A. M. Turing Award Oral History Interview with

Raj Reddy

by John Markoff

Mountain View, California

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Markoff: My name is John Markoff and I'm a historian at the Computer History Museum, and this interview is part of the ACM Turing Award Oral History Project. Today is Monday, February 26th, 2018, and we are at the Computer History Museum in Mountain View, California. I'm conducting this interview with Raj Reddy, who won the Turing Award in 1994 for "the design and construction of large scale artificial intelligence systems, demonstrating the practical importance and potential commercial impact of artificial intelligence technology."

He was the founding Director of the Robotics Institute at Carnegie Mellon University. He was also instrumental in helping to create Rajiv Gandhi University of Knowledge Technologies in India.

So good morning. Can we start by having you tell us your complete name?

Reddy: My complete name is Dabbala Rajagopal Reddy. When I was in Australia, nobody could say the whole name, not even the middle portion of the name, so I shortened it to Raj Reddy. I've gone by that name for now almost 60-70 years, so… *[laughs]*

Markoff: Perfect. That's fine. I'm going to begin by asking you about your family life. Could you give us some family background? I'd be interested in your parents, where they came from, what they did, and maybe your earliest memories and whether you had any siblings.

Reddy: Yes. I come from a small village called Katur, which is about 60 miles from Madras, which is now called Chennai. That village is still there. Our house I grew up in is still there. We were mainly… I wouldn't call it "landed gentry" like in… but we were probably the richest family in the village and in the neighborhood. But compared to other "riches," we were very poor. My father could not afford to send me to college without some strain.

I have… I had three brothers and three sisters. We were a family of seven. All my brothers have passed away, but all my sisters are still alive.

Markoff: Where were you in the family?

Reddy: Right in the middle. *[laughs]*

Markoff: So you were the youngest son?

Reddy: No, I was the third son.

Markoff: Third son. Okay, that's good. Very early memories from the family home? Do you have any childhood memories that are…?

Reddy: Yeah. Basically, I imagine when you read Jane Austen or something, the manor, there are all these animals and chicken and pigs and cattle and the whole place, and then vegetables growing, you can kind of… It was a very self-sufficient community. Everything you needed was there. You never had to leave the village.

Markoff: Was your father a farmer?

Reddy: Yeah.

Markoff: What did he farm?

Reddy: Mainly rice, but also various… At that time, there was a big demand for indigo blue. They would kind of grow the plant and then extract the dye out of it. That was…

Markoff: Did he have people who worked for him? Did he hire laborers to work on the…?

Reddy: Yeah. That's one of the things I remember well. I never worked in the farm, but I would stand around, and even though I was only 10 years old or 5 years old, I'm supposed to be supervising all these workers. *[laughs]* It's not…

Markoff: That's very interesting. I think I saw someplace that you mentioned a significant drought and famine during the Second World War. Do you have memories of living through that?

Reddy: Right, yeah. Basically, I was never hungry or never without food, but a lot of the people in our village did not have enough to eat. Even in my case, compared to what we used to have and what we had afterwards, for that seven-year period, it was pretty lean pickings. Maybe we never had a non-vegetarian, or even an egg once a day maybe, because there was no water to grow the chicken.

Markoff: That's very striking. Once again about the village, were there hundreds or thousands in the village? I'm trying to get a sense of…

Reddy: Hundreds. Maybe 500 people. Maybe, at this point after 60 years, 70 years after I've left, it's probably still only a thousand people.

Markoff: And when you were growing up, was the village electrified?

Reddy: No. There was no electricity nor running water. Most of us walked around barefoot. I didn't have sandals or shoes till I was 16 or something. Not that we couldn't afford it. It's just not the expected thing.

Markoff: Do you remember anything about communications? Was communications about newspapers? Was there any telegraph line that came to the village, or…?

Reddy: No. No newspapers also. Only when I went to the school in the nearby town Kalahasti that I would kind of be interested in finding out what's in the newspaper. At that time, I must be in the eighth grade or something, eighth or ninth grade. Children didn't know about newspapers, didn't care. Just for some reason I was curious, and I would kind of… I can't afford a newspaper, but there would be a newspaper in the shop and I would kind of go sit down and read it there and go to school.

Markoff: Do you remember how you learned to write?

Reddy: Yeah. Basically, the whole school when I joined the kindergarten, first grade, we didn't even have slates and chalk and so on, so it was common practice to kind of make a sand bed and you learned to write with your fingers, the alphabet in it.

Markoff: What was your native language?

Reddy: Telugu.

Markoff: And they were not teaching English in the school in elementary school or high school? Or did you learn English early?

Reddy: Yeah. No. They taught English I think even in the primary school, but mainly the alphabet and a few words and so on. Mainly because it's kind of non-native speakers of English teaching other non-native speakers, it was mispronunciation, all kinds of things. But it was okay.

Markoff: Were there other members of your siblings who went on to attain a higher education, or were you the first?

Reddy: I was the first and maybe the only one to get a degree. My elder brothers, they're all very smart, could have gone to college. But my father said,

"Look, somebody has to look after all this property and land, so you're not going to go." So I lucked out. I was the… *[laughs]*

Markoff: How did he pick you as the person…?

Reddy: Because I was the one that was not needed. *[laughs]* My younger brother also went to college and graduated, but he kind of went back into the family.

Markoff: Before you went to college, do you remember what your favorite subject is or do you remember any interests that were…?

Reddy: Oh yes. Mathematics. It was geometry especially, proving all those theorems and…

Markoff: Was it because of a teacher? Do you remember what sparked the interest?

Reddy: No. The interest was sparked by my maternal uncle, who said, "Hey, let me show you this thing," and that was kind of interesting. Then discovering new results. Kind of when they have a whole set of problems to solve, you solve them and that kind of gave you a lot of pleasure that you were able to solve it by yourself.

Markoff: Do you think that it was the interest in geometry that led to your study of civil engineering? Was there a link to…?

Reddy: Yeah. Basically, the link is, in those days, everybody either did engineering or medicine. That's still the case in most... I could have done medicine probably, but, you know… So when I went to college after finishing high school, I joined Loyola College in Madras, Chennai.

Markoff: Which is about, once again, how far away from your village?

Reddy: About 60 miles, 50-60 miles. And Loyola College was where you did what is called the pre-university or intermediate. That's the equivalent of eleventh and twelfth grades here. Then you essentially specialized in mathematics, math, physics, and chemistry.

Markoff: So the higher grades of high school, you were already focusing on that?

Reddy: Yeah, exactly.

Markoff: Were you living away from home? *[0:10:00]*

Reddy: Yeah. I'd been living away from home from the time I was nine or so, because there was no high school there. Even an elementary school. Education stopped after primary school.

Markoff: I see. Tell me about boarding school in a sense. What was it like to be away from your family?

Reddy: The first six years, I was in a small town about eight miles from the village called Sri Kalahasti. There are no hostels, no boarding, nothing. You lived with some family as a paying guest type of thing. In this case, the family was known and so they were happy to take me in. You know, it was…

Markoff: Yeah. As the family member who was being educated, did your family take pride in your being away in…?

Reddy: No. *[laughs]* I think it was expected. There was no question of not doing it. All my brothers and sisters went to school, but they never went beyond that.

Markoff: And would you go home on the weekends? Or how often did you…? Did you stay in touch with…?

Reddy: Maybe once every 2-3 months. Not on every weekend.

Markoff: In that case, your family would become your classmates in a sense, the people who you were at school with.

Reddy: Right. You had a few friends and you hung out with them, and there was nothing much to do other than, you know…

Markoff: Any chance, did you build any lifelong friendships? Are there people that you remember or are still in touch with from that period?

Reddy: Yes, yes. Two or three of them, yeah. More friendships come in the college, in Loyola College, in engineering college, once you are there. I still meet all my classmates from engineering college. They're all still around.

Markoff: I saw the pictures. Just before… a little bit more of your time as a child. Were there things that you were passionate about besides school? Do you remember having hobbies or things that you remember that you did beyond…?

Reddy: Yeah. I was not very good at sports or anything. I was not bad. Somehow, if I didn't become outstanding within one day of playing hockey, I said, "This is not me." But I liked reading. Whatever I could get my hands on, I would read. That was from the time I was a kid, three, four, five years old. Even in the village, there was a library of maybe fifty, a hundred books. I would kind of rummage through them, and that's…

Markoff: Was there any of what we would call science fiction?

Reddy: No.

Markoff: Were there classics?

Reddy: They were all classics.

Markoff: So you had a good sort of education?

Reddy: *[laughs]* Yeah. Self-education if you want to think of it. Nobody told me to read them. It's just that you're there and you don't have anything else to do. You kind of say, "I wonder what this book is."

Markoff: Who was the author of Mowgli and Rikki-Tikki-Tavi? That's how I became familiar with India. Who was the…? I'm blanking on the name.

Reddy: Kipling.

Markoff: Kipling, yes. Did you stumble across Kipling?

Reddy: No. Yeah. Most of the books I read at that time of my life, it was all Telugu books, not English.

Markoff: Do you remember making the shift from or beyond pure math to science and technology? Before college, were you interested in science and technology, or was it really mathematics?

Reddy: No. Broadly, almost all technical subjects I was pretty good at. But I wouldn't call it interest. It was something you were supposed to do and you did. *[laughs]*

Markoff: When you got to study civil engineering at college, were there textbooks or other kinds of academic material that you encountered that was significant in your development that really stands out in your memory?

Reddy: There were a lot of textbooks. The way I see that part of my life is it was something I had to do, and I was good at it and okay at it, and I did it. It was not… Somehow, I did not become passionate about any of those things. The time I became passionate is when I got introduced to the computer. That came much later.

Markoff: We'll get that. Understood. In high school or in college, were there any mentors or professors that really stick out in your mind? Were there teachers that made a difference?

Reddy: Yes, absolutely. The teachers that made a difference came in my graduate school when I was in Australia. There were two people who I worked with closely, and their claim to fame is they're the first users of computers in civil engineering. I learned how to program by just following them in the evening and while seeing them programming, then I became their programming assistant after a couple years. They were called Stan Hall and Bob Woodhead.

Markoff: I'll ask you about them specifically in just a second. I'd just like to jump forward so that we don't miss it. Would you tell me about your current family, your children, spouse?

Reddy: Yeah. I got married to a young lady from my community – her name is Anu, Anuradha – in 1966. I was already a grad student at Stanford at that time about to graduate. Then she came with me and then we… I stayed in an apartment building in Palo Alto. Then we graduated and then we moved to another apartment, another house, small house in College Terrace.

Markoff: Ah. You remember the street?

Reddy: Yeah. "Harvard"? "Harvard"?

Markoff: Harvard, yes.

Reddy: Harvard. Something like that. *[laughs]*

Markoff: That's something we share together. When I was born, my parents were living on Stanford Avenue in College Terrace about the time… Well, no, it was earlier. But anyway, that's not part of the… *[laughs]*

So that's good. I'll come back. But was your wife… when you say "your community," was she from your village area that you grew up, or was she…?

Reddy: No, no. No. There's this caste system, right? There are a group of people called Kshatriyas or warriors or something. Within that, there are sub-castes and so on. She was about 80 miles from our village. My family and their family knew each other, so there was a kind of a proposal saying, "Would you like to meet?" I said, "I'm right in the middle of my thesis. I…" So I ended up going during the Christmas vacation and meeting her and then getting married.

Markoff: And she came back with you. That's a great story. Very traditional.

Reddy: *[laughs]* And I have two daughters. They were both born here. One of them was born in Stanford, at the Stanford hospital. The other one in Pittsburgh. My younger daughter lives here, in Burlingame. My older daughter lives in Los Angeles.

Markoff: I'll come back to that. In terms of your college career, you were in Air Force ROTC. Is that correct?

Reddy: Yes, yes.

Markoff: Tell me a little bit about that.

Reddy: That was one of the exciting parts during that period. Namely, that was extracurricular. You became… It was called NCC, National Cadet Corps, Air Wing of NCC. I learned how to fly at that time as part of that training. It was kind of exciting to be able to kind of learn to fly, and go solo after 12-13 hours, and then do aerobatics and all those things. The Tiger Moths, bi-wing planes.

Markoff: These are propeller-driven planes?

Reddy: Yeah, propeller-driven, but in a bi-wing plane of the kind that you would see in Wright brothers' movie. You could do aerobatics on it and loops and turns and everything else. It was exciting. Those were the things that kind of removed you from the tedium of just studying and taking exams and so on.

Markoff: And this is flying at some Air Force field near Madras? Is that where you trained at?

Reddy: Yeah. It was basically one end of the Madras airport was a private flying club, Madras Flying Club. Air Force rented planes and space and pilots from there, and you got trained. *[0:20:00]*

Markoff: But at that point, you were heading toward becoming a civil engineer, that was your…

Reddy: Yes, yes.

Markoff: And the people who were your co-students, did they go on to become… would they go on to do commercial building design? Would that be the career path that you would have taken if you had gone in that direction?

Reddy: Yeah. Many of them end up in government service. In the government service, you might be building dams, or infrastructure, roads and buildings, and all kinds of things. Or you might end up in some other… kind of do postgraduate work and become a professor or something.

Markoff: Tell me about how you went from India to Australia for graduate school.

Reddy: So it turned out … I graduated from college in 1958 and it turned out they had some internships as part of the Commonwealth. Commonwealth was big in those days. India and Australia were all part of the Commonwealth, so Australia had internships for students from India. Three of us applied and got in, and the three of us went together. We were all classmates. Not in the same field but different, mechanical engineering and…

Markoff: Do you remember it as an exciting adventure to go to a foreign country and…?

Reddy: Oh, absolutely, absolutely, compared to the boring life *[laughs]* of just going and studying and taking the exams and so on. It turned out that the airfare, if we did not fly straight from Madras to Melbourne, that we could do the same trip for two-thirds of the price. What we ended up doing is take a ship to Penang, take a train from Penang to Singapore, and then take a plane. *[laughs]* I think it was the best thing we did because it gave you all that experiences which you would never experience if you just got on a plane and got off.

Markoff: Do you remember roughly how long it took you to go from Madras to Melbourne?

Reddy: To Penang?

