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CHOOSING A CAREER 1957–63

Advice from a professor – Technical University of Denmark – Ørsted's influence – Distant professors – Easter brew – Fired for being late – International exchange student – Masers and lasers – Radio talk — Graduation trip to Yugoslavia – An attractive tourist guide – Master of Science – Professional goals.

There was never any doubt in my mind that I wanted to become an engineer like my father. But what kind of engineer? I didn't think it would be a good idea to enter civil engineering where my father already had made a name for himself. My choice of electrical engineering may have been influenced by the recent popularity of television in Denmark following the coronation of England's Queen Elisabeth II in 1953.

In senior high school, I was usually the best student in my class. But my chemistry experiments were just a hobby. I did not make any scientific discoveries. And, my interest in literature did not inspire me to write original works of art. Although I was reasonably intelligent, I was not a prodigy.

Since my mother did not have a high school education, she worried about whether I would be able to complete an engineering education. So she persuaded me to call my father's colleague, Helge Lundgren, professor of Harbor Construction at the Technical University. "What was your final math grade in high school?" he asked. "A−," I answered. "Well," he said, "then it is, of course, impossible to say anything with certainty." No, professor Lundgren was not joking—he was absolutely serious. Ah well, I thought, I will just do the best I can. So I enrolled as a student of electrical engineering.

In 1957, the Technical University was still known as Polyteknisk Læreanstalt ("Polytechnic University"). It was founded in 1829 at the initiative of Hans Christian Ørsted, the Danish discoverer of electromagnetism. Since he believed that a well-rounded engineer should master the fundamentals of all fields of engineering, the students were called *polytechnicians* (from the

Greek word *poly* meaning "many"). Ørsted remained the first chancellor until his death in 1851.

I began my studies in a quadrangle of massive buildings from 1890 in Sølvgade, not too far from downtown Copenhagen. They were situated in a corner of the Botanical Garden, across the street from the Eastern Park ("Østre Anlæg"). These beautiful parks were the remnants of the ramparts around the medieval Copenhagen, which were leveled in the 1860s to make room for the growing city.

The Technical University had no dormitories. Most students from Copenhagen lived at home with their parents. Students from other towns rented rooms nearby or lived in public residence halls. Some students could not handle the freedom of living away from home for the first time. They would skip classes and play cards in the student cafeteria.

There was no parking lot for students. Nobody that I knew owned a car. Like most students, I used my bicycle to get from our apartment to the university.

Thanks to Ørsted, all engineering students took the same classes for the first two years: Mathematics, Geometry, Physics, Chemistry, Applied Mathematics, Theoretical Mechanics, Structural Engineering, Material Science, and Geometric Drawing.

By the 1950s, this noble ideal was beginning to look somewhat impractical. Even I could see that an A− in Structural Engineering did not qualify me, as an electrical engineer, to design the transmission tower for a television station.

Material Science was ridiculous: you had to learn a great many physical constants by heart, such as the electric conductivity of copper with eight decimals. (Fortunately, some of the leading digits were zeros.) Before the written exam, I wrote all these constants on a huge sheet of paper. After memorizing them for days on the balcony of my mother's apartment, I passed the exam with a B+. By the end of the summer, I had forgotten most of them.

When you work as an engineer, you soon learn to remember the most important constants in your field; the rest you look up when you need them. It serves no purpose to learn them by heart as a student. My friend Niels Zeuthen Heidam agreed that Material Science was a waste of time. As soon as we had passed the course, we sold our textbooks and used the money to buy rum and coke.

We were now attending lectures in a huge auditorium with a hundred students, or more. In the winter, the auditorium was heated by enormous radiators covered with wooden boards. When I came late to class (as I often did) all the seats were already occupied. The only place to sit down was on top of a radiator. After a while, the rising heat made me drowsy. So I would stand on the floor until my feet got tired. Then I would sit on a radiator again, and so on.

I felt somewhat lonely among all these students I didn't know. And the professors were distant figures on the podium whom I never saw outside class.

