time for

that?" But obviously I was left out. I don't have a Facebook account.

Aspaturian: I have an account, but I don't look at it very much.

Bruck: Well in our generation, there are two options. Either you don't have an account, or you have one and you are apologetic. [Laughter]

Aspaturian: I know people who aren't apologetic. They post pictures of their children and grandchildren and so on.

Bruck: Exactly. I tell people that I will have a Facebook account when we will have grandchildren.

"At that time I think things were moving so fast that we lost the ability to predict . . . but I like to make sure that good things happen"

Aspaturian: When you were developing RAIN, did you have an inkling that it was going to become this highly desirable technology for the Web?

Bruck: No way. You see, at that time, I think things were moving so fast that we lost the ability to predict. I mean, imagine that in the early '90s, I will come to you and whisper, "Go and buy all the names you can in the English language for domain names. Everything in English.com, buy it." If you had done that, you would be a multimillionaire today. But it didn't

make sense. Some people did that. Say you own the rights to art.com. Wow! Yes. And of course, we are very smart, but we didn't think about any of that.

ASPATURIAN: When it developed that someone wanted to offer you and your colleagues a hundred million dollars for your company, did this come as a total shock?

BRUCK: No it's a process, right? It's also, you know—all this M&A business, it's like dating.

ASPATURIAN: M and—?

BRUCK: Mergers and Acquisitions. This is like dating; it's not like that I'm an expert in dating. I was never good in dating, but I did very well.

ASPATURIAN: I see where the analogy is going.

BRUCK: But it's the same as dating. When you are a small company and you're active, then there are big companies that are looking at you, and if you look desirable, then they might look at you even more carefully. And in a small company you always watch the big companies, because obviously they can crush you if that's what they decide to do. Maybe they always want to do it, but if you move fast enough, then they say, "Well it's too late, let's eat them."

ASPATURIAN: I see, the big fish will devour the little fish.

Bruck: Yes. So it's a dance. And of course I was chairman of Rainfinity, so I was the one dancing and talking to the right people

Aspaturian: What was it like negotiating with these guys?

Bruck: Somehow I'm good at that. I have a very straightforward approach, and I'm very consistent and try to maintain my value system, which I'm happy to say I was able to maintain there. So in the end it's about value, right, and the value that we bring as a startup is related to innovation, being forward looking, and the quality of the team. And I built Rainfinity to create a solution that no one else had and which was desirable to the customer. And if that's there, and it looks like a functional solution, then it's easy to communicate that. And for me it was always important to make sure that the team would do very well.

Aspaturian: The group you were working with.

Bruck: Yes. It's not just about the point of the acquisition, where suddenly a lot of money is put on the table and is being divided among the investors, the founders, and the employees. It's also about what happens the day after. Are people going to have a nice environment to continue doing their work? Are they going to be treated well? Is the product going to keep changing the world, and so on.

Aspaturian: So you looked for that also in the companies you were negotiating with?

Bruck: Of course. I took what I learned from the Rainfinity experience to XtremIO, and I feel that I did much better there in terms of the future impact and what was built to control life after acquisition. And it was important for me. I stayed with XtremIO for a few years, also with Rainfinity, and people asked me, "Why are you staying? You already did well. Move on; do something else." But I like to make sure that good things happen.

Aspaturian: You felt you had an investment beyond a financial investment?

Bruck: Exactly. And so I'm very happy about those two experiences. I tell people I have very limited experience with startups, because I only started two companies. Fortunately they both did well.

Rainfinity's role in Caltech's bourgeoning startup culture

Aspaturian: Was Rainfinity one of Caltech's most successful startups up to that time? Were you something of a canary in the coal mine?

Bruck: I'm not sure.

Aspaturian: We talked earlier [*Session Six*] about how Larry Gilbert had just come on board.

Bruck: I think that Larry was very happy about the process. I think that financially it was more complex, because in a startup it takes a long time until there is an acquisition or an IPO and the company goes public. There is an event where the shares turn into cash, right? If you wait too long, then you are going to be left with nothing. So Caltech got a nice return on the intellectual property, because there was no investment from the Caltech side.

But I think the success there was the completeness of the process: It's a project that started here at Caltech with NASA and DARPA funding; it was licensed to a company; the company went through very difficult times, including 9/11 and the dotcom bust and survived it. At the end it was acquired for $100 million, and Caltech got whatever it got. So everything from this point of view was very positive. So I think in this sense, the whole infrastructure that Larry put in place worked very well. But of course if the dotcom bubble hasn't burst, then this transaction might have been ten times bigger, or maybe it would have failed completely. Everything is possible. But you never know; this business is very, very complex.

Aspaturian: Well certainly with the emergence of the internet, and the whole dotcom industry, the number of startups and the amounts of money that were on the table—a lot of this was unprecedented outside, for example, the world of high finance.

Did you have, after this, other faculty on campus coming to you for advice?

Bruck: Yes, that's a good question. Even before the acquisition of Rainfinity many people came and consulted with me. After we sold it and even to this day, I get many people—faculty members and grad students—who come and talk to me about startups, and I tell them that one of the biggest mistakes that people make when they are successful is that they think they know how to be successful, but it's misleading, especially in a startup. The fact that you were successful doesn't mean that you are a genius. It means that you did a great job and that you were lucky. Which means that also in the future you should work hard, do the best job you can and hope for luck.

Aspaturian: And hope for luck.

Bruck: Yes. [Laughter] Because then after XtremIO, people really thought that I'm a genius with startups. So I had to say it even more vigorously that that's not the case.

Serves as head of campus IP/tech transfer committee; Caltech's "osmosis mechanism" in shaping campus interactions

Aspaturian: Was there any more formal work for Caltech on this score? Did you work with the provost's office on tech transfer policy or anything of this nature?

Bruck: I served for a while as the head of the faculty committee on intellectual property and industrial relations. That's a committee that serves as the sounding board for the office of technology transfer.

Aspaturian: What years were these, do you recall? I can look it up in the catalog also [2010–2012].

Bruck: I think I stepped down four years ago, maybe; I did it for a couple of years. I think overall Caltech has a very good system, and that we are lucky to have really excellent people here. It started with Larry Gilbert, who I thought was fantastic. I loved his zest, you know. Maybe some people didn't appreciate his language and his style, but I thought he was great.

Aspaturian: All that East Coast energy.

Bruck: Exactly! And we were lucky to have a really good succession plan; at least the tech transfer people I worked with understand how to interact with faculty, and I wish that other areas on campus were so wise in the way they interact with faculty. Probably that's the only office that I can mention in the administration that has this ability. I think *Engineering & Science* magazine and the other publications were like this.

Aspaturian: The public relations function.

Bruck: In the past, because we knew everyone in public relations and it was just so small, you could walk around and say, "Hi Doug [reference is to Doug Smith, managing editor and

later editor of the former Caltech research magazine, *Engineering & Science*]. Hi Heidi. How are you? What's up?" They tell you, and you tell them some funny thing, and maybe some article will come out of it. Same thing with OTT: you walk in and you see Larry, and he's asking you "What's up; what kind of projects do you have; I saw you just filed a patent," and so on. So there was a more continuous process, and I think with Caltech, that's the style. For example, it's not the case with Development that I will recognize anyone from Development when I walk on campus. Again in the past, when McQuinn was here in Development—

Aspaturian: Bob McQuinn.

Bruck: Yes. He understood this idea, that at Caltech you find a way to be part of the intellectual environment and just have this continuous relationship. It's not about, "Okay, let's schedule a meeting and let's make some decisions."

Aspaturian: "Let's schedule a meeting just to schedule a future meeting."

Bruck: Yes. This was not the style here, with OTT, and it's still not the style. I can call those guys any time and talk about anything, and they do the same with me.

Aspaturian: It's good that they've preserved that.

Bruck: Yes. I think the model at Caltech—and maybe it sounds a bit arrogant but I hope it's actually the opposite—is that this

is a village, and there are 300 partners who are kind of the core because they are faculty. And in a sense we do everything; that's kind of the skeleton of the organization. Of course we cannot do "everything," so we need support from many, many, people who help us with things we don't understand, but at the end of the day we bring in the funding; we teach the classes; we recruit grad students, postdocs and future generations of faculty; we do research; we publish it; and we create everything around it—maybe startups, maybe other things. We have to recognize that, and people here are very modest typically; just very busy doing their work.

So the best way to interact with this group of busy people is through this osmosis mechanism. And that was what I was very impressed by originally at Caltech. I still feel this way, and that's why I love the place. I still tell undergrads, "Any problem you have, and you feel that you cannot solve it, come and talk to me." And I still feel that I can just pick up the phone and solve it in one phone call. That's the beauty here at Caltech. I think it's still correct.

Aspaturian: I think more so than at other institutions. Maybe less so than it used to be here.

Bruck: I agree. That's a very accurate description. You know, I think definitely Everhart was supportive of that.

Aspaturian: Everhart really cultivated that environment. Yes, I agree with you.

Bruck: I think [Jean-Lou] Chameau [Caltech president, 2006–2013] was pushing it in the other direction.

Aspaturian: Do you want to talk about Chameau now?

Bruck: I don't know. We were having a good time. [Laughter]

Aspaturian: Okay.

Bruck: So yes, I think Rainfinity overall was a fantastic experience for me, and also for my students. We rented an office here in Pasadena in '98, and I think it was under rent until probably 2013.

Aspaturian: So you were there for quite a while.

Bruck: I was not there the entire time. The last person who left was Phil Love—Phil Love is a great name because "phil" is also "love," [i.e., in Greek] right? He's a British guy, and so Mr. Love Love did his PhD here in applied math and is a really brilliant person. He's in the Canary Islands now

How Rainfinity got its name & a meditation on how ideas originate

Aspaturian: Speaking of names, who came up with the name Rainfinity?

Bruck: That's a great question. [Laughter] So with one of the founders, I spent a whole night in April or May '98 to find a

name for the company. This is—it's like a very romantic activity.

Aspaturian: Poetic.

Bruck: Yes, poetic activity. It's like when you are expecting a child and you're trying to think. Should it be Paul or George, or whatever. Or Shuki. So, of course, anything we tried was taken.

Aspaturian: What, did you do a Web search to ascertain that?

Bruck: Yes. Today, it's easy to check if the website name is taken. But at that time it was a very laborious process. But after we decided on Rainfinity, I asked Vincent Bohossian, who was one the founders and the guy who designed the Paradise logo in '94, to design a logo for Rainfinity. He came up with like fifty logos, and then we tried to decide. And this is the logo that you see. In fact originally it was a bit different. This is the modern logo, because at some point we hired a VP of marketing, and similar to what happened at Caltech when a VP of marketing came, they are trained to change the logo so they have a project.

Aspaturian: You sum it up very well.

Bruck: So the new guy came, and he said, "This logo doesn't work well on a fax," or something, and then it became this logo, which is okay. And as you can see, the logo of XtremIO is very similar to that, and I had nothing to do with that logo of XtremIO, and it was a surprise to discover they both based on the mathematical sign of infinity.

Aspaturian: Is the sort of cloud shape around Rainfinity intentional?

Bruck: Well, that's the infinity sign in mathematics.

Aspaturian: It also looks like a cloud, which would make sense.

