Lausanne, Switzerland
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Jean-Daniel Nicoud

An interview conducted by
Peter Asaro

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Q: Okay. So we'll start just asking you to tell us where you were born, and where you grew up and went to school.

Jean-Daniel Nicoud: Okay, yes, so my name is Jean-Daniel Nicoud. And I was born in Lausanne, and I stayed in Lausanne for my study. I did, let's see, Ecole Polytechnique, the study of physics, and I was – my intention was to be professor of physic. And I like very much experimentation, and physic is a way to make wonderful experience and building special devices to better explain physic. So after my study, I went to a college, but the situation in that college is the professor of physic was using all the lessons, and I couldn't teach physic. So I get interested in electronics, and I was – I had been fascinated years before by the robot of Gray Walker. And so when I had time to teach, and I finished my studies, I built this robot, clearly inspired from Gray Walker, with the technology I knew. I had been playing with planes, and it was the very first radio-controlled plane. We had difficulty to control, and I was looking for tricks to get several channels from one channel with gears. Okay, but anyway, and you see the logic with telephone relays, and the motor which was the driver and the direction. Okay, so this was my discovery of relay logic. And then as soon as I got transistors, it was more interesting to study logic by itself, and start to do a calculator. So I spent – I came back to the Ecole Polytechnique to study calculators. And then there were the first minicomputers, and a project in teaching with minicomputers, then microprocessors. I designed my own micro personal computers. Nobody knows it, but in '74 I was at Digital Equipment, I built personal computer for them, but as you know, they didn't believe – the big person didn't believe in personal computers. But anyway, I came back to Lausanne. I built six personal computers for Digital Equipment. In – yes, it was '75, '76. And then I had my own family of personal computers, so you can look on the website.

And then in the '90, there was no more interesting things to study with personal computers. The market was coming with all kind of machine, so I directed my team toward robots. We're the first robot contest, like at MIT. And one of the first designed was the c robot, which it was in '91, '92, you can take the picture here. And the cyclop robot is named cyclop, because it has one linear camera, and with a small lamp behind. It was very funny to have all these robot following each other and losing quickly control, of course. But this one already had HC-11. So it was a lot of fun to program, and to have the students doing contest with this, etcetera. And of course, I was fascinated by small things from early on. And the project, I asked student was to make a five centimeter robot in a modular way. And you know, the problem with robots, you need a power supply, you need a motor. And every time things are moving a little bit, you get new battery, you get new motors. So the constraint here was these very poor batteries. The two motors with a gear was justifiable from Porter's Cup (sp?). So this was acceptable to have the wheels not exactly well-positioned. And so this was named Cafer, which is an ugly word in French. So the processor here in this direct is an HC-11. And this was in '71, student project. And from this Francesco Mondada redesigned everything. The technician made a special motor, so it was more compact. We had better battery, etcetera. So Francesco Mondada really make a wonderful adventure with this. But I had invented the name of Khepera, and the name of Cartene, so it was a good stuff.

So now when you talk about small robots, one kind of motor of interest is the stepping motor. And these are the kind of motors you find in all cars for moving the needles. And they are made from – develop by watchmakers. And they just have enough power to move a robot. And of course, the advantage, if you have a stepping motor, it's very precise. You can do exactly the kind of movement you have. Here it was a basic stamp as a processor. And of course, the battery – I hate batteries, especially the nine-volt, but this was a way of doing this. And okay, now you can imagine the different architecture, if you want to have it floating, maybe, or here this one was an idea to go in the sand and be able to move with all kinds of obstacles, so this was not finished. But it was already – there was another project in another lab, that's why I didn't continue this one. And now, okay, so this was another design with the stepping motors. The circuit board flex-around, there's a hole for a pen. And with a lithium polymer, this was the very first lithium polymer, it's possible to get a lot of power, which, of course, solved many problems in robotics. So there was only distance sensors with infrared. But anyway, and I like very much magnets to bring the power, make a small noise. But you see the lights, and now I just have to depress and make a demonstration of it. And I just turned the magnet in the other sense to – no power-on switch. Okay, so now the interest by that time in '95, '96, or even earlier, there were these contest in Japan for one cubic inch, and one cubic centimeter robot. Well, it was named robot, but they were just moving in the maze, and avoiding obstacle while following the maze either with mechanical constraints or with sensors. And the robots are in another lab. But it was a lot of constraint.

In one cubic inch, it was possible to put a battery and have the two motors, have the wheels, etcetera. We make two or three design with it. With one cubic centimeter, we had another design with Swiss motor, and gear box, and wheels, etcetera. But of course, no possibility to put the battery. This design was a research project, not done in my lab, because the wheels include piezoelectric motor. So all the central is empty. It's really two wheels, and okay. But of course, the electronic outside is rather complicated and cannot be put together and especially with a battery. But okay. This was helping to understand the limit of the technology. And still some people are dreaming about very small robots that can do useful work in our bodies, surgical work. But we do not have the correct power supply. So this is a toy, but it's a nice design. It use lithium polymer accumulator. It used two motors. And the problem with electric motors, they spin very fast. So either you put gears, or you put a very, very small wheel, which is the option I've taken here. And so I do not have the ground to make a demonstration, but it spin very, very fast on itself. And the interest of the electronic control, we can take another picture on the table after if you want. There's a microprocessor, of course. Microcontrollers are very, very small, and it's no limitation now to do a lot of things. And okay, that's all. The difficulties, even like these motor are spinning too fast, so that by software you can make them as slow as you want, as long as you have some torque.