I did not attend lectures regularly. I preferred to study at home, until I reached the point, where I was unable to do the homework. Then I would borrow notes from a friend and attend the lectures until I caught up again. Although our homework was graded by teaching assistents, their grades served only to remind us how we were doing. Real grades were only given for final exams at the end of the year. If you needed help, you had to find and pay for a private tutor. I didn't need a tutor and would eventually graduate with a grade point average that made me number 3 of 47 students.

The technical university was undoubtedly an elite institution. It was highly selective and demanding. It made no attempts to retain those who dropped out. I don't think it can be done any other way if your primary goal is to educate competent engineers who can design reliable bridges, airplanes, and computers. (The poor reliability of software shows that programming is still not taught as a rigorous engineering discipline.)

The way it was taught, chemistry became dry as dust, and mathematics became understandable, but intimidating. Erling Følner was professor of mathematics. He married the daughter of the famous mathematician, Harald Bohr. In the days before women's liberation, this brought to mind the old German saying that mathematical talent is passed from father to son-in-law. He would walk into the auditorium, turn his back to us, and fill six huge blackboard in minute handwritting with formulas, copied verbatim from the textbook, and walk out again.

Judging from our textbooks, mathematicians seemed to have the ability to see into the future. In order to prove an important result ("a theorem") they would often start by proving a minor result ("a lemma"), which they would then use to prove the big one. I could not, for the life of me, understand, how they could possibly have known in advance that they would need this lemma to prove that theorem. I was so awed by this gift of foresight, which I did not seem to have, that the thought of becoming a mathematician never entered my mind.

Years later, I discovered that mathematicians are faking it. They do *not* prove theorems the way they present them in textbooks. They fumble with ideas, just like the rest of us, until they realize that some lemma may simplify their proof. Then they turn around and present their results, as if they were discovered by sleepwalking geniuses, who never make mistakes or enter blind alleys. This orderly method of presentation is technically correct, but misleading, since it hides a crucial insight from students: how do mathematicians *really* think?

I enjoyed my physics courses on Mechanics, Thermodynamics, Light, Electricity, Magnetism, and Quantum Theory. However, my diploma shows that I got higher grades in Mathematics. I don't know why.

On October 4, 1957, the Soviet Union launched *Sputnik*, the world's first artificial satellite. Weighing 184 pounds, it was about the size of a football and carried a radio transmitter. It circled the Earth for several months.

This historic achievement gave professor Henning Højgaard Jensen a welcome opportunity to compute the initial speed a satellite needs to escape gravity and stay up there. On Earth, the *escape velocity* turns out to be roughly 7 miles per second (about 11 km/s).

I remember professor Richard Petersen fondly. "Little P," as we called him, was a small, energetic man in his mid-sixties with a friendly smile. He was the only professor I can remember, who knew the names of all his students, no matter how large his class was. He taught applied mathematics: probability theory, queuing theory and Laplace transforms. If that sounds boring, let me assure you that it's not.

Little P once made a minor mistake on the blackboard and ended up with the wrong result. He looked at his formulas for a long time and finally said: "Jeg har et problem med min potens." In English this just means, "I have a problem with my exponent." But, in Danish, it also means "I have a problem with my potency." He looked puzzled when everybody burst out laughing.

Technical drawing was boring to me. (I often tell my students: "When you say something is boring, it is a statement about *you*—and *not* about the subject matter.") The instructor, Helge Christensen, demanded absolute perfection. We were expected to draw geometric figures in India ink with an accuracy of 1/10 of a millimeter (that is, 1/250 of an inch). My friend, Nils Havsteen had to redraw a gateway motive ("porten") ten times before it was accepted. If it was tedious, it was also invaluable for future engineers. Most university students already possess intelligence (otherwise they wouldn't be there). What they lack is the professional discipline required to get minute details right. Helge Christensen taught us that. Fifteen years later, I came to appreciate this lesson in precision: when my first textbook was in production, I told my publisher that the redrawing of my figures was too inaccurate and had to be redone.