Markoff: Or all the way to…

Reddy: From Madras to Penang, it took us like three days. One day to go to Singapore, and we stayed there with some friends. Then from Singapore to Melbourne, it was one of those Super Constellation planes. Maybe 10 hours or something. It stopped in between in Darwin and then refueled and went.

Markoff: You'd already been in a big city for college. Coming to Melbourne, what was it like being in a different country? Was it…

Reddy: It was very different in the following sense. Namely, the three of us went into this dormitory as part of the interns of University of Melbourne. All the kids were there. And it's the first evening, we go into the mess, right? Australia is famous for big, juicy steaks. We read about big, juicy steak but I've never seen one, right? Not only that, you're a Hindu. It's sacred, cows are sacred and so on. So the three of us, they were serving steaks that evening. Everybody was kind of going there for seconds and thirds. The three of us looked at it, saying, "My God, this looks ugly," *[laughs]* a big piece of meat. So that evening, all we had was bread, butter, and jam, because we couldn't… It took me like 3-4 years in Australia to become a full-fledged Australian.

Markoff: A Westerner in that sense of the world?

Reddy: Yeah.

Markoff: Now, was this a master's program? Tell me what you went to study as part of…

Reddy: I just was an intern. Intern means you're just getting experience. After six months or a year, the question was "What do we do?" Different people did different things. Of the three of us, one went to England and another went to work in a multinational company in India. I went to University of New South Wales to get a master's degree with Hall and Woodhead. That's where I got introduced to the computers.

Markoff: Did you start during '58 in the program, the master's program?

Reddy: Yeah. In '59.

Markoff: '59. Okay. And it was University of New South Wales in Melbourne. Did you…

Reddy: No, it was in Sydney. The interesting thing was, until that point, I may have read about computers in the newspapers, but it never sank in. I did not have any idea about what a computer was in '58. By '59, I was kind of fully immersed in it.

Markoff: So you come and your first computer is a mainframe computer, is a…?

Reddy: Yeah.

Markoff: Tell me about your first computer.

Reddy: That's interesting. It so happened, Gordon Bell was also in Australia at the same time – we never ran into… – using the same computer. It was called English Electric DEUCE Mark II. It's a mercury delay line computer. It was called "DEUCE" because it was a follow on to ACE. ACE was the computer that Turing designed. This was kind of an… English Electric and a couple of other… Ferranti made computers based on the British design, whereas in US we used von Neumann computers.

Markoff: So they were NON-VON machines?

Reddy: Yeah.

Markoff: Interesting.

Reddy: They had memory and instruction set, but whereas in von Neumann computing, there were instructions and registers and so on, if you look at the

architecture of ACE, it's kind of stack-oriented. You never… You put things and it becomes a stack, and then you keep adding and then unstacking them. It's more complicated to think about, but I didn't have to think about it because somebody had already done a high-level language and matrix was the only data structure. I could just…

Markoff: Do you remember, if you had to say "the language was like…" was it like any of the other more familiar…? Do you remember the name of the language?

Reddy: Right. It was called GIP. "General Interpretive Program" or something like…

Markoff: It was an interpreter?

Reddy: Yes, it was an interpreter. The closest thing that it comes to is APL of Ken Iverson, which also uses matrix as a basic unit. It was very powerful. I could…

Markoff: And at a practical level, did you program with cards or how…?

Reddy: Yeah. First thing you did was you had a paper and you kind of wrote down, "Take this matrix and do this operation with this matrix, and put it in the results." That's the standard, two operators and an operand and a result. And you wrote it down and then you punched it into punch cards, and then you put them into a card reader, then it would read and do the thing. What would happen is, if you're doing a complicated algorithm, there was not enough memory in the computer. Only a thousand bytes of mercury delay line. So you actually broke it up. You printed out intermediate results and then do another program to take the intermediate results and produce another set of intermediate results. So the punch cards were the memory. If you look at Babbage's computer, that was the same thing. All the big memory was in punch cards, and everything in the Babbage calculator was only registers.

Markoff: Were the first problems problems of the civil engineering study?

Reddy: Yeah. It turns out, matrix algebra is very convenient for doing structural engineering problems. You can design… It's not that different than what's happening now with deep learning. You have to essentially do vector multiplication to translate one set of probabilities to another set of probabilities. So you take all the values and then multiply by this new vector, and then the results go to the next one. Same thing, same kind of operation.

Markoff: You were working as a student with this shared machine right from the beginning. Did you have the kind of problems where you would have to wait to

get access to the machine? How much of the run of the machine did you have then?

Reddy: Fortunately, in ’59, not many people knew about computers. There were a few, and you kind of signed up saying, “I get an hour or half-hour block of time.” Then during that time, you did your calculations. Then sign up for another block of time. *[0:30:00]*

Markoff: At that point… You talked about your early education in math. In terms of… How much did it parallel the mathematical education you would get today? Had you already studied calculus and algebra and geometry, so you were well-versed in…?

Reddy: Yeah. We went through all of those things. If you asked me exactly what did I learn, I learned a lot. I got almost perfect score in it and so on. But if you ask me what did I learn, of course I learned calculus and all the things. But if you look at the kind of syllabus and the things that you would learn in the ’50s, 70 years ago, and look at the stuff today my grandson is studying, there’s a significant difference.

Markoff: Tell me about the two people who you mentioned who were influential, Stan Hall and the other gentleman.

Reddy: Bob Woodhead. Both of them were computer civil engineers, computational civil engineering. They’re the first ones that said, “Oh. I need to do these huge amounts of computation, and I can formulate it as matrix structures and then I can use a computer to do the results.” They went to England on a sabbatical and got trained there, and they came back. I was very lucky. I happened to go about the right time to the right people and learning how to program by learning by example. I never took a programming course. It was by example, seeing what they did and how they did it.

Markoff: And tell me about living in Sydney during that time. Were you so focused on the projects that that was your whole life? Or did you have any experience in the city?

Reddy: It was almost my whole life. But at that time, the Sydney Opera House was just being built. Every day there was newspaper articles about cost overruns and people would say, “Why would we hire this architect? He’s crazy.” *[laughs]* But that turned out to be a fantastic landmark for Sydney.

Markoff: And while you were in this graduate program, did you have a fellowship or did you have to work to support yourself while you were studying?

Reddy: I had to support myself. I'm trying to think. Yes. But I had worked as an intern, I had saved up some money, and that was enough. It was not that expensive.

Markoff: Okay. So you could focus on your…

Reddy: I may have gotten a tuition waiver or something, because I was one of the two top students in the class. But I don't remember.

Markoff: How much were you… To what degree were you actually seduced by computing at that point?

Reddy: The thing about computers was somehow you get instant gratification. You do something. It either works or it doesn't work. If it doesn't work, it becomes a challenge, saying… Debugging, right? That's what Papert and Minsky used to say, "Learning is debugging." *[laughs]*

Markoff: Well, so at about the same time – this is the late 1950s – there was around MIT this hacker culture emerging in the good sense of the word. Would you say that you had a similar experience in…?

Reddy: The hacker culture. I'm not sure it happened in '58-59. It happened in the early '60s. Minsky and McCarthy were just there, and Ed Fredkin was there, and there was a fellow called Hank Ernst who built a mechanical hand at that time. So people were kind of saying, "What else can you do with computers than just number crunching?" The idea that you could do things that are not conventionally algorithmic, like "Can you prove a theorem? Can you play chess?" you don't think of them in the same way as kind of doing some nuclear code or mathematical solutions, matrix algebra, something.

Those kinds of things kind of led these four guys, four people, Minsky, McCarthy, Newell, and Simon, and there was that famous Dartmouth conference in '56 where Shannon was there, a number of… all the senior people, and they were kind of saying, "What kind of things…?" Their problem was how to define intelligence. Turing had already written a paper on intelligence in '51 or '52. They were kind of trying to say… Fortunately, just before they went to the conference, Newell and Simon were able to write a program that proved a theorem on the computer, produced a theorem and a proof. Based on that, they were kind of…

So for the first five years or so until the early '60s, it was all about things that what human beings would think of as being intelligence – you know, proving theorems and doing other kinds of things. But as you went on, even things like seeing, talking, walking turned out to be very difficult to do, and mobility. And after that, other problems of … kind of…

One of the things that was kind of clear at that point was you could not think of AI-type programming as a conventional, regular step-by-step programming, but it is non-sequential. Prolog came out because it was… and most of the early systems... But in mathematics, there's a set of things called Post productions. Post productions were nonsequential. At each step, you say, "Where am I? What is the state I'm in? If I'm in this state, what should I do?" So you had to define preconditions for every action. And you could do conventional multiplication also. You say, "If I'm in this state, I now need to go to the next state and multiply and add," whatever. But Post productions was a way of defining computation, which is like the Turing machine, like functional programming by… a famous logician. It will come to me.

Markoff: When you were using computing as a tool for civil engineering problems, did you become exposed to any of the broader computer world outside of that sort of focus on civil engineering that early?

Reddy: Yeah. Basically, that was like a one-year period where I was exposed. Then I had to decide what I'm going to do. I had to get a job. So I applied to IBM and got hired.

Markoff: Did you have a degree in civil engineering at this point?

Reddy: Yeah, I only had a degree in civil engineering, but they hired me because I knew what a computer was and had actually programmed one. *[laughs]*

Markoff: This would have been 1960?

Reddy: Early '60s, yeah.

Markoff: Early '60s. You were hired by IBM in Australia?

Reddy: Yeah.

Markoff: Then they already had mainframes that had been installed in…?

Reddy: Yeah. I didn't get to work on mainframes for a year or two, but that's the first time they were coming out with transistorized minicomputers. 1401 and 1620. They were still very expensive, 300-400 thousand dollars, and the memory capacity of a 1401 was either 4 Kbytes or 16 Kbytes. The interesting thing was even then IBM was very clever about marketing. They would say, "Yeah, 4 Kbytes, it's $300,000. You want 16 Kbytes, it's $500,000." Then at some point you would run out of space and they would say, "Oh, you want the rest of it?" and a mechanic would come and they would turn one screw. The memory was already there. They didn't want the hassle of going in and installing new memory. It was all built in and it was very clever marketing I thought at that time.

Markoff: What was your first job at IBM?

Reddy: I became what they call an applied science representative, because I had technical background. But you kind of did whatever had to be done.

Markoff: Was it a customer-facing role where you would actually go to the customer premises, or…? *[0:40:00]*

Reddy: I did, but more as a technical support, as a system… I was not a salesman, but…

Markoff: So these were early engineering and scientific applications of IBM computers.

Reddy: Exactly. Yeah.

Markoff: Do you remember the companies that were customers by any chance?

Reddy: Ford Motor was one of them.

Markoff: In Australia?

Reddy: In Australia. They had in Geelong or some place, Ford Motor was manufacturing cars at that time. And so did General Motors and so on, but I didn't work with General Motors.

Markoff: Do you remember, were the problems production-oriented or design-oriented? Were they…

Reddy: Basically, it was databases. It was mainly supply chain management. That's what we now call it. In those days, we didn't use that term. They just needed to make sure that all the parts, all the components were there at the right time at the right place so that they could manufacture them. The logistics of getting them there.

Markoff: How many years did you spend at…? Were you at IBM for the entire period before…?

Reddy: Yeah. I was there for about three and a half years, almost four years, from all of '61, '62, '63, September I went to Stanford.

Markoff: Tell me about the thought process that led you to decide you wanted to get a graduate degree. What was going on in your world?

Reddy: I already got a master's degree, MTech in civil engineering. Once I started working at IBM, early on I said, "Maybe I'll do a PhD," but it was not clear what I would do. Within a year, it was clear I'll never go back to civil engineering. Complete switch. I was fortunate because at that time, there was not that much to learn in computer science compared to what it is now. I could essentially learn everything pretty fast and become as good as anybody else. So I said, "If I'm going to do a PhD, I might as well do it in computer science."

Markoff: Then you looked around. Why Stanford?

Reddy: I applied to two places, Carnegie Mellon and Stanford, because those were the only places that had AI. MIT also had it, but I didn't apply there. Stanford accepted me and Carnegie Mellon put me on some waiting list or something. They didn't have a computer science program at that time, so…

Markoff: But Stanford, what year did Stanford's CS program start? It was…

Reddy: In '65.

Markoff: And you came to Stanford in '64?

Reddy: '63. They already had a program in computer science as part of the math department. George Forsythe… The university recognized that they had to do something in computing, because already, if you remember, from ENIAC, which is like 1944-45, to early computers, UNIVAC and so on in '51, already for 15 years computers were in the news, were being used. So everybody saw this is the up-and-coming area. So Stanford and Carnegie Mellon had computer science programs, but at that time they didn't know what to call them. They basically said, "We'll set up a program." In the case of Stanford, it was in the math department because most of the computing was being done in numerical analysis. At CMU, because of Simon and all the decision-making stuff was in business school, so the first computer came into CMU business school. But in both places, it was obvious this is something bigger than either department.

I think in the community, there was a thing called AFIPS, a regular conference, an annual conference. I think it started in '61 or something. There were people who would come and they would kind of discuss, and kind of at some point they said, "We should set up a department in both places." They were one of the first few.

Markoff: But while you were at IBM and you were looking to go to graduate school, somehow artificial intelligence became an interest and that was important in your selection of those…

Reddy: Right.

Markoff: How did you learn about the field of artificial intelligence?

Reddy: Because, like I said, I like to read whatever I get my hands on. I was at IBM. I was reading papers on operations research and reading papers on Monte Carlo methods, all kinds of things. Then I was reading papers on artificial intelligence. And I said, "My gosh, I wonder if it is really possible. If it is, I should be right there." That's how I… So I knew, I just wanted to do…

Markoff: Do you think it's possible that you had run across Turing's paper by that time? The original paper that he wrote in '51?

Reddy: No, no.

Markoff: So it was not widely…?

Reddy: No. I had read Newell and Simon's papers and I'd read McCarthy's papers, but not Turing's. Turing's paper appeared in some… I think either *Nature* or one of the journals, British journals. As usual, I should have seen it, but I was not that good

Markoff: And it's interesting to me that even though you were sort of still in the Commonwealth community at that point and you might have thought about going to England, you didn't.

Reddy: Because I was working for IBM. *[laughs]*

Markoff: Oh, that's right. Of course.