So this is what, I have a small company now and I try to encourage kids to invent their own robots, and of course, it's – well the technology is easy, you can buy cheap microprocessor, you can buy a lot of cards, you can find motors, you can find everything which was difficult to

find five years, or ten years ago. But unhappily kids have different interests now and it's very difficult to motivate them spending time on one subject. We are solicited by so many things on internet. They try to do everything, and they do nothing. Or very few do something. Okay, so this is basically my story.

Q: Okay, well, let's go back to the first robot that you had. And when did you build that, and when did you first come into Gray Walter's tortoises, or come to know about them? And what motivated you to build –

Jean-Daniel Nicoud: Okay, Gray Walter, there was this paper in *Scientific American* in '50, '55, I do not remember exactly. And of course, this was something every young kids was dreaming about. You know, they dream about too complex things. We were dreaming also about something that was too complex for this day with all the electronic inside, radio tube. And of course, this was what I was able to do with the technology I had. It was the very first printed circuit board I made. Very naïve, very primitive. One sided, no hole, no thru-hole, etcetera. And of course, the next step was to develop the technology, get the manufacturers and with microprocessors, I do not want to tell the story of all my microprocessors. You can see it on microdot-CH.

Q: So this was 1965?

Jean-Daniel Nicoud: This was in '65, yes

Q: Yeah. And were you –

Jean-Daniel Nicoud: And then I came back to the Ecole Polytechnique two years later, I finished my thesis in '69.

Q: Now did your thesis draw on this?

Jean-Daniel Nicoud: Sorry?

Q: Was your thesis about this?

Jean-Daniel Nicoud: No, no, not at all. No, my –

Q: This was just a project on the side.

Jean-Daniel Nicoud: This was just a very – no, no. Because as soon as I was back at Ecole Polytechnique, I had possibility to develop things with better technology. And I invented the logical setup or the teaching equipment. We developed calculators. Okay, so that's another story, huh?

Q: Yeah, yeah. What was your –?

Jean-Daniel Nicoud: Very proud to make a big calculator for operation, make it smaller, smaller. And then everything was in one single integrated circuit, and it was no more game. But the microcontroller came.

Q: It was a physics thesis?

Jean-Daniel Nicoud: No, it was about decimal to binary conversion and relays. And I studied all the possible algorithms, and showed the hardware implementation. It was a time where we were not yet sure if computers should calculate in decimal or calculate in binary. But anyway, we needed some conversion, and so I think I studied all the possibilities to do it.

Q: And when you came back to Lausanne, was it an engineering department that you joined?

Jean-Daniel Nicoud: No, it was the electrical engineering department, which was five, six professor by that time. And in my study about – I had two – one hour about logic system, as an example of electronics and half the semester was on the radio schematic. And only one hour on logic functions with transistors. And maybe two hours on transistors only.

Q: And when you were working with DEC, were you still on the faculty here, or did you leave for a while to go work on this personal computers with digital?

Jean-Daniel Nicoud: Okay, well, I mentioned that I was teaching in school. And of course, still being at that school, I built a calculator with the first integrated circuits that were viable, but it was still RTL logic, not yet TTL, if you know, and plenty of transistors. But it was a very nice machine. And then as soon – I did my thesis in parallel, and then having – I finished my thesis being full-time assistant at Ecole Polytechnique. And I very quickly had students doing work with me, project for making a very small calculator, and even starting a design with an integrated

circuit being done at Neuchâtel. But we were very, very slow compared to the Japanese, and we had to stop all these projects.

Q: And so where did you get the integrated circuits from? You said Neuchâtel, was that a private company there? Or other researchers you were working with?

Jean-Daniel Nicoud: Well, the integrated circuit were just the standard integrated circuit from US, from Texas Instrument. We had distributors there. But really the beginning of my story, but it's not directly related with your concern is Bosch which is a very large company in Switzerland now still working. They had started to do transistors in, oh, well, in '60 – because in '66, '65? '65. In '65, Bosch decided to stop the manufacturing of transistors, because there was no future. And I got 1,000 transistor in a plastic bag. They were very small transistors, very nice, perfect for me. So I use these transistors to do this calculator I was mentioning. And to do a lot of logic block, to study logic. I gave a course – a free course at a school. And okay, that was really my possibility to do something really interesting because with relay you cannot go very far. And with the Ecole Polytechnique environment with all the time I had to spend on this, we really did – and I got excellent students. One of these students, I've been working a lot with transistors by that time made the success of Logitech. Because he was very smart for everything about logic. Saving power, etcetera and he worked for Logitech and made the success. So Daniel Borel made the commercial success, but this guy made the technical success. And you need to have a product which competes, because if Logitech has progressed so quickly, it's because they had really good – better product than the competitors.

Q: What was his name?

Jean-Daniel Nicoud: René Sommer. But he died one year ago, unhappily, and so that's one of my reason I still try to attract young people, because we need young – very young people. They have to start very early to get the experience, and you need a lot of experience, unless you are in a big company with very specialized engineers, and but okay.

Q: So during the early '70s, was there anybody else working on robotics at EPFL? Or other kinds of electric-controlled machinery?

Jean-Daniel Nicoud: Nobody was considered about mobile robots. And Professor Burgard, he was trying. I was not in contact with these people, you see, I was in the electronic department. And the mechanical department built up micro-engineering with Professor Burgard But he was very concerned about optical system, making small mechanical system. But nothing in the direction of mobile robots. And then Clavel invented the Delta robots. And of course, everything was in the direction of the Delta, and these two professors, by the time they had a team of two,

three person. So with my contact, natural contact, I had rather quickly a team of ten people when it was only '95, '96 that I had 30 people, about, to work on robotics. Robotics. What was really a possibility to make a lot of research in many directions. And with personal computers, of course, it was quite interesting. And the company was taking our prototype to make them a product with usually a former assistant, former PhD students of me.