On the last day before Easter, the student cafeteria sold a strong local beer, known as *Easter brew*. On that day, wise professors cancelled their lectures. But there was always someone who forgot this. I remember a professor who entered a lecture hall full of drunk students (I was one of them). So the professor starts lecturing, while a hundred students talk loudly. After a while, the professor shouts "Silence!" For a brief moment, the only sound is that of beer bottles rolling down the steps of the auditorium. Then the talking resumes. When an hour has passed, the students do not wait for the professor to announce that the lecture is over. We all shout "Time's up!" and leave. Outside, I find a friend sleeping on the cold pavement. I wake him up, and together we somehow make it to the street and take a taxi home.

In the spring of 1959, after two years of study, I had completed the first half of my engineering education. I was looking forward to the second half, where I would concentrate on electrical engineering, specializing in electronics and telecommunication. These subjects were taught in an extension of the Technical University in Østervoldgade, built around 1940.

My excellent professors included Jørgen Rybner, who, in his late fifties, was obviously an authority on Electric Circuits and Telephony. However, the major breakthroughs in these areas were made long before my time.

Hans Lottrup Knudsen taught a demanding (but rewarding) theoretical course on Electromagnetic Fields and Antennas. At the oral exam, sitting alone in front of him, without any books, I was asked to use Maxwell's equations to derive the radiation pattern of a linear array of antennas. Such an arrangement has the ability to concentrate electromagnetic radiation in a single plane.

Recent technology was also taught by Jens Rasmus Jensen (Servomechanisms), Per Gert Jensen (Digital Electronics) and Georg Bruun (Transistor Electronics).

For my degree project, I used tunnel diodes, invented by Leo Esaki at the beginning of my studies. Although I got an A−, I no longer remember anything about it. Long after my graduation, I used to dream that the university had just informed me that my diploma was invalid, because I had failed to complete my project!

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Before graduation, all students were required to complete industrial practice working for a participating employer. The intention was to teach future engineers to get along with workers. I worked in the machine shop of a small company, Danish Servo Technology, owned by Søren T. Lyngsø. I admired the professionel skill of the machinists, but my own work was trivial beyond compare: drilling holes in aluminum boxes and cleaning machines with kerosene. I did, however, enjoy playing pool with the workers after hours. After a while, I left the machine shop to work in the company's lab. Here I designed the only electronic device in my entire career: a transistor circuit that could detect if a weaving machine attempted to tie more than two threads together at a time.

At night, I read books about interesting subjects outside my university curriculum: Quantum Theory, Solid State Physics, Semiconductors, and Signal Flow Graphs.[1] But I did not get enough sleep and would often be late for work. Mr. Lyngsø could not very well expect his workers to show up on time, if a student did not do the same. So, eventually, he fired me. This is the only time that has ever happened to me.

He was right, of course, but I was now in a precarious situation. The university administrator in charge of industrial practice pointed out how important it was for him to maintain good relations with Søren Lyngsø. He was hesitant to recommend me to another participating employer. This was serious, since I needed to complete my practical experience to graduate.

It turned out to be one of those unnerving moments in life, when your situation looks hopeless, and then it turns out to be the beginning of an unexpected piece of luck: the university decided to let me continue my industrial practice abroad as an international exchange student.

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My father's career in soil mechanics inspired me to look for an area that was still in its pioneering phase. If a subject was being taught, it was probably already too late to make fundamental contributions, I thought. Throughout

[1] My reading list included D. Bohm, *Quantum Theory*, 1951; C. Kittel, *Introduction to Solid State Physics*, 1956; E. Spenke, *Electronic Semiconductors*, 1958; and S. J. Mason and H. J. Zimmermann, *Electronic Circuits, Signals, and Systems*, 1960.

my studies, I continued to look for something that was not yet being offered by our professors. At the beginning of my studies, I read about television in Frederick Terman's classic text, *Electronic and Radio Engineering* (1955). A few years later, the excitement seemed to be in transistor circuits. However, by 1960, it was obvious to me that electronic digital computers was the technology of the future.