Reddy: No, but even then, US was the center of computing. They had many more computers and many more people working on it, whereas in Britain, they were always kind of stepchildren.

Markoff: So you arrive in Palo Alto at Stanford. How did you come to be McCarthy's student?

Reddy: When I came in, I already knew I wanted to do AI, and I said that's what I want to be and I was assigned McCarthy as the advisor.

Markoff: Ah. Once again, this is '63?

Reddy: '63.

Markoff: So he is just starting the Stanford AI Lab at that point.

Reddy: Right.

Markoff: Maybe… Was it ’62 that it started?

Reddy: Yeah. No. Yeah. He also came just about that time, maybe six months earlier than me. At that time, Stanford only had numerical analysis, George Forsythe and so on, and *[John]* Herriot. So when he came in, he was setting up the thing, and that was when Licklider went to DARPA and he was trying to see who he should fund in this new field of computing. That came about because of Sputnik and all those things. Licklider did an amazing thing. He already had a big picture of what… He had seen what happened with Vannevar Bush and all the Second World War. MIT was the center of a lot of this innovation. So he went to DARPA and was able to immediately say, “Let me fund the three centers where key people are.” So he funded Stanford, he funded Carnegie Mellon, he funded MIT.

Markoff: At that point, you had not moved to Arastradero Road at that point. You were still on campus. Is that true?

Reddy: Yes. We were on campus in Polya Hall. Then all the computers were next to it in Pine Hall. It turns out the big computer was Burroughs at that time. Everybody was using it. And McCarthy got the first PDP-1, maybe first or second that DEC ever made, and it was all by itself and there were people like Steve Russell and others building time-sharing systems on top of it and so on.

The interesting thing was all of them had the American work ethic. They would come in the morning, work till five, and then go and do other things. I would do just the opposite. I would come at four in the evening, talk to them, from six in the evening till eight in the morning, I would work on the computer. I thought I’d died and went to heaven because in those days, the time on even PDP-1 was like a thousand dollars an hour. So every day, I was burning like $10,000 to $15,000 dollars of hour.

Markoff: You basically had an early personal computer.

Reddy: Absolutely. I had nobody else there. The only other person that occasionally wandered in was John Chowning. He was a professor. At that time, he was just a researcher in music, and he was trying to synthesize music. There’s an example. For example, people that conventionally used computers didn’t think… using computers to generate music was not seen as conventional computation, but it was seen as part of AI. If a computer can generate music just like you and me, hey, that’s intelligence. *[laughs]* *[0:50:00]*

Markoff: Was Russell’s time-shared implementation working then so that you and Chowning could share…?

Reddy: Oh yeah. It was not already working. He was doing it simultaneously. But I was only using it as a standalone personal computer. I didn't need the time sharing.

Markoff: Besides Chowning, do you remember any of your classmates in that very early period?

Reddy: Sure, yeah. The two people that are still kind of well-known is Bill McKeeman… The two of us graduated together. He's a very good friend. And the other person was Cleve Moler. He was my officemate. He was in numerical analysis. Cleve then went off and became a professor in Arizona or something, and did this Math Lab, you know, MATPACK. That became MATLAB and MathWorks.

So yeah, there is an example of an amazing career where for the first 20 years, he was just a professor, and then suddenly… They did a very clever thing. Unlike other computer companies, they never took it public. Even today, they probably make a few hundred million dollars of profit. It's just distributed among the founders and a lot of it is just given as bonuses to the employees.

Markoff: Tell me of your first impressions of McCarthy when you came to Stanford.

Reddy: McCarthy even then had a beard and was kind of… He was kind of … dreamy. He was kind of somewhere else. But the first thing was I had to say, "John, I came here to do AI. I don't want to do numerical analysis." He says, "But that's required. You have to do it." So I did, I take Gene Golub's course in numerical analysis. As history would have it, out of the seven or eight students of McCarthy, every one of them failed that course except me. So in the faculty meeting, McCarthy said, "Nobody wanted to take your course. We should eliminate it." Gene apparently said, "That's surprising. Raj Reddy came to me at the end of the course and said he liked it." *[laughs]* I got an A. It turned out both were true. It's what we would call non-monotonic logic. At the beginning, something is true – including me, I didn't want to take it. I said, "Okay. If I'm going to do it, I might as well do it." At the end, I enjoyed it. I was learning new stuff that I wouldn't have learned otherwise.

Markoff: Coming to Stanford in the early '60s, you worked in the evenings on computing, but do you remember much about the community or did you get involved in any of the things that were not related to the AI Lab?

Reddy: Yeah. I knew most of the people in Computer Science. It was a small department at that time. But I did not know much about the rest of the Stanford community. For example, I only went to one football game in my whole six years or something at Stanford. When I first came in, it was not something on my horizon, that I would attend any of those games. Whereas if you're an honest

red-blooded American student, that was part of your culture. You went to football games and basketball games and everything, and they would stand up in long queues to get the season tickets, and so on.

Markoff: It was a big deal at that point?

Reddy: Yeah. It probably still is. *[laughs]*

Markoff: Did you live on campus when you first arrived?

Reddy: I'm trying to think. Yes. I lived on campus for two or three years. There's still a building called Barnes Hall or something. That was one of the places. Before that, there was not enough space for all the students, so graduate students were told to go find their own. But there was some graduate student housing, so I stayed there.

Markoff: When did the move to Arastradero Road for the Stanford AI Lab happen? Was it fairly soon in your…?

Reddy: It was '65.

Markoff: So a couple years?

Reddy: Yeah.

Markoff: Did that mean at that point… Did you have to have a car to get around? Or how did you get out to…?

Reddy: Yeah. I did have a car. It turns out, because I had worked for IBM and so on, I did have enough money to buy a car, so I did. Gene used to say, "You're the only student I know that has a car" or something. *[laughs]* But…

Markoff: And did you look around in the Bay Area at all? On your free time, would you drive to San Francisco at all? Did any of that interest you? Or were you very focused on computing?

Reddy: Yes and no. Basically, I went to San Francisco once or twice, whereas my colleague and friend Ed Feigenbaum, who was on the faculty, would go to his weekend house in San Francisco or on Half Moon Bay or something. Not Half Moon Bay. On the other side of the Golden Gate Bridge.

Markoff: Oh, in Sausalito or…?

Reddy: Sausalito. Then he would come back and say how wonderful it was. *[laughs]*

Markoff: You arrived before Feigenbaum, didn't you? He came a couple years later.

Reddy: Yes. He came a year or so later. He was already a PhD. He was at Berkeley as an assistant professor and he came in as an associate professor to Stanford. And he was on my thesis committee.

Markoff: You were involved in two early communities that are very interesting. One was the SAIL community and the other was the broader ARPA community. When did you start… There are these famous ARPA meetings where the graduate students would go along too. Did you go to any of those early meetings, and do you have any memories of…?

Reddy: I went to them as a young faculty member. After I graduated, I became an assistant professor at Stanford. That was the time when we were just… ARPANET was just getting built, in 1968, '67-68. There were kind of meetings we'd have, and everybody would come to Stanford and we would all have a big meeting. And Marvin Minsky came and spent a year in 1964-65. I think the move to Arastradero happened middle of '64 I think, September '64.

Markoff: Yeah. It was called the D.C. Power Building, and you got to occupy about a half of it or something?

Reddy: Right.

Markoff: And had Les Earnest showed up to manage it by then?

Reddy: You know, Les Earnest came even before, but the reason was at that time, Ivan Sutherland was the head of DARPA and then…

Markoff: Licklider came and…

Reddy: Licklider, Ivan Sutherland…

Markoff: Oh, Bob Taylor.

Reddy: …Roberts. Roberts.

Markoff: Roberts. Larry Roberts, yes.

Reddy: Larry Roberts. I went and Larry decided, "John McCarthy cannot manage millions of dollars and keep track of all the…" He's a great scientist, but as a manager for day-to-day details of the thing, they would fall through the cracks, and DARPA needed all kinds of reports and everything. So Lick … Les Earnest, they had known him at Lincoln Labs together. He had worked on

handwriting and various other things. He's an amazing scientist in his own right, but he was also a good administrator, so he became the executive director.

Markoff: Two questions. What was it like to be McCarthy's graduate student, and also how did you come to that early interest in speech as a research area?

Reddy: The great thing about McCarthy is he kind of let you do whatever you want. *[laughs]* He would kind of suggest some things, and one of the suggestions was "Hey, we just got this computer. It has an A-to-D converter and you can digitize speech. Maybe one of the students can build a speech recognition system." I said, "I'll do it," and that's how I got into that.

Markoff: Wow. At that point, had anybody else done research in the field? How brand new was it at that point?

Reddy: It was brand new to me because I didn't know of anybody else doing the research. Later on, I discovered Bell Labs had a large group of people that have studied speech from the '30s, speech coding. Mostly they were in coding and compression. But Peter Denes, there were one or two people that built speech recognition things, digit recognizers, *[1:00:00]* using computers in the '61 timeframe. Then at some point, I'll remember the name, the senior director of DARPA… or Bell Labs decided they shouldn't be doing speech recognition. They stopped. That kind of set them back a little bit until *[James]* Flanagan and Larry Rabiner came and started it up again, and Bishnu Atal.

Markoff: Tell me a little bit about sort of the nitty-gritty of your early speech work, and what you focused on and what challenges there were.

Reddy: Basically, right on the beginning… I come from Indian language, Sanskrit and so on. They're all phonetically based. You speak what you write and you write what you speak. From that point of view, one of the first things you learn there is all the vowels. Then once you've learned the vowels, then you take the consonants and kind of say they can be modified by the vowels. The vowels can be added to the consonants. So "Ah" and then "kah" and "gah," those are stops, and then "chah" and "tah." They all have the same vowel but different consonants. In Indian languages, all the consonants are organized together that you learn them, and they're either aspirated or unaspirated.

If you're a linguist, you would know all this. I was not a linguist. I came from a different culture. But I invented for myself the same kinds of things. I said, "Let me see if I can recognize vowels as a first thing," and I built a pretty good working vowel recognizer.

Markoff: And you did it all the way from the hardware up to the…? Was it… Did you have any…

Reddy: No. The hardware was already there. The A-to-D converter. And I had help. I think like Steve Russell or somebody wrote the low-level sampling thing, so I could call the subroutine, which would sample whatever was being said. Like you start and stop, and then you get the thing that's a waveform, and then you decide what to do with it.

Markoff: At that point… There's this famous story about an MIT graduate student who was assigned computer vision as a summer research project, because they didn't realize apparently at the very beginning how hard the problem would be. What was your thought about how complex speech would be?

Reddy: I think that is par for the course. All of us in AI were kind of wildly optimistic with no basis, saying, "Oh, we should be able to do all of this." In fact, if you take Marvin Minsky, he said, "Yeah, let's build a Mars rover, and we'll build it, design it and build it in '64-65, and we can put it on a satellite to Mars, and it will go around and be a Mars rover in '67." So we started working on those kinds of things. If you remember, at SRI they were working on Shakey, and at AI Labs they were working on hand-eye coordination and picking up things.

Markoff: Which led to one of the first robot arms.

Reddy: Yeah, robot arms. Vic Scheinman was the guy that was there and designed all of those things. The range of activities at Stanford at that time are kind of broad, all the way from vision and robotics to speech and language. Even then, Roger Schank was there and Ken Colby was there. Roger and Ken were trying to understand language in the specific context of "Can you understand paranoid behavior?" PARRY, you know?

Markoff: PARRY. Had ELIZA already been done on the east coast?

Reddy: Yeah, ELIZA has been done, but except it was not true understanding of language. It was looking at a couple of keywords and then responding. We did that kind of a thing where it turns out we had… Fast-forward 20 years or 30 years, it turned out we had a video interview like we're doing now of Arthur Clarke that was done by WQED in Pittsburgh. We said, "Let us build a synthetic interview system, so that wouldn't it be great if your great-grandchildren could talk to Arthur Clarke or Einstein and ask him a question and they would answer?" And the answer is they would just take a couple of keywords and find anything that he said using those keywords, and then he says, "Huh," and then he would say something. There's some link, but it has nothing to do with understanding it.

Markoff: Did speech become sort of the principal thread of your graduate studies?

Reddy: Yes.

Markoff: And did it lead to your dissertation?

Reddy: Yes. That was my PhD thesis.

Markoff: Describe a little bit of your… What problem were your trying to solve when you…?

Reddy: I was trying to understand connected speech recognition, and then you apply it to some application like hand-eye system, controlling some computer with voice. All of that, we were very good even in those days. Fortunately, we have video. We made a little documentary. The first documentary was called *Hear Here*.

Markoff: H-E-A-R?

Reddy: H-E-A-R H-E-R-E. *Hear Here*. I believe it's in YouTube you'll find it, because we put all the videos we did over the period of time. That was done by the Stanford communication department. They needed some project to do it. They came and then we said, "Okay, why don't you do this?" There, not only did we show that it could recognize speech, then you could say, "Pick up the red block on the bottom-right corner," and then the hand would go and then pick it up and so on.

This was something we actually demonstrated and gave a talk on AFIPS 1968, about the same time Doug Engelbart was doing his thing. *[laughs]* This was actually two sessions parallel. I said, "I wanted to go see that too," but I couldn't.

Markoff: You were making a presentation.

Reddy: I had to make a presentation. But it was an exciting time at that time.

Markoff: That's very powerful. What was it like in that period? Well, I guess it was later on. As the AI Lab evolved, there became kind of a counterculture culture that was part of the lab that became very famous when Steward Brand wrote about it in the early 1970s. That was later. But Les Earnest, didn't he put a sauna in the basement and people were living in the attic? Were you aware of that…?

Reddy: Yeah, yeah. I thought it was okay, but it was not something I would have done. But when I saw there were Jerry Feldman and a few other people, they essentially made a hole and got up into the attic of the thing, and made a little living space for themselves… That was the time. It was the height of hippie culture, '65 to '70. It was not that blatant at AI Labs, but I think people were relaxed in they were not kind of…

And so much so, my favorite story of that era is… The best advice I ever got was from my classmate Bill McKeeman. I was all ready to go try LSD. *[laughs]* I was invited to some LSD party. I said, "Yeah, Bill, I'm going to go to this party. It'd be interesting." He looked at me and shook his head, and he was kind of trying to see how to convince me not to go. He said, "You know, it might be interesting to kill somebody too. You don't want to do that. Let somebody else do it and learn from it." I think that was the best … I never did go, because obviously there are things that you don't know what they…

Markoff: Yeah, the impact it'll have. At roughly the same time, there was work going on to build a speech interface to Shakey. Were you aware of their work and did you ever…?