So it was a very funny period, because everything was growing. And the motivation to study robots was – I still was searching something better than the computers. And neural networks by that time was something we believed in. We had to study neural networks. And an application, a very nice application of neural networks to see if they can do something useful were robots, of course. So you can try to park a car and do some music with neural networks. But I got several research project in saying we intend to apply neural network in robotic mechanism, in general. So and people like Francesco Mondada, before going in the Khepera, he was playing with a kind of a Delta arm, doing juggling, analyzing shape for the camera, and we searched hardware architecture for neural networks. We made a special integrated circuit, and special architecture for this. It was also two, three, four thesis.

Q: And were those successful? Or were you able to get good performance from the hardware?

Jean-Daniel Nicoud: Well, everything you built in hardware is obsolete after two years. Because of the Moore Law. So you should restart and restart and restart, and of course, we can do the first step, because the next step imply an investment in technology, which is much higher. So most of our project were first steps. And with the Khepera was a very good product, because once we had this hardware with a very powerful processor. And the possibility to add to that, depending on the application. We could make plenty of thesis related to the behavior of robots to, well, you know, all what I have done – ach, sometime the name – Dario Floreano. So this was genetic algorithm with also direction. So that's why I ask Dario to come in my lab. And he was – you see, I was a very bad researcher myself. But I wanted to go forward and I was attracting good people to go in these directions. That's why now I'm surprised myself that I've five professor here which made a PhD or post-doc in my lab. And but I was just giving them the freedom and the money they needed to do their research, and okay, so I think that's what most professors should do instead of – some professor, they try to be the big boss, and the other just servants. Which I think is not a good way to go, unless you are really, really smart. But when you are not smart, you have to find other people being smart.

Q: So many questions, I don't know where to begin. So who were some of your early graduate students? When did Francesco start working with you?

Jean-Daniel Nicoud: Francesco, it was in the '90s. And before him, they were just making a project and building something. There was a very nice vacuum cleaner project. But it didn't stay

in the lab. It went to Zurich and then to US. No, Francesco really was a key guy interacting with everybody. And then Martinoli was also – well, I try to think to the people who influence other students and build their own group. So Martinoli, he's around, if you want to see him. And Dario, of course, made plenty of project with a lot of people. And, oh, they spend a little bit of time in my lab, but with,.. okay they had also plenty of ideas. But they – this, you see, in '97 I had to stop all my projects <laughs>, which is very hard, but anyway everything was – because my lab went to a different direction with the – I still, well, it's too complicated to explain and not of your concern. But one great thing, which you should mention, is I had a technician, André Guignard, who made the mechanical design of the mouse, which was copied as long as mechanical mouse were built. It was André Guignard's mouse and he made all my small robots. He really worked with everybody to have mechanical things which were perfect. And he's still working because – he retired five years ago, but, happily, he's still working. You can meet him.

And <laughs> working with Aude Billard, he has built the Salamandra. He has built – well, he's paid now by Francesco Mondada on a industrial project. So I think we – if we got two good results in that school, it's, I think, because the structure of the school allowed to have technician which stay for a long time and you need to have – well, Francesco went to industry very quickly, so that's good. But I have another good student who stayed in the lab and interact with everybody. The professor doesn't usually have enough time to interact with everybody. And anyway you need to be several people to interact in a group and not only one. So in U.S. I've seen wonderful projects made by PhD students, but then the PhD leave and everything is in a corner and the next PhD have to re-invent everything. If you have some permanent person, they transfer the knowledge more easily. And Guignard was one of these guy who's transferring the knowledge and building also things in addition, keeping the experience and allowing PhD students to really use the best technology, and do not lose their time buying small tools and doing things by themselves <laughs> in a dirty way.

Q: Yeah. So where did you get most of the funding over the years for your research projects?

Jean-Daniel Nicoud: Oh, the Swiss government has a research-funding organization and there was a very good applied research funding – well, we have the strictly research funding, we have the applied research funding and we have funding where the company – we work with a company and the company pay half of the expense. But for the company it's not so expensive, I would say, because they say, "Okay, we will put an engineer – one of our engineer working on this project," and they pay him very expensive and he doesn't work so much <laughs>, etcetera. So we were in this industrial project – we were doing most of the work. But, anyway, for us it was very interesting. It was real project and we had money and possibility to interact the Logitech mouse with a sphere, with dots, with one of these projects, for instance. In robotics – I do not remember about that because there were so few people working on mobile robot in industry. But we had a project on sensor so it's not – okay, okay. I do not remember everything, but it was half of my – I had, at least, ten people paid by the school, eh? So this was very easy

money. And the twenty other were research project and very quickly people, like Dario Floreano, they were themselves doing the project, getting the money. I was just signing and it was easy.

Q: So what was the motivation to build the first small robots, the five-centimeter? You said it was a student assignment. But why chose small robots before sort of working with big robots and middle-sized?

Jean-Daniel Nicoud: <sighs, laughs> I'm just fascinated by what is small. I know some people, they like what is big, what is noisy, etcetera. I always have liked to make it as small as possible. And with my company, the first project was to build a five-gram plane when everybody <laughs> was mastering that technology. And it was Jean-Christophe Zufferey who made me see this with a flying robot in a room. And flying in a small room like this mean you cannot go fast. If you cannot go fast, you need large wings and very light weight. So it's interesting to study the battery, the propeller, the motors, etcetera. It was a very good thesis I build. <laughs> But – and you see with these small robot – okay, if I could make it smaller – I don't like flying when it's large. <laughs>

Q: <laughs> So when did you start the company initially? And was that the same company that was doing the PCs or was the robotics company a separate company?