My university did not offer courses about computers. Christian Rovsing, president of the engineering students' union (1959–60), gave me some idea of the nature of computer programming. For three evenings, he taught a handful of students the rules of the first programming language Fortran.

A milestone in computing, Fortran was developed by John Backus, at IBM headquarters on Madison Avenue in New York City, and introduced for the IBM 704 computer in April 1957. Fortran programs were written in a notation that resembles ordinary algebra.

On the last evening of Rovsing's short course, I said: "Christian, I understand most of what you have explained, but *what does it all mean*?" You see, without access to a computer, the rules were just formalities to me, without any connection to practical reality.

Christian Rovsing went on to a distinguished career. After graduating, he worked a couple of years for IBM in Sweden and France, before starting his own computer company in Denmark. In 1984 he received the IEEE Centennial Medal.

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So far I have written from memory supported by a few documents. At this point, my story is supported by letters to my parents and my future wife, Milena.

In the summer of 1961, I spent seven weeks as an international exchange student at IBM's Hursley Laboratory, outside Winchester in Southern England.

On the way to Winchester, I visited London as a tourist. I traveled on a student ticket, which I only received shortly before the train left the central station in Copenhagen. A student representative handed me a bunch of forms and explained that he would like me to be the guide for 75 students traveling to London that day. In return he promised to pay my train ticket, which sounded reasonable to me.

In the southern Danish town of Gedser, I was supposed to help students through the passport control and board a ferry to Germany. I quickly learned to hide my ignorance. When the students asked questions, like: "Is it far to the train in Grossenbrode?" I would improvise: "No, only a five minute walk from the ferry!"

The next morning, when we changed trains in Amersfoort, Holland, I almost lost a group of Swedish girls, who just stood next to their suitcases on the platform, while the rest of us walked decisively in the right direction. I didn't notice them until the conductor signaled the departure of our connecting train. I rushed over, picked up the nearest suitcase and got them moving fast. We boarded the train just in time.

Rotterdam, which had been demolished by German bombers on May 14, 1940, was completely rebuilt and topped by a forest of TV antennas. The silhuette of the enormous harbor was impressive. Behind the apartment buildings, it extended from one end of the city to the other.

In Hook van Holland, we boarded a ferry to England on a sunny day. Sitting on the top deck, looking at the quiet sea, I felt like Onassis on a Mediterranean cruise.

At Liverpool station in London, I left the students in the care of a Norwegian student representative and took the subway (known as the "tube") to Archway. My lodging was one of many similar townhouses: Nice outside, but rather neglected inside, due to the many lodgers who had lived there. When I arrived, there were about ten of us, all young men. The landlady, Mrs. Sheridan, who was rather nice, understandably preferred not to spend her time talking with lodgers.

I shared a small, unattractive room with an English batchelor, who was interested in science and very talkative. Since my roommate went to bed early and turned out the lights, I got up at eight in the morning and left for the center of the city at ten.

Walking around London without any plan, I "discovered" streets and buildings I recognized from movies and books: Oxford Street, Marble Arch, Piccadilly Circus, Charing Cross, Trafalgar Square (full of pigeons you practically had to brush off), and Big Ben in floodlight.

At the British Museum, I was awed by the Egyptian and Assyrian collections I had read about in Carl Grimberg's *The World History* (1959). How marvelous to find an enormous exhibition hall displaying a relief showing the Assyrian king Assurbanipal almost 4,000 years ago, on foot, killing a lion with a dagger. To recognize details of the relief and know that the king once stood before this monument!

Another hunting scene carried the inscription: "I am Assurbanipal, king of the World, king of Assyria. With my strength I held, alone on foot, one of the ferocious desert lions by the ears, and, with the help of Assur and Ishtar, I ran my spear through it."

My strongest impression of London was the striking contrast between the depressing working-class neighborhoods, and the impressive center with its beautiful buildings and multitude of monuments. A dirty city, without the charm of Paris, but fascinating with its endless traffic and people of so many nationalities.