Reddy: Yeah. Stanford, SRI and Stanford had a close working relationship. There was Marty Tenenbaum, who was working vision, who was a graduate student in the Stanford lab, but he was also working for SRI. *[1:10:00]* There were a number of people back and forth – Peter Hart and Nils Nilsson and so on. But basically at that point, they had kind of carved out something they wanted to do, because DARPA would say, "Look, we want you to tell us what you want to do and we'll fund you for that." At Stanford, it was kind of a center of excellence grant where you could do anything you want. That was the difference. At SRI, they would say, "Okay, we're going to fund you some of these things," whereas at Stanford, anything that anybody thought of could be done.

Markoff: During the period when you were a graduate student, did you publish papers or give talks? What was the culture like? How did you share your research as you went along?

Reddy: There were two or three papers I published at that time. One was by myself. That was just in *The Journal of the Acoustical Society of America*. And one was in *CACM*, and one was at AFIPS. The AFIPS was actually a joint paper, because it involved hand-eye, and Les Earnest and McCarthy, all of us were co-authors at that time. Whereas some of the other papers were just narrow, defining how to detect pitch periods or something. That's just a technique.

But the most interesting part of that time is going to two or three conferences. There was a conference in Los Angeles, the first conference where the first Turing Award was given in 1966. Alan Perlis was the first recipient of the Turing Award. He's from Carnegie Mellon. I was still a student and McCarthy, I said, "Can I go to this conference?" he said, "Sure." So he sent me to Los Angeles and it was great. Then the following year, maybe even the same year, there was another conference in Boston where Danny Bobrow presented his paper and Bert Raphael presented his paper on AI problem solving.

There were all kinds of exciting things going on on both sides, on both coasts. The interesting thing to me was to kind of get a big picture, saying, "What's all

happening? How do we find out everything?" And there was no place to go to kind of get a big picture, saying, "Here are all the major advances that have happened, and here's what it means."

Markoff: In an early book, Hans Moravec in the introduction talked about the optimism in the field. I think the thing that he said, that in '62 when McCarthy first applied for ARPA funding, he thought that building a thinking machine might take a decade in that proposal. Do you remember that level of optimism at that point, that it seemed like…?

Reddy: Yeah. When we hear those things, we believe it too. Another one was Herb Simon said, "There'll be a chess machine that will beat the world champion in 10 years." So a number of these kinds of things where we thought you could build a speech recognition system maybe in 10-15 years, and vision and everything, every area that we were touching. We just did not understand the complexity and we did not have the computing power.

Markoff: Were you aware, while you were a graduate student, of the early work that had been done on neural nets and perceptrons, and were they current enough that you thought about the possibility of using them in speech recog-…?

Reddy: Yeah. No. The perceptrons, kind of learning machines and so on were there. I think *[Ken]* Rosenblatt or… did the early work. Somehow the complexity of speech and complexity of vision seemed so complicated, trying to do it with single neurons kind of thing didn't seem to be clear. But the idea that you might want to use learning, machine learning was there. If you read Minsky's paper of '63, "Steps Toward AI," there's a whole section on machine learning and reinforcement learning, all that different kinds of things. And Art Samuel, who built a chess machine, who was also on the faculty who was there at Stanford Labs, also trained the system using the dataset.

Markoff: Was there a lively discussion? Today, the entire society is engaged in discussion of AI and its impact on society. You were there right at the beginning of the research projects in the '60s. Were you already starting to think about the impact of these technologies on society at that point?

Reddy: I think all of us did not think AI is going to turn into a bad science. Even now, I don't think it's going to happen. That's a discussion we can have later. But the right answer to it is, I think either Newell or Simon said to me, they said, "Every science, everything you do will have good aspects to it and bad aspects to it. You cannot not do it," and Simon's statement was "Knowledge is better than no knowledge. You should know, and so if you don't have that knowledge and some other country – Russia, China – goes and creates the knowledge, then you'd be blindsided. In that sense, it has to be done. The question is, it has some potential for negative use, and that's always been the case for every technology that was invented."

Markoff: Tell me about receiving your PhD and then going on to be a faculty member at Stanford.

Reddy: Basically, I finished my PhD. Bill McKeeman and I finished together. We were two of the four that started the first batch.

Markoff: That's '67 then?

Reddy: '66.

Markoff: So just in three years?

Reddy: It was barely three years.

Markoff: Yeah, very quick.

Reddy: The interesting thing was I had my orals in the morning and Bill had his in the afternoon, so I say, "Bill, I was the first PhD." And he says, "Look at the graduation list. 'Bill McKeeman' is first and then 'Raj Reddy.' " *[laughs]* So we both graduated together.

Markoff: And you were hired as a…

Reddy: Both of us. Basically, Forsythe needed young faculty members to teach the courses and so on, so he hired two of his own graduates, Bill McKeeman and me. Then he hired David Gries and Jerry Feldman. As history would have it, none of us stayed back. In my case, I almost stayed back. It turns out Stanford has a policy saying, "You cannot hire your own PhDs." MIT is just the opposite policy – they'll hire their own PhD. So in this case, the dean said, "Hey, George" – this is George Forsythe – "I already made an exception for you to hiring Raj as an assistant professor. Now you want to promote him. Let him go somewhere and then he can come back after a year." And that's what happened. The department unanimously recommended me for a promotion after three years. Then I ended up leaving and never came back.

Markoff: I'll get to that, but I wanted to ask if you remember any of your undergraduate students or any of your students from that time period that you taught at Stanford.

Reddy: Yeah, yeah.

Markoff: For example, did Larry Tesler take any classes from you?

Reddy: No. Larry was there. He was working with Roger Schank and Colby. There were a number of people, Lee Erman, Rick Hayes-Roth who ended up at

HP and Monterey, Victor Lesser who is now a senior professor at UMass, and all of them were students here. Then some of them had not finished when I left, so they came to CMU and finished up their thesis, got their degree from Stanford.

Markoff: Do you remember what your teaching responsibilities were when you first began teaching?

Reddy: Yeah. Mostly Introduction to Programming.

Markoff: And what were the fashionable languages and at that point how did you teach people to program?

Reddy: It was all LISP or FORTRAN. Or ALGOL. We were not using FORTRAN. By then, ALGOL was a respectable language. *[1:20:00]* We had Klaus Wirth, who got his Turing Award in ’84 or ’86.

Markoff: But this was before Pascal, wasn’t it? Or…

Reddy: This was before Pascal. He was there, and then I think he did ALGOL W or something. So he was there for three years or something before he left for Switzerland.

Markoff: You almost ended up going to Berkeley, is that right?

Reddy: Yeah.

Markoff: Tell me about it.

Reddy: Basically, when the dean Halsey Royden, a mathematics professor at Stanford – he might still be there, I don’t know, he might have retired – said, “Look, let him go for a year,” so I started looking, applying. The two places – there are other places also, but I wasn’t interested – was Berkeley, and they made me an offer as a tenured associate professor, but it took them a long time. Like you have to go through the normal process, like maybe four months or six months. Then Ed Feigenbaum mentioned to Newell, saying, “Hey, Raj looks like he’s going to go to Berkeley.” Then Newell called me up and said, “Why don’t you come to CMU for a day? Then you can decide if you want to come here.”

So I went there for one day. I remember it was like Wednesday evening I landed there, I met with Newell, Simon, and Perlis on Thursday, and Friday morning I got an offer. It was that fast. Everything was… That impressed me. *[chuckles*] But more than that, I wanted to work with Newell and Simon.

Markoff: So at this point, you were married, and had you already had children?

Reddy: Yeah. I had one daughter. Shyamala was born here in ’67, so she was

like three years old or two years old when we left.

Markoff: So you arrived in the fall of sixty-…?

Reddy: Nine.

Markoff: ’69. So the weather was okay when you first came to Pittsburgh. What was it like learning to live through your first…?

Reddy: We had a great time. We drove across the country. That’s the first time we got to see… We went to Yellowstone and Badlands and down Nebraska and everywhere else, and it was really great.

Markoff: Great. You’re just making this transition to CMU, but before we leave Stanford, there were some other questions that I had that I wanted to ask you. Did you watch the process of the creation of this computer science department at Stanford and do you have memories about that process?

Reddy: Yeah. In particular, at that time there was a lot of debate about what computer science was. There was a famous paper by Newell, Simon, and Perlis that appeared. They said, “Computer science is the phenomena around computers. We do all kinds of things, and all the things that we’re doing, design of computers, algorithms of computers, and applications of computers, that becomes the science of the phenomena.” So basically… And that is what was published.

I had a very different view, which I still think is right, but I was just a student. What I said was the role of computing is analogous to fields of engineering and medicine. Engineering is a field devoted to enhancement of the physical capabilities of human beings. If you can’t fly, you build a plane. And medicine is a field devoted to repairing the human being. Computer science to me was a field devoted to enhancing the mental capabilities. Anything that you do with your brain, a computer can be used to enhance it. That was my thesis. I think it is still more or less correct, but at that time, it probably looked too grandiose or whatever. *[Scott]* Gottlieb was the elder at that time.

Markoff: If your view had been taken seriously at that point, do you think the field would have developed in a different way?

Reddy: No. Basically, the great thing about the people that were there at that time, they had that expansive view. “Anything goes.” If somebody wanted to come and do music, they could do that. If somebody wanted to build a paranoid diagnostic machine, they could do that. In that sense, they did not limit what you could and could not do within computer science.

Markoff: In that sense, while you were a graduate student, while speech was your focus, to what extent did you dabble in other areas ranging from… Did you do any robotics work as a graduate student? Did you do any vision work as a graduate student?

Reddy: I did not do any robotics work, but I did do vision work. Most of the vision work at Stanford Labs was around hand-eye systems and robot vision, vision for robotics. I said, "There are other aspects of vision." There was a thesis of a student that was at that time on face recognition.

Markoff: Was this Mike Kelly?

Reddy: Mike Kelly. And it turns out about the same time Takeo Kanade did a face recognition thesis. His work was much, much better. When I saw it, I said, "Yeah, this is great." So we hired Takeo a few years later. But basically, I think there was one or two others also at that time. When I went to CMU, I continued working in speech and vision. The robotics thing was something I knew. I kind of grew up with it in that sense, that we knew it can be done, it needs to be done. That's how we ended up creating the Robotics Institute.

Markoff: Before we leave also, I believe the paper that you talked about related to the Joint Fall Computer Conference in '68 was called "A computer with hands, eyes, and ears." That was a joint paper…

Reddy: With McCarthy and Earnest and…

Markoff: Yeah. Just because it's become… It was such a powerful moment in history, the fact that you guys were giving that paper at the same time that Doug *[Englebart]* was giving his. I know that Les Earnest is very bitter about this. He feels that the field didn't give your project enough credit. What did it look like to you at the time?

Reddy: No, I'm not sure it didn't get enough credit. What Doug was showing was a very powerful vision of how human–computer collaboration could happen, how people could do things with the use of computers, whereas AI Labs was primarily thinking about what can a computer do, not what a human and a computer do. I now believe for the next 10, 20, 50 years, it is the paradigm of human and computers together doing things. I think sometimes some people call it… IBM people call it "augmented intelligence" instead of AI, "artificial intelligence." My view is there will always be… I think there's this 80-20 rule or 90-10 rule that I talk about you can… where there are certain things that human beings are good at doing and machines are not yet good at doing. There are many things that machines can do just well. So what we should do is get the machines to do 90% of our day-to-day work and the human beings would do the 10% that the machines cannot do, so the net effect is you and I would be able to be 10 times more efficient. I can do one day's work in one hour.

So I think that is probably the likely paradigm for the next 10-20 years or 50 years. That also kind of has the same seed. Namely, the thing that scares most people is *[1:30:00]* if a robot can do everything, what will people do? And the same scare should be there for the other one also – if robots will do 90% of what we do, 90% of the jobs will be gone, then what will people do? I think the 90-10 or 80-20 is more likely to happen and will in fact improve productivity and all kinds of things, rather than an AI system doing everything by itself.

Markoff: Also, before leaving Stanford, I wanted to ask, if you step back and you had to say, "During that period of my career, my intellectual influences…" what would you identify as your key intellectual influence during that period, either a person or ideas? What really drove your development?

Reddy: Basically, that was kind of a beginning of computer science. You could do almost anything. I feel bad for the current graduate students. Lots of things have already been done. At that time, you could touch anything and it kind of became important.

Markoff: And did it have that feel of a wide-open…?

Reddy: Wide-open field, yeah. There were not that many people working and people…

Markoff: And during that period, how influential was DARPA? First at Stanford and then when you first arrived at CMU, was it instrumental to your…?

Reddy: Yeah, extremely important. Namely, without DARPA and the funding, the field would not have gone anywhere. ARPANET would not have happened, the robotics would not have happened, and speech, vision, all of which are now turning out to be major applications, would not have happened. In retrospect, the fact you can do computer-supported, CSCW, cooperative work that Doug Engelbart was proposing has not created as much long-term impact as the speech, vision, search engines, and all the other things have. That's probably as it should be. Namely, one of the bets I took was I said, "When we look back in 20-30 years, it will be seen that AI was more important than the invention of transistor." Everybody laughed. They said, "No, that's crazy."

Again, it's one of those things that's unwinnable. How do you define which is more important? But in retrospect, today given all the hype about AI, I think if all the things that we're thinking about come to pass, it may be the most important technology we've ever invented. That doesn't mean all the other things are not necessary. They're necessary foundation to do the AI. You can't do AI without all the rest of it. But all that it says is we are able to create superhuman intelligence. When you can create superhuman intelligence, that will probably lead to…

things… I think *[Yuval]* Harari has it right. Namely, we might end up having intelligent design.