Photo courtesy of Shuki Bruck

Bruck: Exactly. So how did we come up with Rainfinity? We wanted something with "rain," and everything that we tried was taken. And then it was 2 a.m., and I decided to go and get some sleep. And that day in the mail I had gotten a publication from the IEEE [Institute of Electrical and Electronics Engineers] Information Theory Society. The front-page article was something on infinity, and I looked at it, and as I was going to sleep, I had a smile on my face; I said, "Rainfinity." And the next

morning I told Anat, "Rainfinity." And she said, "It doesn't sound good." And I said, "You know, it's one of those acquired names, I think. At the beginning you do not exactly know how to pronounce it, but that's the beauty here; after a while you get used to it."

Aspaturian: It's nice that it came to you as you were going to sleep, like the famous story of the chemist and the benzene ring.

Bruck: Well, most of the ideas I have are in funny places, definitely not in my office. The best ideas I have are when I leave my office, after I think about something and go and do something else.

Aspaturian: I think that's true for many of us, actually. We sort of shake our brains out and something else pops up.

Bruck: Yes. You have to let good ideas come to you, because if you chase them, they run faster than you can, and you just see their tail.

Aspaturian: I'm sure you've heard of the great artist who was once asked about this, and he said something like, "The trick is to be there when the picture is painted."

Bruck: Yes. [Laughter]

Aspaturian: Very similar to what you've just described.

Bruck: Yes, it is. You know, there are points in a career where you work on an idea or a problem, and there is a breakthrough and it makes an impact on the community, or when I've tried to see how to explain an idea when I teach, and suddenly it clicks. A startup is a phenomenal experience, I think—to start something from basically nothing and to put together the team and to figure out what to do. At first you maybe have an office, but no one knows that you exist. And no one calls. And even after you have something, no one cares. So this whole adventure creates a satisfaction that's hard to explain. It's very hard to explain, and I feel very fortunate that I was able to do it twice.

Envisioning new approaches to large-scale data storage: the Flash-driven origins of XtremIO

Aspaturian: Why don't we talk about XtremIO? Well, we talked last time about the figurine you got from them, but we didn't really talk about the company. Did that originate with you as an idea for a startup, or was it something that came to you as a research project independently of that?

Bruck: So XtremIO in a sense is not a Caltech startup.

Aspaturian: I noticed that it was based in Herzliya [central coast community in Israel], so I thought there must be something a little different about this one.

Bruck: Yes. So this was in 2005 after the acquisition of Rainfinity, and I had stepped down from the IST. So I suddenly had

some time and some mental energy to meditate and think about the future.

ASPATURIAN: At this point you realized that IST was not going to become a division?

BRUCK: Exactly. And also the Rainfinity project came to an end at the same time; nothing was planned; it's just the way it happened. And I knew that at Caltech what I want to do on the teaching side is create a class that will try to capture the notion of information [*Session Twelve*].

ASPATURIAN: Right. You wanted to synthesize all this.

BRUCK: Yes. So this was a clear project here. On the research side I thought, What should I focus on? What do I believe will be the next big change in information storage? You see, now it's 2005, and there is no iPhone and no Facebook yet, with massive data storage requirements. So as someone who had worked for IBM, I thought maybe the next big change will be a change in substrate.

ASPATURIAN: Meaning what?

BRUCK: The physical media that information is stored in. Instead of having hard drives that are based on magnetic storage, we will have drives that only use solid-state components. We'll have Flash memory. That's what I thought in 2005.

Aspaturian: What would be the advantage of that? More storage capacity? More efficient operation?

Bruck: The density is much higher; the power consumption is much lower; the cooling is much lower; there are no mechanical parts. And those are the aspects that people were thinking about, but there is one aspect that they weren't thinking about that I felt was very critical, which is random access. Because if you think about a hard drive, the access is sequential. It's like a tape; it's moving physically, and if you want to read something you need to go there. And if you want to read something else, you need to get there. So that forces you to store things sequentially so you don't have the flexibility to read from different points. The advantage with Flash is that you can read anything you want with the same efficiency. You don't need to physically go somewhere.

Aspaturian: We're back to the word holistic again.

Bruck: Right. So I hope you understand the difference.

Aspaturian: I think I do; not the way you do, but sufficiently, yes. Suddenly you're somehow able to—

Bruck: Able to access things instantaneously. So that's called random access. That's the advantage.

Evaluating Flash technology: early challenges in achieving reliability & scalability

And what did I know about Flash? Nothing. Well, I knew a little bit from my undergrads. So I sat down and tried to understand it. Now at that time Flash was already in USB sticks. It used to be called disk on key. The first disk on key was created by a company called M-Systems that was based in Israel in about 2000 or 2001, IBM did a deal with them to sell those. So it was all very young. But I knew that all mobile phones—there was no iPhone then—had flash inside. They didn't have disks. Now the first iPods didn't have flash; they had a small disk. Apple wanted the iPods to have large capacity, which at that time was maybe 80 gig [gigabytes] or so on disk, but today you can get a disk on key or a USB stick with one tera [terabyte, equal to 1000 gigabytes]. In any case, I sat down and tried to understand Flash, just to evaluate the idea.

Aspaturian: So you went through some papers and—?

Bruck: I read papers, I got all the books I that could about it, and I reached out to people in industry and talked to them. I still remember going to meet with engineers at Intel in 2005 or '06. And I told them, "Listen, I understand how hard drives work. Tell me how Flash works." And I was literally sweating when they told me, because Flash is a funny way of storing information in terms of its reliability. It has many issues. More and more and more issues. But still it works. The problem is

even today it's a scary thing: Think about storing information as if each transistor that you store information in is like a cup of water, and depending on how much water you put into the cup, it's either a one or a zero. If there's a lot of water it's a one, and if there's very little water it's a zero. The problem is that the number of electrons inside there, for which water is the metaphor, is less than a hundred. So it's extremely sensitive. It's very, very, very sensitive to store information using just a few electrons. In any case, I learned about all this and during 2006, I started to think that the Flash being used in phones was not going to be a reliable solution for large enterprises seeking to store information.

ASPATURIAN: It wasn't robust enough?

BRUCK: It was not robust enough; the endurance was not good. The problem with Flash is that you lose it as you use it—the "water" evaporates, to go back to the metaphor—and it really destroys the substrate in a way that is not recoverable. So there were many issues like that, and realizing that created a very, very productive research program.

ASPATURIAN: So let me see if I understand this: Flash had some inherent instabilities for which you were trying to develop a workaround?

BRUCK: Right. And this is one of the projects that I started at that time in 2005, and it's still one of the areas I am working on today. In fact today, my postdoc, Yue Li, is in Colorado with

our JPL collaborator. They are experimentally evaluating new mechanisms we developed for maintaining the robustness of Flash under conditions in outer space such as radiation.

ASPATURIAN: Ah yes you mentioned this, for payloads that can be flown in space [*Session Eight*].

BRUCK: Yes. So we went through a very long preparation on that, but the key was that I felt that Flash is not ready for the major enterprise—not ready to be used in banks instead of hard drives.

ASPATURIAN: It wasn't scalable to that extent?

Building "the next-generation Flash" with students & postdocs; forging an Israeli connection

BRUCK: Right. And then I thought, "Okay, we will build the next-generation Flash," because we had some actually pretty cool ideas.

ASPATURIAN: You and your students and postdocs.

BRUCK: Yes. Quite a few students and postdocs worked on that, and then when they became professors they still worked on it; and in fact Yue, the postdoc who collaborates with JPL, is a "grandson"—a student of my student. He did his PhD on Flash with my former PhD student and came here for the postdoc. I have had a couple of those already. I might have the third one coming next year. In any case, this story is not over. Caltech has

like ten patents on our Flash research that have a potential to impact future generations of Flash memory.

Aspaturian: These are your patents, basically?

Bruck: Yes, but they're owned by Caltech. And we have been discussing opportunities with large companies that produce Flash about using those ideas in future generations. It's still ongoing; it's a slow process. But when I started those discussions back in 2007, I went and talked to quite a few companies. And through that I met one of the cofounders of M-Systems, the company that created the first Flash-based USB stick, and that is based in Israel. In fact, a childhood friend introduced me to one of the cofounders of M-Systems, and we hit it off. His name is Aryeh Mergi.

Aspaturian: This was not like your experience with Checkpoint [*Session Eight*].

Bruck: Exactly. So I talked to Aryeh about my ideas on Flash, and then one day he called me and said, "You know, I've talked to a couple of guys who have some ideas for a startup, and they want me to invest in it. Can you do me a favor and take a look at what they are suggesting?"

Aspaturian: Were these Israeli students?

Bruck: They were not students; they were professionals in the industry. And so I spent time with them; and again, it's something I do every now and then—I just try to help people. So I

spent time with them and heard their ideas and gave them some ideas, and then I talked Aryeh, and he asked me, "So what do you think?" And I told him, "I think they have some really good ideas, and I'm very impressed by who they are and their overall professionalism," and so on. I was very positive.

ASPATURIAN: Had these guys been trained in Israel?

BRUCK: Yes.

ASPATURIAN: From the Technion?

BRUCK: Yes.

ASPATURIAN: So there was that in common as well

BRUCK: Yes. And then he said, "Thank you very much." And I thought, Okay, we are done. But then a few weeks later those two guys contacted me and said, "You know, we really enjoyed talking to you, and it will be great if you can be part of it." So I told them, "You know what, I'll be in Israel"—whenever it was, and I think this was already early 2008—"and let's meet and we'll get into more details, and we'll get to know each other and so on." So I went to Israel and met with them and really liked the overall direction. And we started working on more detailed ideas about how to build a system based on existing Flash that can be used in the enterprise, like large banks and hospitals.

Aspaturian: This sounds similar to what happened with your RAIN project, where you took existing technology and developed it into something new.

Engineering a successful product launch: XtremIO finds its market

Bruck: Right. And I understood that we cannot tell people who produce Flash "What you do is not good for the enterprise; here is an idea to fix that," because they will come back to you and say, "No one in the enterprise is buying Flash." So there is a chicken and egg problem. And in 2008, I said the only way to deal with the chicken and egg is that I decide what is first. That's the advantage in engineering. When you have a chicken and egg problem you can decide what goes first. So I said, "Okay, let's see if we can first create demand for the existing Flash in big companies, big organizations; and then we'll worry about the next step, which is using the patents we have here to upgrade Flash so that it's usable at these big scales." In fact that's what we are doing now. This was a big "Aha!" moment for me, and a big effort. We tried to raise funding in 2008.

Aspaturian: So when you say "we," was the research effort then carried out primarily in Israel or was it a collaboration?

Bruck: There was nothing related to my Caltech research in XtremIO, because we didn't change the Flash. We actually ac-

quired existing Flash from some companies, then embedded it in our system. The research here was related to, how do we create better Flash?

ASPATURIAN: I see. In other words, you married existing Flash to your new system.

BRUCK: Exactly. And I think there are some beautiful ideas there that we developed. Then we tried to raise funding. You know, to start a company you need someone to give you money. And as we did that, the 2008 meltdown happened. So then no one wanted to talk to us, which is natural. And you know, it was a scary time in the financial market, and we decided to wait rather than to overdo it.

ASPATURIAN: You mean to hold off on future R&D or to hold off on soliciting funding?

BRUCK: Well, we didn't do anything in a formal way. It was all done by just a couple of us in discussions on the phone or when I visited Israel. So in 2009—

ASPATURIAN: After the presidential election.

BRUCK: After the election and when the recovery started. In the summer of 2009, we went back to Israel to raise funding, and we were successful.