Jean-Daniel Nicoud: The name of the company is DIDEL. So DIDEL is from *didactiques électroniques*. And the first letterhead I have is in '71 <laughs>. Because in '71 I had finished my thesis and I was interested to get or to stay as professor, but I was not at all <laughs> sure to be appointed as professor. So I develop a lot of industrial contact because I was expert in integrated circuit and digital design. By that time it's the kind of design I make with integrated circuit – the telephone responder. Well, I had a lot of contact with – the industry was asking for this because they knew it was moving in that direction. Okay, so I was ready to build my company. <laughs> And I always have been disappointed <laughs> to see that I was a professor because – and I made, you see, most of my project was very application-oriented because of that kind of industrial mind. And so I keep it at EPFL for two years in advance at sixty-two and I wanted to see if I was good for building a company.

But, of course, the situation was different because if you are young, if you have family, you push very hard and by that time probably I could have done – <sighs> oh, I'm not sure I would have done a good company, because at least for the last ten years I've developed quite interesting things. I still have ideas, but of course I have to restrain these ideas to what I can do by myself because I do not want to grow. I do not want – this the era – I'm alone in that company and my idea was to stay alone. And, of course, you cannot build a company being alone. <laughs> You need to be two or three with complementary ideas, comple – interests, etcetera. So now it's a complete failure but – because I'm not interested to sell. So the good – if

you're interested to this <laughs> – but it's very quickly said: I was interested in doing these small planes, ultra-light and small robots. I needed small motors. These motors, they do exist – for pager motors – but I needed gears for these motors and I invested with people in China to get the good gears for my application and now I get the money which allow me to survive – well, to pay for the things from the gears I'm still selling. You need plastic gears of modular 02 or modular 03? I have them.

Q: <laughs>

Jean-Daniel Nicoud: And I've been selling. So this is also an interesting business for me because if I sell ten gears to a U.S. university, to a PhD or a researcher, I prefer this than selling one thousand gears to a company I do not know what they will do with it. So, no, it's amazing because two or three years ago I had a lot of contact with U.S. Now I've many more contact with Korea and less Japan. It's Korea and China, which is beginning to ask for my components. And, of course, big industry they invest in the gears they need and do not work like this. But –

Q: And the motors, they're Swiss motors, right?

Jean-Daniel Nicoud: No, because – no, even these were not Swiss motor. Here you can see a gear and I have slotted gears with a – sorry, you want to –

Q: <laughs>

Jean-Daniel Nicoud: –slotted gears to have an encoder. The encoder is from mice – Logitech give me a lot of mice encoders to make and I made the special gears. And Swiss motors are too expensive. It's wonderful, but not only they are too expensive, but they are designed for industrial application with higher voltage. And if you need two- three-volt motors there's little choice with Swiss motors. But all the pager motors, they are quite efficient, quite good, and so cheap that <laughs> I can buy a lot and sell them to researcher also at low price. Okay.

Q: And the idea to make it modular so that you can plug in different turrets and things like that. So when did that come about? When did you start working on that idea? What motivated that?

Jean-Daniel Nicoud: Yes, also, it's a kind of a personal attraction. I've always liked what is modular. And when I started to understand electronics I made small module with wires connecting there. You don't know what it is, but it was really a very good teaching tool for understanding logic, logic circuit, with advantage that you assemble your block and you can very easily change the schematic and test different solution. And then once you have well understood,

you make a PC board and you go to production. And now, recently, that is one year ago, I've started to develop module for teaching C language, understanding real embedded system – programming embedded system in C. And what everybody's do is they take a big board, they put full of LEDs and switches and the connectors. And I prefer to have something modular because you have the processor, you would have a clear identification of the processor and its bases, its input-output ports, and then you connect a dedicated board, which allow to study an application and test different way of programming that application, like a small elevator, for instance.

And, okay, it's my pedagogical approach, which <laughs> – well now, I should try to make some promotional papers about this. But, of course, now – several years ago I was doing all my documentation in English and since my contact was mostly with local people, now I do all my documentation in French. Because it's more easy for me, first, and the day somebody abroad is interested in what I do, it's so easy to translate technical French to technical English, compared to all the investment of improving the hardware, improving the documentation so it match the mind of the – I would like very much to touch kids at twelve. Forty years ago – well. With the first personal computer, the first Smaky – this was in the 80s in in the 80. I was opening my lab on Wednesday afternoon, when the kids are free and I had ten, twenty young guy coming, typing on the keyboard. They were quite free to do what they wanted. And I got very good students later from these kids indeed. <laughs> But apparently now it doesn't work the same. <laughs>

Q: Hm.

Jean-Daniel Nicoud: Okay, but, well. But I still have very good contact with people who have experience all that story of personal computers getting more complex, etcetera, and we meet and talk about new design, new robots and things like that.

Q: Well, and here at EPFL, there's a lot more people now who are working on robotics, right? So there's new labs and professors. So over that time period that you've been here, how has that evolved? And have they mostly come from your lab and become professors, or has the university decided that they want to bring in other kinds of roboticists and develop that as a specialization of this institution?

Jean-Daniel Nicoud: Well, I understand two questions. One, <breaks in recording> two made project with robots, what did they do later? <laughs>

Q: Yeah, yeah. That's bigger question, but –

Jean-Daniel Nicoud: Okay.

Q: Yeah.