Markoff: In 1968, when that paper was presented, "A computer with hands, eyes, and ears," did you have that big vision at that point that you just described? It was already part of your sort of…?

Reddy: Yeah. Basically, the fact that we said "hands, eyes, and ears," we were kind of getting to a system where it would have human-like capabilities. Not human capabilities, human-like, right? The question was "How important is it?" At that time, it was not clear it would happen and when it would happen and how complicated it would be. Even 30 years later in the Year 2000, if you asked me, I would say speech recognition from unrehearsed spontaneous speech from open population would not happen in my lifetime. Now here we have it. That has nothing to do with the fact that we have been doing speech recognition research. It's got everything to do with the fact that we now have a million times more computing power. Without that power, we could not have done it.

Markoff: What was it like collaborating with McCarthy and…? Do you remember anything about writing the paper or putting the paper together with them as a young graduate student?

Reddy: Yeah. No, I…

Markoff: Or you were already faculty by that time.

Reddy: Yeah, I was already a faculty member. But McCarthy didn't seem to care. *[laughs]* He was happy. One of the great things about him is he was very permissive, empowering. He would say, "Okay. You want to do that? Go do it." *[laughs]* That was exciting. But at the same time, if he had kind of taken more time and spent more time with the students and so on, maybe we might have done a bigger, better job, because he had great ideas whenever he would say something. Even I remember we were driving back together to Arastradero Road once and he said that "It is not what the computers do. It's going to be the *applications* of computers that will transform the world." Even then, even though he was kind of doing theoretical AI and so on, he was seeing the applications.

Markoff: Interesting. As a Stanford faculty, as a junior faculty, did you attend – I mentioned it earlier – the DARPA PI meetings, and were they happening at Snowbird at that point? Do you remember?

Reddy: No, they were not happening at Snowbird. Snowbird was a later thing. I remember attending a DARPA meeting at Monterey. This was already in the early '70s I think.

Markoff: So you were at Carnegie Mellon by that time?

Reddy: I was. Steve Lukasik was the DARPA director, and he came. I remember one thing he said even now that's important. He says, "I don't care about what you're doing at the low-level thing. Tell me what you can do to improve the efficiency of the President of the United States. He needs to understand and act on things. If you can kind of create tools, that'll make him do his job much better." That's where his mind was.

Markoff: Do you think that had an impact on the DARPA researchers? Did they actually sort of…?

Reddy: Maybe subconsciously, but I don't think any of us changed anything we were doing as a result of that.

Markoff: When you look back at Stanford, who were your closest collaborators at Stanford while you were there? For example, did you work on any projects with Ed Feigenbaum?

Reddy: No. Basically, I was kind of almost independent. So were everybody else – Jerry Feldman and… But we were close friends. We would have lunch together. But everybody had their little favorite Turing tarpit, and then we were working on the things, and it was a very supportive environment.

Markoff: And when did your association with ISAT happen?

Reddy: ISAT started in 1989 or something.

Markoff: Oh, much later. Okay.

Reddy: Yeah. What happened was I think it was Saul Amarel was the director at the time, after Bob Kahn left, and he asked me to be the first chair of the ISAT. I was the chair for a couple of years.

Markoff: I'll come to that later. I'm getting ahead of myself. Tell me about your early years at Carnegie Mellon, teaching and research. Was it significantly different than Stanford, and what was your focus in both teaching and research?

Reddy: It was not significantly different. Basically, Newell and Simon hired me because they were doing cognitive AI, problem solving and so on. They wanted somebody to do the perceptual AI, speech, vision, robotics, which is what I wanted to do. The great thing was, again, the empowering environment. Basically, they said, "Whatever you need you can have."

And to give you the best example, *[1:40:00]* we were doing the speech demonstration in 1975 or something where – that was the DARPA Speech Understanding Project – everybody came. I needed all the computing power I

could get at that time. We had ordered a second PDP-10 for the use of the whole department. It just came in and I went to Newell and I said, “I need all of it for the next six months or a year.” *[laughs]* He said, “Sure. Have it.” That’s the kind of thing where if something made sense, it was very fast decision-making.

There was a similar story I heard at Bell Labs. Penzias, Arno Penzias was the director of all of Bell Labs, and Bishnu Atal was doing cellphone capsule coding. For that, he needed a huge amount of computation to kind of do the simulation of the whole thing. Then they found that he was using up more than half of the budget of the entire Bell Labs on the supercomputer. So apparently Arno Penzias was saying, “We can’t have him doing that. However, we buy equipment for labs. I’m going to buy a whole supercomputer for his lab.” *[laughs]* And that’s what he did.

So it’s kind of interesting, these kinds of very enlightened leadership.

Markoff: Yeah, that’s very neat. What was your first major speech research project? Did you start with Hearsay, or was…?

Reddy: Yeah. Once I got to CMU, we started Hearsay and the Harpy systems. Harpy system came as a byproduct. Jim Baker and Janet Baker did the hidden Markov model and the Dragon system. Then when they graduated and left, I was kind of saying, “Obviously, there are good ideas there, but it’s also brute-force search. You have to search the entire space to get an optimal … Can we do a combination of the two?” We created this beam search where we say, “We don’t have to look at every possible thing. Throw away all the unpromising things, so you’ll get something. You may not get 100% correct. You may get 99% correct.”

Markoff: That was Harpy?

Reddy: That was Harpy.

Markoff: Then distinguish it from Hearsay.

Reddy: Hearsay was a blackboard model. The idea was here are all the different knowledge sources. Each one was an expert in one thing, in a lexicon or in a syntax or semantics or something. And each knowledge source, if you’re playing chess or understanding chess game, the fact you say, “Pawn to King 4,” knowing the chessboard, you can use that knowledge to kind of constrain what was said. It turns out all knowledge have the same property. Whether it’s knowledge about a sound, knowledge about a word, knowledge about structure, whatever, all that they do is reduce the space of alternatives that you’re to look at. So that idea that you have these different knowledge sources, they don’t speak the same language, but somehow you can use them.

Then the blackboard model simply says, everybody, when they discover something, this "hypothesize and test" paradigm, writes on a blackboard. While the others may not be able to speak their language, they can see the hypothesis. Then, based on what they see, they can do their thing. This is the same thing as the Post productions we talked about earlier. At each state, everybody looks at "What is there? Given that, what can I do?" So that kind of… Basically, the models of AI, this idea of non-sequential computation, simply say, "Human brain works in this particular fashion. They react to the state, and then based on that, they kind of deliver the next state. It's not sequential programming, like an algorithm."

Markoff: Understood. Did those projects start pretty much immediately after you arrived in Pittsburgh?

Reddy: Yes. Basically, the way it happened was I came in. Already CMU had a DARPA grant, so there was funding. Then, in 1971, DARPA said, "We ought to have a big project on speech understanding systems." There's a report that Newell chaired about "Speech-Understanding Systems" report. They used that as a way of kind of funding half a dozen different places – BBN, Lincoln Labs, and CMU and SRI and so on.

The task was you have to demonstrate a thousand-word vocabulary system in five years. A thousand-word vocabulary connected speech system. Almost everybody did it, except depending on the model they chose and the amount of sophistication that went into it, some of the systems were extremely slow, like the BBN system. Whereas both CMU systems, because we were also using heuristics and kind of reducing search, we were able to get sufficient accuracy but 100,000 times faster.

That was essential to get some faith that these things might ultimately be useful. But in reality, the other option is also always good to consider. That's what happened with deep learning. The original backpropagation algorithm was invented by Geoff Hinton when he was at Stanford … at CMU. He was there from 1980 to '86 or something, then he went to Toronto. He always kind of had this one-track mind. He says, "Human beings use neural networks. They demonstrate intelligence. I need to use exactly the same kind of thing to demonstrate intelligence." It's good that he lived long enough to get a computer that's a million times more powerful so his ideas would start to work. But in 1981, '86, when the original backpropagation algorithm, it was kind of disappointing year after year. Of course, you could write papers and publish them and discuss with people, but there was no proof, demonstrable proof that neural networks of any kind, deep neural networks would actually work better.

Markoff: When you first started, who were some of the participants, both students and faculty that you remember who were…?

Reddy: At Carnegie Mellon?

Markoff: Yeah.

Reddy: Main three people were Newell, Simon, and Perlis. Perlis was the expert in programming languages. He was also the head of the department. A very fine person, the three of them. And the interesting thing about them is even though each of them was a leader in the field in their own right, but somehow they subsumed their ego and worked very well together. That was not the case at MIT and Stanford. So you find this collaborative… and then accept and find compromises and do things rather than going off and saying, "This is my idea. This is the way it has to be done." That was what made Carnegie Mellon what it is, even today, those three people.

Markoff: And in terms of the people who worked with you in the early days of speech, who participated with you?

Reddy: Lee Erman, Victor Lesser, *[Rick]* Hayes-Roth, Mark Fox. Then there are some other people a little later.

Markoff: Did Victor Zue come later?

Reddy: No, Victor Zue was always at MIT.

Markoff: Oh, he was not… I see, yes.

Reddy: But we worked together. Namely, we were part of the MIT Speech Group that was part of the Speech Understanding Project. We would meet each other 3-4 times in a year, and it was good.

Markoff: Then early graduate students, how early did Kai-Fu Lee come? *[1:50:00]*

Reddy: Kai-Fu Lee, that was the second batch maybe. They came, he came in 1981 or '82, got his PhD in '87 I think. Then he stayed on as an assistant professor at Carnegie Mellon and went to Apple '90 or '91 or something like that.

Markoff: That's interesting. But describe the roots of the… You then were instrumental in the creation of a robotics group. What's the story of the…?

Reddy: Basically, we had a president, Dick Cyert, at Carnegie Mellon, and he convened a meeting saying, "Hey, I came from Washington, DC. There's a lot of concern that the Japanese are eating our lunch with robotics, this, that, and the other. Do we have anything to show for it now in that area?" I was there and Newell was there, and Joe Traub, who was head of the department, was there, and so on. We said, "We are doing robotics and we have our various things,

vision and speech and so on, but the scale at which we are doing is very small. We're spending maybe a million dollars a year. We should be spending 10 to 100 million dollars a year to have real impact on the world."

What he did was contacted the head of Westinghouse. At that point, it was still one major corporation. Tom Murrin, who was kind of number two or number three, was put in charge of working out what might be done. So Tom, after listening to my presentation, gave us $5 million for five years sight unseen, no proposal, nothing. And we got a similar amount of money from Admiral *[Albert]* Baciocco of ONR. Those two sources of funding were the seed. DARPA might have given, but that came later.

Markoff: Was this late '70s then? When did…

Reddy: Yeah. The meetings happened in '77-78, and we started the Robotics Institute in '79. I became the Head of Robotics because I roughly knew what I wanted to do, but I was myself not competent to do them.

Markoff: What were the first projects or prototypes? What did you set out to…?

Reddy: The two big themes then were autonomous systems – the autonomous vehicle projects, and the drones, all of that came out of there – and the other one is manufacturing automation. Even early on, we built systems, what we call lights-out manufacturing, where there was no human being at all. In retrospect, I'm saying that's probably a bad design. What you need is human-machine manufacturing systems where machines are doing all the boring and difficult and dangerous things, but still a human being is there.

The reason that becomes very important, there was a very good example that came out. I don't know if you remember Taurus, when Ford introduced Taurus. This was mid-'80s or something. They built based on the advice we gave or... *[laughs]* They built a fully autonomous system for making fenders. The car was selling like gangbusters and this autonomous system was not designed with human beings anywhere in the loop. So one thing broke down, everything came to a grinding halt, and there was no space for a human being to the do the job that the machine was doing. So what did the manager of the factory do? He said, "To hell with it, we're going to only use people," and got rid of all this automation. *[laughs]*

Markoff: Interesting. I didn't know that story.

Reddy: Because he's under pressure. He needs to deliver the fenders.

Markoff: From a focus point of view, when you started the robotics group, did you set the speech work down?

Reddy: No. It was going on simult-… In the ’80s, that’s when Kai-Fu Lee did his work. We were doing vision. Takeo Kanade came. He was doing that. In fact, that was part of the robotics group. There was a vision stream, and that was the beginning. Now we still have 20-30 outstanding vision faculty at CMU. Then there was robotics of two or three different kinds. One was, can you build a system that drives itself? It took us 20 years to demonstrate. Again, the computers were not fast enough. Red Whittaker and so on.

Markoff: Was he one of the young faculty that came as part of this?

Reddy: Yeah. He was one of the first faculty members. He was also in civil engineering, and he was not publishing any papers so they were not going to promote him. I said, “That doesn’t matter.” So I hired him in robotics and then his career has kind of…

Markoff: He had a big impact.

Reddy: Big impact, yeah.

Markoff: You started with a total of $10 million from these two sources, but ultimately it grew to being even bigger than that.

Reddy: Oh, much bigger. Right now, it’s close to $100 million a year. About a half of that work is applications of robotics, in defense and various other things.

Markoff: Did that participation or the creation of that robotics group lead to your participation in the NASA Machine Intelligence and Robotics Study Group, or were they separate?

Reddy: No. That was in parallel. That happened… If you look at the date of publication of the Carl Sagan report, it was published in ’79, and we were meeting in ’76 and ’77-78, because NASA wanted to know what impact AI might have. That whole report is on the web, and it was scanned and you can see it. If you want, I can send it to you also. And it had all the who’s who. Minsky was there, Pat Winston was there, and people were there. Again, by accident, I ended up being the vice-chairman of the thing and we put the whole report together.

Markoff: Just in terms of the debate about the role of humans in space, there’s been this philosophical sort of debate over whether you should have machines explore space or whether humans should explore space. Did you guys come down on one side or another? Was that a live part of that debate at that point?

Reddy: Right. We did not come down on one or the other, but what we said is there should be both kinds of exploration. You can have autonomous systems, Mars rover–like things, but many times, if you’re going to colonize space, if you’re going to exploit space, mining of rare minerals or whatever, space colonization,

space mining, space exploitation, there you may need both… human beings also may have to be in the loop because… It's what we call 90% self-replicating machines. You can drop a DNA on the surface of the moon and have it build itself a factory, but the technology for doing that is not there yet. Rather than saying you got to do everything 100%, we will ship some minimum equipment there and then it can reproduce itself.