Aspaturian: Was there any problem for you, as a professor at Caltech, doing this sort of arrangement with businesspeople in another country?

Bruck: No. They are not now on faculties in Israel; they are all in industry. On the Caltech framework for faculty, we are basically allocated one day a week where we can do whatever we want, so I think this came under that. In any case, we got funding, and we started XtremIO in November 2009. XtremIO was acquired in May 2012, so that was two and a half years after we started it. Remember Rainfinity took seven years. This time it was two and a half. We were acquired for $450 million. We didn't have a product, and we didn't have paying customers, but we had what we call an alpha version of the product. So it was something that works and that some customers had played with, but it's actually not the final product. We planned to have the product out in the market eighteen months later, which we did—in November of 2014.

Aspaturian: This was after you had been acquired.

Bruck: Yes. Eighteen months after we were acquired. And we reached $1 billion in sales in eighteen months.

Aspaturian: So I guess it was a shrewd investment.

Bruck: Yes. Three years after the product came out, we reached a milestone of $3 billion of sales. So this is probably one of the highlights of my professional career.

Aspaturian: I would say so. You're looking at raw numbers, yes.

Bruck: Did it make the Caltech website ever?

Aspaturian: I was gone by then. A lot of good people were. Did it make the website?

Bruck: No! Of course not. I think no one even today pays attention to it. But you see the magnitude of the impact is huge. Today it exists in every enterprise that you can think about. Every bank, every hospital, almost. So I'm very proud of the team that was able to pull it off this way.

Aspaturian: I can imagine. XtremIO, was that your name?

Bruck: No, the name existed when I met those guys in Israel. Of course in parallel to all of that, Anat and I moved into Avery House in 2006, so some of those beginnings happened while we were in Avery [*Session Ten*].

Aspaturian: That's right, of course, because you were there for two years, I think.

Bruck: And I started teaching IST4 in 2007, so you know, the other things happened in parallel.

Session 10, March 20, 2017

Joining Avery House as faculty residents: "They asked us if we knew anything about *Star Wars*"

Aspaturian: After a pause of three months, we're going to talk today, among other things, about your experiences as faculty member in residence at Avery House. I think that started in 2006?

Bruck: Yes.

Aspaturian: So let's begin by asking how you happened to decide to do this.

Bruck: Yes, it's actually a very good question. When they built Avery, and I don't recall now when they did, maybe '98 or 2000 —

Aspaturian: I can check the date. [It was 1996.]

Bruck: I went to see all the construction and went to the opening of the building and all of that. They were advertising for faculty in residence, and I really liked the idea, and I talked to Anat, and we thought it can be cool, actually, to do it. You know, we are both educators. My wife is a teacher, and we thought maybe it will be a good thing for our kids, who were young at that time. They were still at home when Avery

opened. And I think I checked into it, and the largest apartment there for faculty was two bedrooms. And we have a boy and a girl.

So we decided to wait, and then there were a few things that were happening in 2006. One is that our daughter graduated from high school and went to UC Santa Barbara. Our son started being a bit more serious about studying, and he was attending PCC [Pasadena City College]. So you know how it works—life goes on in kind of a linear fashion if everything is fine, but then suddenly there are points of change where you pause and think about what to do next. I think it happens to everyone. So we thought, maybe we should remodel the house, because we had lived there since '95, and we like it a lot and we thought that maybe we should do something so we can keep being there. So all of those parameters were there, and we thought that maybe we should do the Avery thing now. And there was an opening, suddenly—someone moved out. And the process is quite interesting because the resident faculty candidates are interviewed by the students.

Aspaturian: A committee of students within Avery house?

Bruck: Yes, but it's even more than a committee; it's like everyone who wants to be there. I found out more about it later, because after we joined Avery we participated in a few of those meetings with some other faculty. There were three faculty members in residence at the time that we were there. Two families and one single, which has a smaller unit. In any case, it was

exciting. They invited us for an interview. We were sitting in the courtyard in Avery. You know Caltech undergrads, some of them were able to look at us. [Laughter] Not all of them. And my wife is a very warm person and very wise. I told them, "Listen, it's the first time ever in my life that I'm in an interview with my wife. Also it has been a while since I was interviewed for anything in a serious way. But, honestly, the key for you really is to figure out if you like Anat, because you know who I am. I'm a nerd exactly like you are, with all the benefits and all the not-so-great things. But you need to see that you will have someone who is warm and helpful, and so on, which is not me. I'm okay, but pay attention to Anat."

So they talked to us; it was a fun encounter; and I remember that they asked us if we know anything about *Star Wars*. And I said that I never watched it. Because at the time *Star Wars* was defined as 50 percent of everything outside classes.

ASPATURIAN: So you'd have something to talk about at dinner.

BRUCK: Exactly. But I don't care about *Star Wars*. [Laughter] So it was fun. And we were offered to join.

ASPATURIAN: They offered you this job.

Experiencing life in Avery House as "honorary relatives"

Bruck: Yes, they offered us the job. And just, I have to say up front, this is one of the highlights of our life.

Aspaturian: Period, or here at Caltech?

Bruck: I think period. Because as a couple suddenly we were in a position that we'd never been in before. That we live in the dorms with eighty or hundred students who are more or less the age of our kids, and we get to interact with them continuously. We had a fantastic time. Fantastic.

Aspaturian: What was the make-up, class-wise, of Avery House? Was it mostly freshmen and sophomores?

Bruck: No, it's everyone.

Aspaturian: And the gender breakdown?

Bruck: I think probably like 50/50. Avery is a house that was fighting for its identity during the time that we were there, still trying to convince everyone that they are a legitimate student house. Basically the other undergraduate houses have a history, and Avery didn't have a history at that point. Now it has. The other houses had "traditions," which means doing mainly stupid things and making sure that the new people that join also do those stupid things and also that those stupid things stay for

the future. Avery hadn't accumulated anything stupid that they can pass forward.

So that's why it was a strange group of students; they had nothing they can do that looks awkward and so on. Honestly, I felt that if I was a student here I'd probably join Avery, because if there's anything I don't like, it's people telling me how to behave because I'm part of some group. I don't like this type of restriction. So it was fantastic. Our son lived with us there. And we also wanted to have a room for our daughter for when she comes home from college, because there was no home. This was our only place.

ASPATURIAN: Were you there seven days a week, or did you go home on weekends?

BRUCK: No, we didn't have a home.

ASPATURIAN: Because it was being remodeled?

BRUCK: Yes; we emptied our home. We burned the ships, you know. We moved all our stuff to storage. We took just a couple of things to Avery because it's a very small apartment. In terms of space, our son got a dorm room that was next to our unit, so he could come into our kitchen. So after being in a large house, it was great to live in a small place where no matter where I'm at in the apartment, I say, "Anat," and she says, "What?"
[Laughter]

We used to live in very small apartments in Israel, and then in the Bay Area, so it was fun for us. We were there all the time, so the idea is that on weekdays you eat dinner with the students every day. And this is really the mechanism for the students to start feeling comfortable with you. Because the role of faculty in residence is not to be the RA [resident associate, usually a graduate student] or the policeman, but to be more of an uncle or a grandparent. So, when students will feel that they need to talk to someone, they will feel comfortable reaching out to us.

Aspaturian: Kind of like an honorary relative.

Bruck: Exactly. I like that. "Honorary relative." That's a great one. So dinners are served at round tables, and we just ate at different tables, and slowly but surely we got to know them. Also Anat is a great cook, so she always prepared nice meals over the weekend when dining room meals were not offered, and we invited smaller groups of students. Anat is a very open and warm person, so people immediately gravitated towards her and talked to her about what is on their mind and heart.

Aspaturian: They found her easy to talk to.

Bruck: Yes, they just knocked on the door and came over in the evening. During those years, Anat was working, but she typically came back in the afternoon and early evening and then she was there for dinner. And over the weekends, we organized many, many events; we were part of the community. We still have very close relationships with the students from Avery. For

example, we went last year to a wedding in Philadelphia of a former Avery resident who is now a professor at Penn. When students come to town, they send us an email and we have lunch with them; they're all over the place, all over the USA. I just talked to another student, Christina Lee, who's now at MIT interviewing for a faculty position in different places. She's getting married this summer.

Her brother, David Lee, who also lived at Avery, did a SURF project with me; he's currently a professor in UC Santa Cruz.. He was my next-door neighbor in Avery so there was basically a wall between our heads when we were asleep. Because in our bedroom the bed was on the wall, and then behind the wall was David's bed. So our heads were a couple of feet apart. At that time, he was taking my class, IST4. And I told the students, "David knows all the answers to the questions because, during the night, it radiates from my brain to his brain."

Aspaturian: Were you in Avery for two years or three?

Bruck: Two years.

Aspaturian: Who were the other faculty there with you at that time?

Bruck: There was a faculty member from astronomy, Re'em. He actually moved back to Israel, and he's at the Hebrew University. I think his last name is Sari.

Aspaturian: Oh, Re'em Sari. Astrophysics I think.

Bruck: Yes. I call it astronomy.

Aspaturian: I think he was astrophysics.

Bruck: Also in GPS [geological and planetary sciences] and physics. And then Thanos Siapas; he's in CNS. I know Thanos well. So those were the two.

Gaining new insights into Caltech undergrads, their lives & challenges: "I was surprised by how little I knew"

I think the faculty-in-residence program is a brilliant idea; I learned more about the students in those two years than in all my years up to that point and since then. I think I have a much better understanding of the undergrads since I lived in Avery. I was ignorant; it's very simple.

Aspaturian: Did you think you knew more than it turned out you knew?

Bruck: I was surprised by how little I knew. And there are many layers here. The students here on average are very shy. And most of them are introverts.

Aspaturian: Yes, that often goes with a certain type of high intelligence. Not always, but often.

Bruck: Right. It's a little bit better now but whatever "better" is, there is no problem with people being shy. I actually like it.

But being there with them, you have the opportunity to interact with them, which for people who are more introverted is not going to be happening in class settings at Caltech. But sitting there in the evening in the apartment and watching a basketball game together, then you get to talk to them.

ASPATURIAN: What kinds of issues and ideas and feelings did they bring to you and your wife?

BRUCK: A whole spectrum of issues. First of all, at any given point, there is a relatively large group—I would say around 10 percent, or maybe even more—that have some hardship.

ASPATURIAN: You mean emotional hardship?

BRUCK: Emotional hardship. Either they're depressed, or they are at a point that they are extremely anxious; they don't sleep well; they're withdrawn; and then they're young and away from home. Most of them used to be the academic stars of their schools, and a lot of their self-worth comes from that.

ASPATURIAN: Their sense of self-worth.

BRUCK: Yes. And now maybe they do not feel special, and it leads to difficulties. Let me deconstruct it and talk about the importance of focusing on *who* you are and not on *what* you are. What you are means, "Okay, I'm a student at Caltech; I got a perfect score on the SAT; I am this, I am that," but that's irrelevant. You need to figure out who you are. I think they didn't have the opportunity, many of them, to explore their

"who" because they were so successful with their academic work. However, sometimes you need to get hit in the nose to ask yourself, Wait, who am I? And they definitely get hit in the nose when they start Caltech because suddenly they discover there are ten people who are better than they are in almost every topic. So there is one guy that is naturally very talented in mathematics, another that is naturally very talented in playing the piano, and then a third that is talented in everything. That's a disaster; how come there can be someone like that?