Jean-Daniel Nicoud: And, well, it's difficult <laughs> to be global –

<overlapping conversation>

Jean-Daniel Nicoud: – but I would say that I've influenced this professor who was still around here. But '95, '96 Professor Siegwart came here. And you have heard about him, etcetera. And, of course, all the robotic interest went to Siegwart because I had no future. It was clear that I had to leave at year 2000 then all the – and there was a big exhibition in Switzerland and where there was a House for Robot – how do you say? Not a *bourse* – there was a wonderful experien – exhibition with robots. And, of course, all that effort was done with Siegwart. And all these people who did the project, the thesis with Siegwart, they continue and went to industry, build their own industry like "BlueBotics" and – Khartim [sp?] had some problem. But, anyway, I would say that Siegwart influence a lot of people to stay in robotic activity. And maybe I influence more to stay in the academic <laughs> kind of activity. But, anyway, Khartim was really – and by that time of Khartim very few – there were very few start-up. Now, you have to do a start-up to show that you are smart. <laughs>

Q: <laughs>

Jean-Daniel Nicoud: But by that time, it was not so easy to do a start-up: a lot of paperwork, explanations – and the worse with the personal computer, the Smaky, I designed because my wife made a business with this, with former students, and people in the industry couldn't understand that my wife was doing the work. It was me who was <laughs> using EPFL to do the research, using my salary to do the business with the Smaky <laughs> and not teaching my students. It's amazing how mentalities have changed and it's happy that they have changed because now it's – I see Jean-Christophe Zufferey who made the flying robot. He spend a lot of time and now he has a company, a start-up. So he was really encouraged to spend time preparing his start-up.

Q: Was that the five-gram flying robot, or was that a different flying robot?

Jean-Daniel Nicoud: No, my structure – the structure – the accumulator, the propeller, the motor was five-gram. And Jean-Christophe added five grams <laughs> of radio sensors, speed control, etcetera, transmission, so he could see exactly what was happening. And I had enough power for ten grams, because I wanted to have something which was acrobatics. So with five grams I was able to do almost vertical flight. And so with ten gram it was staying almost horizontal and avoiding the obstacles.

Q: And when was that?

Jean-Daniel Nicoud: This was three years ago.

Q: Oh.

Jean-Daniel Nicoud: Three years ago and then – this – there was – nobody's doing five-gram planes anymore <laughs> because the situation is with better battery, which still progressed. And with the motor, which saw brushless and brush motors, you get so much power that you can build a twenty-gram plane and you can do anything in the twenty-gram range. So all the commercial product are twenty grams. Personally, I've no interest to do what everybody else is doing. <laughs> So I've stopped these kind of activities and also I've difficulty to make robot which are really better than what other people are doing. I'm back now to educational constraints, trying to help people to build their own "stupid robots", between brackets, instead of my – well, let's see. This was something which is not completely stupid. I put a display – so the exercise is not only to avoid obstacle, because you build any kind of – you see any kind of robot now, it do exactly the same than twenty years ago. The sensors are maybe slightly smaller. This was twenty years ago. And we already have the infrared sensor, the camera, and I cannot do something really better now. So if you have a laser beam – but it's a five-kilogram robot immediately if you have a laser beam. <laughs> And what is interesting, you get all the cleaning robots; they do things which are very difficult to copy. So, well, here the idea was to <electronic sounds> put a display. Of course, I do not have a lot of power, but – well, a Swiss cross, at least.

Q: <laughs> So in that time – I mean <bells sounding> within this size-frame or – not a lot's been done, but there's been big advances in batteries, for instance.

Jean-Daniel Nicoud: Yeah.

Q: But also different kinds of sensors, but I guess they're big sensors. But LEDs, too, have improved significantly.

Jean-Daniel Nicoud: Yes, things improve but these accelerometers is the only real real progress, and, of course, it's in iPad. How do you pronounce "iPad" in English? "Ee-pad" or "eye-pad"?

Q: "Eye-pad".

Jean-Daniel Nicoud: "Eye-pad"? Okay. Okay, but, again, it's not specially for robots.

Q: No. What about the microprocessors or the kind of control that you can program them with? That's developed.

Jean-Daniel Nicoud: Well, it depend on the application. So I like very much to work with a sixteen-bit microprocessors. <laughs> But if you need a larger one, okay. The idea was a kit. People had to solder the components and learn – I'm changing a little bit my mind because if I say to people, "You have to buy a soldering iron first," they say, "No, I'm not interested." They've no space at home. They have no motivation to do things by themselves, especially young one. Those who made it – okay. Now I do not have all my idea here, but – well, this one is important. Well, this one aspect is that really was <laughs> – I'm not sure if you have something similar in U.S., but in Europe there is – we have "Astérix and Obélix", which are Gaulois people living in France, Roman-time. One is fall – <laughs> He fall in the – no, I cannot translate it. <laughs>

Q: <laughs>

Jean-Daniel Nicoud: But you should have the equivalent in U.S.: Some people they are special because from always they try to do things and they succeed in doing things and where we say in French, "*Qu'ils sont tombés dans la magie*." They fall in the magic bottle and due to this <laughs> everything is magic with them.

Q: <laughs> Charmed.

Jean-Daniel Nicoud: *Alors, tombé dans la marmite* [So, falling into the potion cauldron] and now, you see, I still continue to try to invent things and interact till tomorrow. But I've only five, six people <sigh> between forty and sixty who come to follow a course on C. We're using my logic modules. And I would like to have contact with young people. Francesco is a great success with his festival, but all these guys, they come for a spectacle. Uh? I was very disappointed after the first one, because they all say – all these kids say, "I would like to do robotics," <laughs> but they are not ready to buy a soldering iron first and build some small kits and learn. It takes time and usually when we remember thirty years ago <laughs> with enthusiasm of these young kids – okay. But continue to ask your question, because –

Q: What about the Lego robots? I mean – those are more just programming, but they also sort of build it. It's a kind of a way to get them involved.