There were two projects we started there. One of them was with Fritz Prinz, who's at Stanford now. He used to be head of the department, chaired professor in mechanical engineering. The basic idea there was "Can you build a lathe which will make a copy of itself?" even with human help and so on.

The other one was Paul Wright, who is also a professor of mechanical engineering who is now at Berkeley. He's the dean there too. Paul started a project on parts-on-demand we called it. *[2:00:00]* If you remember, there was a thing called MOSIS to build silicon chips. This was a mechanical MOSIS, where anybody can design a part and send it somewhere, and it will make that part and send it back to you next morning.

Markoff: Was this the father of 3D printing, or…?

Reddy: It was part of the… In fact, the first demonstration of 3D printing was done at CMU by Fritz Prinz using the stereolithography stuff, the plastic. That was in… But actually we made a 3D model of statues of people, like you and me and the president at CMU, and then we would create a statue out of it. This was in 1987 or '88 or something. That's when stereolithography first came out. Except it was both time-consuming and expensive. What 3D printing has done now is the diversity of materials you can use in the printing is much larger, not just a plastic thing, and the speed. In order to make those 3D statues took us like a whole day or 2-3 days. Now they can do it much faster, a tenth of the time.

Markoff: I want to ask a couple more questions about your early days at CMU. Did you fairly soon after you arrive begin consulting for Xerox Palo Alto Research Center?

Reddy: Yes.

Markoff: So you kept a foot on the west coast, sort of?

Reddy: Yes.

Markoff: Tell me about what your role was at PARC.

Reddy: Basically, Xerox PARC was kind of founded by friends of mine, right? Basically. They were all there and so they also wanted to do speech and other things, so I was a consultant for them. Allen Newell was a consultant. The two of

us would come at different times. And Alan Perlis was also a consultant. By that time, he was at Yale. And I used to work with George White. George kind of went on to various things. He's now at Carnegie Mellon in Qatar, teaches entrepreneurship. But George was doing speech recognition. He was doing it at Stanford with me when I was there, and then he continued that at PARC.

Markoff: And at what point did Winograd show up, and did Winograd and you overlap at PARC?

Reddy: No, Winograd never came to PARC. He went to Stanford. Terry Winograd went to Stanford as an associate professor a few years after I left, maybe '71 or '72. Don Knuth came the same year I left. And Bob Floyd also was at Stanford and at CMU, he came here, about one year before I left.

Markoff: As a consultant at PARC, did you have any participation with Alan Kay's Learning Research Group? Or was that a separate group?

Reddy: Yeah, yeah. More of a cheering role, because Alan and I go back to Stanford and previous days. He was at Stanford, so we were kind of good friends. Whenever I'll see him, he would kind of drag me and saying, "Look at this Smalltalk, object-oriented…" *[laughs]* I mean I said… He was passionate about it.

Markoff: Did you have a perspective on Smalltalk and object-oriented programming? Did that seem like an intellectually important thread to you?

Reddy: I didn't understand the full power of it until I started using NeXT. Basically, Steve Jobs internalized the concept and implemented it on NeXT. The interesting thing is, if you designed like a Word document on PC, and on the screen it would look at one size and then you print it, it would be a completely different size. Had no relationship. Whereas on the NeXT, what you see is what you get. It'll show you exactly what you're likely to see if you print it. It doesn't matter where it is. And all the properties carried forward. There was only one place you can edit. Whether you're editing in a Word document or you're editing in a spreadsheet or you're editing somewhere else, it's the same thing. It would work over and over again. That was very powerful.

Markoff: Was that the first time you met Steve, was when he was selling the NeXT idea academically? Did he come around and…?

Reddy: I met Steve before then, before he even left Apple the first time, because he was interested in speech even then. So George White dragged me along, saying, "Hey, you have to meet Steve, Steve Jobs." I said, "Okay." We went and he was in a little trailer somewhere, and we had a talk.

Markoff: This was during the Macintosh era while he was designing Mac, or…?

Reddy: Yeah. It was even before Macintosh. I think seventy-…

Markoff: Had he started on Lisa?

Reddy: ’76, ’77.

Markoff: Oh, that’s very early.

Reddy: Yeah. He had already come out with Apple II. I remember Carl Sagan asking me, “I’m looking to buy a computer. What should I get?” I said, “I don’t know, but…” “You think I should get Apple II or something?” I said, “Sure, why not?” So basically, at that time, I had not used Apple II but I knew about it. Then he started working on the Mac system. Then once he had the Mac, he came to CMU before this was… and he was showing it. He was so excited. My daughter was kind of small. He said, “Let me show you,” *[laughs]* and “Isn’t this cute? You can do this and that.” In that sense, he was kind of passionate about everything that he was doing. It was fantastic.

Markoff: Let me ask you, during this whole period, you left and you went on to become a faculty. Were you ever tempted in that early period to do something entrepreneurial or leave an academic community? Were there…

Reddy: Yeah, I have been involved in entrepreneurial stuff, but I never felt that I’m built mentally to be an entrepreneur. We founded a company about the same time Feigenbaum and others founded a company here…

Markoff: What was it called?

Reddy: …called Teknowledge here.

Markoff: Oh, you were part of the Tek-…?

Reddy: No, no, no. Teknowledge was founded here. We founded something called Carnegie Group. That was Mark Fox, Jaime Carbonell, *[John]* McDermott, and me. It did well. Then it went public, and then it went up and down and so on. So we rode the whole thing through the…

Markoff: But it never pulled you out of academia.

Reddy: No. I never wanted to leave academia. I said, “I’m happy to be a consultant. I’m happy to be an advisor. But I don’t want to be full-time running a company.”

Markoff: You were at Stanford at the very beginning, you went to Carnegie Mellon, and I’ve always been struck about the two different cultures at the

different institutions. I mean Stanford has evolved to the point where it sometimes feels like people come simply to make the toe touch on their way to start their company. CMU seems to have an academic culture that persists. Did you have that sense of different…?

Reddy: No, it's a matter of degree. If you look at them, after you peel away the academic part, every faculty member there also is involved in some startup company, even now. I don't know about all of them, but I keep discovering, "So-and-so is in…" The best example at CMU is Luis von Ahn, who has done Duolingo and before that he was doing other things.

Markoff: And CAPTCHA as well.

Reddy: CAPTCHA as well. reCAPTCHA and so on.

Markoff: And then Uber more recently has had this big impact on the…

Reddy: Yeah.

Markoff: But that was… Tell me about the students that you had who had a significant impact. The ones that I know of are James and Janet Baker, Kai-Fu Lee, Xuedong Huang, and Harry Shum. Let's see. The Bakers went to IBM ultimately, I guess.

Reddy: No, not ultimately. First they went to IBM, and then they went to Exxon on something, and then started their own company. They built it up and they sold it for $650 million to Lernout & Hauspie, which ended up having the Enron problem. They lost…

Markoff: They ended up as part of Nuance ultimately, didn't it? I think they got acquired by Nuance ultimately. *[2:10:00]*

Reddy: Yeah. And so what happened was they lost a large part of their money. They took Goldman Sachs to court and the court said, "Goldman Sachs told you can do this or that. You did whatever you did. You can't hold them…" In that way, in that sense, people in the auditors and the advisors in mergers and acquisitions, they cover their bets, right? *[laughs]* So that they're not responsible.

Markoff: Good. I'm thinking about the influence of your graduate students. The Bakers of course had this big influence on the development of speech, as did Kai-Fu, and then Huang and Shum at Microsoft, their research and development impact on computing was significant. Are there other students that come to mind that…?

Reddy: Yeah. The current head of Microsoft Research in China, his name is Hon, Hsiao-Wuen Hon. He was also there about the time. And if you look at say

Victor Lesser and Lee Erman, they were also earlier students, but their impact is more academic than the other ones. The other person who was part of the time my student and then went to work with Bob Sproull is James Gosling. He gives me credit for the invention of the interpreter of the Java. *[laughs]* He says, "I invented it when I was working with Raj," or something like that.

Markoff: Was he working on speech with you? Or what did he do?

Reddy: He was working on systems. Basically, you have to understand, in order to work on speech and vision and robotics, you also need to dabble in hardware. In particular, microprogrammed hardware, signal processing and various other things. So we built in fact a vision computer, and we were working with these workstations that were microprogrammable about the same time SUN workstation and…

Markoff: Was this PERQ or was it…?

Reddy: …PERQ, PERQ workstation came about. All of them had the opportunity, the option to either use Unix or something else. The main mistake that happened was PERQ started with PERQ Pascal, Pascal p-code, whereas everybody else just bit their bullet and licensed Unix. And ultimately that's the right thing to have done.

Markoff: And I wanted to ask also, did CMU play a role in the development of SPICE? Or did that come from Berkeley?

Reddy: No. SPICE as the personal computer project? No, you're not talking about… SPICE, the circuit design?

Markoff: Yeah, I was thinking… Was there…

Reddy: There are multiple SPICEs, yeah.

Markoff: Okay. There's SPICE as the circuit design tool.

Reddy: Yeah. That was only done at Berkeley.

Markoff: Berkeley. But then there was something called "SPICE" that led to Mach, and that is what I was asking about.

Reddy: Yeah. That is the campus-wide networking project. Something ... "Computer Environment." I'll find out what it is from… One person that has been there, still there, is Scott Fahlman, who is involved in that whole campus networking project.

Markoff: And out of that came Rashid's work on Mach.

Reddy: Yeah.

Markoff: Okay. And Rashid, did he study with you at all, or no?

Reddy: No, no. I had recruited him.

Markoff: Oh, was he on faculty?

Reddy: Yeah, into the faculty, and gave him all my initial funding to do the distributed networking, because I had a project from Bob Kahn on distributed sensor networks. I said, "Before I can do my research, you have to build a distributed system," and that's how Mach came about.

Markoff: And what was the relationship between the distributed networking work and the creation of the Network File System standard?

Reddy: The distributed networking, Mach is just an operating system, but the Andrew File System is part of a campus-wide networking project. The problem Jim Morris faced, who was the head of the whole IBM campus networking project where IBM funded us to demonstrate a campus-wide networking, was we wanted to have fiber to every office. This was in 1981 and we used to call it "the greening of CMU with computer science." In order to make that whole thing work, you had to build a campus-wide network and you had to have workstations, personalized workstations throughout the campus, and they had to be usable in various ways. The operating system could be Mach, it could be Unix, whatever.

And one thing that became clear, students will go from building to building. These workstations were not yet portable, like laptops, so they have to go sit somewhere and use them. And when they sit somewhere, magically that system must become their personal computer. That means within a matter of a second or so, it should download the entire environment, all their files and all their stuff they're working on. Everything must be there. And the minute they log out, it all goes back into the thing. That is the origins of the cloud computing.

Markoff: Yeah, that's remarkable. I saw in 1997 a picture of you with a group that I believe won the World Championship Computer Chess award. What was your participation?

Reddy: Basically, we set up a prize called Fredkin Prize. Ed Fredkin, at my suggestion, gave $100,000 to something and we put it up in an endowment at CMU, and then the basic idea was the first time a computer beat the world champion, which according to Simon was supposed to happen in the end of the 1960s… It happened in the end of 1990s, 1997. Kasparov was beat by Deep Blue. So we said, "Okay. Now we should give this prize." But it turns out chess championship did not happen overnight. It was built on top of a lot of other

people's work. It was like I think this saying of Newton, saying, "If I've invented these things, it's because I'm standing on the shoulders of other giants."

Similarly, what happened was there was Greenblatt Chess Program at MIT, an early one. There were two or three programs at CMU – the TECH*, [Jim]* Gillogly did it, then there was HiTech that Hans Berliner did. Then there was Deep Thought. That was the same team that did the Deep Blue at IBM. And all of them kind of demonstrated higher and higher levels of competence. There were two other people that made important contributions. Ken Thompson at Bell Labs built his own Belle system, B-E-L-L-E, and there were people at Northwestern that did work.

So we said, "We really ought to honor all of them, not just the people that did the…" So we gave the $100,000 prize to the three people. That was C.B. Hsu, Thomas Anantharaman, and Murray Campbell, and one other person. They got the Fredkin Prize. But then we also gave everybody else a Newell Medal of Research Excellence and some… I don't know whether there was any financial thing also. All the others, we invited all of them, paid their expenses. It was done at the AAAI conference in 1997. I think at that time, that year, it was in either Boston or Rhode Island or something.

I think if you look at almost any advance, major advance in any of our fields, it is kind of built on lots of earlier work. *[2:20:00]* We need to figure out a way of not losing all of that connection. And that was the first time we did it.

The second time we did it was... If you remember, you came to SAIL reunion. Fortunately, McCarthy was still alive at that time, and we gave medals, McCarthy Medal of Research Excellence to about 10 people, each of whom, like Larry Tesler and various other people, that did major things that were just below the level of kind of becoming big industries.

Markoff: I looked in Google Scholar, and your most-cited paper is a paper titled *Spoken Language Processing: A Guide to Theory, Algorithm and System Development*. Can you tell me much about that paper? Was it a broad overview of the field? Is that why it's so often cited?

Reddy: Probably. I forget. *[laughs]*

Markoff: *[laughs]* Yeah, okay. Besides Harpy and Hearsay, there was also SPHINX. Was SPHINX a follow-on project in terms of your notion of "built on top of…"?

Reddy: They're all follow-on in the sense they're built on what worked and what did not work, but there was no software migration. There may have been some local signal processing or something, but the SPHINX was built… While we were doing SPHINX, we were also doing another system. I forget the name of it. We

had SPHINX, and the idea was… again, it's kind of the same kind of a blackboard model type thing, where… At that point, we all believed knowledge-based systems capturing and encoding all the knowledge is the way to build AI systems. It turns out, when it comes to speech and vision and robotics, we do things in the brain which is not written down in any textbook. We don't understand how we recognize speech. So we imagine and we make up models of it, and linguists make up their own models.

If you talk to any linguists or phoneticians, they will say they can transcribe any language. I did an experiment of that in the mid-'70s. I brought five distinguished phoneticians, Gunnar Fant and Ilse Lehiste and so on, and gave them a set of sentences from many different languages – Swahili, Marathi, all kinds of things – and said, "I know what they're supposed to be, but let us see if you can… You can listen to it as many times as you want. Write down a phonetic transcription of what they said."