ASPATURIAN: There always is.

BRUCK: And I always told my kids when they went through that, "Listen, also mediocre people have the right to be alive and support themselves and be happy. They have the same rights. Everyone has a gift!" But I think that as a young person, it's very difficult to come to terms with these ideas.

ASPATURIAN: Especially when you come to a place like this, and you've been covered with local honors before you do that.

BRUCK: Yes. You know, I personally discovered that I'm an average guy at Caltech; however, I'm a happy average guy and that's important because you cannot be creative if you're not happy every now and then. So at Avery I noticed that there are a relatively high percentage of Caltech students with emotional problems. I started reading about that, and I talked to some university physicians who I know, and I asked them, "Do you think the percentage of college students that have mental

health issues is higher today than twenty or thirty years ago?" And they said yes, that they think it's the case. I'm not an expert, and it was an eye-opener for me.

And there are different theories for that. One of them is that in the past, people who had some of these issues didn't end up in a place like Caltech because they didn't have access to the treatments that they have access to today. On the other hand, today we have computer games, and people who typically are withdrawn and not in a good place emotionally or psychologically escape into playing computer games for many hours, and it just aggravates their situation. Of course we were not seeing the depth of this issue at the beginning, but after a while we—

ASPATURIAN: When you say "we," you mean you and Anat?

BRUCK: Yes. I mean this job is not a job for one person.

ASPATURIAN: No, but I thought perhaps you and the other faculty. But you meant you and your wife.

BRUCK: Yes. She was the key in this whole process. People felt very comfortable with her. To this day, she is communicating with these students from our time at Avery. Anat provided wonderful help and support to the students. There were many different things were going on, and I think it's good that we have faculty families in Avery. I think if I were single, it would be more challenging to deal with those issues on my own. This way we could talk to each other and brainstorm to see what we

should do. We are not professionals but we knew how to connect the kids to the professional people here on campus. So we worked with the deans' office and with the counseling center. You know, we cannot force anyone to go to counseling. But it helped me also later, and even today with the undergrads when they come in and sit where you sit and talk to me. Then I can see where they are, and I feel more comfortable talking to them about the challenges they have, whereas before I was seeing my role more as just being academic advisor. But that's secondary, I think.

I tell the students, "Listen, for you to decide which classes to take and making sure that you graduate on time, you don't need me for that. You're smart enough to do a great job. And if you have questions about that, you can ask your friends, ask me, ask anyone. And that's an easy thing. That's not where the issues are, but I'm here so that you can talk to me about anything that is on your mind. You should never feel that if you have an issue or something bothering you that you cannot just knock on my door and talk to me about it." Because again, for many of those students, it's the first time that they're away from home, and they can't come home every day and have someone to talk to about what they're going through. Also, every family has a different degree of functionality.

Aspaturian: Some students will come in with problems because they come out of a dysfunctional family to start with.

Bruck: And that's natural, because there is a whole spectrum of that. So things go on here, and the parents think that everything is okay. We've seen all of those things going on. Parents visited the students, so we got to know the parents over the years too. I feel that we learned a lot, and we also made an impact in a small way on the quality of life for the students and their overall experience here. And again I didn't say anything about academics because I don't think that's the issue, even though I was teaching IST4 at that time. Students sometimes came over in the evening to my apartment, and they asked me about their homework set.

Aspaturian: Did you get to the point where you had students from other houses coming to talk to you as well? Not necessarily students from your class, but who had perhaps heard from other kids in Avery House?

Bruck: Yes, it happens. Because they are friends of someone. And there are groups of friends, and we watched basketball together. Our son at that time was probably twenty-one. And he played on the teams of the inter-house leagues, and he used to be a very good basketball player. As a result, one year the other houses tried to pass a new rule that the kids of the faculty in residence cannot participate in the league, because suddenly Avery was winning.

It was a fantastic experience for our son, and he has friends from that era. Overall, it was great. The Avery community is the best you can hope for. Friends from Israel visited us many

times here, and they asked me, "How close are you to your campus office; where is it?" And I said, "I'll count the steps." So I did. It was, door to door, 140 steps from leaving Avery to coming here.

ASPATURIAN: You also had Citrus right outside your window.

BRUCK: Exactly. I loved Citrus. It was the best food ever on Caltech campus.

ASPATURIAN: It was very good, and very sad that it went out of business.

BRUCK: So, by the way, the construction site that you see out of my window is where they are building the Bechtel dorm. And they're going to have faculty in residence apartments there. So maybe Anat and I will come back.

ASPATURIAN: Well, you'd be even closer to work.

BRUCK: Less than 140 steps. [Laughter]

ASPATURIAN: That's right. They could build a tunnel to your office from this particular location.

[*By agreement between Professor Shuki Bruck and the Caltech Archives, this portion is currently closed.*]

"I think the students need to see that we are just normal people, and we need to see that they are just normal kids"

BRUCK: You know, we talked earlier about how in 2005 the vote on IST was no [*Session Seven*]—

ASPATURIAN: Although it really was yes.

BRUCK: It was yes, but not yes enough. Only Y with a capital letter, not the e and the s. And then I went into Avery 2006, and then Chameau came. So basically since the "no" vote in 2005, I still feel that I'm in Siberia when it comes to the administration.

ASPATURIAN: Really?

BRUCK: Yes. I know it's a strong statement, but I hope it will turn into a better experience over the years. Because I didn't really serve in any administrative capacity since then. And not only didn't I serve, but I was not involved.

So politically I am a complete failure right now, but I'm happy. [Laughter] Because Avery 2006–2008 was a great experience. In 2007 I started teaching IST4 [*Session Twelve*]. And in 2009 I started XtremIO [*Session Nine*], which I consider the biggest impact I made from the engineering point of view in my career. So I did other things. It's all fine.

Aspaturian: If you had to name a couple of chief takeaways from your time at Avery, what would you say?

Bruck: First I think it's a great program. Second I think that we should find other ways to make connections between students and faculty, we are all people, and I think that especially in a place like Caltech we can develop familiarity and project emotional availability that in other places is very hard to develop. Now, not every faculty member is interested or capable of doing that. Which is fine, but I think for those people who are, this is something they could do.

During this time, we used to be invited to other houses for dinner, and I really enjoyed that. You know, Caltech is an intellectual village, but during the usual kind of schedule that I have, I come here to work and I leave. I don't eat dinner with the students. I'm not involved with their life, and if I don't teach I don't see almost any undergrads, so there is this disconnect.

I think at the end, they need to see that we are just normal people. And we need to see that they are just normal kids. And we can develop a relationship. Again, not everyone feels comfortable with it. And it's okay; you don't have to do it. It's the same with students. Not every student in Avery felt they could knock on our door and come in, but quite a few did. So I think we need to figure out a way to increase these contacts even when there is no faculty in residence—which is a great program, but in the end it's a very small number of faculty

members that can enjoy the program. And there are different mechanisms of relating to and interacting with students, like taking your students for lunch or faculty and student conferences.

I strongly believe in culture. What is culture? It's something that happens without planning, right? You just decide that you will eat dinner every couple of weeks with students. I would be happy to do it. So I miss that, and I think that's something we should think about. Because how will we continue making Caltech, a special place? I think that's a big question, and I don't think we have a good answer to this question. And at the end, it's not about MOOCS [massive open online courses] and iPads and online classes. I think in the end, it's people sitting and looking at each other and connecting at the emotional level, not just the intellectual level.

Aspaturian: It's a good place to stop.

Session 11, March 28, 2017

Recalls & reflects on involvement in 2000 Caltech–MIT Voting Technology Project

Aspaturian: I want to start by asking you about your involvement in the voting technology project, which I believe started after the presidential election in 2000.

Bruck: Yes. I'll tell you the story: I became a US citizen in '98, so obviously I didn't have an opportunity to vote before that. And in fact, I also didn't vote in the 2000 election. I think I was in Israel during that time. My father was very sick during those years; he had late-stage Alzheimer's disease, and I came back, I think, on election day. The following day, I gave an invited lecture in some conference, which I forget now the details of, but in any case, I came back to the hotel and watched CNN announce that Gore won. And I went to sleep. I think that's more or less correct. Of course, it's many years back, but I remember thinking, "Okay, Gore won; I can go to sleep." [Laughter]

The next morning I discovered that it's much more complicated. I followed it with interest like everyone else—the Supreme Court, and all of those things. I had no clue how voting is done in the US because in Israel we do it very differently. Also I didn't know anything about the voting technology. So I was completely ignorant about this topic. I'd never voted myself. And that's it.

Then one day, on campus at the Ath [Athenaeum, the Caltech faculty club], I see David Baltimore, who was the president at the time. He approached me and he said, "You know, I talked to Charles Vest, the president of MIT. And we thought that it might be useful and helpful if we put together a team to look into the national voting technology and what happened." And I said, "That's great." And he said, "What do you think about

participating in it?" So I told him, "You know, I don't know much about it." And at the end I told him, "You know, with voting, the public in the future will have to decide if they have more trust in politicians than in scientists." And he was laughing; he liked that. But I actually still don't know the answer to that.

ASPATURIAN: Yes, well, it depends on the situation and the demographic, doesn't it?

BRUCK: Yes. So that's how I felt at that time, but in retrospect, given where we are today, it still feels like a relevant question. In any case, this was our discussion. And I was very busy—this was around the time of graduate admissions, and I remember I was sitting at home one Saturday, checking my email, and I see one from a guy called Chuck Vest. This is a name I don't recognize, so I assume he's a graduate student trying to contact me with regard to admissions to Caltech, and I almost put it in a folder of things to deal with later. But then I looked at it, and it was an exchange between Vest and Baltimore, that I was copied on, about trying to get some funding from a foundation with regard to a voting project. So, okay, I was not sure how I can contribute there, but I was happy to know that they appreciate my feedback.

But I still didn't take it too seriously, and during this time I was also very busy with Rainfinity [*Session Eight*] and used to go to the Bay Area every Thursday during those years. And this particular day was, I remember, a meeting of the Rainfinity board. I

had a cell phone at that time, and that's important because I was sitting there in the board meeting—I was the chairman—so I was very busy, and then we had a little break and I see that everyone, more or less the whole world, is calling and leaving me voicemail. And it turns out that on that Thursday—I don't remember the date—Caltech and MIT announced the voting technology project in a press conference.

ASPATURIAN: I remember the press conference. It generated a lot of publicity.

BRUCK: Yes, and it's one of those things that you recognize only in retrospect. I don't think I have ever had such a visible project since then, and I'm not someone that enjoys the limelight. In any case, everyone is calling me, and I think I was at the San Jose airport getting ready to fly home when one of the people from Caltech PR called me—I think her name is Deborah?

ASPATURIAN: Deborah Williams-Hedges.

BRUCK: Yes. Deborah said, "All those reporters, they want to interview you about the election." And of course I told her I don't know anything about the election.

ASPATURIAN: They wanted your expert opinion.

BRUCK: Yes, my expert opinion. Never in my life there was such a gap between what I know and what people think I know. [Laughter] There is always a gap, one way or the other. Sometimes they think you don't know anything, and you know more

than that, but this was the largest gap ever. It was such a large gap that it was not even stressful for me, because I could only laugh. It turns out that in the press conference they announced the two Caltech faculty members who were the initial team for the project. After that we added more people, but the original two people were one from political science and one from engineering. Tom Palfrey, whom I had never met, was the guy from political science, and I was the specialist engineering guy on voting. Then Deborah told me that Larry Mantle wants to interview me at eight in the morning the next day and am I willing to do it.