The parks of London were enormous and beautifully landscaped. I walked in Hyde Park, saw Kensington Park from a rowing boat on the Serpentine, and enjoyed Green Park, close to the Queen Victoria Memorial.

The main railroad stations were huge: Paddington, Waterloo, St. Pancras, Victoria station—noisier and dirtier than anything else I saw.

Winchester was completely different with a population of about 30,000, and much cleaner than London. The town had a historical continuity without parallel. Outside the town was a hill crowned by a gigantic rampart from the Iron Age. Nearer the city, sections of the town wall dated back to Roman times. Between the 9th and 13th centuries, Winchester was the capital of England. The Danish viking king, Canute the Great (about 995–1035) ruled here and is buried in Winchester Cathedral. "Canute had two sons, Halfacanute and Partacanute, and two other offspring, Rathacanute and Hardlicanute" (Sellar 1964). Two city gates from the 13th century were still standing, and the oldest houses were from the same period. Half-timbered houses from the 16th century were common.

I rented a room just outside town, in a former farmhouse on Andover Road. The room was a huge improvement over the one in London: 18 by 24 feet, with a large armchair, a radio, and a view of the garden.

My landlady, Mrs. Early, was kind and helpful. The first evening, she made me a big dinner with meat, potatoes, and bread pudding. At home, my mother had taught me that you must eat everything on your plate. Otherwise, your hostess will think that you don't like her cooking. She would have been shocked by the American habit of eating a steak, leaving the fat on the plate. So I ate it all. Mrs. Early apparently thought that this young man must be starved. The next day she gave me twice as much food for dinner. Again, I did what my mother had taught me, and, with some difficulty, ate the whole thing. On the third day I gave up, when she offered me even more food.

In the room next to mine, her grandchild watched TV every day, for hours. On my side of the wall, I would mostly hear gunshots and horses neighing. I saw this as a premonition of the childhood of my future children. When my own children grew up, we only had a TV in the living room, and their viewing time was restricted. As far as I can tell, this discipline had no lasting impact.

Hursley Park was a former manor with enormous oak-paneled rooms, which IBM had turned into a research center. It was 3 miles outside Winchester. On my first day, I was shown around and introduced to many people. The English struck me as incredibly helpful and charming.

I did what I could to improve my English. I listened to BBC on the radio, read newspapers, wrote technical notes in English, and talked to technicians during the lunch break.

Weekends I spent with a Danish engineer, named Svend, who had bought a Volkswagen on credit (known in England as the "never-never"). After my first week in Winchester, we drove back to London for a one-day visit.

The purpose of our trip was to see the recently opened Soviet Exhibition. The astronaut, Juri Gargarin, had just visited England. In April 1961, he became the first man to orbit Earth in a spacecraft. Since the British government had no protocol for visiting astronauts, it took three weeks to decide who should receive him.

First we went to a Russian fashion show. The models were rather hefty by western standards, and the few party dresses looked clumsy. But the everyday clothes looked quite attractive.

The space exhibition was located in a fantastic planetarium, where movies where shown simultaneously on five screens, accompanied by electronic music. Walt Disney could hardly have done it better!

The rest of the exhibition was somewhat disappointing. The huge number of visitors, mostly Asians and Africans, made it difficult to see the exhibits. And there was very little written information about the machines and instruments shown.

We stayed at the exhibition for most of the afternoon and returned to the city in the evening. Piccadilly swarmed with people, and it was nice to be there again. Back in Winchester, at 1 a.m., all lights were out.

A month later, Svend and I went on a three-day vacation to Cornwall. On the way back, we visited Stonehenge, Europe's most famous Stone Age monument. This mysterious circle of huge stones, was built between 3000 and 1900 BC, about the time when the Egyptian pyramids were built. The average stone, weighing about twenty-six metric tons, was about 18 feet tall.

The original thirty stones had supported a circle of curved lintels.