Amazingly, they only agreed with each other about 66% of the time. That kind of told me that the human ear, if somebody says, "I can transcribe a completely new language," he's transcribing what he thinks he heard, but that may not be the same as what is being spoken and may not be the same as what somebody else would hear. This is especially true if you or I are listening to tonal languages like Chinese. We won't hear those distinctions.

Markoff: When you were doing that work at that point, were you aware of Chomsky's work in linguistics and what was your… were you…?

Reddy: Yeah. I was very aware. At that time, I didn't have a strong opinion, but I do have now. I can tell you what it is.

Markoff: Yeah, what have you come to…?

Reddy: Basically, Chomsky's main thesis is human beings are born with innate knowledge of language. It is built into them and built into the DNA. I have a slightly different hypothesis, which is they do demonstrate understanding of language at 10 months old and 12 months old, so the question is "Where did they get it?" If you imagine a child developing in the womb, the hearing apparatus is already formed at the end of three months or four months. If you are hearing what your mother is speaking and if you are hearing what your mother is hearing, or whoever it is, every day-in and day-out for 16 months, you would acquire some amount of sound clustering, sound language, and understanding of phrases and common things that you might have seen. That would appear to be linguistic or language, but it is not built-in, it is not in the DNA. It is learned behavior.

And I believe the same is true with respect to vision. Unlike speech, where you are learning speech from when you're three months in the womb, until you're

born and you open your eyes, you don't have any ability to see. But after six months of seeing your mother's face many times, you're able to recognize that particular impression and smile. And there's a professor at Carnegie Mellon, Michael Tarr, who wrote… He's a brain scientist, neuron scientist, head of the Department of Psychology. His thesis is there is a computer in your brain, one millimeter cube or something, a million neurons, which does nothing other than recognizing your mother's face. There are about 10,000 such in the brain. And that's what… Your brain is a collection of a million specialized computers. When Daniel Kahneman says fast thinking or slow thinking, all the fast thinking happens because it's instantaneous recognition. Slow thinking is when you have to reason and discover something rather than instantaneous recognition.

Markoff: That sort of theoretical insight that you have, how does that shape your view of machine learning and the way, chart a path forward in terms of design of those systems?

Reddy: In machine learning also, my view is we can think about building one humongous deep learning network which will recognize everything under the sun. It may be doable, but it will be extremely expensive and time-consuming. What we should be doing is building a large number of highly specialized recognizers. If you take your language and my language, if I told you, "Give me a break," you'll recognize it, and that's because that's a phrase… What I'm saying is we should build a million recognizers of contiguous phrases, all the way from sounds to the thing. Then if you suddenly hear a brand-new phrase that you never heard before, "Brzezinski," you don't know that it's a word, you don't know whether it's the name of a city or a name of a person, a name of anything, but you can at least write down what you heard as a spelling. That spelling won't be perfect, but it will be there and it will be close enough.

I believe Minsky had the right idea when he… in the book called *Society of Minds*, his idea was that it's not one single intelligence which is doing all the things, which is the basic thesis of Newell and Simon. I believe it's really a million of those things, but they can't be by themselves. They have to interact with each other in the following sense. If I'm going to spend some money to buy something on Amazon, there has to be a link to say, "Is that money there in my bank account? If not, what do I do?" So that kind of… Even if you have a buying agent and a banking agent in your brain, they have to somehow interact under some conditions. *[2:30:00]* So this conditioning of each other, prior conditioning of agents turns out to be very important.

Markoff: Were the projects like Hearsay and Harpy and SPHINX the projects that were the basis for the Turing Award?

Reddy: Right.

Markoff: Were there others that were important to mention?

Reddy: No, I think those were the ones, basically. The Turing Award came in ’94. It’s a collection of work that was done until that point, cumulative collection, which demonstrated large vocabulary connected speech recognition is possible. And what it did not demonstrate, which we now know, is unlimited vocabulary unrestricted language open population unrehearsed speech. Unrehearsed spontaneous speech from open population was not even on our horizon at that time. That’s what is kind of amazing to me today, sitting and saying, “My gosh, we made huge progress.” And not because we invented some new speech algorithm. It’s the same algorithms we did 30-40 years ago. It is because now we have a million times more computing power, which makes it possible for us to train from huge amounts of data.

Markoff: You know that flippant comment made by an IBM executive a number of years ago about every time he fired a linguist, his speech processes got better?

Reddy: Better. *[laughs]*

Markoff: It was flippant, but it sort of speaks to the fact that the machines were… the ideas were there but you didn’t have the computing power to…

Reddy: Right, exactly. No, the way to think about it is if you hire a linguist and then he says, “This is the way I think my brain is recognizing speech,” it may be machines do not recognize it that way. We don’t have a knowledge or a textbook on how humans recognize speech, unlike chemistry or physics or something.

Markoff: What are the memories of the time you spent with the group that Jean-Jacques Servan-Schreiber created, Le Centre Mondial in Paris, and its impact?

Reddy: Again, there’s an example where old friendships come back. I was sitting in my office in the ’80s, early ’80, and Alan Kay walks into my office saying, “Raj, I’ve been working with Jean-Jacques Servan-Schreiber. I think you’re exactly the right person to come and get involved with it.” I said, “What was ‘it’?” So we talked, had lunch together, and I said, “Look, I am right in the middle… I’ve just agreed to heading the Robotics Institute we just started last year. I can’t take off from here.” But I am very interested in how technology can be used to help society, in particular poor and illiterate people, so I agreed to become the Chief Scientist for that center. And Nicholas Negroponte came, and he was the Secretary-General, kind of its chief executive. Then Jean-Jacques Servan-Schreiber was the Chairman.

It’s a great experience in international science projects actually. It turns out when you have two or three big personalities, there will be clashes. That’s what happened between… Negroponte was great and he was doing what he thought, and Servan-Schreiber thought it should be something else. Finally, Nicholas said,

"I don't need this" and went back. Same happened with Alan Kay. Alan didn't have any conflict. Terry Winograd and Alan Kay and a number of others were there. None of them could deal with the French bureaucracy. And I didn't have that problem. Number one, I was not being paid at all. I said, "I don't want any pay." Everybody else was. And secondly, I was commuting back and forth. So I was happy to be able to be there and help kind of do the projects that they were doing.

Ultimately, in '84, before… I think Mitterrand left in '86 or something. In '84, when Mitterrand came to USA, he went to different places. Who was the mayor of Atlanta? Young, something?

Markoff: Oh yeah. Andrew Young.

Reddy: And he was given a *Légion d'honneur* medal. There were two or three. I was one of them. *[laughs]* I think it was mainly because of my contributions to the thing.

Markoff: There was a generation of young students who went there. I know some of them. People like Mike Holly and Mark Siden who worked there as young kids, but it influenced them, so…

Reddy: Oh yeah. A lot of young people came. For them, it was kind of like being in a candy store. There were all these personal computers. They could come and use any of them. There were no restrictions. Negroponte was trying to create a world, what it could be like when everyone had unlimited access.

And in addition to Jean-Jacques Servan-Schreiber, there was another famous personality. I don't know if you know the name Sam Pisar. Sam Pisar was a Holocaust survivor and had a very colorful history. It's very interesting to read his book *Of Blood and Hope*, how he survived from the concentration camp and ended up in Australia. Then he became advisor to John Kennedy, then migrated to France and became a lawyer there. He has all kinds of interesting stories about how they avoided paying New York State taxes for Elizabeth Taylor's big diamond. Apparently, it was the seller took the diamond on a plane and the buyer was on the plane also, and somewhere on the mid-Atlantic when there was no country, they exchange the check and thing. These are the kinds of little anecdotes. They have nothing to do with… *[laughs]*

Markoff: That's great. What was your role in the creation of the AAAI? And when did it happen and…?

Reddy: Yeah, AAAI was created also around '78-79. The first conference was held at Stanford in '79. Or '80. The reason it happened was I was looking at various other activities. SIGGRAPH was a good example. It's a very interesting conference you go to. There was a president of ACM at that point who was

cantankerous. I forget now who it was. It turned out Ed Feigenbaum wanted to have a conference in Hawaii. ACM said, or the president said, “No. It’s a boondoggle. We’re not going to sponsor it.” They had the conference anyway without the sponsorship.

So at some point, there was a feeling, “AI’s getting bigger and bigger,” already the technology and all the other AI companies were there and were coming up. I was the chairman of IJCAI the previous year, so people came and said, “We should have our own annual conference in USA because there’s so much activity.” So I kind of took it upon myself to create the whole thing, and all of that is recorded in the twentieth anniversary issue of AAAI. And it worked beautifully. We had a nice conference. I got Newell to become the first president and Feigenbaum to become the second president, set up a council and advisory committees, program committees, how it would run the conferences and so on. And we made a lot of money because we were having exhibits at the same time. They made a lot of money. At that time, AI was right at the top, again.

The thing in retrospect 30 years later I regret is at that time I wanted it to be free for the students *[2:40:00]* and I wanted to limit the registration fees to be $200 or so. Now the registration fee is like $1,000 and students have to pay half the price or something. And the reason was even though I said it and told everybody, the people that were there at that time are no longer in charge. New people come, new things happen. That’s why I have a huge respect for the Constitution of the United States. You have to write down everything, every detail, and say, “This is the way it has to be,” and then you have to make every president swear that they will follow this constitution of the AAAI. We never built a constitution. So this is something I think that anyone that builds a new organization has to worry about.

Markoff: The field that you were a pioneer in had two periods… Well, one was just in England, but there were two periods that were referred to as “AI winters,” one in the late ’70s when British funding was cut back and then in the 1980s in America. Did that affect you at all as an academic, or…?

Reddy: It did. The good thing was even DARPA, even when they cut off the funding for Speech and Image Understanding in the early ’80s, they gave us some money saying, “This is kind of a center-of-excellence money. You can use some of it for speech if you want to keep doing it.” So we could continue to do all of those things, including autonomous vehicles work and so on, for many years, and then slowly the money came back. DARPA has been the main source of innovation in computer science in everything that came out.

Markoff: In terms of sort of your administrative responsibilities at CMU, you created the Robotics Institute. You were the Dean of Computer Science?

Reddy: Yes.

Markoff: Was there an additional role that you had after, beyond that?

Reddy: No.

Markoff: No. Okay, so…

Reddy: I kind of helped out. We started a west coast campus and Institute for Software Research. I kind of helped out, and then Jim Morris took over the west coast campus and Bill Scherlis took over the Institute for Software Research.

Markoff: Then back to the point about the impact of the AI winter. It came sort of after this period that was influenced by the administration funding of something called the Strategic Computing Initiative. Did that have a big impact on Carnegie Mellon and your own work, or was it separate?

Reddy: No. The good thing about CMU is it's so big and so diverse, we have seven departments. We have a department of computer science, robotics. We started the early Language Technologies Institute. Lycos, the first search engine, was built out of there. And we have the Machine Learning Department, department of computational biology, the Human-Computer Interaction Institute. There are about seven different departments, and so that activity was and is sufficiently diverse. More than half of it is in AI. Although people may not think natural language processing or Language Technologies Institute is AI, it's right in the center of AI.

Markoff: Did any of the SCI money end up helping speech, or was it more focused on more general AI?

Reddy: Yeah. Strategic Computing was more general, basically. But overall, we had reasonable funding.

Markoff: I'm interested too in some of your more recent, relatively recent work about the impact of computing on society. At some point, you were involved or did you start the Million Book digital library project?

Reddy: Basically, after I stopped being the dean, I said, "I can publish some more papers on speech or vision or whatever, and there are lots of other good people doing work and they'll publish the papers. It's not important that I publish them." So I decided to see if I can work on things that would have major impact on society as a whole. And I kind of…

I'll give you my today's distilled version of it. I now believe AI can be used to create a humane society. That means, whether you believe in human rights of the United Nations or you believe in strategic sustainable development goals of United Nations, or even basic needs… Like everywhere, you take everywhere in the world there are some disasters, there's water scarcity, food scarcity, energy

scarcity, health and education, housing, all kinds of things that are essential for everyone. I am saying if I can instrument everybody with a smartphone so that I can find out where they are, time and location, and then I can also find out anything else they do they do with the computer, I can predict exactly what they're doing and where they are, what's happening to them. Then, if I can look at a community of people, all of whom are having difficulty because of water scarcity and they're going and forming a big, long queue and waiting there for an hour, I can from that predict that there's a water scarcity problem. Same is true for hunger. Same is true for almost everything that you do. I can predict what's happening. Including slavery. At this point, in the world there are 25 million people that are in some kind of slavery. A lot of them are in bondage and some of them are sex trafficking and so on, and in each of these cases, it can be done.

The big elephant is privacy. If I can monitor everything everybody's doing, then I know… So the question is "How do we preserve privacy?" I believe the existing anonymization technology is not good enough, but it can be made better so that I can theoretically guarantee that the likelihood that your data can be de-anonymized is one in a billion, arbitrarily small. That in conjunction with opt-in process, that is… Like I'm sure you use Waze or something like that. Waze works because it's opt-in. I say, "I want you to tell me there's traffic jams. In return, I'll let you monitor my travel, where I'm going and where I'm stopping and all of that," and based on that, you infer where the jams are and then re-route me. That's an opt-in process.

So if I were to give… There are more than 800… no, no, no, more than three billion people, maybe five billion that don't have smartphones in the world. The question is how do you get them smartphones? Many of them maybe can afford it, but two billion people cannot ever pay for it. I believe the government should give them the phones, and the stakeholders can pay for it because it will increase the… There is a professor called Eric Brewer at Berkeley. You might know him. He says if you create this information infrastructure, it will raise the economic activity of everybody. And once you have the improved economic architecture, then you can build all the rest of the infrastructure, electric grid and so on.

Markoff: When did the Million Book Project happen and what was it, your idea, or…?