Jean-Daniel Nicoud: Okay, okay. No, no. I'm quite positive about Lego. But I'm an inventor, I'm not a buyer. So if something exists, okay. I will criticize it a little bit because it's too expensive. But if you take the Lego – if you take the new robot from Francesco – it has a strange

name, which I do not come by <laughs>. He has a wonderful robot with a software support at a level where you can write the behavior, develop the behavior of the robot, plenty of LEDs and accelerator, plenty of application. Wonderful. But both these tools you come to an end where you cannot do anything more, because you cannot work inside. You cannot change the parameters, you cannot build your own brick in Lego. You cannot add memory and the things. So I position myself by saying, "If you learn to do C, if you learn to do bread board, you can do everything. It's – the limitation is your intelligence and not the intelligence of <laughs> a toy manufacturer." So that's why I would like to propose – how do you say? A set of robots – well, I have a rather successful robot, which I didn't bring. It just larger than the very small mouse-like robot, which 2000 have been sold as kits in the festival, in holiday activities, etcetera. So it's, I think, a reasonably good result for the French part of Switzerland. Because the French part of Switzerland is one million person. This is, of course, my big problem to have a company who sell other places. Because in U.S. you have twenty million. Or two hundred million. You make a little bit of publicity, you're sure to sell one thousand pieces. But here in the French part – and France is very protective; Italy, it's a different language; German Switzerland is a different language. So. <laughs> Okay, but back to what I was trying to say – I do not remember. I'm sorry – I get tired.

Q: That's okay. Well, I thought it was a good point about being able to really create systems –

<overlapping conversation>

Jean-Daniel Nicoud: Okay, okay. We was talking about Lego and all the – what exists on the market.

Q: –programs and solders.

Jean-Daniel Nicoud: Exactly. Exactly. So Arduino, if you know, is something good so people can start with it and – well, what I'm doing now is in Pinguino but it's a similar product, except that Arduino is hiding things which, I think, prevent to really understand the microcontroller, which is below.

Q: Hm. Even though it's open source, it's got some hidden elements?

Jean-Daniel Nicoud: It has to be open source today, because – and well documented. So I try to improve the documentation so people really understand. Because I was mentioning Arduino; people are impressed because there are plenty of hardware, plenty of libraries, but what is important is to have one hardware that you understand and a library you can modify and understand. So people are impressed because they see publicity and there are plenty of forums

mentioning things, but you see a forum – the questions are completely stupid. People do not understand usually. Okay, but anyway. This is what I'm trying to do. <laughs>

Q: <laughs> I'm still fascinated by your original 1965 robot. So what did it actually do? So it has a light sensor and it follows the light like the tortoise, or it's got some bump sensors?

Jean-Daniel Nicoud: Well, <laughs> apparently because I'm discovering, myself.

Q: <laughs>

Jean-Daniel Nicoud: It was in a corner, I say, "Okay. That could be fine to show if they are concerned about the history of robotics." So the motor was already a kind of brush – no, no. Okay. This mechanism to have the motor, which give the motion and the direction, is rather simple for robot. If you see, I have photo-sensors and the lamp. So with this I can follow a track, which is still a typical application of toy robots. So it didn't change in almost fifty years. And I wish also to avoid obstacles. So, again, if you want to do something – so by that time, we had no way to measure distance. We could follow – we had the first – well, <laughs> for the photo-sensors we were using germanium transistors, which were inside a glass and black paint. And by removing the black paint we had a transistor that was sensitive to the light. The efficiency was not as good, but with a good infrared lamp like this, it was possible to do something. And then, apparently, I see that I have some switches here to probably detect when I'm in the center. I must have also some limit of angle position. So with this digital information and getting a digital information from this – I do not see an electronic board, but – okay. I do not remember everything.

Q: <laughs>

Jean-Daniel Nicoud: But at least with a relay I was able to avoid the work of – oh, I do not remember.

Q: Did it do the sort of scanning behavior like the tortoise? That was kind of – it actually kind of swirled around on its front wheel, Grey Walter's version of the tortoise.

Jean-Daniel Nicoud: Apparently, I do not have the good sensors, but with the end switches I was able to scan.

Q: Yeah.

Jean-Daniel Nicoud: And if the light is in the good direction, I could probably. But I build the hardware. I would – I didn't really <laughs> make it work as well as Grey Walter because I was more concerned about using the relay to do logic and then using the transistors. As soon as you have transistors, of course, you do arithmetic units and you can go to the complexity. I built either a set of small modules and I built – it was on a table – a kind of calculator and what was amazing is that it was making music because I put some resistor to get from the digital – some digital system, the digital logic – to go to something that was changing the frequency. And for making a division, it work for five seconds playing the melody of the division <laughs> because the division is a sequence of subtraction, correction, etcetera. <bells sounding> I was studying all these algorithms by that time and, okay, that was the kind of – many people who saw this still mention this calculator was making music while calculating. That was funny.

Q: And what's your recollection of the first kind of robotics conference or meeting that was specifically on robotics that you went to?

Jean-Daniel Nicoud: Hm. Well, I remember even in Trento because I was very – it was really the very first one – conference – dedicated on robotics and –

Q: So tell me about that? When was that and who did you see there?

Jean-Daniel Nicoud: It was in – well, hm. I was showing – well, it was in '91, something like '91. Yes, about sure: '91. I search on Internet but I couldn't find exactly the reference to that conference. But I saw in a publication from last year, if I remember well, that he was mentioning the paper he had presented it at Ivano Trento. It was in '91 and it correspond – usually my technician was putting the dates. Well, November '92. Okay, so maybe it was '93, because I remember these were the robots I brought it to Ivano Trento where – in the case; I kept them carefully. But not working; I do not have the battery pack anyway. In '93 then, Fukuda was organizing these micro-robot contests. This was – well, apparently it went very quickly because it exploded interest in – mobile robot exploded. All the work of Rodney Brooks was widely published and it's easy to see from the publication of Rodney Brooks what the small robots he was building. And it was the time in '92 where the PC was getting so cheap there was no more interest to work on the architecture with the new microprocessors. And so the Khepera came – well, the Capri – well, not the Khepera. This one is mention '91. But it took probably two years before. Francesco will give you – will say exactly when he started. And there was – as soon we had enough Khepera to make collective behaviors, this was fascinating. We had plenty of interesting projects and just making the robot learning to avoid the walls with Dario. That was really something. Well, I see –

Q: Did you have other collaborations with labs outside of your own or in Switzerland or around Europe or Asia or the U.S.?