Aspaturian: The whole public relations sequence. On "AirTalk."

Bruck: And at that time I didn't listen to NPR at all! Now I only listen to NPR, but at that time I had no clue—who is Larry Mantle? What is NPR? I didn't know any of that. So she said, "He wants to talk to you, and it's a big deal for Caltech." Of course when I hear that I always say yes. I love Caltech. But what do I know about the technology for voting? So I was very nervous, flying back home, and I was supposed to meet Deborah at PCC early the next morning for the live interview. I came home and I told my family, "Listen, I don't know anything about the US elections. I never voted in the elections. I was not part of the press conference today, and I have never met Tom Palfrey. But tomorrow at eight o'clock, I'm going to be interviewed."

So I talked to my son, Or, who was fifteen at the time and who always loved to listen to talk shows and to NPR since he was a young child. I went to get his advice, because that's the only expert I have. I told him, "I don't know anything about voting, and I have an interview with Larry Mantle. What do you suggest that I do?" He said—I can still remember that— "First of all, you normally speak very slowly, and you take your time to explain things. That's not how you talk on the radio. You need to answer very fast, with a short sentence, and let the person who is interviewing you ask the next question."

ASPATURIAN: Your fifteen-year-old kid!

BRUCK: That's what his advice was. So then it's the next morning, and I go to PCC, and I meet Deborah for the first time. And she said, "Thank you for doing this." I still remember that she also told me, "Make sure you mention Caltech as often as you can in the interview."

So here I am: My fifteen-year-old son is telling me, "Dad, react fast. Speak quickly and just say one or two sentences." And Deborah is telling me, "Caltech! Caltech! Caltech!" I go in, and here is Larry Mantle. I had never met the guy, never listened to this program. Of course, now I do, and I actually like his program. And then he has a mike, and I have a mike, and we are sitting almost face to face. And then, given what my son, Or, told me, I had this very clear view of the situation: I said to myself, "Okay, now I know what to do. I should think about this whole setup as a game of Ping-Pong, of table tennis. He will

pass the ball to me; I need to pass it quickly to him. He passes the ball; I pass the ball."

So that's it; that's all I remember. He asked me a question; I returned the ball. I remember in the middle I forgot what is the last name of Tom. He said, "You mean Tom Palfrey?" I said, "Yes, I forgot the name; never met him." [Laughter] By the way I still have the tape of this interview.

Aspaturian: I'm sure you do. The Archives probably has it, too; they get a copy of all of them.

Bruck: It's somewhere in my office. Now the funny thing is, I actually don't remember any questions or any answers. But afterward we started getting phone calls from friends—from the East Coast, from Chicago; apparently it was broadcast nationwide. Friends from all over the US are calling Anat and telling her, "We just listened to Shuki on the radio. It was an amazing interview." I said, "I don't know what I said! I was in the middle of a table tennis game." [Laughter]

Aspaturian: It all went off okay.

"I learned a lot about how unbelievably arcane the voting technology is"

Bruck: This was the opening, and this was a fantastic project for me. I still don't know much about voting, but what I realized and what I learned a lot about is that it's unbelievable how

arcane the technology is. There were those one-ton machines in New York—special custom-made machines for mechanical voting—and then there were the punch cards with the chads. And then there were some places that had touch screens. And the whole registration issue is really complex and awkward. So many issues.

And the team was phenomenal. Tom Palfrey and I have since become very good friends. Also Mike [Michael] Alvarez [professor of political science], who became the leader at some point. We had a fantastic coordinator, Mary Sikora. She was hired because suddenly this whole project exploded, and we needed someone to help us. And she did a phenomenal job. In fact, a few years later I hired her to be the programs manager for IST [*Session Seven*]. And now, I think she is running the KNI [Kavli Nanoscience Institute]. So we had a great team here, and I realized that I can learn a lot from them. And a great team also at MIT: I especially worked with Ron [Ronald] Rivest, who is a computer scientist.

ASPATURIAN: Had you known him before this?

BRUCK: Only by name. He's actually one of the inventors of a cryptographic scheme called RSA. R is Rivest, S is [Adi] Shamir, A is [Leonard] Adleman, and the three of them won a Turing award, which is like the Nobel Prize for computer science. I really enjoyed working with him and the MIT team. And we actually worked together. It's something I still miss—I missed it when I first came to Caltech, and I miss it today—the

ability to work with colleagues. I had that experience when I was at IBM, and here we typically work mostly with students. On the voting technology project, we suddenly became individual contributors who are collaborating with other faculty members. And I really enjoyed that. So our goal was to analyze what happened.

Aspaturian: In the [George W.] Bush–[Albert "Al"] Gore election of 2000.

Bruck: Yes. And we collected a lot of data.

Aspaturian: Were you looking at the state of Florida?

Bruck: No, in general.

Aspaturian: It was a nationwide assessment.

Presenting Project recommendations before Congress & AAAS; frog data storage meme gains renown

Bruck: Yes. And trying to estimate different errors. But the most important part, I think, was to actually come up with recommendations for the future. And the outcome was a report, but not only a report. We made presentations and recommendations at different places in D.C. I remember we had a presentation at the AAAS [American Association for the Advancement of Science] and at the US Congress. So for me, it was like a different planet.

Everyone wanted me to give a talk about the voting technology project, so I gave many, many talks. For example, I gave a talk to the Los Angeles MIT alumni chapter, along with one of the MIT partners on the project. So it was a lot of fun.

Aspaturian: Who funded this work? Was it the NSF?

Bruck: No. We wrote a document that we distributed to everyone, so there is a little book that we wrote as a result. I've forgotten which foundation gave us the money, but it's a private foundation [the Carnegie Corporation of New York and the John S. and James L. Knight Foundation. –*Ed.*]. I think we then raised more money. My guess is that the project is still ongoing. I decided to step down after four years.

So I'll tell you what I recommended. I actually thought very deeply about this whole notion of election. Now this was 2000 when the technology was very different. I felt that people should first of all not rush into making decisions. Take the time. Don't necessarily make all the decisions in the voting booth, or whatever, but have a way to think more deeply about that. I also thought that it will be even better if they can somehow have a framework where you do the voting at home, store the result of the voting in a way that is not readable to anyone else, and then deliver it when you go to vote. And this whole process is secure.

Now you have to recall that at that time, there was no smartphone. So I vividly remember flying to Boston for one of our

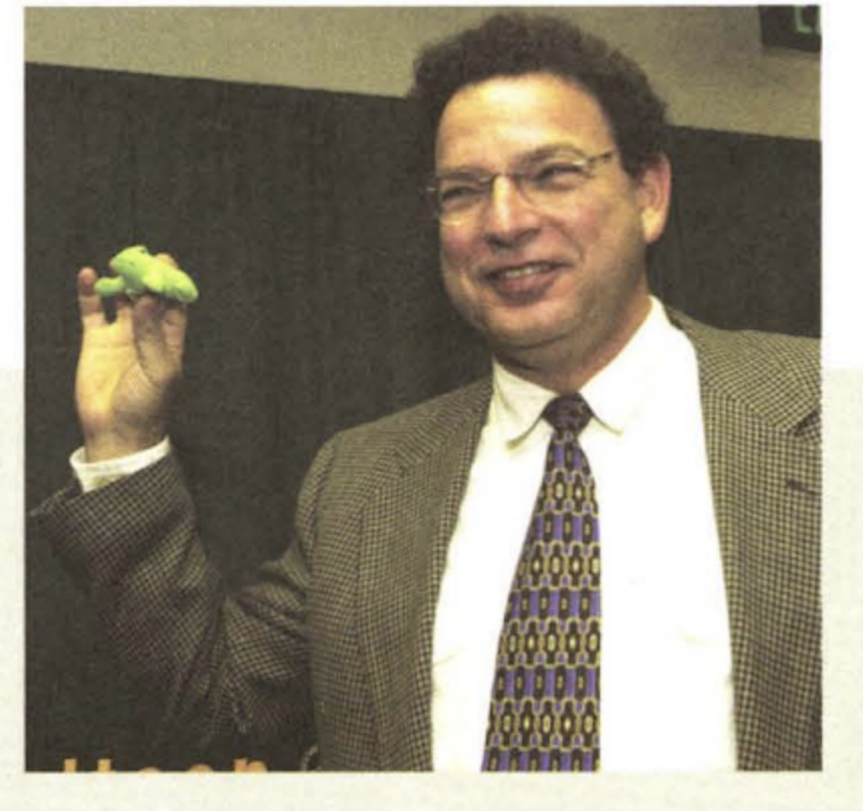
meetings at MIT, and I was finishing preparing the presentation that I was proposing for secure voting. Of course you don't want to walk into a polling place with a page that everyone can read. So the question is, where do you put it and lock it such that no one else can read it? I defined all the properties of this security framework, but I didn't know what to call it. I remember sitting on the flight looking for some clip art, and I found a picture of a frog.

So I said, "Okay, temporarily I will put a frog there as a symbol of how you kind of store your data when you work on the voting—you store all the decisions in the frog. Then you walk with the frog in your pocket to the voting booth, deposit the frog, and then you come back." So I had this whole story line in the workflow. And when I got to MIT, I ended up giving the presentation with the frog, explaining that I still didn't have a good idea for what I should put there as a token. And this made a huge impact because everyone thought we should keep the frog.

Aspaturian: Everyone could relate to the frog?

Bruck: Yes. The frog actually appeared in the report.. And I remember we had it for a press conference with all the media, NBC, CBS, CNN. I think I still have the frog somewhere here.

Aspaturian: The prototype frog?



Caltech News photo & courtesy of Shuki Bruck

Bruck: I don't know where my frogs are. I used to have like twenty of them in my office, in fact at that press conference, I pulled out a small frog and I put it on my head.

Aspaturian: I think I remember something about this.

Bruck: Yes. So as a result, everyone brought me frogs, and it felt a bit like the Passover story.

Aspaturian: The plague of the frogs?

Bruck: Yes. You know, frogs everywhere.

Aspaturian: Fortunately you didn't pick a locust. That would be disastrous.

Bruck: Yes. [Laughter] And the idea for secure voting was pretty neat. I still think it's a good idea and one that you can actually implement today with a smartphone. And so this was a lot of fun.

Assesses Voting Technology Project's impact on conduct of post-2000 US elections

Aspaturian: Do you think that any of your work and the work of your group had any impact on the way elections are conducted in this country?

Bruck: That's a very good question. One thing I discovered is that when it comes to elections or anything political, it's extremely difficult to create change.

Aspaturian: Yes that's right. The inertia is very strong.

Bruck: So we had a workshop here with people from the local and state government, from the county, from different political parties, from ACLU. Many groups that I didn't even realize had something to gain or to lose. And what you discover is that people are very suspicious when a third party comes in and

says, "Here is what we propose as a change in voting technology, and we're not changing anything else, just the technology." This guy is a scientist, and he really has compelling arguments why we should go in this direction. So we listen and the first thing we think about is, How is this going to affect our success?

ASPATURIAN: What will it mean for turnout?

BRUCK: "What will it mean for whether we'll do better than the other side or not." That's the first reaction. So if you're a Democrat and say, "I actually like this change," my first reaction, if I am a Republican, is "I don't like it." Why am I against it? Just because you're for it. If you are for it, probably you have some insight that I don't have as to why you will gain and I will lose, which means that I should be against it.