Every morning, a technical assistant, named Dave, would give me a lift from Winchester to Hursley Park. The English engineers were very relaxed. In the morning, they would usually chat for the first half hour. At ten o'clock, they took a coffee break and, at noon, they went to lunch. After lunch, Dave and I might go for a long walk, or I might play chess with a technical assistant. At three in the afternoon, there was a tea break and, at 5:30, everybody went home.

The lab was not quite what I had imagined. They did not waste time on "unnecessary research." They all worked on two computer projects. The largest employed about 75 people, including 25 engineers, for several years.

My knowledge of semiconductor physics turned out to be irrelevant. If the engineers knew *what* a transistor did, it didn't interest them *how* it did it. I concluded that the difference between transistor physics and computer organization is similar to the difference between biochemistry and physiology.

The first couple of days, I was completely lost. The engineers hardly had time to answer my questions, and I discovered that, without a certain amount of knowledge, one cannot even ask relevant questions.

The machine, they were working on was, of course, not yet described anywhere. So, initially, I spent most of my time at work reading about computers. However, when the lab started assembling its computer, I was given a necessary, but monotonous task.

The computer memory consisted of hundreds of thousands of tiny ferromagnetic rings (known as "cores"). Each core stored one bit of information (a zero or a one). The cores were arranged in two-dimensional arrays with two perpendicular wires passing through each core. A particular core was selected by sending currents simultanously through both wires that passed through it. The magnetic state of the selected core would then be sensed by means of a third wire passing through all the cores.

My task was to test the memory, one bit at a time, by observing, on an oscilloscope, how each core reacted when it was selected. Although I performed this task carefully, my lack of enthusiasm must have been obvious.

The design team had an unusual organizational structure. It was headed by two people: a technical leader and a management leader, who, as far as I could tell, got along well. It was interesting to watch what happened when the management guy took a week's vacation: after a couple of days, the technical leader and the rest of the engineers slowly stopped working, waiting for the manager to come back.

In 1960, IBM became concerned that their computers were incompatible with each other (Bashe 1986). At that time, IBM was selling eight transistorized computers, six of which were incapable of executing programs written for the others. A year later, a companywide task force recommended that IBM create a family of compatible computers with the same architecture. This was the beginning of the IBM/360 computers.

It was also the end of the computers developed at Hursley. I was there the day a manager announced that the development of their small computer, called SCAMP, would be stopped. This was devastating for the engineers, who had put their whole effort and creativity into a project that went nowhere. Twenty years later, the same thing happened to me, when an American company built a multiprocessor to my specifications. But I am getting ahead of my story.

After seven weeks, my enjoyable summer at IBM came to an end. One of the managers wrote a report (Fig. 2.1) for IAESTE (International Association for the Exchange of Students for Technical Experience).

I returned to Denmark with the impression that I knew very little about computers, but would like to dedicate my career to these miraculous machines.

Employer's Report:

Name of Student: Brinch Hansen, Per
Period of practical experience in weeks: 7 weeks
Rate of payment per week: £7
Gross payment made to student: £50 8s. 0d.
Conduct: Excellent. Time-keeping: Good.
Observations on the student's general aptitude:
Worked on a variety of constructional and checking jobs. He showed himself to be a keen, intelligent, theoretician with a more limited aptitude for practical work.
Date: 7th November, 1961. Signature: (unreadable)
On behalf of IBM World Trade Laboratories (G.B.)

Figure 2.1 The IBM manager's report.

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As a student, I wrote my first technical article—about the exciting American inventions of the laser and the maser. Not that I felt competent to write about it, being only a student, and not a physicist. But, even though American technical magazines frequently mentioned the laser, and had done so for some years, nobody else in Denmark had written about it.

The laser is able to create light 100 million times stronger than the light on the surface on the sun. The maser, which emits microwaves instead of light, was used, in July 1962, to amplify the extremely weak signals from the first television satellite, Telstar.