Jean-Daniel Nicoud: I was visiting people as frequently as I could. So I've been several times to Japan, to U.S. I knew the places where some action was happening. But – I was interested, but I did not had a team really working on this. This was after '92, '93, that. But, of course, before all the technology around personal computers, discs, screens was moving and I was very concerned about the technology in general.

Q: Just any other students you want to mention? You've already talked a bit about Francesco and Dario and Martinoli. But other students of yours that have gone off to start labs or done important work in robotics and industry? You had a Logitech student. 'Cause part of our project is to –

Jean-Daniel Nicoud: Yes, yes. I'm thinking. But nobody build a company in that direction. Nobody became professor in another university. One of these guy was – Francesco me mention it. He made the vacuum cleaner project and he was progressing very well in U.S., but he got dead in a street accident. That was really stupid. But I do not remember about – <pause> and even Aude Billard I do not remember if – because she quickly – she made study here, but she quickly went to England and got all this knowledge from there. But you – well, you talk with her this morning. So you must know.

Q: Well, she said that you helped her to translate the robot that she'd built in Scotland into the lab here before she went to USC. So there was a humanoid robot that she had built.

Jean-Daniel Nicoud: We, yes, she came from England with a doll, and a robotic inside the doll – <laughs> I was not at all pleased about that, that electronic. So I propose her to remake that electronic and this was the doll – we built five or ten of them – she continued to play with at USC. But it was just a very simple electronic. Because the electronic I made was only the interface between computers sending orders and my microcontroller was distributing to the motors.

Q: Okay. And what do you see as the big problems facing robotics over the next five to ten years? Or what do you want to see solved?

Jean-Daniel Nicoud: Hm. It's energy problem. There is no hope really improving the power sources and we can improve a little bit the motors. But I was quite impressed with a video I see is not so far with a moving arm with a speed and a precision, which now is possible with the electronic. Because the electronic is still progressing so if you have better information from the sensors and enough power to send to the motors you can really do things which are faster than a hand and things like that. And, of course, now it will not save energy. <laughs> So if you want to have something which is autonomous for some time, that will stay a big problem and specially if

it's getting small. Now I have very little hope and the only hope for the future is to master some biological effect and be able to have them work for more than a few seconds. <laughs> Because a muscle is something incredible efficient. And so what can we do with cells and with living organisms? And that's a big challenge, but I think it's not impossible to find mixed solution. I've looked carefully to artificial muscles for a long time. But <laughs> very, very little hope in chemical – pure chemical or pure physics. <pause> So.

Q: Did you have more?

Jean-Daniel Nicoud: No, no. Nothing more to say. But it's – now the market is opening with these cleaning robots, but anyway. Even the big cleaning robot exists for twenty years and they made no progress. And this is – of course, I was used with the Morgan Law to have some new things to study every year in robotics. It's a little bit disappointing, but –

Q: What do you think will be the big applications, especially for small robotics in the next decade or so?

Jean-Daniel Nicoud: Well, they will be not necessary humanoid-like because walking with two legs is really something we have difficulty to do now. Even with battery pack [ph]. Again, if you bring the power from outside you can make wonderful things. But as soon as you have to carry the battery, we have – I do not see any solution. So for helping the elderly, for there will be a growing market. That's clear. I worked a lot – we didn't mention this: on mines, searching mine. And I made a funny robot, which was not supposed to explode the mines and search for them. And we had to stop the project because we had no sensor. So sensor for finding mines – it's a field which just do not progress because there is no market. Nobody is interested in removing mines in a country where people can buy only for few dollars a month of technical equipment. So microcomputer progress, USB-key progress very fast because there is a market which develop. But so a robot for removing mines could be an interesting application, of course. Now one of my worker on this project, he's building big tanks to prepare the fields, because there is no good way to remove mines instead of scanning by hand and recognizing very small signals and doing it in an appropriate way. But if you do it in an appropriate way, it's not dangerous. So the cost of these people is very low, compared to the cost of possible technology you have to develop, etcetera. So it's a field which doesn't move and now robot for farming exist for some time. It develops also very slowly for taking foods or – apparently, people are still so much efficient with a vision and hands that it's very difficult to build robots for this.

And so I think it's – so surgical robots are quite interesting, if they can be controlled by hand, controlled by the vision of somebody and since you can put more small camera and sensors and avoid to make a big opening to – that's wonderful application for this I think. But mobile robots, no. Well, you know the application where military <laughs> is still paying a lot of

money to improve some operation. And, of course, I follow from very close, the flying robots. Well, the flying camera. It's only flying camera so the soldier can spy, see better what's around it and evaluate the dangers. So there are beautiful progress, but still they have energy problem and cannot fly long enough, cannot go far enough. There's a Morgan Law, which is a progress – a factor by two every twenty years maybe, <laughs> which is very slow.

Q: Yeah. You mentioned it a few times, but that's usually the question we close with, which is for young people who are interested in robotics, what do you recommend for them to do? What's your advice to them?