Reddy: Again, all of these have a long history. It was McCarthy's idea. McCarthy's idea was "Hey, everybody's writing their thesis on the computer anyway," in 1973-74, "Why don't we simply put all those theses on the web?" That was his idea. And the founder of Adobe…

Markoff: Oh, John…

Reddy: Yeah, John Warnock and…

Markoff: Warnock and Geschke, Chuck Geschke.*[2:50:00]*

Reddy: Chuck Geschke. Chuck Geschke is one of our students at CMU. He did his first thesis on the XGP printer that we built using equipment that Xerox PARC gave us. That was in '73 or something. So when I was the Chief Scientist for Centre Mondial, I said, "Let's get all these books online." I invited John McCarthy to come and we went to Provence to set up a center there for digitizing all the French books.

Anyway, all of those things never fully happened. So this idea has been kind of ticking around in our heads. In 1995, we had conference at CMU on electronic libraries. I invited Bob Kahn and Vint Cerf among others to that. I think Vint came up with the idea "Let's not call it 'electronic libraries.' Let's call them 'digital libraries.' " That's what I remember of the first use of the word "digital libraries." And we've been doing it. There's a video that Mike Shamos did in 1997 for prototype digital library system we had. The idea was even then it was not just the books. It is the movies and it's the music and it is the paintings and newspapers. Everything should be online.

Markoff: Then another project that you were involved in was called FiberAfrica.

Reddy: Yeah. We had funding from World Bank, Wolfenstein *[sic: James Wolfensohn]* and Wolfowitz, basically Wolfenstein, where we did a feasibility study for them saying, "You can connect every country and every major city of Africa for a billion dollars." And the reason is the following. Namely, in the United States, if you want to dig in and put fiber, it costs a hundred thousand dollars a mile. In Manhattan, it's like a million dollars a mile. But in Africa, digging and putting silicon fiber, which no one wants to steal anyway, is only like $5,000 per mile, and another $5,000 for all the equipment and lighting it up and so on. So $10,000 a mile is what we came up with. We kind of counted connecting all the… we built a whole thing, and the total number of miles to connect all the major cities in the thing was like 20,000 or 25,000 miles. So you multiply those two numbers and then you get a billion dollars. And we said, for a billion dollars you can connect every country and provide high-bandwidth connectivity.

Then there were all kinds of things we were not aware of. For example, apparently in Ethiopia, there's no electricity. So there's a prerequisite here. We assumed there's electricity. In many other countries, there's no electric grid. And secondly, there's no cities. People are all over the place, spread out. So you can solve those problems, but the basic idea is you can connect everybody, and then using WiMAX towers, you can essentially connect all the smaller towns. And the cost is reasonably small.

Then we extended it to the global grid. If you had three east–west fibers, three or four, and seven north–south fibers, you can have a global grid that will cost like $20 billion, and it will be completely redundant. Even if somebody comes and

cuts one or two fibers, you can still be connected. And it's only $20 billion. Compared to the world product, I think the current world product is like $80 trillion or something, or $100 trillion. It seems like… Even if you were to do the last mile, then it increases by a factor by 10, so it's $200 billion.

The question is… In my optimism, I went to people at Microsoft and Google and everywhere. I said, "Look, you should be doing this. Forget about the balloons and all the rest of it."

Markoff: Roughly when did the FiberAfrica work that you participated in, when did you begin participating?

Reddy: That was done in the early 20-… early… late… I was the chairman of PITAC, President's Information Technology Advisory Council. As part of that, the Next Generation Internet study we did, it was clear to me that fiber, a gigabit to every home is not only feasible, it can be done economically. And FIOS you know, Verizon is doing it, but in general that could have been done long ago, especially if the government decided they wanted it. That's what my, our recommendation was.

Markoff: Did you get to know either Vice President Gore or President Clinton during your period as…?

Reddy: Yeah. I met them. I don't know whether I would call it "getting to know." Usually, it's they're polite and friendly. And I was at Davos and Clinton was there, and I was invited to the reception he hosted. And he kind of… *[laughs]* It's very good.

Markoff: But you didn't get a deeper…? You know, it's so controversial about Gore's role in the creation of the Internet.

Reddy: Yeah. I'm not sure it should be controversial. He did not create the Internet, but without him, we would not have the World Wide Web. Basically, the government had to get involved at some point and say, "This is an important technology. We're going to do it." And it needed him to do that. Until that point, it did not.

Markoff: Was there also a certain point where you became involved in helping higher education in India? Did you sort of return to your roots in some way at a certain point, and when was that?

Reddy: Yeah. Basically, as part of this "technology in service of society," which is what I've been doing in the last 10-15 years after I stopped being the dean, I've been constantly exploring in what ways can technology help. So, like I said, if I had connect with every person, I can actually improve the human rights, and help

predict and correct… And various subparts of it – education, health care – can be done even better, earlier.

So one of the things that I offered to do was to kind of set up a rural university on the basic reason that came to be is I come from a village, and most of the other kids that went to the school with me are still there in the village, and I escaped. It so happened I was having lunch with the head of the state of Andhra Pradesh. I said, "You are also from a village. Look, we are black sheep. There are probably at least 10 times as many people who are equally brilliant in each village. I wonder if there's something we can do." And he said, "Whatever you suggest, let's do it."

So this particular university, Rajiv Gandhi University of Knowledge Technologies, we admit like half a percent of the top students from the tenth class into a six-year program. Everything is free. The food is free, the accommodation is free, the tuition is free, the clothing is free, the shoes are free. And because they're the top students, my assumption was "We can admit thousands of them and give each of them a laptop, and they would learn by themselves." That's where I was wrong, actually. It turns out most people from villages and so on, their basic needs are not yet met. For example, if you look at the United Nations, Declaration of United Nations, Eleanor Roosevelt and all the other people that created it came from rich countries and rich families. They had no idea that there may be people with no water, no education, no health. They're not there in the Universal Declaration. The right to water is not there, right to clean air is not there. *[3:00:00]* Because for them, it is a given.

What happens is when you kind of take these people, and I say to them, "I'll give you a laptop. You can listen to any lecture you want. All you have to do is study and then you graduate and so on," and they're coming from poor families, they've never had any money, they've never had any shoes, they haven't clothes, and so everything becomes a problem. We were discovering we have 58% women students, and these are all 15-year-old, 17-year-old coming in. They have all kinds of needs which none of us could anticipate and provide for.

Markoff: So are you continuing to redesign the university?

Reddy: Yeah, continually, constantly. *[laughs]*

Markoff: How big is it at this point?

Reddy: It's 18,000 students.

Markoff: Wow. And do you have a formal role in it?

Reddy: I am the chairman of the board. They call them "Chancellor." I don't take any money or anything else. I go there twice a year.

Markoff: What year was it created?

Reddy: It was created in 2008. I think it's doing a useful service. There are many kids that would never have gone to college that are going to college, and they're getting degrees and so on. But where I'm kind of disappointed in it, I thought, "These are all the top students. They'll be excited to learn, motivated to kind of learn everything they can." No.

Markoff: That's interesting.

Reddy: They just *[laughs]* come, they have a different set of…

Markoff: You sent me, you shared with me a talk that you gave recently where you talked at the end about sort of roads not taken. I think we've talked about most of them. We talked about the possibility of becoming a pilot, working for IBM, becoming a Silicon Valley entrepreneur – we might not have talked about that – and possibly going to UC Berkeley. All those would have led to very different outcomes in your life.

Reddy: Very different. Basically, you must remember, in 1966 when I graduated, Intel was not yet being formed. It was formed in '68. I knew Gordon Moore. I met them at some lunch or something. I could have joined them, maybe, but it never occurred to me to even think of it. There were other people that were starting startups at that time. There was one guy starting some optics stuff. And Syntex was formed at that time. I don't know. Carl Djerassi and others were doing these birth control pills. All of them needed computer science, right? Computing. But it never occurred to do any of those. But you could have taken… those are the kinds of roads not taken, as Robert Frost says, right?

Markoff: I think we've touched on many of the high points. I was wondering at this point if there are other interesting things that you've been involved in that I haven't raised that were important in the course of your life.

Reddy: I think we have done most of them. The good thing about my life is I have been in this birth of computing from the beginning, 1959, which is not quite the birth, but most of the exciting things started happening after around that time, after mid-'50s. And I was fortunate to be in the right place at the right time to kind of be exposed to all these things for 65 years, is it? No, 60 years. Something like that. And I feel very lucky.

Markoff: Let me close by asking you, since you were very close to the roots of the field of AI and you've watched this through this arc of history, now in this field there are two debates. Well, there are many debates. But the two that I wanted to ask you about, one is in terms of rate of progress, whether you think what is now described as artificial general intelligence will be possible. I won't ask you to pick

a date, but do you think we'll be able to reach that period where the machines will be able to do the vast majority of human capabilities?

Reddy: I think if you agree on the rule of 80-20, yes, it will. What that says is the general intelligence a machine must exhibit, is to know what it does not know. If it is not sure, it should come back and say, "I don't understand. Why don't you do it or tell me what to do and I'll learn from you?" So a lot of the issues of commonsense reasoning, which is the biggest area of AI where people will give you examples saying you can't tell the difference, if you believe in the million-computer theory, to me each one of them is a special piece of knowledge that's learned as an exception, and it's there and whenever you need it, it's there. It's not something you reason. And that will only happen if we build these man-machine systems or human-machine systems where every time there's a problem, somebody's giving the answer, and ultimately the computers will have much better answers than any one human being because they have the collective intelligence. That assumes that we can solve the privacy problem.

Markoff: In Silicon Valley, there is a fashionable perspective that's in some schools referred to as "the singularity," this notion of an intelligence explosion. And in some cases, there's a debate about whether we're evolving into another species. Do you have a philosophical sense of whether that's possible?

Reddy: I believe we will evolve into a new species, but it is not a species that you and I will be able to not recognize. Basically, a small group of us, maybe people in Silicon Valley or maybe in United States, or some small group of us will have superhuman capabilities. That means we'll be able to do things that nobody else in the world can do, because we have created tools to do that. There's this movie called *The Gods Must Be Crazy*. Have you heard…?

Markoff: Yeah.

Reddy: Where they drop a Coke bottle. Same thing, namely. Arthur Clarke used to say that truly advanced technology is indistinguishable from magic. That's what it will look like. That is, even before you open your mouth, I can tell you what you're thinking and what you're going to do and how to do it. In that sense, it is not going to be a completely silicon-based robot that's taking over from us. It is the evolution of some of the human beings so that we may look the same but we have superhuman capabilities. In that sense, we are probably… we can say the *Homo sapiens* are different Neanderthals. We had better capabilities and they survived. So now the question is, the superhuman-capability people, rather than robots, are they going to kill everybody else? I don't believe so.

Markoff: Maybe let's end on that, because over the last two years, people like Hawking and Gates and Musk and Russell at Berkeley have all raised these warnings about a machine intelligence that might be hostile to humanity. It sounds like you don't feel that that's true.

Reddy: It could be true in the following sense. Am I hostile to chimpanzees? Most of the time I leave them alone. But if they come and bother me, I might swat them, right? Occasionally, somebody might go hunting for pleasure, hunting a giraffe or something. But most of the time, most of the people will be left alone and they'll coexist.

Now the question is the much better threat that is lost in all of this is half of the people will lose the jobs that they now have, and the society must create solutions for them. *[3:10:00]* The best idea I've heard so far is the idea of basic minimum income. It's not enough to say, "I'm going to train you." "I don't want to be trained. I'm a coal miner. I've been working in the field for 55 years. Now you want to train me to become something else? I don't want you to create any policies and decisions that take away my job and give it to some Mexican or Canadian. If you're going to do that, then you make sure that my salary is preserved. Tax everybody and give me my salary. Then you can make any stupid policy you want." That's where I think the society has to evolve to. We're not there yet, but basic minimum income is a starting point so that every person, whether you're a billionaire or nothing at all, gets $30,000 a year.

Markoff: One more last point. You're spending a significant amount of time in China, and China recently made it a national priority to compete and be a significant player in the field of artificial intelligence. How well do you think they'll do?

Reddy: They'll do very well. But important thing is today's *New York Times* article has a very interesting story on Xi Jinping which says they want to be the leader in the economy of the world, they want to kind of do that by having a single-party system, and they want to have one leader who's a benign dictator. We can disagree with any of those things, and then when you disagree, they say, "Look at the democracies. They're complete chaos." *[laughs]* And so I'm not sure what the right answer is, but that's what they're leaning towards.

In every technology they've started, they have a huge amount of resources, mainly because they don't have the problem you and I have of paying high wages, so there's a large part of the people and there's no ownership of property. The government owns the property, so they can actually collect… There's no taxation. Everything goes to them. Then they distribute whatever money they want on anything they want. So it's a Marxian philosophy saying, "No ownership of property." But people do own things, but it's a different economic system which they're trying to enforce. And when you have a 1.3 billion people, it's not clear how they're going to do it.

But from a technology point of view, they're doing extremely well. They have the three largest supercomputers in the world. In order to build them, they built their own chips and they're building their own networking systems, they're building all

the fiber. In every area, they're able to innovate. And the important thing to remember is, China, the DNA of innovation has been there for thousands of years. They invented paper, they invented compass, all kinds of innovations. Many of them. Gunpowder. Everything came from China. So you don't want to underestimate their ability to innovate on every dimension, including AI.

Markoff: How should we compete, America, in response to that kind of competitive challenge?

Reddy: I don't know. *[laughs]* It'd be easy to say, "We should become a dictatorship or something," which we can't. So the issue is, when you have our Constitution, our style democracy, our style of checks and balances in government, things will be slow. The only threat is… This is between… The analogy is exactly the same. In 600 BC, there was a democracy, Athens. Greeks had a democracy. Next to them were Spartans, and they didn't have a democracy. They kind of trained all of them to be warriors and they invaded and killed the democracy. So this issue of how do you respond to somebody who claims that they're going to be the supreme leader of the world and going to kind of create all the technologies and everything. Not clear. I don't know. Fascinating.

Markoff: Let's end at that point. Really, it's a privilege for me to share your journey, because it really has transformed the world, so thanks very much.

Reddy: I hope we will be able to create a humane society. I don't care whether we have exactly our style of democracy, but if there's a humane society where everyone's problems are taken care of. If you're a coal miner, they have to make sure that your life is not affected. If you do that, then the rest of the things, whether you're a democracy or a dictatorship…

Markoff: Fingers crossed. *[laughs]* Thank you.

[end of recording]