So it's kind of a strange phenomenon, but I think we made an impact on the way people do their registration, which is a big deal. I think a lot of the modernization that has happened in many of the counties was encouraged by what we proposed. Punch cards—we were strongly against them and they were phased out. We strongly supported using the optical scan, because we felt it's a relatively stable technology, also not very expensive. I was also a big supporter of absentee ballots.

ASPATURIAN: Yes, there's a lot of momentum for that now.

Bruck: And I think that's something we supported as well. So I think at the end of the day, being involved in that gave a feeling, I hope, to the general public that voting is an important issue. For me that's probably the most important outcome. That there is an issue where a group of scientists gets involved. That's good; it shows that we are connected to important issues, and also it kind of elevates the importance of this issue.

Aspaturian: Given that feeling, did you vote at all yourself during this period?

Bruck: Which period?

Aspaturian: Between 2000 and 2004.

Bruck: No. [Laughter] I'll tell you something. I'm a very bad citizen. Luckily my wife is very dedicated.

Aspaturian: Conscientious.

Bruck: Yes. She votes for everything, propositions and everything, and she does her homework. My daughter is the same. My son sometimes votes. But my daughter and my wife; they are very, very good citizens. I'm terrible.

Aspaturian: After this election, I hope you will reevaluate that position.

Bruck: So I didn't vote in the last election. I felt it's not a big issue. But I joked with my wife, Anat, and I told her that the

reason Trump was elected is related more to the fact that she voted and I didn't. I said, "Listen. I didn't vote, so I couldn't even make a mistake. But you voted, which means that you wanted to vote for Hillary. But say you made a mistake marking the ballot, and you voted for Trump? That cannot happen to me." [Laughter]

By the way, we discovered in the voting technology project that sometimes the whole interface can be so confusing that people just make mistakes.. In most of the voting technology lectures I gave, I tried to put in as many jokes as I can. Why? Because it's the general public, and I have no clue about the topic anyhow, so at least I can invent good jokes. So I was taking a shower on the morning of my lecture at the AAAS and I still didn't have a joke, and then it came to me. I started the lecture saying, "For many years, I've noticed that I have terrible hair days when I'm travelling. And I didn't know why until today as I was preparing for this talk because I was thinking about interfaces," and then I pulled out my samples. So when you go to the hotel, there are the little bottles of shampoo, conditioner, and body lotion.

ASPATURIAN: I see where this is going.

BRUCK: [Laughter] I brought those bottles to the talk, pulled them out of my pocket, and put them in front of me. And if you look, the shampoo is very distinctive—you can see it's a shampoo. But the lotion and the conditioner look basically the same, and it is a true story that I have ended up using the lotion

instead of the conditioner, and that obviously will not work well with your hair. So this was like an opening joke for the whole interface issue.

Aspaturian: You drew the analogy to the confusing ballots.

Bruck: Yes. So I don't know if Bush is the lotion or the conditioner, but some people got confused.

Takeaways from four years with Voting Technology Project

Aspaturian: That is exactly what happened in south Florida with the butterfly ballot. Did you feel that doing this gave you a better understanding of some real-world issues that you hadn't really been engaged with for a number of years?

Bruck: I'm pretty engaged in the world, but I didn't understand the kind of the political system that exists in the US. It definitely was a fantastic introduction to that.

Aspaturian: That was an eye-opener.

Bruck: And, you see, the way the system in the US works is that it's very hard for anyone to make any change. The only way to create change is by compromises. And I think that unless there is a major crisis people just hope that the leaders will make the right decision. And they don't overanalyze it and use

their ability to oppose it as a way to gain some political progress.

I realized that during those years of working on the voting technology project that when we vote for a leader we do not necessarily optimize based on his or her ability to be productive. I think [Barack] Obama is a great guy, and I'll be happy to have dinner with him and enjoy his intellectual depth and his courtesy; and, you know, as a person he's really nice, but I think as president it was very hard for him for different reasons to create a momentum for change through compromises. And I think that's unfortunate, because the efficiency of governing is very low. So we don't get much progress. And it seems that in some sense, it's easier to distract than to build. It's yet to be seen what will happen with President Trump.

Aspaturian: Well, we're kind of in unprecedented territory here with him; there's no question.

Bruck: Yes, I think he is trying to push it in his direction, which I'm not sure what it is. But I think his ideas are definitely more radical. So maybe that's the reason it's so hard to make changes. So maybe I'm getting the answer I was looking for.

Aspaturian: Maybe so.

Bruck: But yes, definitely, this project really helped me to get to know the humanities and social sciences division. In fact when we started the IST initiative, I invited some of the people that I

knew from social science to participate in the process, and in fact one of the original IST centers that we had was related to social science and economics. John Ledyard was the first director, and Tom Palfrey was on its steering committee [*Session Seven*]. So I think at least from my perspective, my awareness and appreciation of HSS stem from this experience of the voting technology project. So yes, it was a fun project. Definitely.

Aspaturian: Something different for you too.

Bruck: Yes, I felt suddenly that a big part of what I did was to communicate to the general public. Typically, you know, we work on science and engineering projects, and it's very internal, either in our head or in our collaborations with colleagues or students. It was very different in terms of our intellectual focus, right? Suddenly we're discussing, "Okay, how are we going to talk about that?" Typically we don't need to worry about that. Here a lot of the energy was related to, how do we make an impact on opinions and on policy and so on.

Aspaturian: Starting with Larry Mantle.

Bruck: Right. [Laughter] Without knowing what I was talking about. And I discovered some people have their whole career going this way nationwide.

Aspaturian: That's true. Do you have any time constraints today?

Bruck: Probably about ten more minutes.

Comments on evolution of EAS division, leadership & programs during Caltech tenure

Aspaturian: Do you want to talk about the division and how you would appraise its evolution over the time you've been here.

Bruck: I will, but in general I don't like the word "division" because it's a bit divisive.

Aspaturian: I understand, but it's the nomenclature we've got.

Bruck: When I came here, again, I didn't know exactly what the structure of Caltech was—how it is organized and all of that. Of course, over time, doing the different service jobs I did, I kind of realized how it all works, and I think one of the biggest challenges we have at Caltech is that engineering is underrepresented. There are six divisions currently at Caltech, and only one focusing on engineering, and if you look at research schools like Stanford or MIT, you discover that between CS and EE, it's much bigger than any other groups on campus.

Aspaturian: Those programs are probably bigger than a number of small universities, actually, in terms of population.

Bruck: Exactly. And even here, I think EE is the largest group of graduates, and CS is the largest group of undergrads on

campus. We had kind of predicted that in the IST report [*Session Seven*]. Today's students come because of CS, and, I think, EE. So when I came here, as you know, there was no CS major, no CS degree. Creating it was led over the years by people from EE, first with a computer engineering major that was kind of between CS and EE, and was then phased into a CS major; and then we cancelled the computer engineering major, so it was a process. At the end, the group of people who make decisions about the strategy and the intellectual focus of Caltech are the president, provost, and the division chairs, and if you look at this group, there is only one guy currently representing engineering, the EAS division chair. The current provost and the president, they don't have an engineering background.

So there is an intellectual imbalance, and I think that's a big issue. When we had discussions about splitting the EAS division and creating IST, people tried to think about it more as a way to help the division chair manage such a diverse division, and all of that, but from my perspective the key challenge is the fact that at Caltech, we have an underrepresentation of an area that is very central these days. Now, I think different division chairs tried to deal with that in different ways. When I came, John Seinfeld was the division chair, and he is kind of an outsider.

Aspaturian: He came from chemical engineering.

Bruck: Right. And in fact, as I mentioned earlier [*Session Six*] in '98 when I had only been here for four years and was an out-

sider to CS at the time, he asked me to lead the search to recruit five faculty members to CS. I think he tried to do his best to improve the activities in CS. I think Richard [Murray] definitely made the biggest impact on that, and I worked mostly with him. I think after that, a decline started. After Richard we had Dave Rutledge, but he excused himself after a year or so, and then we had Ares Rosakis. I think his tenure, from my perspective on this side of campus, was not effective. He came from the so-called south part of engineering—GALCIT and aero—and I think his understanding and focus was mainly on that. He prides himself on creating "the department structure," as opposed to the options, but I think we are more about creating centers of ideas and intellectual centers rather than administrative units. And one result of this departmental division is that he felt that CNS cannot be a department, so it has to be folded into EE.

Aspaturian: Why did he think that?

Bruck: Because he didn't want to have too many departments, and we had like ten different options. I think now, in a sense, with the new leadership, that this whole idea of the fixed departments is changing, and I think people will think again about options.

Aspaturian: You mean within the EAS division?

Bruck: Yes. I think CNS is in a bit better shape, at least administratively. I think intellectually it's always very exciting to

study the brain. So I think at the end of the day, Caltech is a relatively robust place, because it's not easy here to affect what an individual faculty member does. We still are going to do what we love doing. The organizational part might go through different changes, but we will still do what we enjoy doing. That said, I think that organizationally we still have a lot of work to do, and I don't think we're there yet. One of the issues of being one division out of six, is also if you say, well, we want to be two out of seven now, who is going to support it? It's a political issue.

Reflects on ongoing legacy of IST initiative

ASPATURIAN: That's what you ran into with IST (*Session Seven*). Do you think that your experience in the voting technology project gave you any better sense of how the politics were going to play out with IST? I'm asking, because you were talking about developing some new familiarity with policy making and partisanship and so on.

BRUCK: Yes. I'm not a political person. Luckily I had a very good life and career without that. I'm not someone who will work and try to talk people into voting this way or the other way; it's not my style. There are the ideas that I believe in, and I will communicate the same ideas to everyone. And that's sometimes not what you need to do as a politician.

ASPATURIAN: That's probably true.

Bruck: So politically, probably IST is not a successful project but—

Aspaturian: Intellectually?

Bruck: Intellectually it is a successful project, and I believe the politics will fall into place because there is no other choice.

Aspaturian: That's true. Sometimes the intellectual agenda precedes implementation by years, if not decades. You just have to wait for the future to catch up with you, basically.

Bruck: Yes. In general, I must say that my happiness here at Caltech over the years—and I have been very happy throughout—is not driven by coming to my office and thinking about the structure and politics of Caltech. I come in every morning; I look at the mountains from my window.

Aspaturian: Which you can still see despite the construction.

Bruck: Yes. And I feel extremely lucky that I am here, and I enjoy doing what I'm doing in the science part, and the teaching part and working with the students, and that's the source of my joy in being here. The very big projects and complex undertakings that I did that outside of Caltech in industry and startups and so on are very different, because it's not a political experience—it's a real experience. And you take the responsibility and the blame if it doesn't work. That's how you do startups. I think that within Caltech, some people enjoy that aspect more, so they spend more time in administration. I do

enjoy that, and I enjoy working with people, and the organizational service that I did here gives me a lot of satisfaction, and I am very grateful that I was able to contribute, but that's not the reason I joined Caltech.

Catching up with iconic innovators of the past: Alongside Intel cofounder Gordon Moore's image at Intel headquarters in 2020, and with Caltech professor and VLSI pioneer Carver Mead at Caltech's celebration of Mead's 90th birthday in May 2024. *Photos courtesy of Shuki Bruck*

Session 12, April 11, 2017

Conceiving & teaching IST4: exploring the history & mathematics of information & logic

Aspaturian: Today we're going to talk about your IST4 class. I'll mention for the transcript that we will be including a link to the interview "The Book of Bruck" that I did with you for the Caltech homepage back in 2009, after you won the Feynman Teaching Prize. Some of our discussion questions will take off from various points in the interview. First, how has the class changed since we last talked about it?