In Niels Bohr's classic model of the atom, electrons orbit around a nucleus at discrete distances. When atoms absorb energy from their surroundings, electrons jump from inner orbits with low energy to outer orbits with higher energy. As the electrons fall back to their inner orbits, light is emitted in discrete amounts. This *spontaneous emission* of light is random and diffuse in nature. That's why you can only focus a flashlight beam at short distances.

In 1917, Einstein predicted that light emission could be increased dramatically by shining light of the right frequency on atoms. If the atoms start with a lot of electrons in their outer orbits, the presence of light starts a chain reaction, where some atoms emit light, which then stimulates the emission of light from other atoms, and so on, until all the atoms emit light at practically the same time.

The *stimulated emission* of light, which does not occur in nature, is the principle behind the laser. The laser uses an artificial, oblong ruby coated with silver at both ends. When the ruby is stimulated by light, it emits spontaneous light in all directions. The light that happens to be reflected from the ends of the ruby will travel back and forth numerous times, stimulating further light emission from the atoms. This creates a strong ray of red light, which is pencil-thin and remains focussed at enormous distances.

On May 1, 1962, the monthly magazine for Danish engineers, *Ingeniøren*, published my article on *Maser—a new amplifier element that makes communication at optical frequencies possible.* (I had not yet mastered the art of using titles of five words or less.) A professor of physics had been kind enough to check that my derivation of Einstein's laws of electromagnetic radiation was correct.

I was now invited to record a popular talk on the magic ruby for the Danish Broadcasting Service. Perhaps someone older, and more experienced than me, ought to have done it. On the other hand, I thought, this is my chance, and I can't afford to pass it up.

During the recording of my talk, I was nervous and kept talking, without breathing, until I had to stop and gasp for air. Fortunately, the radio technicians were able to remove this sound effect from the tape. On March 14, 1962, the Danish radio broadcast my program on *The Red Ray of the Ruby.* Notice the alliteration, as in "James Joyce" or "Buddy Bolden's Blues."

The editor of the science program was very enthusiastic about my manuscript. He called the editor of the popular science magazine, *Vor Viden* ("Our Knowledge") and encouraged him to print it. It appeared in print on May 31 and June 14, 1963.

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In the summer of 1962, our graduating class traveled abroad with a professor, visiting foreign companies and relaxing before final exams. The organizing committee consisted of Johannes Arboe Brøndum, Paul Waltenburg and me. Paul had spent two months in Yugoslavia as an international exchange student. His brother Carl had just married a woman, named Renata Stankovič, from Zagreb. So we decided to invite Professor Georg Bruun to accompany us on a graduation trip to Yugoslavia.

We traveled by train from Copenhagen to Munich, Germany, a twelve hour journey. Whenever we had to change trains, the forty students (or so) lined up on the platform with their luggage, while one of us ran ahead and found out where to go from there.

After another ten hours by train through Austria, we arrived after dark in Ljubljana, the capital of the Yugoslav republic Slovenia. At the railroad station, we were met by two female guides and driven in an ancient, dark bus to a student dormitory.

The next day, we were given a guided tour of a large manufacturing company, named Litostroj. Afterwards, we had the opportunity to ask questions of the management. I remember asking: "How much does a worker and a manager earn?" One of our guides translated the question into Slovene. When a manager responded to my question in Slovene, there was a brief discussion between the guide and the manager (still in Slovene). She finally translated the answer to my question. Later, she explained to me: "When the manager first answered your question, I told him, it will leave a bad impression on these foreigners, if we tell them how much a manager makes." After some discussion, they agreed among themselves that perhaps the figures ought to be lowered. Their final answer turned out to be much lower than anything I knew from Denmark.

On the third day, we traveled by bus to the famous Postojna caves, south of Ljubljana. A local tourist guide showed us a small white salamander that lived in the caves. In heavily accented English, he explained: "The human feesh, it valks on de ground and svims in de vater."