Jean-Daniel Nicoud: Well, they have to master embedded system programming. That's, I think, a very first step because microprocessor can do so much things to help with interaction of the man. The man is always here to check that things are going well and if they are more automatized, that's perfect. But I think we still need the man to really be true, be sure that everything is going well. So you need to master programming. And now processor are getting so powerful that you can program with language which close from the application. But I think you just do the same as other people if you wait to have the tools. So if you can develop yourself the tools or develop yourself the application with simple tools which allow to make complex things I think it's an economic advantage. I mentioned Logitech with good engineers and good organization. This is what is important and not just the buying a tool which make things more easy, but limitation – a lot of limitation with what you can do with these tools because – okay, now for the hardware, for the mechanical construction, you need also people with some feeling about how to assemble things and – CAD allowed to check a lot of things. 3-D printing allowed to build prototype, which may give the impression it's easy to make something which works, but I think you still need to be clever and just by using existing tool you will just do – have the same limitation as all the other people using the same tool. No, that's why you need to invent and be able to invent solution and this means that you need to know a lot of things to select among our technological world what will solve your problem at best.

And now once you master the technology I think there are so many application and in the application you are interested in and you see there could be a market, you will find a solution which is better than the other people. Then, of course, you do not need only to produce prototype. You need to manufacture and sell and this is getting more and more complicated, because it's a lot of investment just to go to the market. Being sure that you do not infringe patent, that you do not – that you can sell large quantity, enough that – then you have to go abroad to manufacture. Everything is getting out of the hand of one or two smart people who would like to succeed by doing the start-up also. Is it more easy if you do pure software? Well, apparently all the fast-growing company are more or less pure software now.

Q: Great. Is there anything else you'd like to add or anything we missed?

Jean-Daniel Nicoud: Miniaturization is a – but really I do not [pause]– in relation with all these small robot I was looking for similitude law – how do you say this, *loi de similitude*? Similitude? Or it's another word?

Q: Similarity.

Jean-Daniel Nicoud: Similarity? Similarity laws. And, of course, for very small dimension you get different kind of electrical motors which could have a better efficiency, etcetera. But what made the success of computers and tablet, etcetera, is we know how to improve a technology which is flat. And with optic, with chemical attacking, we can do wonderful things and we're not yet at the limit. But as soon as you have to build in three dimension, apparently – and this is true for making – well, you can make flat motors but then you cannot make the gears and all the layers which are required as soon as you need to transmit power outside a flat chip. So I do not see how to do things in three dimensions instead of machining them and gluing, screwing and using the present technology when the watchmakers made the wonderful things for watch for many, many years. And I do not see – well, first, how the watchmaker technology – when they make these movements or rotating to compensate the orientation of the hand. It's wonderful, really wonderful on the mechanical design and the mechanical assembly and they can produce it very cheap. So can we use that expertise to make special robots? Of course, medical application are good, because there's a lot of money for developing medical applications. Okay, so I do not have <laughs> wonderful solution or wonderful direction to indicate. But I think I would encourage young students to work in that direction because they are really – well, for me, of course, it's interesting to study and there are many things to invent, if the pleasure is to invent.

Q: Great. Did you have an interest in clocks and –

Jean-Daniel Nicoud: What?

Q: Did you have an interest in watches and clocks prior to your work in robotics? Was there any relationship?

Jean-Daniel Nicoud: No, not specially. Except I like the stepping motors, which are some kind of watch technology, <laughs> because it's what? It's low power. But, of course, a hundred years ago <laughs> I would have became a watchmaker, clearly.

Q: Yeah. Okay, thank you very much.

Jean-Daniel Nicoud: Because it's 65.

Q: Wow, yeah.

Jean-Daniel Nicoud: Before the transistors with relays and –

Q: That's an Analog Er.

Jean-Daniel Nicoud: Okay, so I can briefly comment on this. This one also is very significant, because if you have heard about the Ivano Trento Conference with Rodney Brooks etcetera, I demonstrate these set of robots, which of course, they have a camera, and they were following each other, keeping the distance, and the ground was very rough with stones, and I was really surprised to see that it was working. So with your camera, we can prepare them on the ground, and you just make a – it's too complicated and takes too much time to really make it work. So we should see that… It was the very first linear camera. So I think – we can zoom on this. And now I have here a little bit of the Khepera story. So Francesco will continue the story, but this was my motivation to go in that direction, so I think it's – and I've not yet given it to Francesco, because his building this museum, and I give him all what I do not want to keep it. So I will give this to him sooner or later. So this is a Khepera. Okay, so we do not need – so I do not know how – well. The comment I can do is I've tried many solution to develop small robots, also for toys, like toys for kids, and my company is trying to do business with this, I do not succeed, but I like to develop and this is my satisfaction. So I can make some comment about this later. And of course, an important point, but I do not have the hardware, but the hardware is not so far. We have been working with an excellent technician and one cubic centimeter robot, and one inch-cube robot. So I can make some comment about this. And if you want to take picture of these, they are in my former lab, where Francesco – you stay how long here?

Q: Till tomorrow, yeah.

Jean-Daniel Nicoud: Till tomorrow.

Q: Then I go to –?

Jean-Daniel Nicoud: You have some other people to see like Martinelo, No?

Q: I would love to –

Jean-Daniel Nicoud: Francesco, I can make a list of the people – of the key people. Okay, so maybe I will – and this is – I started a paper someday about the constraints of designing some

more robots, and it does mention the one cubic centimeter and the problem to put the battery, and the reference to my – no, maybe there are no. In Japan, they still have this contest for one cubic centimeter, not robot, they are tele-operated. But it's amazing, because it was – they started this almost 20 years ago. And the field of things are moving very fast, but in this field we have no energy sources for this dimension, so everybody has to find new tricks to try to make it slightly different than last year. Okay, so you can put it on your thing.