Bruck: Yes. it's a dramatic change. Because with the synthesis of the class is still ongoing, I am still learning, acquiring insights and knowledge. At the beginning, I tried to do the best I could, given what I knew. I was very enthusiastic, but I think I was more enthusiastic than knowledgeable. I'm still very enthusiastic, but I know more. There were big questions that I didn't know the answer to, and I think, as I look back, that every year I was able to add more pieces, and most of what I was teaching today definitely didn't exist in my class in 2008 or '09. I taught it for the first time in 2007 and have taught it every year since then, except for 2013 when I was on a short sabbatical.

You know, the whole heritage of the class goes back to when I worked on developing the IST program, and I went and talked

to people outside of Caltech, and they asked me, "What is information?" I still don't know how to answer it. [Laughter] But at least now I can say, "Take my class." [Laughter] That's the best answer I can give. So, for example today, I taught the third lecture of the term. The first one was related to just setting the stage, so that students understand what I'm trying to do in terms of teaching this material from a historical perspective and showing the ideas as they were conceived. And talking about the first information system, which is life.

The material that I was teaching in the first lecture, which you attended, didn't exist until about a year ago. The second lecture relates to the human brain, and I tried to discuss what's special about humans, and the whole notion of language—that it is natural to us, but also we have the gift, as humans, to develop languages that help us capture an area. For example, music is a language and physics is a language.

Aspaturian: Yes, and mathematics.

Bruck: And then I try to explain what's special about a language, and again, it took me a while to figure out how to do it in a way that is clear. And I talk about two properties: The first one is that a language has building blocks, and typically a very small number. "Natural language," like DNA, has a small number of letters: DNA has four. But with the DNA alphabet we can still design many, many species. And similarly, in every language there are building blocks that we can use in different ways to address different settings. Then, there is the second

property, that I call separation—that there is no necessary connection between the syntax and what actually happens, the semantics.

Aspaturian: Ah, that's interesting, yes.

"What's the first language beyond natural language that we developed as humans?"

Bruck: Those are the two central elements, and the whole idea that we, humans, are very good at creating fictions. The fictions are something that we all believe in; it's not real. For example, money is an example of something that we all believe in it, but it has no real value; it's just something we invented. It's hard to convince a dog to give you a ball for a dollar bill.

Aspaturian: It's a form of symbolism that emerged from the barter system, yes.

Bruck: Exactly. But today I kind of put it all together and ask, what's the first language beyond natural language that we developed as humans? And of course, there's music and art and so on, but I talk about a number system or a system for quantities that evolved from the need to do trade. And that happened about 8,000 years ago. And then we look at what the limitations of that initial system were.

Aspaturian: How many systems do you look at? I mean there were the Americas, there's Mesopotamia, China—

Bruck: Well I'm addicted to the Babylonians because they were the most advanced, and we still use what they created.

Aspaturian: And regionally, that's also some of your own history probably.

Bruck: Right. I don't talk about it in class, but Jews actually went to Babylonia when they first went into exile [c. 600 BCE]. And this was the best thing that happened to the Jews, because they were not very educated before they went, and whoever returned to Palestine—most people stayed in Babylonia—came back knowing writing, and as a result the Bible was written. The Passover *Haggadic* was written afterward. So the whole idea of focusing on writing as the center of the religion is something they picked up in Babylonia. That includes the Jewish calendar, which is in fact the Babylonian calendar. The names of the months in the Jewish calendar are words from Babylonia. *Tammuz*, *Iyar*, *Sivan*—these are not Hebrew words. So I think Jews were lucky to be "held captive" in "the Babylonian Silicon Valley." [Laughter]

Aspaturian: That's an interesting way to look at it.

Bruck: I think that's what happened there. And I think that today there is so much more depth in my understanding of those processes compared to seven or eight years ago.

Aspaturian: You've read more, of course.

"This class is probably the richest scholastic project I have had in my career"

Bruck: Yes, my office here is full of books related to IST4, and in the other room also.

Aspaturian: I'll just put a few of the titles into the record. *A History of the Ancient Near East*, *Babylon*, *Gilgamesh*, *The Unfolding of Language*—

Visiting the Yale Babylonian Collection in 2018 to get up close and personal with "my favorite tablet—the square root of 2 written in base –60." *Photo courtesy of Shuki Bruck*

Bruck: Yes, Fibonacci's *Liber Abaci*. You can see the book of algebra of Muhammad ibn Musa [al-Khwārizmī], whose Latin name is Algoritmi—the word algorithm is named after him. Fibonacci is the guy who brought the decimal system and algebra to Europe, and that's why Europe was able to progress scientifically, so all of those topics on this shelf here are related, and on the other side, there are many, many, more books; and it is probably the richest scholastic project I have had in my career.

Aspaturian: You know in many ways it's like a history of science class. Do you have any links with the history of science program over in HSS?

Bruck: Not really. I do talk to the people there. Moti [Mordechai] [Feingold, professor of history] and Jed [Buchwald, Dreyfus Professor of History]—I talk to both of them. They have interests, I would say, more in the history of physics and Renaissance science and maybe before that, and my interest is more in the history of information, and my whole approach is very mathematical. All the homework sets I give are very mathematical. The class is both mathematical and conceptual, and there are essay topics that evolve over time, and again, those are more like liberal arts type of projects and they get to present them at the end of the term. So this year I changed the topic of the first essay. For quite a few years, the first essay subject was "Everyone has a Gift" because I talk in class about many people

that made tremendous contributions, and I want to encourage the students to remember that they also have a gift.

Aspaturian: In case they forget that they're at Caltech.

Bruck: Right. And also it relates to the question I discussed with them in the first lecture: Why are they at Caltech? Which is to discover what their gift is, what their passion is, and so on. And those essays are very moving, typically, because they might write it about themselves, about their siblings, about one of their parents, an uncle, a grandma or just someone that they don't know personally. I really enjoy reading those essays.

Aspaturian: But now you've changed it.

"I'm still waiting for a computer to come up with relativity theory"

Bruck: I changed it. I asked them—because it's a very topical subject and very related to my class—"Will computers outperform the human brain?"

Aspaturian: I wonder what your answer to that question is?

Bruck: The short answer is no.

Aspaturian: And the slightly longer answer is?

Bruck: The slightly longer answer is that if it will happen, it will happen for the wrong reason. It's because people will

decline in their abilities, not because computers will go up. We will forget certain things that we are good at.

Aspaturian: Our brains will atrophy like the appendix or something.

Bruck: As a community, yes. I think if we get stuck, then of course computers will do better, but I'm still waiting for a computer to come up with relativity theory. I think it's very difficult.

Aspaturian: Well, only one human was able to do that.

Bruck: But there are many things that we did as humans over thousands of years, such as making the jump from a society without writing to a society with writing, where before no one had this concept. Same with relativity. And the invention of new languages—I don't think that computers will be able to do it, but, you know, maybe I'm wrong. However, asking questions, especially deep questions, is something that is not so easy to do.

Aspaturian: Creativity is what you're talking about.

Bruck: Right. So this will be the first essay. I've already received a few, and the deadline is on Thursday, but right now, the second essay topic might again be "everyone has a gift." And I will ask them to relate the gift essay to the question of the first essay: Can a computer have this gift? For example, the whole emotional aspect is not clear-cut, so that, again, if we

become emotionally flat as people and we lose the capacity for empathy, maybe computers will do better than us on that. But if we don't, I'm not sure if a computer can have deeper emotions than people. [Laughter]

Aspaturian: I was just thinking that if you do pose that question, some of the students may discover in answering it that they've changed their minds about what they wrote in the first essay.

Bruck: Yes, maybe. So there is a little trap there.

Aspaturian: That's right.

Bruck: That's the whole idea.

Aspaturian: There's a new level of thinking that's required. I don't think there are too many other classes, if any, like this at Caltech. Have you found any similar courses outside the Institute that you are aware of?

Bruck: No. A few of my have colleagues looked at the class, like a colleague at Stanford. He thought it's amazing and maybe I should come there for a term and teach it. So I want to go and teach it in some other places as well. After our interview in 2009, I think in 2010 and '11, I recorded the classes and in fact if you look at Annenberg 105, there are cameras there, with a whole setup where TAs can remotely operate a camera.

Aspaturian: Can this be found online?

Bruck: I don't think so. They were online at some point, and I got a lot of feedback. This was before Coursera. But I would say for the record here that most of my classes are recorded, but not posted.

Aspaturian: Recorded but not publicly available.

Bruck: Yes. Why do I do that? Because it helps me improve. As I approach the time that I need to start teaching, then I start preparing new material, but during the actual preparation for a lecture, I always listen to the recording from the previous year or years. I evaluate myself and typically I find many gaps and problems, and I write many notes to myself and then I do a complete revision of the lecture, and inclusion of some new things that I identify. Also after the lecture I write notes to myself regarding how I felt about the lecture, and I keep those for the next year. So I use all of this material that I collect to improve the story. Because you know it's about eighteen or twenty lectures each year, with about eighty slides as well as homework sets, so there is a lot of material.

Aspaturian: Do you have discussion sessions?

Bruck: No. But we talk during the lecture. So I keep revising every year, and I think I feel better about the quality. I still feel it's far from where I want it to be, but I started feeling better about a year ago. Last year was the first year that I felt I reached the 50 percent of the quality that I wanted. And hopefully this year I will keep pushing it higher, not lower. [Laughter]

Student engagement with IST4 course material & the "aha" moments

Aspaturian: Do your students talk to you about why they took this class in the first place? What they expected? I did notice when I was there last week that some of them looked a little bewildered for, oh I would say, a good half hour. "What is happening here?" was the expression I read on some of these faces.

Bruck: I have talked to them about it, and, you know, the simple answer is they take the class because they have to. Not this specific class, but it's a menu class.

Aspaturian: It's one of the breadth requirements.

Bruck: Yes, so they have to take one menu class during their time at Caltech. There are something like four classes that are offered, and this is one of the four. At some point I had too many students taking the class, because somehow the collective belief of the undergrads was that it was the best way to manage the requirement of a menu class. I don't know why, but I had 140 students, and this was way beyond what I'm willing to do because it was just too big.

Aspaturian: Hard on your TAs also.

Bruck: Yes, we had a large group of TAs. It became very logistical, I would call it. So then I limited enrollment to 120, and now

luckily there are other classes that are very interesting, or at least the collective belief is that they are great, like geology, where they go on a field trip to Mammoth for three days.

Aspaturian: It's not like you're going to take them to Mesopotamia.

Bruck: I'm working on this field trip, but it's a bit dangerous with Isis there. I think this year is the smallest class I had in quite a few years, and it's the best attention I've received ever. At least based on the first three lectures.

Aspaturian: They're listening to you and not looking at their phones.

Bruck: They're listening and they're participating, and they are responding, and I think they know what I'm teaching by now. I think for many of them, the first lecture is like, "Am I here, or are we at Williams College?" That's the feeling I want them to get. I've talked about how for me categories like liberal arts and mathematics don't exist. We invented these disciplines so that we can organize knowledge and teach knowledge, but I'm just trying to break this mold. I don't like the word interdisciplinary—I just think that it's very important to think about ideas, not along the lines of disciplines.