I now had a chance to look more closely at one of our tourist guides from Ljubljana. She was a small blonde woman, with the figure of a model, walking elegantly in high heeled shoes with a deliberate little twist of the instep. Her name was Milena Hrastar. She had a master's degree in English and German from the University of Ljubljana. During the summer, she worked as a tourist guide for foreign students. On our last evening in Ljubljana, I invited her out for dinner at restaurant "Rio."

The next morning, all of us left Ljubljana and took the train to Belgrade, the capital of Yugoslavia. However, it was not Milena, but another guide, named Zorka, who accompanied us.

In Belgrade we visited the wrong factory, a small place that produced loudspeakers. The manager quickly recovered from his surprise and gracefully gave us a tour of the factory. When we left, professor Bruun said: "That was today's visit. The rest of the afternoon is off." My friends went to a large outdoor swimming pool, while I walked around Belgrade on my own. I remember a poor neighborhood, where a Turk in baggy, black pants was walking with a barrel on his shoulders.

From Belgrade we flew to Dubrovnik, on the Adriatic coast. This is the most beautiful city I have ever seen. Inside the walls, which surround this medieval city completely, cars were not allowed. In the evening, the only sounds you heard on the main street, were the shuffling of feet on the marble sidewalk, and voices echoing from the white sandstone houses.

Further north, in Split, I remember sitting in an outdoor cafe in the middle of the ruins of the palace of the Roman emperor Diocletian. The emperor retired to this palace on the Dalmatian coast in 305. I found it charming that the modern inhabitants stretched clotheslines between the antique columns and the nearby apartment buildings.

On the train to Belgrade, I discovered that I had forgotten my raincoat in Ljubljana. That gave me an excuse to leave my friends in Zagreb, a couple of days later, and take the morning train back to Ljubljana, where Milena was waiting with my coat. We spent the afternoon together. After a nice dinner at restaurant Šestica, we walked through the quiet, rainy streets to the railroad station. The evening train from Zagreb to Munich had already arrived at the station, and my friends were anxiously waiting for me to turn up before the train left. They were all standing at the windows cheering when I kissed Milena goodbye. My friends teased me, as I walked through the train looking for my luggage (which they had taken care of). As we approached Austria, the dark flat country of Slovenia changed into the rocky silhouettes of the Julian Alps.

Back in Munich, I had two hours to eat breakfast, buy cigars, and send Milena a postcard. Then the long train ride through Germany. In Hamburg: another card for Milena, and, early in the morning, back in Copenhagen and pretty tired.

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In the last year of my education, my professional goals became much clearer to me. I was very interested in the construction of computers. The few available books, I had read, looked at computer design from the point of view of an electronic engineer. These books explained the electronic design of switching circuits, arithmetic units, memories and peripheral devices.[2]

And then I read a completely different book that described computer organization from a programmer's point of view.[3] It was a revelation to me.

Project Stretch was an experimental supercomputer designed by IBM in the late 1950s. Although it was a commercial failure, this ambitious effort was a milestone in computing. The Stretch designers introduced the term *computer architecture* to describe the functional aspects of a computer that are of interest to programmers only. These aspects are independent of the underlaying electronic circuit technology.

I had never before seen a reasoned essay on the choice of a character set. In the 1960s, this was a problem of considerable practical importance in computing. Inside a computer, the letters of the alphabet are represented by numbers, as are the digits and special characters. The trouble was that different computers used different character codes. In order to process text, output by one computer, on another computer, you first had to replace each character code by a different one. The problem of character incompatibility would disappear in the late 1960s, when computer manufacturers adopted the ASCII character set, which is now standard on all computers.

The Stretch book discussed other general issues in computer architecture: Should computer arithmetic be decimal or binary? How should computer

[2]My own book collection included A. P. Speiser, *Digitale Rechenanlagen*, 1961; and H. D. Huskey and G. A. Korn, *Computer Handbook*, 1962.

[3]W. Buchholz, *Planning a Computer System: Project Stretch*, 1962.

instructions address their data operands? How can program execution continue during input/output operations? How can a computer execute several programs at the same time?

I knew I wanted, someday, to be able to understand this book completely and become a computer architect.