Aspaturian: To synthesize in a more—

Bruck: Holistic way.

Aspaturian: Well, as I said, I was in the classroom, and the students seemed to be genuinely perplexed for a while, some of them. And then you could suddenly see this attitude of, "Oh, I see how it's beginning to all fit together."

Bruck: Yes. I think at least for me, and I assume that I'm like everyone else, it takes time, and it takes care, to really understand certain concepts. It's a very long process and non-trivial, and that's what I'm trying to get across. I've now been teaching this class for ten years, and there are students who come back and talk to me about how valuable a class it was for them.

Aspaturian: What did they find so valuable?

Bruck: Because they could see how it is all connected. And also, the type of questions that I asked them in their homework sets are typically questions where it's not obvious at first how to even approach them. And I explained to them that the homework problems have a feature where you look at them and you need to basically socialize with the question until suddenly you see the light, and there is this click—and you see what to do. And that's a feeling you typically get when you engage yourself in a creative process—that you need to dance with whatever you are struggling with and then suddenly everything falls into place.

I want them to experience this internal feeling—that I'm not just asking them to solve this problem in a very mechanistic

way. So they really appreciate that. And because we look at so many things, they discover all of these very good intellectual links that they can follow when they actually confront real-world problems. Because you always ask yourself, What do you really know after being done at Caltech? Because we forget most of what we learn.

Aspaturian: As you said about calculus in the classroom.

Bruck: Yes, it's true. We do forget most of what we did, but the question is, does everything need to be readily available for us to make progress, and the answer is no, because if we have a good foundation, then we probably know when we need to use this or that tool that I can't remember much about, so let me pick this book and remind v need to organize those ideas in a way that is not necessarily at the level of the details, and that's very hard to teach because we measure people based on the details. And I don't do it that way—I cannot care less about the details.

Personal reflections on synthesizing science & the humanities

Aspaturian: You are a scientist, trained as a scientist. You have designed and are teaching a class that, from my perspective, is basically within a humanistic framework. Was that a challenge for you? Not just in terms of learning the information and getting more resources about the history and so on but to some

degree developing a different way of thinking about and looking at the world. Was it difficult in the beginning to articulate some of this the way you wanted to?

Bruck: This is one of the best questions you asked me in all of our interviews.

Aspaturian: Oh, that's interesting. Okay.

Bruck: Not to say that you don't always ask me fantastic questions, but the point is that no one has really asked me this question, and that's really the key question.

Aspaturian: Well, my educational background is in liberal arts, so I see this, yes.

Bruck: This is really the key question, and that's why there is no other class like this. Because, you know, grad students and postdocs—very educated people, brilliant people—have also taken this class and they have told me that it's unbelievable, the collection of ideas that I put together, and they encourage me to teach Coursera and all of that. Because it hasn't previously been accessible to them, and it's very interesting, not just to them but also to faculty here that are trained as scientists.

But the answer to your question is, I love liberal arts. I read in it all the time, for many years before the class, so I have self-training in liberal arts. I wish I could do more formal training, but I studied philosophy, history, psychology and anthropology. I love literature. All of those things that I read on my own

again, and again; they are not in science. So in some sense, really, this class is who I am. It's more about connecting with who I am than feeling uncomfortable with it. That's why I think your question really hit it right on.

Almost every day, not just when I teach it, I read about things that are related to IST4. It's not because of the class; it's because I'm interested in this material. For example, now I'm teaching about the whole notion of collective memory.

Aspaturian: This is not the Jungian collective unconscious; this is a modern collective memory?

Bruck: I want to include this idea in class one day, but I need to first understand and refine it and figure out how to include it, but if you look at religion, you can think about religion as a memory system.

Aspaturian: A unifying memory system as opposed to—

Bruck: Let me be a bit politically incorrect, okay? Say you want to remember stuff related to value systems, related to the calendar, related to many things, this model that we carry in our "cognitive backpacks." How do you force people to do it? You invent God. Then everyone fears, and then you make it mandatory to learn all of those stories and to pass them down through generations. So if you look at Passover, which was yesterday, the whole purpose of the Seder is that you need to keep telling the story of Exodus to your kids. It's a knowledge

system—a memory system with a lot of symbols—and this is how you move it forward. So I think the core method of trying to pass collective memory on was religion. It's a system to transmit ideas and values to future generations. And civilization was successful in doing that using this system. I think today, it is not clear how to keep doing it.

Aspaturian: Well, certainly now, at least among many educated and intelligent people, science and rational thought has filled many of the spaces that used to be occupied by religious belief. It's not clear what the transmittal system, as you describe it, might be.

Facing the uncertain future of knowledge transmission

Bruck: It's not clear. I gave a couple of talks about a year or two ago about who and what future generations will remember. Today we teach, but in the end when you ask students or other people about something, the first instinct is to Google it. We all do it. And it's wonderful. But we don't teach this way. So there is a disconnect here between how we operate with regard to all the data that we need to transmit over the generations, and how we teach it. And then there are many questions related to this gap. For example, are we going to get to a point where no one alive will really understand the critical deep ideas. Everyone will be able to say something about them, but there will be no

real understanding and no real progress beyond just syntactically repeating what they read in Wikipedia.

Aspaturian: That's a very disturbing and provocative question.

Bruck: So this was the talk I gave. I went through a few other ideas, but that's the key one. And I feel that we are already there, because, you know, when you look at every topic, you get a certain snapshot or a certain angle, but then you say okay, what happens if you turn it a little bit like this, do you know? What were the assumptions to create those ideas? You don't know, because you never looked at it deeply. So I think it's not clear what will happen. I have this picture that I show in IST4 where you see an adult and a child, and an arrow going between the adult and the child, and that's the normal teaching. Then we added external memory, for example, books, and today we've added Wikipedia and Google. And now the question is, what do we teach?

Aspaturian: The atomization of knowledge.

Bruck: So I think it's a very exciting time in this sense. And today I told the class, "Look at me. I'm a dinosaur. I still teach the way we always taught. But your generation will need to answer the question of how we will teach the next generation after us.

One interesting book that I'm reading now is by C. S. [Charles Sanders] Peirce. He was active at the end of the nineteenth

century; he was a logician, and he studied many topics. Most people don't know about him. But he studied a lot about the history of science, and he wrote notes to himself, and I have those books. In a sense I wish he could come and teach a couple of classes in IST4, but it's too late for that.

So I'm reading his books—he has two—and he's very critical of al-Khwārizmī and he really likes Fibonacci, and he's trying to understand the dynamics of how ideas evolved, and so on. He's the only guy whose work I would say is close to what I'm trying to do, and I discovered him only last summer. It's very interesting. He missed many things, of course. But on the other hand, I learned a lot from him.

So I always have projects. They may or may not appear in the class, but they will be part of this corpus of ideas that I have.

Aspaturian: Have you ever thought of putting this into a book?

Bruck: Yes. All the time. I have quite a few question marks related to how to approach this project. I'm not sure who the audience is. Because this will determine what will be written there. I can decide to write about my personal journey, however, it's not clear that that's a wise idea. I believe Peirce wrote his books about his personal journey, and that's why no one reads what he wrote.

So that's one aspect. The other is more a technical aspect. Are books as we know them the right format for the future? So I

keep asking myself this question, and I know that the answer is no, but I don't have a good idea how to organize around that yet. And I think it's not easy to write, and I talked to a few people. Of course, you are a professional.

Aspaturian: It's still work.

Bruck: Yes, it's work. And I talked to a few colleagues who've written books about how they approached it, and my realization is that it will be very challenging for me to pursue this project while being busy with other activities.

Aspaturian: You were asking earlier, sort of rhetorically, what kind of category this topic falls into. It's intellectual history.

Bruck: Yes, the origin of ideas.

Aspaturian: It's intellectual history, which can encompass a very wide range of topics and approaches. It's a little unusual for intellectual history because of the fairly substantial quantitative element, but maybe that's a good thing to introduce.

Bruck: But people don't usually approach this kind of thing this way. I would say all the similar things that I've seen are written by people who are not as connected to the quantitative material. And for people that know the quantitative material, their writing approach is very different. That's what we do, how we are trained, and it's very easy for us to write this way. So, yes, it's a process of maturing intellectually for me—this whole class.

Finding peace, purpose & stability in family & a legacy of survival

Aspaturian: I'd like to close out this series of interviews by going full circle for a moment. We started several years ago, although it will now be part of this oral history, with your father's history and your grandfather's, as well as your mother's and her parents'. I wonder, as you look over your background, at what happened to your grandparents and what they went through and how your life evolved—and here you are now in Pasadena, California, some seventy years after the Nazis came into your father and grandfather's community in Poland—how do you frame your thinking about that?

Bruck: Yesterday after the Passover Seder, we talked with good friends of ours about the history of the families, and it was very interesting talking about the stories of my generation and especially the generation of our parents. The friend who was hosting us was born in a camp in Germany of dislocated people.

Aspaturian: He was in a DP camp, as we would say.

Bruck: Yes. And these were very complex stories. We talked about the fact that our parents actually didn't talk to us about what they went through and why didn't they talk to us, and why didn't we ask questions as kids. And I basically think it's a miracle that I'm here, and I feel very lucky, because it's really miraculous that some of the Jews in Europe survived, including

only about 10 percent of the Jews in Poland, out of 3.3 million. But honestly, I did ask my father and I think we talked about it in a previous interview [See *Preamble* to this oral history], how he managed to continue. I think it comes down at the end not to what happened to you or your family but to what you have right now. And trying to live in the present, right?

And in the present—and this is what I learned from my parents—the most important aspect is the family, and I think that's where you feel that you are complete, in a sense. The past is fractured, but the present is complete because of the completeness of the family. And I feel very lucky with Anat, my wife, and my son and daughter, Or and Gal. And, you know, without Anat's support I wouldn't be able to do all of what I accomplished. I think when everything is going on in a linear fashion that, you know, you're born in California, and you go to school here, and you go through the UC system and you get a job, then you don't appreciate the most important aspect in life, which is the family; but when you come from a family that had a very fractured past and a very challenging trajectory, then you discover that that's the source of the stability you have.

And the fact that my parents barely survived and that they reached Israel meant that when Anat and I reached here and lived in many places and all that, that part was easy. It's easy because we have each other. We have the love and support of each other, and we have kids that subscribe to the same value system, and it doesn't matter if the house is big or small, or if

there is a lot of food or less food because at the end what counts is who do you have in your close proximity, and that's the value system that we received from our parents and grandparents.

You know, I fondly remembered at yesterday's Passover, that in Israel for Passover we used to go to our grandparents, the parents of my mom, and everyone came We were there for a week, and all the grandchildren—eight of us—slept in one small room on the floor. This was a highlight of my childhood. Because we never went to hotels, never went to restaurants.

ASPATURIAN: Destination Passovers.

BRUCK: Yes. The only outing that we had every year was going to our grandparents in Tel Aviv and spending a week there with the rest of the family. And I still remember those days. Just the warmth, togetherness, the support, and you feel that everything is fine, and all the other stuff doesn't matter. So I think the answer to your question is: This history of the family is a source of strength because it helped us simplify the way we looked at life.

And it gives a lot of peace, I would say, peace in our souls.

With Anat at Caltech commencement '22. *Photo courtesy of Shuki Bruck*